Orthopedic and reconstruction surgery : industrial and civilian / by Fred H. Albee.

Contributors

Albee, Fred H. 1876-1945.

Publication/Creation

Philadelphia ; London : W.B. Saunders, 1919.

Persistent URL

https://wellcomecollection.org/works/fdt9qh22

License and attribution

Conditions of use: it is possible this item is protected by copyright and/or related rights. You are free to use this item in any way that is permitted by the copyright and related rights legislation that applies to your use. For other uses you need to obtain permission from the rights-holder(s).

wellcome collection

Wellcome Collection
183 Euston Road
London NW1 2BE UK
T +44 (0)20 7611 8722
E library@wellcomecollection.org
https://wellcomecollection.org

Digitized by the Internet Archive
in 2017 with funding from
Wellcome Library

https://archive.org/details/b29812100

ORTHOPEDIC AND RECONSTRUCTION SURGERY

INDUSTRIAL AND CIVILIAN

BY

FRED H. ALBEE

A. B., M. D., Sc. D., F. A. C. S., Lieutenant Colonel M. C., U. S. A.

Professor and Director of Department of Orthopedic Surgery at the New York Post-Graduate Medical School and at the University of Vermont; Chairman Rehabilitation Commission of State of New Jersey; Member of Advisory Orthopedic Council to the Surgeon General; Chief Surgeon U. S. Army General Hospital No. 3, Colonia, N. J.; Visiting Orthopedic Surgeon to the New York Post-Graduate Hospital and to the Blythedale Hospital; Consulting Orthopedic Surgeon to the Mary Fletcher Hospital, Burlington, Vt., the Sea View Hospital, N. Y., Staten Island Hospital, N. Y., Muhlenburg Hospital, Plainfield, N. J., Memorial Hospital, Newark, N. J., Waterbury Hospital, Waterbury, Conn., the New Jersey State Hospital and the Rahway Hospital, N. J. and the Lutheran Hospital, New York; Member of the American Orthopedic Association; Honorary Member of Chicago Medical Society, Etc.

WITH 804 ILLUSTRATIONS

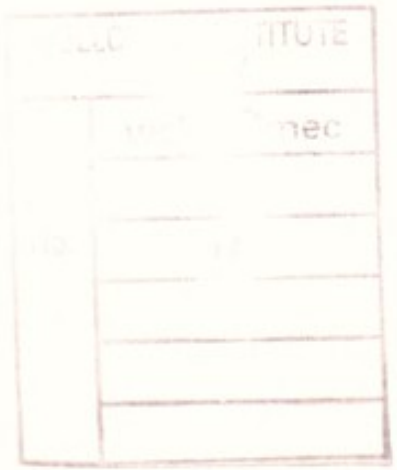
PHILADELPHIA AND LONDON

W. B. SAUNDERS COMPANY

1919

-5 APR 1950

Copyright, 1919, By W. B. Saunders Company



PRINTED IN AMERICA

This Book is Dedicated

to

Colonel E. G. Brackett

and others of the profession

who have at great sacrifice

offered their services to

their country in an hour of

great peril

PREFACE

During the past ten years the old order has so changed that the Department of Medicine which was formerly designated "Orthopedic Surgery" is to-day scarcely recognizable by that appellation. The metamorphosis from an almost exclusively conservative therapy has been wrought by the ever-increasing application of surgical procedures to the numerous deformities and distortions which heretofore have been regarded as hopeless, or amenable to relief only by conservative treatment. The rapid and extensive evolution of this work, plus the epoch-making influence of the recent world-wide war, have justified the publication of a work which, while in no wise *detracting* from the *importance* of *conservative methods*, aims to assemble and bring to the attention of the profession in a practical manner those surgical procedures which have contributed so largely to the reclamation of the cripple and to the rehabilitation of the physically incompetent, and which offered to the great armies engaged in the titanic world struggle an alleviation of their sufferings and a reconstruction of their physical deformities.

This treatise includes, in addition to the subject matter usually classified as "Orthopedic Surgery," the consideration of a large number of conditions originating either in the various present-day industrial organizations or in the great war. Although these are not generally included in this realm of surgery, they are so closely allied that it has been thought wise to include them in the same work, hence the title "Orthopedic and Reconstruction Surgery."

It is an indisputable fact that this department of medicine has been sadly neglected not only in our medical schools but also in our general hospitals. The meager armamentarium for bone and joint surgery to be found in many of our hospitals emphasizes to an even greater degree this lamentable defect. A hospital may be equipped with all the latest instruments for abdominal, thoracic, gynecologic, and urologic surgery, yet entirely lack facilities for the proper surgical treatment of fractures and other bone and joint lesions.

Additional inspiration for compiling this work has been derived from the following sources:

1. Appeals from the author's graduate and undergraduate students alike for a book which should consider not only conservative methods which time and experience have demonstrated to be efficient, but also the well-tried *operative methods of treatment* of bone and joint conditions, diseases and deformities—an aspect of the work that has been woefully neglected in the orthopedic text-books and treatises of the past.

2. The tremendous influence which is being exerted upon surgical practice by the recent war and, to a slightly less extent, the effect upon traumatic surgery of Workmen's Compensation Laws, executed by the industrial organizations on the one hand and the insurance carriers upon the other. The present day and hour marks a most important "milestone" in the evolution of the work this volume attempts to present.

3. The importance of combining in one treatise both the conservative and the operative systems of treatment, thus demonstrating the interrelationships of the two and the mutual dependence of the one upon the other.

Acknowledgment should be made of the obligation and indebtedness due to the members of the American Orthopedic Association and the profession in general, especially to Sir Robert Jones, to Colonel E. G. Brackett, to Alfred Herbert Tubby, C. M. G. and to John Fraser, M. D., F. R. C. S., for investigations freely drawn upon in the views presented in this treatise. Sincere gratitude should be expressed to all those who have so intelligently and loyally assisted in the preparation of this work, especially to the late Dr. W. L. Thompson, to Dr. P. G. Skillern, Jr., of Philadelphia, for reviewing the text, to Dr. Leo Mayer for his contribution to the chapter on "War Surgery" and his many helpful suggestions and criticisms.

Extensive quotations are made from Sir Robert Jones' valuable and timely book, "Notes on Military Orthopedic Surgery;" from the manuscript of Dr. Mayer's excellent work entitled "Orthopedic Treatment of Gunshot Injuries;" and from the Report of the Orthopedic Division of the Surgeon General's Office, particularly the material relating to the amputated and to artificial limbs.

Appreciation is also due to Mr. K. K. Bosse for his co-operation in the production of the original illustrations and to W. B. Saunders Company for their sustained interest and efficiency in the publication of this book.

FRED H. ALBEE.

40 EAST 41ST STREET,
NEW YORK CITY,
July, 1919.

CONTENTS

PAGE

INTRODUCTION 17

CHAPTER I

TUBERCULOSIS OF BONES AND JOINTS 26

CHAPTER II

TUBERCULOSIS OF THE SPINE. 72

CHAPTER III

FUNDAMENTAL PRINCIPLES UNDERLYING THE USE OF THE BONE-GRAFT IN SURGERY 142

CHAPTER IV

ROENTGENOLOGY 163

CHAPTER V

THE ELECTRO-OPERATIVE BONE OUTFIT AND TECHNIC OF ITS USAGE. OTHER INSTRUMENTS 177

CHAPTER VI

TUBERCULOUS DISEASE OF THE HIP-JOINT 190

CHAPTER VII

TUBERCULOSIS OF THE KNEE-JOINT 230

CHAPTER VIII

TUBERCULOUS DISEASE OF THE ANKLE, TARSUS, LONG BONES OF THE HAND AND FOOT, SHOULDER, ELBOW, WRIST, SKULL BONES, INFERIOR MAXILLA, SUPERIOR MAXILLA, MALAR BONES, AND RIBS. 258

CHAPTER IX

FOCAL INFECTIONS 285

CHAPTER X

INFECTIOUS DISEASES OF THE BONES AND JOINTS. 303

CHAPTER XI

CHRONIC INFECTIOUS ARTHRITIS 320

CHAPTER XII

TRAUMATIC AND OTHER AFFECTIONS OF THE SPINE 347

CHAPTER XIII

STATIC DEFORMITIES OF THE SPINE. 396

CHAPTER XIV

MISCELLANEOUS AFFECTIONS OF THE HIP-JOINT 447

CHAPTER XV PAGE

Miscellaneous Affections of the Knee and Other Joints 490

CHAPTER XVI

Infectious Osteomyelitis 530

CHAPTER XVII

Malunited and Ununited Fractures of the Long Bones: Their Surgical Treatment by Bone-graft 549

CHAPTER XVIII

Fracture of Neck of Femur. Fractures of Patella and Olecranon. Habitual Dislocation of Patella. Fracture of the Tarsal Bones. Fracture of the Carpal Scaphoid 595

CHAPTER XIX

Constitutional Affections Producing General and Localized Distortions . 640

CHAPTER XX

Infantile Paralysis 665

CHAPTER XXI

Infantile Paralysis (Continued) 692

CHAPTER XXII

Spastic Paralysis, Neuropathies and Myopathies, and Their Deformities . . 790

CHAPTER XXIII

Deformities and Other Affections of the Ankle and Foot 821

CHAPTER XXIV

Congenital Dislocation of the Hip 873

CHAPTER XXV

Other Congenital and Acquired Deformities 903

CHAPTER XXVI

Tortioollis or Wry-neck 929

CHAPTER XXVII

Neoplasms of Bone 937

CHAPTER XXVIII

Ankylosis and Arthroplasties for Mobility 960

CHAPTER XXIX

Plaster-of-Paris Technic 985

CHAPTER XXX

Military and Industrial Reconstruction Surgery 994

Index 1095

ORTHOPEDIC AND RECONSTRUCTION SURGERY

INTRODUCTION

The Scope of Orthopedic and Reconstruction Surgery.—The demands made upon the energy and ingenuity of the orthopedic surgeon are to-day greater than ever before. There has been added to his regime in civil and industrial life a broad and diversified work in a new field, *i.e.*, the formidable array of complicated surgical conditions which have been evolved from the recent war. Orthopedic surgery is being forced into especially strong relief because of the fact that a very large percentage of all the surgical affections produced by this great war belongs to the category of deformities and distortions amenable to corrective surgery.

The efficiency of modern orthopedic treatment in military work can be no better appreciated than by a statement of Goldthwait, that "of 1350 cases discharged from the Orthopedic center at Shepherd's Bush Hospital in a given period, just about 1000 were sent back into the army as Class A, Class B, and Class C men, and of this number 294 were Class A men. The remaining 350 cases were sent back into civil life better, and industrially trained, so that although crippled they were still of use to themselves and the community."

The broad scope of military orthopedic surgery as defined by both the United States' and the British Governments' classification is shown by the following table:

UNITED STATES AND BRITISH GOVERNMENTS' CLASSIFICATION OF ORTHOPEDIC SURGICAL CONDITIONS

(*a*) Derangements and disabilities of joints, including ankylosis.

(*b*) Deformities and disabilities of feet, such as hallux valgus, hallux rigidus, hammer-toes, metatarsalgia, painful heels, flat or claw feet.

(*c*) Malunited or ununited fractures.

(*d*) Injuries to ligaments, muscles, and tendons.

(*e*) Cases requiring tendon transplantation or other treatment for irreparable destruction of nerves.

(*f*) Nerve injuries complicated with fractures or stiffness of joints.

(*g*) Cases requiring surgical appliances, including artificial limbs.

As Goldthwait says, "the magnitude of the problem which such a classification imposes, is shown by the fact that in all the estimates of the percentages of the injuries requiring orthopedic treatment that it has been possible for me to obtain, none has been less than 30 per cent., while others have been as high as 50 per cent. . . . . In the British Isles there are about 310,000 military hospital beds, apart from the 120,000 beds for the British forces in France (Sept., 1917) . . . . ."

As can be readily observed, this would aggregate, if all these beds were full, a total varying from 120,000 to 215,000 cases requiring orthopedic treatment in the British army alone at that time (September, 1917).

Furthermore, a well-known Canadian surgeon who is actively engaged in military work, stated to the author that of all the surgical cases returning to Canada, approximately 75 to 85 per cent. required orthopedic treatment.

In reference to our own army it has been stated that of all invalided soldiers returning to the port of New York, 65 per cent. are orthopedic.

Actuated by the sense of justice and humanity to the individual, and by a realization of the tremendous economic stress upon the State, the portent of these huge figures has been appreciated by the several countries involved in the war and has caused them (particularly England and Germany and our own country) to develop complicated and well-organized "centers" to meet the situation.

These orthopedic centers have served not only to reconstruct surgically the crippled or maimed soldiers but, by means of electrotherapy, hydrotherapy, psychotherapy, massage, special exercises, gymnastics, curative and vocational re-educational workshops, commercial schools, and artificial limb-factories (with schools in which to educate men in the proper use of their artificial limbs) they have re-educated and re-equipped them to return to the army or to civil life—in the latter instance wholly or, at least, partially able to support themselves and thus to relieve their families, their friends, and the state of the enormous burden of their maintenance. Indeed, many, with their re-educational training are better able to support themselves and families than before they went to the trenches.

The Introduction into Surgery of Electricity and Motor-driven Instruments.—The introduction into surgery of electricity and motor-driven instruments has not only inaugurated a new era in the technic of bone surgery but it has also tremendously extended the scope of the work. Operations hitherto considered not feasible can now be performed effectively and within reasonable limits of time. The motor outfit is not only indispensable in every technic of bone-grafting but it is also of the greatest value in all plastic bone procedures. The electromotor operating set was devised and introduced by the author some eight years ago; necessity for speed, accuracy, and the elimination of trauma in bone operations was the "mother" of the invention, while the immediate incentives for its production were the inlay bone-graft for fractures, the peg-graft for fracture of the hip, and the spinal graft for Pott's disease, etc. This outfit, with its twin saws and dowel-shapers, introduced for the first time machine work and the automatic tool into surgery, and represents a new departure in that field. It enables the surgeon to perform his work with the greatest nicety and accuracy. The surgeon can thus fashion and fit a dowel peg with as great precision as the artisan who makes and fits a leg to the bottom of a chair by means of his lathe or automatic machine tool. The dowel-shaper which the craftsman uses to turn out the end of the chair leg is a counterpart of the bit or drill with which he makes the hole in the chair bottom; the diameter of the dowel-shaper and that of the bit or drill is the same, thus insuring a perfect fit. The author's motor-driven instruments have been constructed on the same mechanical principles as the artisan's tools—the adjustable circular twin saw enables the surgeon to remove from the tibia a bone-graft of uniform width which will fit with perfect coaptation into a groove made with the same saw in the fragments of an ununited fracture. The same accurate "machine work" is secured by the author's dowel-shaper with its drill of corresponding size. These motor-driven instruments not only minimize time but make

possible the performance of operations which could not otherwise be contemplated. Their efficacy in reconstruction surgery is attested by the fact that they have been in use in the base hospitals of the chief warring countries in the recent world conflict.

As is enlarged upon elsewhere in this book, the paramount advantages of motor-driven instruments in bone surgery are: (1) the diminution of operating time; (2) the absence of shock; (3) the avoidance of traumatization (from blows of mallet and chisel and from drying by exposure to air); (4) the accuracy of the technic; (5) the conservation of energy on the part of the surgeon.

The diminution in the degree of shock since the advent of these instruments is very striking and is undoubtedly explained by the brevity of the operation and the lessening of afferent nervous impulses to the brain centers on account of the high rate of speed with which the cutting instruments are propelled while severing the nervous tissue existing in the osseous parts being cut. An analogous condition is observed at the front in the case of a projectile of high velocity which frequently pierces a non-vital part without trace of shock, pain, or even interference with locomotion; while, on the other hand, the injury produced by a slow ("spent") bullet is accompanied by a varying amount of shock (see Chapter XXX) and, in many instances, prostration of the individual.

Absorbable Ligatures.—The importance of sedulously avoiding the implantation in bone of ligatures or other internal fixation agents composed of metal or other non-absorbable material cannot be overestimated. Metal is not only a source of danger by contributing to immediate or remote infection through local devitalization of tissue (*locus minoris resistentiæ*) but is, moreover, an inhibitor of bone growth and a destroyer of the bone (Fig. 1) with which it comes in immediate contact, especially the graft before its nourishment has been established. The absorbable ligature, on the other hand, when used in conjunction with inlays and mortises of the bony parts, is locally innocuous and, if sufficiently strong, serves every purpose of the non-absorbable materials. Because of its great strength and consequent reliability, kangaroo tendon of proper size is the ideal bone suture. The author has repeatedly emphasized the above statements in various publications during the present decade and is now more than ever convinced of their importance.

Superiority of Bone over Soft Tissue as a Stabilizing and Supporting Agent.—Irritation from any cause, persisting for a long time, produces certain classic types of deformity: in case of the knee, flexion; in case of the hip, flexion and adduction; in other words, the flexors always predominate over the extensors, and the adductors over the abductors. However, cicatricial or fibrous tissue, even when very dense, cannot withstand long-continued stress, *e.g.*, a pseudo-arthrosis in transverse fracture of the patella has been known to stretch as much as 5 inches, while for the same reason operations for the relief of habitual dislocation of the patella, when reliance is placed upon reefing the capsule and periarticular tissues, are notoriously unsuccessful.

Therefore the untrustworthy nature of cicatricial and fibrous tissue, so far as withstanding stress is concerned, explains the wisdom when possible, of always planning reconstruction operations so that bone and not soft tissue will bear the brunts of stress and strain. This is well exemplified by the failure of the numerous plastic procedures in which reliance is placed on the soft parts to maintain the correction of a deformity such as luxating hip or patella, and renders more intelligible the wisdom of employing some such

bone plastic procedure as that of Albee (wedge bone-graft) in these affections, whereby the unfavorable mechanical conditions are directly obviated by building up the acetabular rim or, in the latter instance, elevating the external condyle, thus increasing the depth of the patellar groove in the femur by

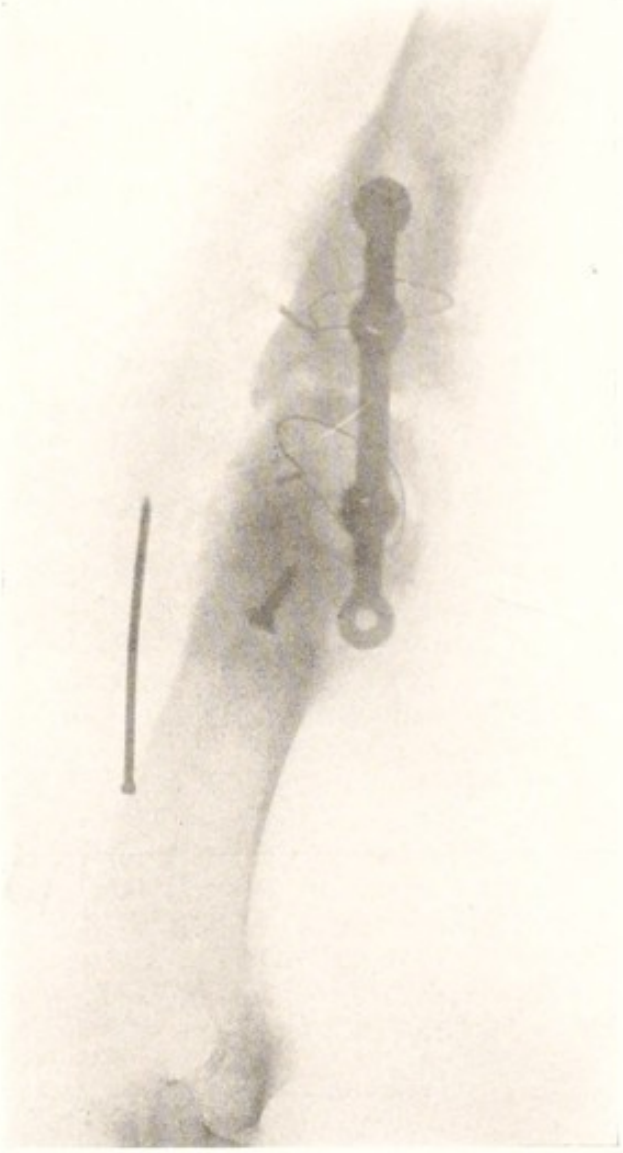


FIG. 1.—A graphic illustration of misconception of the fundamental principles of bone growth and the repair of fractures.

A surgeon of good technic attempted to repair the fracture here shown, in the following manner, in four separate operations, all failures:

1st Operation: Lane plate: inserted. 2d Operation in eight months: removal of Lane plate for non-union; fragments "toe-nailed" with wire-nails. 3d Operation six months later for non-union: nails removed and silver-wire applied. 4th Operation two years later for persistent non-union: at this time all the metal fixation agents previously used were applied—Lane's plate, nails, silver-wire. Non-union persisted and the fragments were infected when the case came to the author in the condition depicted by the radiograph. These operations were performed at intervals during a period of five years. They were performed, not twenty years ago, but in the past five years; and not in the rural districts, but in a hospital in a large city.

Even after the fourth operation, the surgeon's technic was so good that immediate primary union of the soft tissues occurred despite the later non-union and infection of the bone-fragments.

The author does not wish to take issue with the surgeon as to the wisdom of the initial application of Lane's plates (although he never uses them himself), but he does wish to go on record as opposing the three subsequent applications of metal which were not only contra-indicated in this particular case but were in defiance of all general laws of bone-repair.

producing a shoulder of bone which, by virtue of Wolff's law, will adapt itself to the requirements of the case.

The same principle of utilizing osseous rather than soft tissue in stabilizing procedures applies with even greater force to the transplantation of tendons. Whenever possible, the surgeon should remove a portion of the bony insertion of the tendon to be transplanted and implant it beneath the periosteum at the site of its new insertion. The physiological influence of stress upon bone causes it to strengthen and proliferate. Furthermore, one should never rely upon fixation ligatures or internal splints to maintain alignment or to correct deformity when it is possible to interlock two bone segments by means of a carpenter's "joint" or mortise. Ligatures under stress tend to cut through and to cause absorption of bone as well as of soft tissue, while, on the other hand, bone segments brought together by accurate mortises are stimulated to osteogenetic activity because of the stress and friction to which they are subjected by the mechanical method of their coaptation. This is the *frictional-irritation law of Roux*. Its efficacy is of the greatest importance in producing and accelerating callus formation and union in fractures, and should never be lost sight of. It has also a very especial bearing upon the technic of bone-grafting.

Tonicity of Soft Tissues.—A fundamental principle involved in reconstruction orthopedic surgery is that when the normal tonicity of soft tissues, especially muscle, is diminished over long periods of time, those tissues become shortened and adapt themselves to the new conditions, particularly in the growing period of life. In other words, normal tissue is physiologically in constant mechanical tone; absence of this tone, from any cause whatever, is taken advantage of by nature and is manifested by contracture (whether of muscle, tendon, or any other soft tissue). This is exemplified in all deformities and contractures due to infantile paralysis, *i.e.*, it is not the unhealthy or paralyzed muscle that shortens, but the normal muscle which is constantly relaxed on account of the diminution or absence of the opposing pull of its paralyzed antagonistic muscle or group of muscles. During the actively growing period of a child's life such a deformity, if not treated, becomes extreme. The surgical prophylaxis is simple, viz., maintenance of tonicity of the healthy muscle by some mechanical appliance or, according to Sir Robert Jones, some operation, such as removal of an elliptical piece of skin from the dorsum of the foot and closure of the resulting hiatus as recommended by him. This same mechanical principle of tonicity of unstretched soft tissue may be utilized therapeutically to advantage; an illustration of this is Lorenz' "frog" position following the reduction of congenital dislocation of the hip; this position is not only favorable to maintenance of the reduction but it also relaxes to a superlative degree the posterior portion of the capsule of the hip-joint, and if the position is maintained for a prolonged period these structures will become physiologically shortened and the capsule so restored that the hip will remain in position even during function. It is said that the first reduction of a congenitally dislocated hip was performed by a prominent surgeon in this country but, failing to realize this fundamental principle of the adaptability of tonicity of soft tissues, the hip was kept fixed for a relatively short time only (*i.e.*, a period sufficient for the repair of a traumatic dislocation, where the reparative processes are of an entirely different character, consisting merely of the union of lacerated tissue).

Disuse Atrophy.—Joint affections and interference with their function cause muscular atrophy, which in the case of large joints may come on very rapidly. The fundamental consideration in the treatment of this atrophy

is the treatment of the primary etiological factor, *i.e.*, the joint lesion itself; when normal function of a joint has been restored, the muscular atrophy will, as a rule, spontaneously disappear.

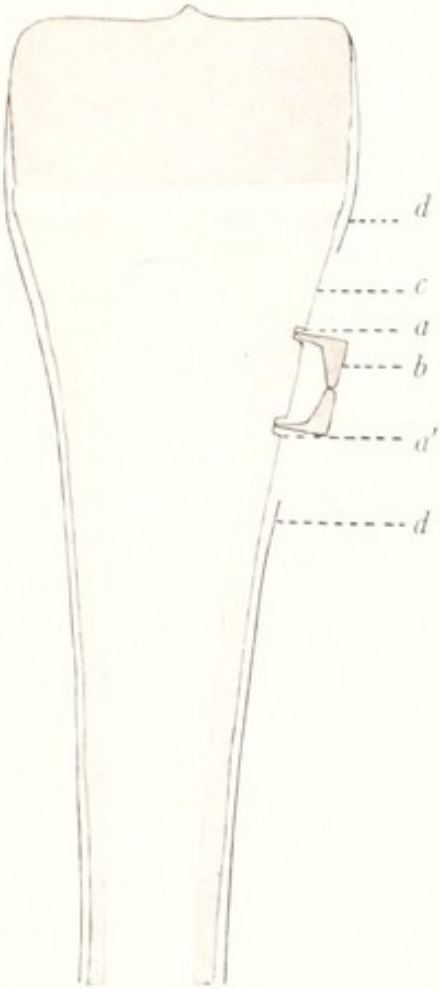


FIG. 2.—Diagram of the tibia in longitudinal section, illustrating the principle of the cap experiments. (After Mayer and Wehner.) The shallow groove in the cortex; *b*, the cap, showing the depression for the wire; *c*, the bone bared of periosteum; *d*, the periosteum. A steel cap was inserted in a groove made for its reception on the anterior-internal surface of the tibia.

The region in which cap was inserted had been previously stripped of its periosteum in a zone 3 cm. in width. The cap effectively excluded the ingress of regenerated periosteum, therefore no new bone growth occurred beneath the cap, whereas external to it, where the regenerated periosteum functionated, extensive bone formation had taken place. This experiment emphasizes the osteogenetic function of the specific osteoplastic cells of the periosteum.

The Position of Neutral Muscle Pull.—In 1908 (Albee, "The Post-Graduate," June, 1908) the author emphasized the value of "the position of neutral pull" in fractures of the upper end of the humerus. While this position of neutral muscle pull in both upper and lower extremities has proved of the greatest service in civilian practice, its usefulness has been many times magnified in gunshot fractures in the recent war. In such fractures, coaptation or plaster splints, etc., may be inapplicable, or may lose their potency if applied, and such cases are best controlled by means of traction applied in the position of neutral muscle pull and, as a rule, best maintained by the Balkan frame or similar apparatus.

The Portable X-Ray Apparatus.—The portable *x*-ray apparatus which has been developed in the course of the war is of the greatest service as an adjunct to this treatment, since it enables the surgeon, without disturbing his patient, to have right-angled or stereoscopic radiographs made at the bedside without disarranging the traction, the position of neutral muscle pull, or apparatus. On account of the laceration of soft parts, sensitiveness and swelling, which occur in military cases, the older methods of palpation, etc., must necessarily be largely supplanted by fluoroscopy or radiography at the bedside.

Ankylosis.—Ankylosis of the joint is due not to intelligent prolonged fixation but to *disease* and destruction of the joint. In fact, efficient fixation of an inflamed joint leads to its functional restoration or to eventual increased amount of motion rather than to stiffness.

Referred Pain.—In the practice of orthopedic surgery, as well as in all other departments of medicine, the significance of referred pain cannot be overestimated. This is often lost sight of. The author has had many cases which have been treated for "trouble with the knee" in which the lesion has been found to be located at the hip; also many cases in which a child has been treated for "indigestion" when the lesion was found to be tuberculosis of the spine.

Osteogenetic Power of Bone (Fig. 2).—Increased knowledge of the osteogenetic power of bone has effected some revolutionary changes in our

surgical practice. This can be no more strikingly illustrated in the author's work than by the change in his method of performing arthrodesis of the hip. In his early practice he carefully removed every particle of loose bone, even irrigating the deep hip wound to insure this, because of the popular



FIG. 3.—This is a case of simple fracture of the femur which was Lane-plated five months before this *x*-ray was taken and was followed by suppuration and death of the complete diameter of both ends of the fragments. The case was brought to the author three months after operation. The lesion still suppurating profusely. At this time the author removed the Lane plate and a large number of detached necrotic fragments, purposely leaving *in situ* the one shown at the inner aspect of the femur because its periosteum was attached to the soft parts and a portion of it was still viable, thereby justifying the hope that osteogenesis therefrom would aid in ultimate union. The present radiograph shown here demonstrates a firm bridge of callus developing from the fragments and from the above-mentioned island of bone.

This case illustrates the importance of always leaving in position any viable bone fragments in a compound fracture, whether they are infected or not. In this case, alignment of the fragments was maintained by a plaster-of-Paris spica in the position of neutral muscle-pull (flexion and abduction) and its length was preserved by means of 20 pound traction applied to stickers placed beneath the plaster-of-Paris splint.

fear of untoward results from these loose bone fragments, and it should be noted that this fear still persists in the minds of many. At the present time, every satisfactory particle of bone is allowed to remain to act as an additional source of osteogenesis and to hasten union. This same conception of the

osteogenetic power of bony particles bears upon the question of the disposal of the fragments in a compound, comminuted fracture. In the absence of infection, it is inexcusable to discard comminuted fragments, irrespective of their number or size, as is often done (Fig. 3). The author places especial emphasis upon this statement because he has frequently been compelled to resort to bone-grafting to repair defects (often in cases of *non-compound* fractures) because at the time of the primary treatment the surgeon had removed the comminuted fragments.

Physics of Bone.—From the standpoint of stress bearing, bone is mechanically the most wonderful material known. The strongest and most highly tempered metals, including metallic alloys, will weaken and give way when subjected to constant overloading: in marked contrast to this, bone, when overloaded, will not only increase in size and strength, but will undergo readjustment of its external contour and its internal architecture to withstand added stress or stress exerted in different planes. In other words, bone will adapt itself to an added load or to stress exerted upon it at a mechanical disadvantage or in an abnormal plane; this may or may not involve total increase in the amount of bone. It will also hypertrophy or re-adjust itself until the overload becomes a physiological load.

Laws of Bone Architecture.—At the conclusion of a masterly study of the laws of bone architecture, John C. Koch thus enunciates their practical application (Am. Jour. Anat., vol. xxi, No. 2, Mch. 1917, p. 289):

"If the mechanical structure of bone is correctly understood, the repair of fractures and the general treatment of bone diseases and deformities may be handled with greater efficiency and the proper prophylactic measures against deformity may be undertaken with greater hope of success.

"The theory of the functional form of bone proposed by Wolff and also by Roux (1881) with that of the functional pathogenesis of deformity, though long supported by abundant clinical evidence and practically applied by many surgeons and orthopedists as a working basis in the treatment of deformities, has been the subject of so much controversy that much confusion has arisen as to the value of the theory in everyday practice.

"The mathematical demonstration of the relation between the form and the function of bone under normal conditions . . . . . is believed to place this theory upon a sound foundation. The close adaptation of the structure of normal bone to its function leads logically to the conclusion that continued deviation from the normal static conditions to which a bone is subjected must be followed by a structural adaptation to meet the changed conditions (altered function).

"Whether the persistent altered static (mechanical) conditions in the bone be due to fracture, bone disease, paralysis followed by postural changes, or other causes, the fundamental mechanical principles apply with equal force—transformation of the inner structure of bone takes place, and the inner structure of the bone is altered with mathematical accuracy to conform to the new mechanical conditions, usually with a high degree of economy.

"Fractures unite without deformity when there is good coaptation, because in such a case the original mechanical conditions are restored and there is no need for excess bony material for resisting the normal stresses. However, if coaptation is not secured, and there is a gap between the fractured ends of the bone, union usually takes place with more or less shortening and the gap is bridged in the most economical manner that the altered positions of the parts of the bone will allow. The increased amount of material is required because of the greater stresses produced at the fracture.

"In diseased bone, the gradual weakening of the bone is followed by changes in form in accordance with mechanical laws; wherever the stress in the bone exceeds the strength of the bone, distortion occurs until equilibrium of these forces is attained. It is clear that the essential in such cases to prevent deformity is by relieving the overloaded structures, as completely as possible.

"Postural variations from the normal produce increased stresses in certain regions, and in others decreased stresses; if persistent, such variations will produce corresponding changes in the inner structure of the affected bones. In many instances there results a progressive increase of deformity, until a condition of equilibrium is reached.

"Whenever from any cause a persistent change occurs in the manner in which loads are transmitted to the various parts of the skeleton, an adaptive change must occur in the inner architecture of the bones in which these altered conditions exist. In the same manner that the application of this principle explains the production of deformity, it may be used to explain the cure of deformity. The proper mechanical means of imposing new mechanical conditions by which the original structure of bone may be restored, is by the use of braces, jackets, [tendon, bone, or nerve transplantation, or other plastic operations—F. H. A.] or other suitable means which over-correct the deformity and reverse the transformation process.

"These results, so commonly secured by the orthopedic surgeon, depend upon the mathematically exact adaptation of the living bone to the mechanical conditions persistently imposed upon it by whatever cause or causes, and the necessary structural re-arrangements are usually attained with great economy of material."

CHAPTER I

TUBERCULOSIS OF BONES AND JOINTS

ETIOLOGY

The immediate causative factor in the production of tuberculosis of the bones and joints is the Bacillus tuberculosis. Although this organism is found in the infectious processes of cattle, birds and fish, the bovine bacillus is the only one aside from the human type with which we are concerned.

The interrelationship between human and bovine tuberculosis has been the subject of endless investigation and discussion since Koch's publications of 1897.

Although quite readily distinguishable from one another by cultural, morphological, and inoculation tests, the bovine and the human tubercle bacilli are undoubtedly of common origin. That the two organisms are both responsible for human tuberculosis has been abundantly demonstrated, although what percentage of infections is due to each, is the subject of divergent opinions. Bacteriological investigations by reliable workers have demonstrated the relation of a large proportion of bovine infection to an infected milk supply and a young age incidence. This is a natural sequence of events. The chief article of diet at the age when osseous tuberculosis is most common, is milk. If this staple food is contaminated by the bovine tubercle bacillus, its ingestion is very naturally followed by tuberculous disease of the lymphatic nodes, cervical and mesenteric, and from this focus, a distribution of the bacilli to the bones and joints readily follows.

Portals of Entry of the Bacilli.—Antenatal infection may be disregarded as an unlikely possibility. The two most accessible channels of inoculation are the respiratory and alimentary systems. The relative importance of the two is still under discussion but unquestionably varies with the time of life; the preponderance of surgical tuberculosis in children suggesting the probable ingestion source at that time, while in adults the process is reversed, pulmonary lesions becoming the commonest and suggesting the respiratory origin.

Other less common means of entrance are the tonsils, the pharynx, the skin (following wounds), the genito-urinary passages and the teeth; in the pulp of carious teeth tubercle bacilli probably infect the submaxillary groups of lymph nodes.

Source of Infection of the Bones and Joints.—Direct infection of a bone or joint from without so rarely occurs as to be a negligible factor. The indirect avenues of invasion are of course the blood stream and the lymphatic system. Much important work has been done by investigators to determine whether one or both of these routes provided the path of infection and whether the bones and the joints were equally liable to invasion or stood in relation to one another as primary and secondary infections.

From the mass of data accruing from these investigations, four conclusions may be drawn: (1) Experimental tuberculous lesions are difficult of production; (2) trauma is a relatively slight factor; (3) joints are much more susceptible to tuberculous infection than bones, and (4) the joints are infected through the medium of the blood stream.

Predisposition to the tuberculous condition may be exhibited by reason of (1) injury, (2) heredity, and (3) general causes.

1. *Injury.*—Although a history of previous injury is nearly always given, there is no doubt that in a certain number of cases traumatism is an important factor. The effect of injury may be felt in two ways, viz.: (*a*) by the production of a *locus minoris resistentiæ* consequent upon a small effusion of blood and lymph in the cancellous tissue and a stagnation of the organism; and (*b*) where a pre-existing tuberculous lesion has been circumscribed, encapsulated and quiescent, trauma may provoke active spreading of the process and the production of an infiltrating tubercle; this, in the case of a tuberculous focus in or near the articular extremity of a bone, may cause extensive involvement of the neighboring joint. It is believed, however, that in the histories of tuberculous joint cases the frequent occurrence of trauma as a possible etiological factor is partly accounted for by the fact that emphasis is placed upon the injury because the joint was sensitive from the lesion already present.

2. *Heredity.*—The subject of direct heredity has aroused strong discussion, and although cases of apparently true congenital tuberculosis have been reported, it is believed that a tuberculous parent reacts upon its offspring in a less direct manner, viz.: (*a*) by actual transmission of the tuberculous virus to the subject during intra-uterine life (Baumgarten); (*b*) lowering of the vitality of the subject by reason of the impoverished state of the parent's blood; (*c*) a tuberculous parent stands as a constant source of infection by virtue of proximity to the child.

3. *General Causes.*—These all operate to lower the vitality of tissue and to render the soil fertile for the implantation and growth of the offending bacilli. Among the more important debilitating states are the exanthemata, influenza, inadequate feeding and want of fresh air and sunshine.

FREQUENCY OF AFFECTION OF THE VARIOUS BONES AND JOINTS

The incidence of tuberculous involvement of the various bones and joints varies with different clinicians. The greatest available mass of material is that collected by Cheyne, who combined the cases collected by Jaffe, Schmalfuss, Billroth and Menzel with 602 other cases collected by himself. The following table of his figures shows the preponderance of lesions of the vertebræ:

	Per cent.		Per cent.
Spine	23.2	Sternum, clavicle and ribs	5.2
Knee-joint	16.5	Pelvis	3.5
Hip-joint	14.6	Femur, tibia and fibula	3.5
Tarsus and ankle	14.4	Shoulder	1.5
Elbow joint	6.3	Scapula, ulna and radius	1.0
Wrist and hand	6.0	Humerus	0.8
Skull and face	5.5	Patella	0.1

NORMAL ANATOMY OF BONE

An accurate knowledge of the anatomy and histology of normal bone is essential to a proper understanding of its pathology.

Bone is a type of connective tissue impregnated with lime salts, chiefly calcium phosphate.

Bone is classified as *compact* or *cancellous*, according to the amount of interspaces which it contains. Generally speaking, the periphery is compact and the deeper portion cancellous.

The structure of each bone follows definite architectural lines, best seen in any long bone. The greater portion of its length is formed by the *shaft*, at the end of which is the *epiphyseal cartilage*, the portion of the shaft immediately abutting it being known as the *metaphysis*.

Distal to the epiphyseal cartilage, and forming the more or less rounded extremity is the *epiphysis* covered by *articular hyaline cartilage*.

The above arrangement is seen in all long bones at *both* extremities, but the short long bones possess but one epiphysis.

Microscopic Anatomy of Bones.—The framework of bone is composed of *lamellæ* or strands of connective tissue in a calcified ground-substance. The intersection of these lamellæ affords *interspaces* in which is lodged the *marrow*, while scattered through the substance of the lamellæ are the branching *bone-corpuscles* which send branches into the surrounding bone through the capillary channels called *canaliculi*. Larger, tube-like structures, the *Haversian canals*, channel the bone throughout and afford passage to the blood-vessels. These are most numerous in compact bone. Each canal contains an artery and a vein, with a protective covering of connective tissue which contains lymphatic vessels and endosteal cells (osteogenetic).

The arrangement of the lamellæ is of several varieties: (*a*) *concentric* lamellæ surround the Haversian canals; (*b*) periosteal lamellæ run parallel with the periosteum; and (*c*) *intermediate* lamellæ extend between the Haversian and the periosteal lamellæ.

Canals, similar to the Haversian, pierce the periosteum in a vertical direction and carry blood-vessels from the periosteum to the interior of the bone. These are called Volkmann's canals.

The Periosteum.—The periosteum is the tough fibrousvascular sheathing intimately applied to the bone surface. Its outer fibrous layer carries the periosteal blood-vessels, while the inner layer is composed of cellular osteogenetic tissue, endowed with active bone-forming properties. The natural cleavage is between these two layers. The periosteum performs two important functions; by virtue of its blood and lymph supply it carries nutrition to the underlying bone, and by its osteogenetic cells, it increases the thickness of the bone.

At its junction with the epiphyseal cartilage, the periosteum sends one division inward in deep connection with the epiphyseal cartilage, while the main division passes onward to invest the epiphysis. This anatomical detail explains the rarity of infection of the epiphysis or joint cavity by a subperiosteal abscess.

The Articular Cartilage.—The articular end of a bone is surmounted by a cap of hyaline cartilage, which meets, peripherally, the periosteum of the shaft. Articular cartilage is extremely rich in cells which have a typical arrangement, those at the periphery lying with their long axes parallel with the surface, while the deeper cells are arranged in spiral columns, radiating from the head of the bone.

At the junction of articular cartilage and periosteum, the fibers of the latter pass inward between the cells and blend with their ground substance.

The Epiphyseal Cartilage.—The epiphyseal cartilage, lying between the epiphysis distally and the metaphysis proximally, affords the bone its increase in length. The long bones possess two epiphyseal cartilages, the short long bones but one.

Grossly, this structure is recognizable as a thin bluish plate separating the epiphysis from the diaphysis.

Microscopically it is cartilage of the hyaline variety.

This epiphyseal cartilage is divided into two distinct zones. Just beneath the bone of the epiphysis is a clear hyaline zone containing few cells,

while at a lower level and comprising nine-tenths of the whole structure the cartilage is essentially cellular. These cells are actively proliferating and lie in pod-like spaces. Where they contact with the diaphysis they are distributed in irregular masses lying upon the diaphysis. The cells in these irregular masses are large, oval or circular, and possess a distinct membrane and a nucleus with eosinophilic granules.

The superficial layer of the epiphyseal cartilage plays no part in the ossification of bone, this function being performed by the deeper layer, between the cells of which lime salts are deposited, later gaining access to the cell membrane.

The Epiphysis.—In structure this resembles the metaphysis, except that its interstices contain only red marrow.

The Diaphysis.—The shaft, or diaphysis, is filled with yellow marrow except that portion which immediately adjoins the epiphyseal cartilage and contains red marrow.

Bone-marrow.—Bone-marrow is classified according to the character and number of its cellular elements, in three grand divisions, viz.:

1. *Red marrow* in which the blood-forming cells and their derivatives predominate.

2. *Yellow marrow* formed by proliferation of the fatty elements with a corresponding deficiency of cellular constituents.

3. *Embryonic* or *myxomatous marrow*, the result of proliferation of loose, fine connective tissue.

The actual marrow-cells are themselves classified according to the presence or absence of granules and the character of these granules within the protoplasm, viz.:

A. *Non-granular* cells, subdivided into
   (1) Large nongranular basophilic cells.
   (2) Small nonbasophilic cells.

B. *Granular* cells, subdivided, according to the type of granule which the cell contains, as
   (1) Neutrophilic myelocytes (precursors of the polymorphonuclear leukocytes)
   (2) Eosinophilic myelocytes.
   (3) Basophilic myelocytes, including mast-cells.

C. *Precursors* of the *red blood-cells*, nucleated, and denominated according to size.
   (1) Normoblasts.
   (2) Megaloblasts.
   (3) Microblasts.

D. *Fat*-cells, *connective-tissue* cells and *giant*-cells.

PATHOLOGY OF TUBERCULOSIS OF BONE

The Histology and Histogenesis of the Original Tubercle

Tuberculosis of bone is primarily an osteomyelitis. The avenues of approach to the marrow are two, vascular and perivascular, constituting:

1. *Intravascular infection*, where the infectious agent is carried directly by the blood-stream.

2. *Perivascular infection*, extending along the perivascular structures, especially the vessels connecting the interior of bone with the synovial membrane of the neighboring joint.

The completed tubercle is similar in both varieties, but the histology and histogenesis differ in the two.

1. **The Intravascular Tubercle.**—In this variety a vessel becomes occluded by an embolus impregnated with tubercle bacilli. In the course of their development, the bacilli elaborate toxines which produce necrosis of the

perivascular structures. Surrounding this central necrotic area there is developed a ring of mononuclear cells and at its periphery a zone of fat cells undergoing granular changes.

Epithelioid cells next appear as a development of the mononuclear and the connective tissue cells of the part. These intermingle with the mononuclear cells and invade the central necrotic area.

The focus has now the identity of a tuberculous follicle, viz.: an aggregation of epithelioid cells surrounded by a zone of mononuclear cells.

2. **The Perivascular Tubercle.**—The perivascular tubercle of bone nearly always arises from tuberculous synovial membrane in a neighboring joint. The lymphatics are invaded and the development of the tubercle is slower than in the intravascular variety.

The infectious material within the affected lymphatic acts upon the blood-vessel which it accompanies and upon the perivascular tissues.

The *vascular changes* consist of an accumulation of round-cells, all mononuclear and arising from the bone-marrow, about the periphery of the vessel. The vessel-wall becomes relaxed and structureless and its cells lose their nuclear staining properties. The living endothelial cells become swollen, rounded and detached from their bed, coming to lie outside as well as within the lumen. These changes are due to the toxemia resulting from bacterial growth, and eventually produce occlusion of the vessel.

The perivascular changes consist of an area of necrosis about the vessel with a peripheral zone of round-cells. Epithelioid cells appear, invade the part and complete the picture of a typical tuberculous follicle.

3. **Retrogressive Changes in the Original Follicle.**—(*a*) *Giant-cell Formation.*—Giant-cells resulting from a confluence of individual epithelioid cells are formed early in development, and are unique in size and in number of their nuclei.

(*b*) *Reticulation.*—This is probably due to the metamorphosis of individual epithelioid cells into branching myxomatous structures, giving the follicle an open, "woolly" appearance.

(*c*) *Peripheral Fibrosis.*—By changes in the epithelioid cells at the periphery of the follicle they become converted into fibroblasts, eventually encapsulating the follicle with fibrous tissue. This process, with fibrosis of the marrow, illustrates the tendency toward spontaneous cure in bone tuberculosis.

(*d*) *Caseation.*—Caseation results from a combination of toxic activity and defective blood supply. It occurs in all tubercles which have attained any considerable size.

(*e*) *Cystic Degeneration.*—This is a common, but little understood, phenomenon. Disappearance of cells begins in the center and extends toward the periphery. This process is responsible for the porous appearance of certain tuberculous lesions, viz.: tuberculous dactylitis.

(*f*) *Calcification.*—This is rare in bone tuberculosis, but occasionally occurs, originating in the center of the larger giant cells, occasionally involving an entire nodule.

Associated Changes

Coincidently with the enlargement and growth of the original tubercle, which appears as a minute grey point in the marrow, structural changes are taking place in the tissues which collectively compose bone.

These pathological phenomena involve the marrow, the lamellæ, the periosteum and the blood-vessels, and are of exceeding importance, explaining many of the characteristic features of the disease.

1. **Marrow Changes.**—The marrow exhibits the effect of the tuberculous process by a cellular change, antedating a later alteration of its fibrous structure.

(*a*) *Cellular Changes.*—The red background is in sharp contrast to the greyness of the follicle and this redness is indicative of the cellular changes taking place in the marrow.

Microscopically it is a neutrophile leukoblastic reaction, at first of immature cells but later consisting of adult polymorphonuclear neutrophiles.

These cells are highly phagocytic, containing blood-pigment and probably active in destruction of the tubercle bacilli.

After a reactionary period of about five days, the character of the cells changes. The polymorphonuclear neutrophiles diminish in number and are superseded by two varieties of cells, viz.: small lymphocytes and large mononuclear cells. The connective-tissue cells are little altered, but the fat cells diminish. These cellular changes progressively decrease in intensity from the focus of infection.

(*b*) *Fibrous Changes.*—Succeeding the cellular changes, fibrosis of the marrow begins. This is a slow, gradual process, inaugurated by disappearance of the lymphocytes and an increase in fat cells and young connective tissue, the latter coming from two sources, (1) connective-tissue corpuscles among the fat cells and (2) the perivascular connective tissue. As these strands of connective tissue increase in number and density they give the effect of a mosaic. The fat cells become strangulated, atrophied and sometimes disintegrated.

The connective-tissue formation is most marked in the immediate vicinity of the disease focus. The process goes on during activation of the lesion, when the marrow undergoes sclerosis to limit and encapsulate the focus. Fibrosed marrow is yellowish-white in appearance and of very firm consistency.

2. **Lamellar Changes.**—The tuberculous process affects the lamellæ in two ways, viz.: by rarefaction (osteoporosis) and by thickening (osteosclerosis). An individual bone may be affected by one or by both types of change at the same time.

(*a*) *Osteoporosis* is caused by disuse and toxemia and is occasioned by the action of osteoclasts which come to lie alongside the lamellæ and by their action produce excavations in the bone known as Howship's lacunæ; or it may be caused by metaplasia whereby the lime-salts disappear and the fibrous elements remain. These two methods of rarefaction may occur synchronously in the same bone.

(*b*) *Osteosclerosis.*—Increase in thickness of the lamellæ is brought about by the action of osteoblasts, cells derived from the connective tissue, which come to lie along the surface of the lamellæ and there deposit layers of new bone. Osteosclerosis is indicative of a chronic type of bone disease and usually does not appear in tuberculosis.

3. **Periosteal Changes.**—Occasionally an accompaniment of tuberculous disease of the underlying bone is extensive subperiosteal thickening. This is due to the formation of new subperiosteal bone, and its determining cause is increase of vascularity of the part consequent upon the tuberculous process within the bone. This new periosteal bone is of two varieties, *porous* and *dense*.

(*a*) *Porous Periosteal Bone.*—It is well known that in the deep layers of healthy periosteum osteoclasts as well as osteoblasts exist in a quiescent state. Possibly under the stimulus of increased vascularity coincident with tuberculous infection, the osteoclasts are activated to produce lacunæ

(Howship's) in the bone surface. After rendering this surface roughened, the osteoclasts cease their activity, and a new thin layer of bone is deposited by the osteoblasts. This deposit is made in successive layers which form, not a smooth surface but an uneven one due to multiple conical projections. In the depressions between these new bony ridges lie granulation tissue and blood-vessels. Connecting the summits of these spines or ridges are arches, formed in successive series, and it is to these arches that the porosity of the new bone is due.

(*b*) *Dense Periosteal Bone.*—The primary stages in the development of dense new periosteal bone are similar to those observed in the production of the porous variety. The important difference, however, is the absence of arch-development and hence a greater condensation of bone results. This is the type of new bone occurring in the neighborhood of joints where, if the more prolific porous variety were formed, limitation of movement might ensue.

4. **Changes in the Blood-vessels.**—The characteristic pathological change in the blood-vessels is endarteritis obliterans. Although most marked in the smaller vessels the process occurs occasionally in the primary divisions of the nutrient artery. The inflammatory process is due to the circulation of tuberculous toxin within the vessel. Disturbances of nutrition naturally follow this obliteration, which, in many vessels, becomes total occlusion, and fibrosis of the marrow is dependent in great part upon these changes.

Gross Pathologic Bone Lesions

According to Fraser, four different macroscopic varieties of lesion may be recognized, each possessing its peculiar characteristics, viz.:

1. The encysted tuberculous lesion.
2. The infiltrating tuberculous lesion.
3. The atrophic tuberculous lesion.
4. The hypertrophic tuberculous lesion.

1. **The Encysted Tuberculous Lesion.**—When a tuberculous bone focus becomes circumscribed and shut off from the rest of the bone it is known as an encysted tubercle. This type is the commonest of osseous tuberculous lesions and is the most chronic.

Macroscopic Appearance.—In size the lesion varies from that of a pea to that of a walnut. The center is composed of a jelly-like substance with opaque grey foci scattered through it. Caseation of this central mass later takes place, leaving an encapsulating shell of the original gelatinous matter. Peripherally is a zone of pinkish-white substance merging with the marrow, the latter being congested and in sharp contrast to the encysted focus. The center, when old, becomes semifluid by retrogressive changes, giving it a cystic appearance.

Microscopically this lesion has as its progenitor a loose reticular tuberculous follicle, which appears as a grey pin-point focus in a setting of red marrow. Its ground-work is composed of branching connective-tissue cells, their interstices filled with epithelioid and mononuclear cells and often giant-cells.

Rarefaction of lamellæ is accomplished by osteoclasts. If absorption is deficient, lamellar necrosis occurs resulting in the small sequestra known as "bone sand." Central caseation occurs but is confined to the tubercle by a limiting band of connective tissue, recognizable in the gross specimen as a pink limiting structure. The surrounding marrow is very little affected.

2. **The Infiltrating Tuberculous Lesion.**—This lesion is essentially an acute process.

Gross Appearances.—The arrangement of the constituents of this lesion is in zones. The central focus is pale yellow and friable. This portion is made up of rarefied bony frame-work, interspersed with caseous detritus. Immediately surrounding this central mass is an area of grey transparent tissue composed of tuberculous granulation tissue which has not as yet become caseous, while more peripherally is the outer red zone of congested marrow.

Microscopically the initial stage of this process is a coalition of groups of epithelioid cells in the marrow. Masses of mononuclear and epithelioid cells crowd the interlamellar spaces. A noteworthy feature is the paucity of connective tissue. The blood supply is deficient, hence caseation occurs early. The caseous areas are at first discrete, then coalesce, producing the yellow appearance of the central portion. By the action of osteoclasts rarefaction of the lamellæ begins, but as a result of toxic action and a deficient blood supply, the process of absorption is suspended and death of the lamellæ ensues with consequent sequestration. There may be several isolated sequestra in an infiltrating tuberculous lesion.

If the infection is very rapid necrosis occurs with no absorption of bone and large composite sequestra of lamellar areas are the result. The surrounding cellular reaction is peculiar, polymorphonuclear leukocytes predominating to the exclusion of lymphocytes and mononuclears. In this the process resembles an acute infection and has suggested the possibility of mixed infection. There is occasionally an attempt at fibrous limitation of the process on the part of the tissues adjoining. During the elaboration of the infiltrating process the periosteum becomes activated and deposits new bone in a manner already described. There is always a local or generalized congestion of the periosteum.

The characteristic special features of infiltrating osseous tuberculosis then, are: (*a*) its origin in a dense mass of epithelioid cells; (*b*) early occlusion of its blood-vessels by sudden thrombosis and destruction of their endothelium; (*c*) early and rapidly spreading caseation; (*d*) necrosis and sequestration before rarefaction is complete; (*e*) failure of the tissues to localize the process; and (*f*) the characteristic spreading and infiltrating character of the lesion.

Spina Ventosa.—This is a variety of infiltrating tuberculosis affecting the diaphysis of long bones, but chiefly seen in the shorter long bones of the hands and feet, as "dactylitis." The medulla of the shaft becomes distended and bulbous with new and diseased material. Sinus formation is common.

The disease affects also the smaller bones of carpus and tarsus and the bodies of the vertebræ. Of the flat bones, the ribs are most often affected.

3. **The Atrophic Tuberculous Lesion.**—In this type of osseous tuberculosis atrophy and wasting of the bony lamellæ is the dominant characteristic.

Some authors classify "*caries carnosa*" and "*caries sicca*" as independent pathological entities, but it is believed that they represent merely gradations of one process and are regarded as forms of atrophic tuberculosis.

Gross Specimen.—Primary involvement of the metaphysis is characteristic of this lesion. An atrophic tuberculous bone is lighter than normal. Its surface affords on pressure a peculiar "crinkling" effect. The bone is uniformly and diffusely enlarged in the region of the disease but smaller in all its diameters elsewhere. Periosteal activity is moderate, only a thin layer of new bone being formed. Transverse section through the diseased area shows the interior occupied by soft granulation tissue of a flesh color inter-

spersed between the lamellæ, giving the structure a spongy appearance. The articular cartilage may be encroached upon but is never invaded.

Microscopic Appearances.—The marrow of the metaphysis is the first structure affected in this lesion. The connective tissue increases at the expense of the fatty elements of the marrow, to produce a granulation tissue of a myxomatous type, characterized by great vascularity, in which there is a tendency to cystic degeneration. Scattered throughout this mass of tissue may be seen tuberculous follicles, giving the section a reticulated appearance. Fibrosis of the granulation tissue gradually takes place.

Secondary to the marrow changes the lamellæ undergo rapid absorption, due to the action of osteoclasts. This process begins in the center of the bone and extends peripherally to the shaft, giving the structure extreme porosity.

Coincident with these changes in the interior of the bone, the periosteum may be suddenly activated to the formation of highly vascular, cancellous new bone. But synchronously with its formation, absorption of this new bone usually takes place, leaving a mass of granulation tissue between the shaft and the outer sheath of periosteal new bone, so that although the circumference of the affected bone is increased its quality is highly defective.

4. **The Hypertrophic Tuberculous Lesion.**—The characteristic feature of this lesion is the great thickening of the bony lamellæ. The process always attacks the metaphyseal portion of a long bone. Its occurrence, however, is rare.

Gross Specimen.—The predominating change is a diffuse thickening of the metaphysis from its point of origin at the junction of epiphyseal cartilage and diaphysis to the center of the shaft. The periosteum can be easily detached. There is noticeable increase of weight in the affected bone which, on section is dense and firm in texture. The increase in size and weight is due mainly to hyperostosis from endosteal newgrowth of bone. The central portion of the diaphysis appears to have undergone absorption and its lamellæ are replaced by a grey, semi-fluid material in the center of which is usually a long dense sequestrum.

Microscopic changes are to be observed in the blood-vessels, lamellæ, marrow and periosteum.

The determining factor in producing the features peculiar to this type of lesion is unquestionably vascular. An unorganized effusion surrounds the large branches of the nutrient vessels, which also exhibit endarteritis. The effusion rapidly becomes organized into granulation tissue and the endarteritis becomes occluding and finally obliterates the vessel.

Those lamellæ lying nearest their obliterated blood supply undergo absorption and are replaced by tissue of a fibromyxomatous nature, while those most peripherally situated become greatly thickened, to form a dense bone.

Central sequestration occurs by repeated alternations of absorption and redeposit of bone until the mass is densely sclerosed. Cross-section of such a hypertrophic tuberculous bone shows a dense peripheral shaft and a zone of soft granulation tissue interposed between it and the central sequestrum.

The bone-marrow undergoes fibrous degeneration, while throughout its substance are disseminated tuberculous follicles.

The periosteum when affected becomes activated late in the process and forms only a thin layer of new bone.

The essential features, then, in the production of a hypertrophic tuberculous bone lesion are the initial endarteritis dependent upon the circulation

in the vessel of a tuberculous toxin; consequent disturbance of nutrition which results in absorption of the bony lamellæ surrounding the obliterated vessel and their replacement by granulation tissue; and hyperostosis and sclerosis of the peripheral lamellæ due to the irritation caused by the central changes.

Tuberculous Sequestra

The formation of sequestra is practically the rule in the process of development of bone tuberculosis. Three different varieties are commonly recognized—(*a*) minute sequestra (bone-sand); (*b*) rarefied sequestra; and more rarely (*c*) sclerosed sequestra.

(*a*) **Bone-sand.**—The minute sequestra, commonly termed "bone-sand," are by far the commonest variety. They are usually present in the encysted and infiltrating types of osseous tuberculosis, and may be identified as small irregular particles of bone disseminated in the tuberculous tissue. Their formation occurs toward the end of the process of absorption of bony lamellæ when disintegration is almost complete, the suspension of the process following rapidly after obstruction of the circulation. Aside from their varying minute size and shape, these particles of "bone-sand" usually possess serrated edges and unusually large lacunæ. They present the characteristic staining peculiarity of dead bone in their rejection of the acid dyes and their affinity for basic stains.

(*b*) **Rarefied Sequestra.**—This variety is usually met in acute infiltrating tuberculous bone disease in which the process spreads rapidly and involves large areas of bone lamellæ. On account of this rapidity of invasion, absorption of bone proceeds to a limited extent only before necrosis of lamellar bone occurs en masse, and the area of necrotic bone, at first attached to the living structure by a zone of granulation tissue, becomes isolated and constitutes a sequestrum.

(*c*) **Sclerosed Sequestra.**—Density and eburnation characterize this form and prompted Ollier to give it the name "séquestre dur." It is the type of sequestrum found in hypertrophic tuberculous disease of bone. Its formation is consequent upon a deposit of new bone on portions of lamellar bone undergoing absorption or upon a sequestrum already formed. The essential factor producing the characteristic density of structure of this type of sequestrum is a process of alternating deposit of new bone, its absorption and reposition; constant repetition of this phenomenon results in an exceedingly solid, dense sequestrum.

THE FATE OF A TUBERCULOUS BONE LESION

The ultimate natural history of a given osseous tuberculous lesion is in one of two directions, viz.:

1. **Localization.**—As best exemplified by the encysted bony tubercle, a lesion may remain confined to the interior of a bone, the only anatomical evidence of its existence being a more or less marked thickening of the affected bone.

2. **Extension.**—Extension may occur in several ways, viz.:

Abscess Formation.—This occurs by perforation of the periosteum, the tuberculous material being distributed in one of two ways, viz.:

(*a*) *Subperiosteal "Cold Abscess."*—Confined to the immediate vicinity of the original focus; or more commonly

(*b*) *Subcutaneous "Cold Abscess."*—The tuberculous material makes its way to a point beneath the skin, either that overlying the bone focus, or as

frequently happens, gravitating to a point often far removed from the primary focus.

Nature of a "Cold Abscess," or Ichor Pocket.—The term "*abscess*" in this connection is a misnomer. An ordinary abscess is a circumscribed collection of pus. On the other hand, the tuberculous material with which we are here concerned, contains *no pus*, is *primarily sterile* and consists of a *circumscribed collection of tuberculous detritus from the disintegration of bone and soft tissue, plus the exudate from tuberculous granulation tissue*, and to describe it H. L. Taylor has substituted the term "*ichor pocket*" for the inappropriate word abscess. Infection and the resulting conversion of this sterile ichor pocket into a true abscess is an accident only and usually results from its



FIG. 4.—Shows pockets and sinuses mapped out with bismuth-vaselin paste. The patient, a child of six, had a pocket (abscess) over the hip; the proper diagnosis of tuberculosis of the sacrum was not made until this skiagram was taken. After five or six injections, the discharge had nearly ceased. (Hospital for the Ruptured and Crippled.) (Taylor.)

unfortunately becoming connected with the exterior, either by ill-advised operations (the usual event) or by other means. Diffuse extension of an ichor pocket is an infiltration of the tissue under the influence of (1) gravity, aided by (2) muscular activity and (3) the direction of fascial planes, the thin watery ichor infiltrating in all directions and as a rule giving rise to no symptoms (Fig. 4).

(*c*) *Diffuse tuberculous diaphysitis* may follow rapid dissemination of the infection.

(*d*) Taking a course through the epiphyseal cartilage, the process may involve the *epiphysis*, or by still further extension through the articular cartilage, *tuberculous arthritis* may ensue.

PROCESS OF REPAIR IN BONE TUBERCULOSIS

The striking feature of the process of repair of a tuberculous bone lesion is that the phenomenon is *accomplished almost entirely by the formation of fibrous connective tissue in which the regeneration of bone takes place only to a very limited extent* if at all, except in the very latest stages. This is a most significant event and of vast therapeutic importance as will later be shown, especially with reference to tuberculous spondylitis and is thus one of the principal indications for the insertion of the bone-graft. Spontaneous healing frequently takes place. In the healing process every tissue in the neighborhood contributes to consummate the fibrosis. The stroma of the marrow increases at the expense of its cellular elements. The perivascular connective tissue proliferates and the lamellæ become sclerosed. The general tendency of this connective tissue is to contract, with a corresponding increase of density. In the older healed lesions calcification may occur. At the outer limits of this fibrous mass a rim of thickened bone may be found, while the healthy lamellæ in its immediate neighborhood exhibit a varying degree of hyperostosis. The tendency of connective scar tissue to contract frequently results in anatomical deformities.

LOCALIZATION OF THE BONE LESION

Assuming the hematogenous origin of osseous tuberculosis, an embolus of tuberculous material finds its localization influenced by several factors, chief of which is the distribution of the nutrient vessels.

Bone is infected by tuberculous disease in one of two localities; either in its shaft (rarely when not complicated by secondary infection) or in one or both of its extremities, in the neighborhood of a joint.

In tuberculous disease of the shaft of a long bone, a short long bone or a short bone, the primary focus is nearly always at or near the central point of the bone. This point of election is influenced by the anatomical arrangement of the nutrient artery which bifurcates into its primary divisions soon after piercing the shaft. After the manner of arteriosclerosis, development of the tuberculous process is favored by a preliminary tuberculous endarteritis, facilitating the arrest of tuberculous matter and the production of tuberculous osteomyelitis.

When the infectious material finds its way to the extremity of a bone, its avenues of approach are many. The blood supply of epiphysis and metaphysis is profuse and anastomosis exceedingly generous. In addition to the vascular arrangement, the factors which chiefly determine the location of a tuberculous embolus in the extremity of a bone are the point of reflection of the synovial membrane, and the vessels piercing the bone at that point. If this reflection occurs at the epiphysis, the latter will nearly always be the region involved; if the synovia is reflected on the other side of the epiphyseal cartilage, the metaphysis will harbor the tuberculous focus. Although much discussion has taken place as to the relative importance of these factors, it is unquestionable that in different bones, different individual portions are primarily involved, viz.: in the femur, its lower end usually suffers tuberculous epiphysitis, while metaphysitis is the rule in its upper extremity.

Although Stiles and Fraser of Edinburgh have found involvement of the diaphyses of the long bones to be frequent, the experience of observers in the United States, Germany, and elsewhere is that diaphyseal tuberculosis of the long bones is clinically rare.

THE NORMAL ANATOMY OF JOINTS

A joint or articulation is the aggregation of structures forming the connection between contiguous parts of the skeleton.

Because of their vast importance in orthopedic surgery and because their proper comprehension is necessary to a complete understanding of pathological conditions, considerable space will be devoted to a consideration of normal joints.

An individual joint exhibits articular surfaces, ligaments and synovial membrane.

1. **Articular Surfaces.**—The contiguous surfaces of bone are covered either by hyaline cartilage, white fibrocartilage or connective tissue.

(*a*) *Hyaline cartilage* occurs on the freely movable articular ends of bone.

(*b*) *White fibrocartilage* appears as

Connecting fibrocartilage (vertebræ and symphysis pubis).

Interarticular fibrocartilage (temporomandibular and sternoclavicular joints, and in the menisci in the knee-joint).

Marginal fibrocartilage (in the shoulder- and hip-joints where it deepens the sockets).

(*c*) *Connective tissue* exists between the bones of the skull as suture membrane.

2. **Ligaments** of dense white fibrous connective tissue in the form of tough bands extending from and continuous with the periosteum, lash the bones together. Re-enforced by accessory bands from the intermuscular septa, these ligaments constitute the *capsule* of the joint.

3. **Synovial membrane** lines the deep surface of the capsule and extends to, but not over, the articular cartilage. In structure it is really a tube open at both ends (where it is attached to the articular cartilage) and is made up of loose connective tissue carrying blood-vessels and a variable amount of fat. It is lined by endothelial cells resting on a basement membrane of connective tissue. Folds or fringes of the synovial membrane occasionally project into the joint cavity and sometimes fill the interstices between the bones. It secretes a glassy fluid, "*synovia*," which lubricates the joint. The synovial membrane sometimes communicates with bursæ and vaginal synovial membranes in the neighborhood of joints.

Kinds of Joints.—*A. Synarthrosis.*—This is the primary form of articulation and constitutes immovable joints, viz.:

1. Those in which only a thin layer of fibrous tissue, continuous with the periosteum, separates the contiguous bones (as in the sutures between the bones of the head).

2. Those in which bone and cartilage are directly united (as the first rib and the sternum).

3. Synchondrosis, a temporary form of joint, in which the thin layer of cartilage between the bone usually ossifies before adult life (as between epiphysis and shaft of a long bone).

B. Amphiarthrosis, applied to joints where slight movement is possible. These include

1. *Symphysis* where the apposed surfaces are united by an interposed plate of white fibrocartilage (intervertebral disks, pubic symphysis).

2. *Syndesmosis*, where an interosseous ligament is interpolated between two bones, as the lower tibiofibular articulation.

C. Diarthrosis, applied to more freely movable joints containing synovial cavities. The following varieties are distinguished:

1. *Arthrodia.*—Limited gliding motion. Examples; carpus, tarsus, articular processes of vertebræ.

2. *Ginglymus.*—Hinge movement. Flexion and extension on one axis. Examples: elbow, ankle.

3. *Condyloid Joints.*—Spheroidal surfaces. Movements of abduction, adduction and circumduction, flexion and extension. Examples: metacarpo- and metatarso-phalangeal articulations.

4. *Saddle Joints.*—Same motions as condyloid joints. Apposed surfaces reciprocally saddle-shaped. Example: carpo-metacarpal joint of thumb.

5. *Ball-and-socket Joints* (Enarthrosis).—Most movable of all joints. Motion possible in every direction. Examples: shoulder- and hip-joints.

6. *Trochoides* (Diarthrosis Rotatoria, Lateral Ginglymus or Pivot Joint). A joint between a pivot and a ring. Only movement is rotation. Examples: radio-ulnar and atlanto-axial articulations.

Kinds of Movement.—1. *Rotation.*—Movement about a longitudinal axis, often its own.

2. *Angular Movement.*—Decreases the angle between two bones. Several varieties of angular movement can be demonstrated, viz.:

(*a*) Flexion, decreasing the angle.

(*b*) Extension, increasing the angle.

(*c*) Abduction.

(*d*) Adduction.

(When motion takes place, from or toward the median plane of the body, middle finger of the hand or the second toe of the foot, it is called abduction and adduction respectively).

3. *Circumduction.*—Combination of the four angular movements. The moving bone describes a cone-like figure, with the apex at the joint, the base at the distal end of the bone.

4. *Gliding.*—A simple sliding movement without marked angular or rotatory movement.

PATHOLOGY OF JOINT TUBERCULOSIS

Much discussion has been provoked by the question of origin of tuberculous disease of the joints, as to whether it is an extension of an osseous tuberculosis from a neighboring bone or is primarily a synovitis. *Volkmann* believed that in children it began almost without exception in the epiphyses. *Nichols* stated that in 120 specimens of joints he saw none in which "if all the bones were sawed across in thin layers one or more bone foci were not found." *Krause*, on the other hand, states that at operation 23 per cent. of his series were primarily synovial. *Sir Watson Cheyne* believes primary synovial disease to be common. *Ely* contends that synovial membrane and red bone marrow are the only tissues primarily affected.

Whatever the location of the primary tubercle may be, tuberculous disease of the joint involves, sooner or later, all its component parts (synovial membrane, articular cartilages, underlying bone, blood-vessels, ligaments and soft parts).

A. **Changes in Individual Structures of the Joints.**—1. *Synovial Membrane.*—The endothelium becomes thickened and velvety, due to (*a*) an admixture of cells resembling epithelioid cells, (*b*) giant cells, (*c*) gelatinous degeneration and swelling of the connective-tissue cells, and (*d*) increase in the amount of subendothelial fat.

2. *Cartilage.*—(*a*) *Superficial Changes.*—The articular surface undergoes fibrillation and conversion to fibrous tissue. Its substance becomes infiltrated with tuberculous granulations, a pannus of which spreads over its

surface and is derived from the surrounding synovial membrane. The cartilage is congested, opaque and pitted.

(*b*) *Deep Involvement.*—An infiltration of tuberculous granulation tissue also occurs between the articular cartilage and the bone. This constitutes a thick zone and may undermine the entire cartilage, eventually resulting in separation of the cartilage in flakes or en masse. Another pathological change is the presence of numerous flask-like areas in the cartilage filled with young fibrous tissue and connecting with the cartilage surface above and the bone beneath. The cartilage rarely disintegrates and many times acts as a foreign body and a barrier to union of the bony elements of the joint which would be a distinct aid in healing the tuberculous lesion.

3. *Bone Changes.*—The marrow changes from red to yellow and also becomes altered in structure, its connective tissue becoming converted into fibromyxomatous tissue. The marrow later changes from yellow to a grey gelatinous character, due to the presence of this fibro-myxomatous tissue.

4. *Vascular Changes.*—Endarteritis takes place in the subsynovial vessels, followed by peri-arteritis. These changes enhance fibrosis of the surrounding tissues.

5. *Ligamentous Changes.*—The joint ligaments degenerate, becoming swollen and gelatinous from an increase in the deposit of fat and the accumulation in the interfibrillary spaces of myxomatous material. The ligaments are eventually converted en masse into a hybrid cicatrix. Occasionally osseous deposit takes place in this mass.

6. *Soft Parts.*—The degeneration spreads to the peri-articular soft parts, muscles, tendon sheaths, and skin, which become pale, swollen and edematous, and fused into a conglomerate mass, described as "*white swelling.*" There may be actual infection of this mass with tuberculosis. According to Legg (Am. J. Orth. Surg., 1908–09, vi, 84–90), gelatinous degeneration occurs in the intermuscular structures about the joint, with muscular atrophy and ascending degeneration of the surrounding nerves.

B. **The Gross Varieties of Tuberculous Joints.**—The classification of the gross pathological varieties is based on the typical appearance of the synovial membrane in each, as follows:

(*a*) Acute miliary tuberculous synovitis.
(*b*) Chronic tuberculous synovitis.
(*c*) Fungating or granulating tuberculous synovitis.
(*d*) Fibrous tuberculous synovitis.
(*e*) Arborescent tuberculous synovitis.
(*f*) Caries sicca.

(*a*) *Acute Miliary Tuberculous Synovitis.*—This is the most acute and the rarest form, and is of hematogenous origin. The joint contains fluid, at first serous, but later purulent. The synovial membrane is congested and the endothelium desquamated. The synovial lining is studded with opaque, yellow, caseating foci, millet-seed in size, each surrounded by a red zone of congestion. The articular cartilages show a superficial deposit of fibrin and the ligaments and soft parts are swollen and edematous.

(*b*) *Chronic Tuberculous Synovitis.*—The joint contains an excess of clear fluid. The synovial membrane is thick, gelatinous, firm, pale and its subserous fat is increased in quantity. Through the synovial membrane are disseminated minute opacities representing early tubercles. The characteristic of this chronic form is the nodular, wart-like appearance of the serosa due to bulging nodules caused by the contraction of connective tissue. The deeper layers of connective tissue become fibromyxomatous and this degenerative change extends to the ligaments and peri-articular soft parts, producing the "white swelling."

(*c*) *Fungating* or *Granulating Tuberculous Synovitis.*—The characteristic feature of this variety is the conversion of the synovial membrane into granulation tissue, giving it a red, soft, spongy appearance, with a dissemination of opaque yellow points, representing tubercles. Subchondral inflammation causes exfoliation of the articular cartilages. There is an excess of fluid which is sometimes semipurulent and blood-stained. The peri-articular structures are involved in the usual "white swelling."

(*d*) *Fibrous Tuberculous Synovitis.*—Conversion of the entire synovial membrane into dense fibrous tissue is the typical change in this variety. The surface is pale and roughened, resembling fresh pig-skin. There is an excess of fluid present. There are frequently found smooth, rounded, flat or spherical foreign bodies occasionally attached by pedicles to the synovial membrane; these are the so-called "*rice bodies.*"

(*e*) *Arborescent Tuberculous Synovitis.*—This form is characterized by branching arborescent tags, which, if a large amount of fatty tissue is present, assume a villous appearance, yellow to deep red in color, and constitute the "*lipoma arborescens.*"

(*f*) *Caries Sicca* (Dry Caries).—All the preceding forms of tuberculous synovitis are accompanied by an excess of synovial fluid. In this variety fluid is absent. It is encountered chiefly in the shoulder-joint.

Clinical Varieties of Joint Tuberculosis.—Tuberculous synovitis may be divided clinically into five groups, viz., (according to Fraser):

1. Tuberculous synovitis with effusion.
2. Pyarthrosis.
3. Tumor albus (white swelling).
4. Abscess and sinus formation.
5. Disorganized tuberculous joint.

1. *Tuberculous Synovitis with Effusion.*—The predominating feature of this type is the accumulation of fluid (tuberculous hydrops) and is characteristic of chronicity.

2. *Pyarthrosis.*—Distention of the joint with true pus indicates a secondary infection of the tuberculous ichor, consequent upon sudden invasion of the joint by a bone focus, and infection.

3. *Tumor Albus* (white swelling).—Conglomeration of the periarticular and synovial structures into a more or less fusiform swelling characterizes this variety.

4. *Abscess and Sinus Formation.*—The joint may be characterized by the presence of an ichor pocket in the peri-articular tissues communicating with the exterior by multiple fistulæ.

5. *Disorganized Joint.*—The apposed bone surfaces may be denuded of their cartilages and the cancellous tissue of the contiguous bones destroyed to a greater or lesser extent.

Process of Healing in Joint Tuberculosis.—Whatever the degree or extent of the pathological process, natural healing involves the formation of fibrous tissue, resulting in dense fibrous adhesions between the apposed surfaces and occasioning fibrous ankylosis. Occasionally, if the osseous structures have been involved in the disease, regeneration of bone occurs to a slight degree.

CLINICAL FEATURES OF BONE AND JOINT TUBERCULOSIS

As compared with bone disease, tuberculosis of the joints has a far greater array of clinical signs and symptoms, because the large apposed surfaces, subjected to constant friction, present exaggeration of all symptoms.

The clinical picture will be considered as to (*A*) *General features* and (*B*) *Local features:*

A. **General Features.**—The general features of the disease are manifested in the same manner in osseous and joint tuberculosis, and are dependent upon three elements, viz.: (1) *dissemination;* (2) *toxemia* and, (3) *secondary infection.*

1. *Dissemination.*—Dissemination of the disease is uncommon. When it occurs, *glandular involvement* is usually the first indication and tuberculous *meningitis* a terminal event.

2. *Toxemia.*—The circulation of tuberculous toxine accounts for the following common symptoms: *Loss of weight; debility; indigestion* and *fever.*

3. *Secondary Infection.*—Dependent upon the formation of sinuses and their early secondary infection are the following: The so-called "*hectic fever,*" *emaciation, sweats, diarrhea* and the *amyloidosis* (waxy or lardaceous disease of the viscera).

B. **Local Features.**—Osseous tuberculosis (rare in this country) is characterized by very few physical signs, while those of joint tuberculosis are numerous.

SYMPTOMS AND SIGNS

Symptoms and Signs of Bone Tuberculosis

Considered in the usual order of their appearance, they are (1) *local thickening;* (2) *pain;* (3) *muscular wasting,* and (4) *abscess formation.*

1. **Thickening.**—This is usually the first sign and the most characteristic feature of bone tuberculosis. It is caused by the production of new subperiosteal bone. The thickening proceeds slowly and steadily until the circumference of the affected bone is often double the normal. It can at first be indented, but later becomes dense and unyielding. It is usually confined to the vicinity of the lesion, but may eventually involve the entire circumference of the bone. There is slight tenderness to deep pressure, but the skin is not reddened, nor is the surface temperature elevated.

2. **Pain.**—This is due to pressure on the terminal nerve endings and is usually slight and frequently absent. When it does occur it is consequent upon one or more of the following conditions: (*a*) *subperiosteal effusion;* (*b*) *increased intra-osseous tension* (as in tuberculous osteomyelitis); or it is due to (*c*) *irritation* of the *nerve-trunks* (referred pain) from changes in bone structure, granulation tissue or an ichor pocket, and follows the distribution of the nerve affected.

3. **Muscular Wasting.**—Muscular atrophy is due to *disuse* and possibly to a questionable extent to the influence of reflex irritation.

4. **Abscess** (Ichor Pocket).—Under the pressure of the caseous focus, the attenuated necrotic periosteum yields and the ichor pocket becomes subcutaneous, where it may remain localized or may wander under the influence of gravity, muscular action, position, arrangement of fascial planes, etc., to a distant point, and in either event may finally communicate with the exterior by sinus formation.

Symptoms and Signs of Joint Tuberculosis

The common clinical manifestations of joint tuberculosis in the order of their usual appearance are:

1. Stiffness.
2. Limitation of motion.
3. Alteration of position.
4. Pain.
5. Night cries.
6. Tenderness and elevation of surface temperature.
7. Muscular rigidity and muscle spasm.
8. Swelling.
9. Muscular atrophy.
10. Alteration in bony outlines.
11. Abscess formation.

1. **Stiffness.**—Stiffness is due to a diminution in the amount of synovial fluid, to tissue infiltration, muscle spasm or disorganization of the joint. It is most noticeable in the morning on arising but exercise of the joint stimulates the secretion of synovia with consequent decrease of the stiffness later in the day. The amount of fluid, however, never reaches normal.

2. **Limitation of Movement.**—Alteration in use of the joint is manifested in various ways; in the lower extremity by a limp, and in the upper extremity by impairment of some of the finer and more complicated movements. It is primarily due to an early degree of muscular irritability and spasm.

3. **Alteration in Position of the Joint.**—At first this is purposeful—an attempt to secure less joint tension and the widest possible separation of the joint surfaces. As *flexion* best secures this, it is the usual position assumed. At a later period, however, alteration in position is due to other causes, viz.: (*a*) inequality of muscle-pull in state of spasm; *increased amount of fluid*, forcing the joint surfaces apart and into an abnormal position. (For instance, the hip automatically becomes flexed, abducted and rotated outward on distention of its capsule); (*b*) *bone destruction* also may be responsible for the altered position of the joint.

4. **Pain.**—The causes of pain vary with the extent of the disease process. It may be due to (*a*) *tension* and *pressure* (thickened membrane, increase of fluid, subchondral infiltration) or (*b*) *exposure* of the *osseous surfaces* from destruction of the cartilages. Pain varies in degree and is increased by joint movements. It is either local or referred (as in hip disease, to the front and inner side of the knee-joint, following the anterior crural and obturator nerves).

5. **Night Cries.**—These are due to ulceration of the articular cartilages and are produced by relaxation of the muscles in sleep, allowing these ulcerated surfaces to come in contact with or rub against each other, or motion to occur. The consequent distress is manifested sometimes only by restlessness, again the child awakens with a cry, and is surprised to find no cause for its awakening, muscular action having broken the contact of the painful joint surfaces.

6. **Tenderness and Elevation of Surface Temperature.**—Tenderness to pressure may be due to (*a*) *increased* intra-articular *tension*, (*b*) pressure upon a *disorganized* portion of the joint, or (*c*) to irritation of some *periarticular structure* (as an inflamed bursa). It is not a constant phenomenon.

Raised surface temperature is caused by hyperemia incident to the changes within the joint.

7. **Muscular Rigidity and Muscle Spasm.**—Both are protective measures produced reflexly by the disease for the protection of the joint. Actual muscular rigidity varies in degree, often being apparent only on the extremes of normal movement, or being so severe as to simulate ankylosis. Its causes are reflex. It may be elicited by passive movement.

Abnormal muscular contraction may thus be tonic, reflex and constant, when it is called muscular rigidity; or it may be transient, voluntary and elicited only on attempts to touch or move the joint (muscle spasm).

8. **Swelling.**—Swelling of the joint is due to (*a*) *thickened synovia*, (*b*) *effusion*, and occasionally also to (*c*) *osseous thickening*. It is a prominent sign in disease of all the superficial joints. When due to thickened synovia, it follows its anatomical distribution, but is most marked at the periphery of the joint. When due to fluid the distention is uniform and fluctuation is present. It must be borne in mind that muscular atrophy accentuates the size of the joint, and this may cause misconception as to the amount of actual swelling present.

The superimposed skin is often anemic and its superficial veins dilated and prominent.

9. **Muscular Wasting.**—This is an early and constant accompaniment of tuberculous joint disease. It is due partly to the toxemia of the disease and partly to reflex stimulation from within the joint. The muscular reflexes are diminished. Atrophy also affects the adjoining bones which undergo more or less rarefaction and diminution in their actual diameter, thus causing part of the shortening.

10. **Alteration in Bony Outlines.**—Destruction of the joint surfaces alters the bony outline of the joint, causes shortening of the limb and *deformities* of position (viz., abduction or adduction in hip disease). These abnormalities are more marked if in addition to the joint involvement a bone focus exists.

11. **Abscess Formation.**—An abscess may appear about the joint in one of three locations (*a*) *intra-articular* (within the synovial cavity); (*b*) *periarticular* (outside the capsule); or (*c*) *superficial* (incidental to the edema and degeneration of the tumor albus, the amalgamated muscles, ligaments, etc.) and having no relation with the joint itself.

DIAGNOSIS

Diagnosis of Bone Tuberculosis

Actual Diagnosis.—Significant facts in the family history, personal history, physical examination and the results of clinical tests, leading to a diagnosis of bone tuberculosis are as follows:

1. *Family History.*—In the family history, *inherited predisposition* is less significant than *direct contagion*. Fraser (Tuberculosis of Bones and Joints in Children, 1914, page 50) states that as a result of investigation of a series of cases of bone tuberculosis from which the human tubercle bacillus had been isolated, he found that in 71 per cent. of cases the children had been residing with a consumptive.

2. *Age.*—The age of greatest incidence is five to twelve years, the acme at ten years.

3. *Position of the Lesion.*—The ends of the long bones are the favorite sites. Vertebræ are the commonest location, the short bones of the hands and feet the least common.

4. *Symptomatology.*—The most significant symptom is the insidiousness and intermittency of onset.

5. *Physical Signs.*—*Thickening* and *abscess-formation* strongly suggest the presence of tuberculous bone.

6. *X-ray Examination.*—Reasonably conclusive proof is offered by this method. Interpretation of the *x*-ray findings will be discussed in the next section.

7. *Tuberculin Tests.*—A valuable diagnostic aid is the reaction, both local and general, following the exhibition of tuberculin. A test may be positive from an old lesion and thus bear no significance to the lesion in question. All tuberculin tests depend upon the heightened susceptibility of the tuberculous subject to the toxin of the tubercle bacillus, which is indicated in two ways, viz.: (1) *General reaction* (malaise, headache and fever); (2) *local reaction* (increased hyperemia at the point of inoculation). The tuberculin tests in common use are the *ophthalmic*, the *cutaneous* and the *focal* (subcutaneous injection).

(*a*) *Ophthalmic Reaction* (Calmette).—Conjunctivitis produced by the instillation of 1 drop of tuberculin (0.5 per cent. tuberculin prepared

from a precipitate of Koch's old tuberculin by 95 per cent. alcohol, or a standard solution of old tuberculin in 0.5 per cent. phenol). The reaction begins in six hours and is fully developed in twenty-four hours, and lasts several days or weeks. It should never be practised if cornea or conjunctiva are diseased.

(*b*) *Cutaneous Reaction* (von Pirquet).—This consists of vaccination of the skin with tuberculin. The reagent is composed of tuberculin, 1 part, normal saline, 3 parts, containing 25 per cent. carbolic acid.

Two small superficial abrasions (without drawing blood) are made on the prepared upper arm. One abrasion is inoculated, the other remains sterile as a control. The hyperemic reaction is reached in twenty-four hours and may go on to papule formation.

(*c*) *Cutaneous Reaction* (Moro).—The method is the same as in the von Pirquet test, except that the material employed is 5 per cent. old tuberculin in lanolin which is rubbed into the intact skin.

(*d*) *Focal reaction.*—This consists of the injection into any part of the body of a small dose of tuberculin. The reaction is both local (congestion and hyperemia at the site of injection) and general (malaise, headache, fever) if the lesion is tuberculous.

The amount of tuberculin injected varies. A useful standard is 0.1 milligram for children and 0.2 milligram for adults. Repeated injections depreciate the value of the test by enhancing individual susceptibility, so that a healthy person will finally respond to the test.

8. *Opsonic Index.*—The principles underlying the opsonic index and the details of its estimation may be found in works on hematology. Its diagnostic importance in tuberculosis of bones is due to the following facts. (Riviere: Tuberculosis in Infancy and Childhood, Kelynack, 1908, page 283).

1. The index for normal people is found to vary between 0.8 and 1.2 (Bulloch). When the index is persistently below this, if there is a localized infection which may be tuberculous, it probably is tuberculous. When the index remains normal it is not tubercle; when it is high, and especially when it fluctuates from time to time, there is active tuberculosis.

2. The effect of a small dose of tuberculin on the opsonic index is of diagnostic value. In the tuberculous it leads to a negative phase followed by a positive phase. The negative phase is absent in non-tuberculous subjects.

3. When the local lesion contains fluid (abscess) the bacteriotrophic power of the fluid is lowered toward the organism causing the lesion, *i.e.*, the opsonic index of the fluid is found to be lower than that of the patient's blood-serum.

4. The "heated serum test" depends on the fact that the serum of the tuberculous and tuberculinized retains more of its opsonic power after heating to 60° C. for ten minutes than does normal serum. The tuberculo-opsonic determination has little use in clinical application. (From Fraser's Tuberculosis of the Bones and Joints in Children, 1914, page 53.)

9. *Milk History.*—This is an unimportant item in countries like the United States where dairy inspection is enforced. In Scotland and other countries where dairy inspection is lax or does not exist, the question as to the milk supply is important, because in bone tuberculosis bovine infection is a fertile source of the disease. This may account for the fact that in Scotland, according to Fraser's statement, portions of the long bones such as their shafts are frequently affected with tuberculosis whereas in this country, where bovine tuberculosis is not so prevalent, these osseous parts are rarely affected.

Differential Diagnosis.—The following conditions may be confused with bone tuberculosis:

1. Syphilis (periostitis and periosteal nodes, gummata and sclerosing osteitis).
2. Chronic staphylococcal osteomyelitis.
3. Subperiosteal lipoma.
4. Periosteal sarcoma.
5. Central sarcoma.

Disease	Points of resemblance	Points of difference
1. *Syphilis*, periostitis, periosteal nodes, gummata and sclerosing osteitis.	Bony enlargement, with pain. Chronicity.	*History* (congenital or acquired). *Night pain. Middle of shaft. X*-ray. Wassermann, positive. Evidence of syphilis elsewhere.
2. Chronic staphylococcal *osteomyelitis.*	Bony swelling with pain and sinus formation.	Acute onset. Exacerbations and relapses. Frequent hyperpyrexias. Local inflammation, edema and tenderness. Sequestrum formation common. *X*-ray. Tuberculin test may be absent.
3. *Subperiosteal lipoma.*	Subperiosteal enlargement simulating a cold abscess.	Entire absence of bone thickening. Limitation and slowness of the disease. *X*-ray shows bone healthy. Less pain.
4. *Periosteal sarcoma.*	Bony enlargement, connected with the periosteum.	Very rapid growth. Pain severe and persistent. Suppuration entirely absent. *X*-ray usually shows periosteum laminated.
5. *Central sarcoma.*	Central disease of bone, with pain.	Rapidity of growth. Persistence of pain. Uniform swelling. "Egg shell" crackling. *X*-ray. Tuberculin test may be absent.

Diagnosis of Joint Tuberculosis

Actual Diagnosis.—In forming an opinion as to the tuberculous character of the joint malady, (1) the family history, (2) the age, (3) the various tuberculin tests, (4) the opsonic index, and (5) the milk history have the same bearing and importance in the diagnosis of joint tuberculosis as in tuberculous bone lesions.

Symptomatology and Physical Signs.—Three features are unique and almost pathognomonic, viz.: *synovial thickening*, *muscular wasting* and *night pains*.

(*a*) *Synovial Thickening.*—The *uniform outline* of the swelling and the *doughy sensation* to touch are the outstanding characteristics.

(*b*) *Muscular Wasting.*—This is more rapid and extreme than in any other joint disease.

(*c*) *Night Cries.*—The characteristic gradual and intermittent onset and the relief attending extension and immobilization distinguish these night pains from those due to other ulcerative joint lesions.

Other suggestive but less characteristic signs are:

(*d*) *Alterations in Use and Position.*—The striking feature is the very gradual onset, often without the patient's knowledge when limitation began.

(*e*) *Abscess Formation.*—This is distinctive but a diagnosis ought to be made prior to its occurrence.

(*f*) *Muscular Rigidity.*—The important feature is that every individual movement of which the joint is capable is more or less affected.

X-ray Appearances.—In the earliest stage, the frequent absence of characteristic findings is disappointing. The very earliest change in appearance

is indistinctness of the bony outlines within the joint, due to loss of bone salts, thickening and congestion of the synovial membrane. Later, when destruction of the cartilages begins, the picture is still more suggestive, and in the latest stages, identification of the tuberculous process is simple, as evidenced by general bone rarefaction with or without areas of bone proliferation.

Differential Diagnosis.—A tuberculous joint may be confused with the following joint affections.

1. Traumatic synovitis.
2. Infectious synovitis and arthritis.
3. Epiphysitis and osteitis in the neighborhood of the joint.
4. Periarticular bursitis.
5. Syphilitic joint disease.
6. Rheumatoid arthritis or osteoarthritis.
7. Still's disease of the joints.
8. Infantile paralysis.
9. Hysterical joint affections.

Disease	Points of resemblance	Points of difference
1. Traumatic synovitis.	Synovial effusion with resultant thickening of the synovial membrane.	History of a distinct etiological trauma. Attendant tuberculous signs absent. *X*-ray. Course of the lesion.
2. Infectious synovitis and arthritis.	Rapid and abundant effusion into joint.	Sudden onset. Constitutional disturbance. Tends to suppurate. Occurs at earlier age (infancy) than tubercle. *X*-ray. May be focus of infection elsewhere.
3. Epiphysitis and osteitis in neighborhood of the joint.	Joint effusion.	Symptoms acute. Considerable swelling. Continuous hyperpyrexia. *X*-ray. Rapid onset.
4. Periarticular bursitis.	Alterations in use and position of the joint. Swelling.	Absence of characteristic synovial thickening, muscular spasm and wasting and night cries. *X*-ray examination. Swelling limited to area of bursa.
5. Syphilitic joint disease.	Effusion in joint. Chronicity.	Infancy (4th–12th wk.). Other evidences of syphilis. Gummatous synovitis of older children, absence of constitutional disturbance, knee-joints usually, mobility. Wassermann positive. *X*-ray study of various long bones for periostitis.
6. Rheumatoid arthritis or osteoarthritis.	Enlargement of joint. Limitation of motion.	Rare in children. Bony changes. Polyarthritis. *X*-ray. May be a primary focus of infection.
7. Still's disease.	Thickened and pulpy synovial membrane. Stiffened joints. Marked muscular atrophy.	Polyarthritic. Pain and true muscular rigidity less. Associated splenomegaly and lymphadenitis. *X*-ray.
8. Hysterical joint affections.	Joint-sensitiveness, lameness and pain.	Variable intensity. Inconsistency of symptoms with one another. Other hysterical or neurotic stigmata. *X*-ray. Possible elimination of true muscle spasm.

RÖNTGENOLOGY OF TUBERCULOUS BONES AND JOINTS

The subject of röntgenology in general is thoroughly treated in a separate chapter of this book and a knowledge of the proper manner of studying a röntgenogram and the appearance therein of normal bones and joints can be obtained in that chapter.

1. The *X*-ray Appearances of Tuberculous Bones

1. **Central Changes.**—The characteristic change is a *relative translucency* to the *x*-ray—an area of diminished density (tuberculous granulation tissue). Within this light area are dark streaks (lamellæ) of varying degrees of intensity, more pronounced toward the periphery.

Cavity formation is indicated in the *x*-ray negative by a *dense black shadow*, which may be located in the center of a light tuberculous area.

Sequestrum (detached) is indicated by a *lighter area* (relative impermeability to the rays) than the diseased granulation tissue.

2. **Peripheral Changes** (New Subperiosteal Bone).—An early appearance in the plate is a *space* between the periosteum and the underlying bone (new osteogenetic granulation tissue prior to ossification and hence permeable to the rays).

The surface of compact bone in tuberculosis should be *smooth* in contradistinction to the irregular worm-eaten appearance of the thickening in periosteal sarcoma.

3. **Special Types of Bone Tuberculosis** (*a*) *Encysted Tubercle.*—Location, metaphysis. The *x*-ray negative shows a *light area* (tuberculous granulation tissue) within which may appear a *dark shadow* (cavity) or a *lighter, irregular appearance* (*sequestrum*). A *dense dark ring* at the *periphery* indicates the encapsulating fibrous tissue. Beyond this, there is a *broader* and *lighter zone* (condensed lamellæ).

(*b*) *Infiltrating Tubercle.*—A long exposure is necessary to get a satisfactory negative of this condition. An *irregular light area* (diseased tissue) is apparent, and within it *darker spots* (cavities) and *lighter points* (multiple minute sequestra) or a *single light point* (a large composite sequestrum). At the periphery there is no limiting band or condensation of the lamellæ.

(*c*) *Atrophic Tubercle.*—The outline of the bone is enlarged, but it appears like an empty shell. The interior is *clear* (absence of bone) but *scattered* through it are *light streaks* (traces of thin, wasted lamellæ). A *light peripheral zone* indicates new subperiosteal bone. Scattered through the field are *dark areas* (cavities) but *no light points* (sequestra).

(*d*) *Hypertrophic Tubercle.*—Location, the center of the shaft. The striking feature in the plate is a *dark tortuous line* representing the nutrient vessel. This is normally invisible, but on account of endarteritis is here apparent. The center of the bone is occupied by an *oval dark area* (cavity) and in its center a *light area* (sequestrum) stands out like a spot-light. *Thickened light streaks* (surrounding lamellæ) are apparent.

2. The *X*-ray Appearances of Tuberculous Joints

(*a*) **Early Changes.**—The synovial membrane is now visible as a *smoky, indefinite band*, bulging outward the ligaments and muscles and projecting into the interior of the joint.

In the ends of the bones, the cancellous structure is indefinite and rarefied, the *outlines* are *blurred, shadowy* and *indistinct*.

(*b*) **Medium Changes.**—In addition to the smoky outlines of the synovial membrane and the shadowy outlines of the ends of the bones, the cartilages

at this stage appear gouged-out at the periphery, their free surfaces have an irregular appearance and a dark band (subchondral granulation tissue) separates them from the ends of the bones.

(*c*) **Late Changes.**—All traces of the original joint outline are lost. A white, blurred mass is present between the ends of the bones, and the surfaces of the latter are eroded and irregular. A secondary deposit within the bone substance is represented by dark spots in the plate. The articular ends of the bones are widely separated by fluid.



FIG. 5.—Tuberculosis of the spine, complicated by marked amyloid degeneration of the viscera. The mistake made in incising and draining complicating cold abscesses in the early stage of this case, led to sinuses and secondary infection and ultimately amyloidosis.

PROGNOSIS IN BONE AND JOINT TUBERCULOSIS

General Considerations.—The prognosis of bone tuberculosis is influenced by two factors, viz.: (1) The general body resistance to toxemia and bacteremia and (2) local resistance to dissemination by fibrous encapsulation.

As compared with tuberculosis of other tissues, the prognosis of osseous tuberculosis is good, for the following reasons:

(*a*) Bone is difficult to destroy.

(*b*) Its peculiar blood supply and meagre lymphatic distribution minimize the danger of dissemination.

(*c*) The marrow cells are endowed with phagocytic power.

In joint tuberculosis, however, conditions are not so favorable; motion produces irritation, prevents encapsulation and interferes with the process of healing; local resistance is less and there is a greater tendency toward dissemination of toxins and bacteria on account of the freely anastomosing blood-vessels.

Life Prognosis.—This is generally good. Children readily respond to treatment and their powers of resistance and recuperation are great. The dangers to life are:

1. *Age.*—During the first two years of life the prognosis is grave.

2. *Position of the Lesion.*—The spine and skull are the most dangerous sites.

3. *Multiplicity of Lesions.*—Extension of the primary process signifies low vital resistance and is a bad prognostic sign.

4. *Cold Abscess.*—An ichor pocket is a danger signal because of the chance of its becoming secondarily infected and the consequent sepsis leading to amyloid degeneration, septic absorption, etc. (Fig. 5).

5. *Mixed Infection.*—Secondary infection is the most serious complication. It usually follows injudicious surgical interference with an ichor pocket. Chronic sinuses, septicemia, amyloidosis, or invasion of other structures (the meninges most frequently, the lungs rarely) makes the prognosis grave. Occasionally miliary dissemination of the tuberculous process follows.

Local Prognosis.—*Bone Disease.*—The outlook for functional recovery is good on account of the resistant nature of bone and the strong natural tendency to heal. As long as the tuberculous process is limited to the primary bone focus, mobility is usually recovered (except in vertebral caries, where the superimposed body-weight, respiratory motion, etc., cause great deformity and eventually loss of spinal movement unless prompt and absolute fixation is secured).

Joint Disease.—Here the resistance is less, the joint function is usually deranged, and ankylosis with loss of function is common.

TREATMENT OF BONE TUBERCULOSIS

The treatment of bone tuberculosis differs considerably from that of tuberculous joints and will be dealt with separately and under the following headings:

1. Preventive treatment.
2. General treatment.
3. Local conservative treatment.
4. Tuberculin treatment.
5. Operative treatment.

1. Preventive Treatment

Although the prevention of tuberculosis of bone is rarely within the province of the orthopedic surgeon, it must be briefly considered from two viewpoints, viz.: (1) *segregation* and (2) *bovine infection of milk.*

1. **Segregation** of consumptives is of paramount importance because contagion of infants and children, in whom bone tuberculosis is chiefly seen, is unquestionably due, in a considerable number of cases, to their intimate contact with victims of pulmonary tuberculosis. The dangers of this close proximity are the inhalation of their dried tuberculous sputum, from the air or in the act of kissing, or its ingestion with food.

2. **Milk.**—Bovine tuberculosis is readily transmissible through milk. The dangers from this source are not so serious in this country, although rampant in countries, like Scotland, where dairy inspection is not strictly enforced. Sterilization or pasteurization of milk should be uniformly practised where bovine tuberculosis abounds.

2. General Treatment

This embraces the subjects of (1) hygienic home conditions (when local treatment is carried out there); (2) hygienic hospital conditions (for cases undergoing institution treatment); (3) climatic conditions (including a consideration of the relative merits of sea-coast, inland and mountain climates) and heliotherapy; (4) diet and (5) the use of drugs in osseous tuberculosis.

1. **Hygienic Home Conditions.**—If a patient is obliged to take treatment at home, attention should be paid to the questions of (*a*) fresh air, (*b*) clothing and (*c*) the sick-bed.

(*a*) *Fresh Air.*—An out-of-door life, night and day, and in all weather, should be enforced. Protection in severe or inclement weather can always be obtained by the exercise of a little ingenuity.

(*b*) *Clothing.*—This should be neither unduly heavy nor ill fitting. Many patients are literally buried under bedding in the mistaken notion that fresh air *per se* is the cause of "taking cold."

(*c*) *Bed.*—The ideal bed for a recumbent case is a narrow, single hospital bed of wrought iron.

2. **Hygienic Hospital Conditions.**—Although residence in a hospital is ideal and usually necessary during the period of local operative treatment, the patient should be removed as early as possible to the mountains, sea-coast or inland regions where the best climatic conditions suited to his particular case may be obtained and where the important elements of fresh air, nourishing food and heliotherapy enter into his life.

3. **Climatic Conditions.**—Even if a radical change of climate is impracticable, the beneficent effect of a change of air and scene is always apparent, particularly in early cases.

Climate, from a therapeutic standpoint, includes (*a*) sea-coast, (*b*) inland and (*c*) mountain regions.

(*a*) *Inland Climate.*—Its advantages are its dryness and higher temperature. It may be better suited to cases of pulmonary tuberculosis than to those with bone involvement.

(*b*) *Sea-coast.*—This is characterized by its low temperature, moisture and winds, and is ideal for children. It is contraindicated in advanced cases with cachexia and wasting. It is favorable for bone and joint cases.

(*c*) *Mountain Climate.*—The mountain atmosphere is rarefied, slightly humid and of low temperature. Its *rarefaction* is its most important therapeutic attribute. Experiments by German physiologists (Zuntz, Loewy, Müller and Caspari) in 1900 and 1901, showed that rarefaction of the atmosphere at high altitudes caused an increase in the number of red blood corpuscles and the amount of hemoglobin, a stimulation of the hematogenous powers of red marrow and a relatively greater increase in growth. Its only disadvantage is its tendency to excite irritable neurotic subjects. It is very favorable to bone and joint cases.

Heliotherapy.—In this connection attention must be directed to the subject of heliotherapy (literally "sun-cure"). The beneficient effect of direct sunlight on the lesions of so-called "surgical" tuberculosis cannot be gainsaid. It appears to act as a tonic and reconstituent, reduces the pain, forms a microbicidal agent and conduces to sclerogeny. This therapeutic effect is due to the action of *ultra-violet sun-rays* obtained at *high altitudes*.

The most enthusiastic and prominent advocate of heliotherapy is Dr. A. Rollier of Leysin, Switzerland. High up in the Swiss Alps, 4200 feet above sea-level he has established sanatoria for the administration of heliotherapy. In the ten years from 1903–13, 1129 cases of "external tuberculosis" were treated by Rollier (including all varieties of bone and joint tuberculosis), with the following results:

	Per cent.		Per cent.
Cured	84.1	Stationary	3.2
Relieved	10.0	Dead	2.7

Rollier's first care on the reception of a patient is to apply a removable apparatus (which will allow local exposure to the sun), and employ recumbency as a means of immobilization. Then by degrees, and very carefully, to submit the patient to the rays of the sun, allowing him from three to ten days to acclimatize himself. On his arrival he is kept in bed in his room. Ventilators and glass doors are gradually opened. After the three-to-ten-day period his bed is wheeled on to a large gallery adjacent to the bedroom, where the patient stays an hour the first day, two the second, three the third and so on. During this time, temperature, pulse, respiration are recorded regularly and the blood and urine examined.

Clothed in linen or white flannel according to the season and with a screen and wearing smoked or yellow glasses, the patient begins the sun-cure.

Wherever the lesion is localized, the sun-cure is always begun on the lower extremities, thus avoiding pulmonary congestion, cephalalgia, giddiness and an intense focal reaction.

Dr. Rollier thus described, in detail, his method of heliotherapy before the International Congress of Medicine in London in August, 1913:

"The first day only the feet are exposed, at intervals of one hour, five times, and for a period of only five minutes. The next day the legs will be exposed, and the same method followed. The third day, the legs will be exposed as far as the groin. The upper portion, from the knee to the groin will be exposed for five minutes three or four times; the lower portion, from the knee to the ankle, for ten minutes, three or four times, while the feet will be exposed three or four times for ten minutes. The fourth day, the abdomen will be the new segment; the fifth day one will proceed to the insolation of the chest with the same precautions, and covering the region of the heart with a damp cloth.

"If the condition of the patient will allow of it, he will be placed on his stomach and present alternately the front and back of his body to the sun, which increases the total number of exposures to six or eight. Lastly, the sixth or seventh day, we will be able to expose the neck and head, due attention being paid to how he accustoms himself to it, and to pigmentation of the integuments. The preliminary precautions will soon be no longer necessary, and the patient will be able to tolerate the sun for six or eight hours with perfect comfort in winter as in summer.

"The pigmented teguments, over all their surface, take a beautiful bronze tint, varying from copper to chocolate color. We have insisted particularly on the importance of the pigmentation . . . . . which is nearly always proportional to the resistance of the patient. Delay or absence of its appearance permits one to form a prognosis with the utmost certainty . . . . ." A very frequent mistaken impression has been gained that the practice of heliotherapy will permit less vigorous local immobilization and support to the tuberculous joint. This error has led to many grave and unfortunate results.

4. **Diet.**—In all forms of tuberculosis there is usually a continuous loss of weight. This can be counteracted to a considerable extent by a proper diet. Actual "forced feeding" is unwise, in that the enforced lack of exercise induces derangement of the digestion, with anorexia. The ideal diet is one in which fats and carbohydrates predominate, with a considerable quantity of albuminates.

If fever is present a fluid or semisolid diet must be given until the temperature returns to normal.

The staple articles of food for the tuberculous are eggs, milk, cream, butter and fresh (preferably raw) red meat. The milk should be sterilized or pasteurized; its digestibility is aided by the addition to each glassful of two tablespoonfuls of hot water in which have been dissolved six grains of sodium bicarbonate and a pinch of table salt. Cream is more readily assimilated if diluted with hot water. If the patient cannot take the full raw red meat it may be finely ground, or very slightly cooked or heated in a closed glass jar in a water-bath and the fresh juice expressed.

5. **Drugs.**—There is no drug which has any specific effect upon the tuberculous process.

Cod-liver oil is beneficial for its nutrient properties on account of the high percentage of fat it contains. *Iron* and *arsenic* (preferably as Fowler's

solution) aid in combating the secondary anemia. *Laxatives* are essential in keeping the bowels active inasmuch as intestinal toxemia is common in these cases as the result of the sedentary or recumbent postures.

3. Local Conservative Treatment

1. **Fixation of the Part.**—The cardinal principle of treating any tuberculous lesion is absolute *rest*.

Of the many materials used for this purpose (celluloid, wooden splints, aluminum, etc.) the author prefers *plaster-of-Paris* on account of its cheapness, malleability to completely adjust itself to the shape of the affected part and because of the relatively complete fixation it affords. The only disadvantages are its weight and the muscular atrophy accompanying its use. The details of its application will be found in Chapter XXIX.

2. **Hyperemic Treatment.**—Rokitansky's observation that sufferers with incompetent mitral heart lesions with venous stasis of the lungs rarely were afflicted with phthisis, led August Bier to formulate a system of hyperemic therapy, whose application to tuberculous bones and joints has in some cases a beneficial effect. The results of local congestion or hyperemia in osseous tuberculosis are:

(*a*) *Edema* from the periphery to the center of the limb and later in the reverse direction, carrying to the diseased focus the antagonistic leukocytes, lysins and opsonins and, on reversal of the circulation, removing dead bacteria and their products.

(*b*) *Fibrosis* and *hypertrophy* of bone.

(*c*) *Bactericidal action.*

(*d*) *Absorptive* effect on an organizing exudate.

(*e*) *Relief* of *pain* and muscle spasm and lessening of the activity of progressive joint disease.

Hyperemia may be induced in four ways:

1. Active hyperemia.
2. Passive hyperemia.
3. Hyperemia by cupping.
4. Suction hyperemia.

1. *Active Hyperemia.*—This is produced by the *local application* of *dry heat*. It is secured by fixing the part in a baking machine or an equivalent apparatus, and subjecting it to a high temperature. Each séance should last thirty to sixty minutes and be repeated 2 or 3 times a day. Hyperemia begins at a temperature of 30°C., perspiration at 60° and the maximum is attained at 100°. The limit of saturation is 114°.

2. *Passive Hyperemia.*—This is attained by constricting the limb above the focus of disease sufficiently to retard the venous circulation but not to cause pressure upon the arteries. A 2-inch elastic bandage applied over gauze above the level of the lesion, or the leg tightly bandaged with flannel or other semi-elastic material down to the lesion, will accomplish this.

The skin becomes dusky red, the part swollen, and the superficial veins distended. The pulse should remain strong and the limb not allowed to become cold or painful.

Compression may conveniently be secured with the pressure bag of a sphygmomanometer.

The results of passive hyperemia are better in the upper limb—particularly in the carpus, metacarpus and phalanges—than in the lower.

3. *Dry Cupping.*—The effects of hyperemia can be more focalized and concentrated by the use of dry cupping, as suggested by Klapp (Prof. Bier's assistant). Glass cups, of various shapes and sizes to fit different parts, and

supplied with rubber bulbs are employed. A negative pressure of 200–400 mm. of mercury may be secured over a circumscribed area.

4. *Suction Hyperemia.*—Glass chambers of various shapes and sizes to contain an entire limb are to be had. A loose rubber cuff is attached to the open extremity of the chamber which can be tightened about the limb by a bandage to exclude air. The air is withdrawn from the chamber by an exhaust pump and this partial vacuum is sustained for five minutes. Air is then re-introduced. This process is repeated every two minutes for half an hour every day at the beginning, later every two or three days.

Conclusions.—Hyperemia applied to tuberculous bones of the upper extremity (particularly the hands and wrists) gives far better results than when applied to the legs. It is inapplicable to the shoulder and hip-joints. The results are better in children than in adults. The treatment must be combined with immobilization. It apparently hastens the formation of ichor pockets.

3. **Counterirritation.**—In deep-seated, uncomplicated bone disease, counterirritants are undeniably useful to relieve pain. For this purpose the *actual cautery* (used to the production of a superficial eschar), cantharides, iodin, etc. are employed.

4. ***X*-rays.**—A superficial lesion, lying not more than $^3/_{16}$″ below the surface may occasionally be benefited by the *x*-rays. The surrounding soft parts should be protected, and the rays should be filtered through an aluminium plate 1 mm. thick (Quervain, La Semaine Medicale, Jan. 1, 1913, page 347). No more than three applications should be made. If the osseous lesion is situated near a joint in a growing child, the *x*-rays should be used with care because of the danger of injuring the epiphyseal cartilage.

Schede, writing upon this subject (Schede, Fr., Zeit. f. Orth. Chir., 1913, Bd. xxxi, Heft. 3–4) advised that the treatment be given in small doses without protection of the skin. He obtained the best results in fistulous cases. He saw no instance of damage to the epiphyses. He suggests that *x*-ray treatment always be combined with general and orthopedic treatment, and states that *x*-ray therapy is contraindicated in cases of abscess near the surface.

Bittrolff's (Münch. med. Wochenschr., Feb. 17, 1914, No. 7) cases were all exposed at intervals of three to four weeks, as often as possible. In 17 of the 21 reported cases, 12 showed definite cure, 2 a probable cure, and 3 considerable improvement. All were serious cases, and many had been previously treated without results. In all cases with sinuses, the latter closed in a few weeks or months. Bittrolff advises that as much diseased tissue as possible be removed by operation before administering *x*-ray treatment, and suggests that general measures be employed throughout.

Iselin's technic (Iselin, H., "Von der Behandlung der Knochen und Gelenkstuberkulose mit Röntgenlicht," Deutsch. Zeit. f. Chir., 1909, ciii, 496) is as follows: At the beginning of treatment, the joint or the limb is exposed for a short period, three or four times in succession, but on each successive occasion in a different place, and a full dose administered. He hardens the light by passing it through an aluminium plate 1 mm. thick, the length of the sitting being determined by the use of a Sabauraud pastille under the aluminium. Since the effect on the skin is not apparent for two or three weeks, the treatment should not be repeated until three or four weeks have elapsed. Usually not more than three of such sittings were necessary. If cicatricial contraction is present, the position of the affected joint should be carefully selected before exposure to the rays; the smaller joints do not

need to be fixed. After the tuberculous tissues have been replaced by cicatricial formation, some after-treatment, such as hot-air baths and massage, should be instituted for the purpose of securing joint mobility. This treatment was practised in ten bone and joint tuberculous cases; in most instances improvement was noted, and in some instances a complete cure was effected. Iselin does not recommend that this treatment be applied to children, because of the danger of injury to the epiphyseal cartilages. Whether or not in the case of adults the rays penetrate a sufficient depth into the large joints, such as the shoulder and hip, has not been determined. On the whole, this treatment seems to have given good results, and in certain instances, such as tuberculous joint lesions of the hand and foot, and in the case of elderly persons, it may be practised when surgical procedures are contraindicated.

5. **Treatment of Ichor Pockets** (Cold Abscesses).—An ichor pocket (or "cold abscess") is the commonest complication of tuberculosis of bone. Its

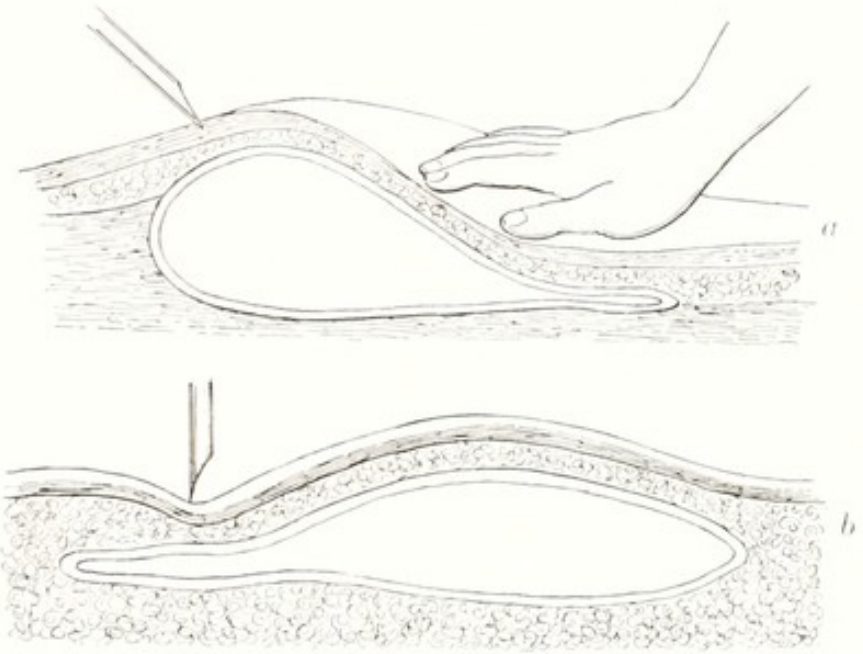


FIG. 6.—(*a*) Illustrates the desirability of compression of a large ichor pocket (cold abscess), during aspiration.

If the counter compression is used and the trocar is introduced at a right angle, as in (*b*) the contents is likely to be displaced by pressure of the overlying tissues and the trocar driven throught both walls of the pocket into the subjacent tissue. (After Calot.)

pathology has been already fully discussed in this chapter. It should be borne in mind that this collection of tuberculous detritus is innocuous and sterile, and the general rule regarding it is "noli me tangere," except as noted below.

Treatment of an ichor pocket is to be considered as (1) *conservative* and (2) *operative*.

1. *Conservative Treatment.*—Even when pointing beneath the skin, a collection of tuberculous ichor usually causes no symptoms. If let alone it is frequently absorbed, providing its origin (the bone or joint lesion) is controlled by appropriate treatment.

2. *Operative Treatment.*—This consists of (*a*) *aspiration* and (*b*) *incision*. The former is the operation of choice when interference is demanded by any of the following indications:

1. Pressure necrosis and thinning of its wall with danger of sinus formation.

2. Mechanical interference with function (viz.: a psoas abscess interfering with the application of a brace or splint, or with locomotion).

3. Discomfort from tension.

4. Evidence of secondary infection indicated by the local signs of inflammation and fever.

(*a*) *Aspiration.*—This is performed with an aspirating syringe. The needle should be introduced into a *thick* (*not* a thin) portion of the abscess



FIG. 7.—Correct method of introducing a trocar into an ichor pocket (cold abscess) at an acute angle to its surface. The puncture holes in the several tissue planes are not superimposed upon each other and there is, therefore, little danger of secondary infection from the exterior.

wall, and *obliquely* to avoid the danger of sinus formation (Figs. 6, 7, and 8). Care should be taken to *avoid disturbing the granulations* lining the walls, because of the danger of blood-clots (which are a favorable culture medium), collecting in the cavity. After withdrawal of the ichor, the puncture wound is closed with collodion and dressed with sterile gauze and a large compress applied under firm, even pressure. Aspiration should be followed by *recumbency* in such a position as to aid in the return, by gravity, of the ichor to its point of origin and the relief of tension at the point of aspiration.

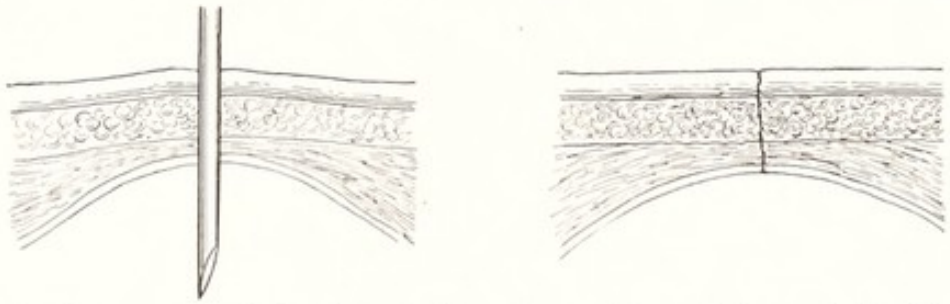


FIG. 8.—Incorrect method of introducing a trocar into an ichor pocket (cold abscess) at right angles to its surface. Here the points of puncture in the several tissue planes are superimposed upon each other and, on withdrawal of the trocar, form a direct pathway from the surface to the interior of the pocket and present an avenue of approach for secondary invaders.

Aspiration with the Injection of Medicaments.—Although the author does not as a rule practise the injection of medicaments into the cavity following aspiration, the procedure is followed by some, and deserves mention.

The following preparations are used for this purpose:

(*a*) 10 per cent. solution of iodoform in glycerin.

(*b*) A solution of iodoform in ether (Kirmisson Surg. of childr. (trans. by Keogh Murphy) page 384).

(*c*) Thymol-camphor injection: Thymol 1 part, camphor 2 parts (Ménard, Étude pratique sur le mal de Pott, Paris, 1900).

(*d*) Oily solution of creosote and iodoform—olive oil 70 G.; ether 30 G.; creosote 5 G.; guaiacol 1 G.; iodoform 10 G. (Calot: Orthopédie indispensable, page 176 et seq.).

(*e*) Solution of naphthol and camphor in glycerin—naphthol-camphor 2 G.; glycerin 12 G. (Calot; ibid.).

(*f*) 10 per cent. solution of zinc chlorid.

(*g*) Tinct. iodin, 1 part; iodid of potash 1 part; water to 100 parts.

(*b*) Iodoform	5 g.	Creosote	2 g.
Ether	10 g.	Sterile olive oil	100 g.
Guaiacol	2 g.		

(Calvé and Gauvain, Lancet, Mar. 5, 1910.)

The rationale of injecting medicaments is based on the production of an inflammatory reaction with its consequent fibrosis. Thymol has the specific power of liquefying caseous material. The accumulation of leukocytes incident to the inflammatory reaction and their subsequent destruction is said to liberate a proteolytic ferment capable of converting albumin into readily absorbable peptones.

(*b*) *Incision.*—Incision of an ichor pocket is undertaken only as a necessity and is performed with trepidation because of the great liability to infection which often occurs despite the utmost care in technic and dressings. As soon as infection does occur it spreads like wild-fire into the extensive recesses and ramifications produced by the tracking of the hitherto sterile tuberculous ichor and deep infection, profound toxemia, lardaceous disease and death not uncommonly result.

In opening an uninfected ichor pocket, the following precautions should always be observed:

1. Rigid asepsis.
2. In the case of a large abscess pointing in two localities (as the loin and the hip in Pott's disease), incise the one on the higher horizontal plane rather than the dependent one, to avoid pressure on the sutures and the danger of wound necrosis from gravitation of the ichor.
3. Incise through a *thick* part of the wall.
4. Avoid injury to the granulations lining the wall. Gently express the contents.
5. Make the incision long enough to allow fibrinous clots to be expressed.
6. No instruments should be introduced into the cavity.
7. A large, even compress should be applied to prevent re-accumulation of ichor or the formation of blood-clot.
8. Recumbency should be enjoined for two weeks after incision to prevent gravitation from causing the wound to break down.
9. Suture the incision carefully in layers, using absorbable material.
10. Heliotherapy after operation whenever possible.
11. *Never drain* an uncomplicated ichor pocket on account of the danger of secondary infection. An already existing secondary infection may, however, necessitate it.

6. **Treatment of Sinuses.**—Sinuses are usually a sequel of incised or spontaneously ruptured ichor pockets, which have been secondarily infected. Occasionally, however, they occur as an independent affection. They are often of very considerable length, due to their extreme tortuosity. The sinuses are lined with tuberculous granulation tissue and studded with follicles which may be in a state of caseation, and are delimited by a peripheral formation of fibrous tissue. There are no symptoms directly referable to sinuses, but they serve to continue the secondary infection and demand treatment on that account. They may be prevented by guarding against infection of ichor pockets by injudicious interference and by aspirating before thinning of the abscess wall or spontaneous rupture. They are difficult to cure because of their tortuosity and the consequent impossibility of excision together with inability to obtain primary union. Treatment, therefore, resolves itself into palliative measures which consist of (1) autogenous vaccines; (2) the injection of medicaments; (3) Bier's hyperemia and (4) Wright's treatment.

(1) *Autogenous Vaccines.—Mixed Infections.*—A large proportion of cases of osseous tuberculosis are complicated by secondary infection. The chief offenders are the pyogenic organisms, the streptococcus and the staphylococcus albus and aureus. Cultures should be made from the pyogenic focus or sinus and an autogenous vaccine prepared and administered in conjunction with tuberculin. It may be given mixed with tuberculin, or the latter administered alone for a certain period, and vaccine therapy used to supplement it.

(2) *Injection of Medicaments.*—Bismuth paste has for some time been injected into sinuses for the purpose of röntgenography. E. G. Beck of Chicago (ref. "The Surgical Treatment of Tuberculous Sinuses and their Prevention," Trans. 6th Int. Cong. Tuberc., 1908) noted that many of the sinuses subsequently healed and taking advantage of this phenomenon he advocated the therapeutic injection of bismuth. His technic is as follows:

A mixture of bismuth subnitrate 1 part, and vaseline 2 parts, is heated on a water-bath. The mixture is injected at a temperature of 40°C. using a glass syringe sterilized by boiling and then washed out with absolute alcohol. The skin about the orifice of the sinus is sterilized. The injection is made slowly, using about 10 c.c. of the mixture. Rarely one injection suffices, but it usually requires many (occasionally as high a number as 20 or 30) to get the desired effect.

Contra-indications to the Use of Bismuth Paste.—These are summarized by Ridlon and Blanchard (ref. Am. Jour. Orth. Surg., vi, 1, p. 13) as follows:

1. The presence of a *sequestrum.*
2. Coincident *amyloidosis.*
3. The presence of *large pus sacs* at the terminus of the sinus.
4. Sinuses of tuberculous bone disease which are less than two or three months old.
5. Extensive ulceration of the skin with undermining of large areas of it.

Dangers.—There are certain real dangers attending the use of bismuth injections, viz.:

(*a*) *Bismuth poisoning* of all grades of severity. The cause of this poisoning is still in dispute. Baer (J. H. H. Bull. xx, 223, Oct., 1909) believes that when the bismuth subnitrate comes into contact with colon bacilli there is an elaboration of nitrites and in such cases the toxemia is a nitrite poisoning. He also suggests that a small portion of the metallic bismuth may go into solution. The symptoms of poisoning vary from fever, salivation, stomatitis and headache to delirium, insanity and occasionally death.

(*b*) *Acute toxemia*, due to a damming back of the pus.

(*c*) *Infection* of a *neighboring joint*, as in a case reported by Baer (*loc. cit.*).

Results.—Despite the occasional untoward results, a considerable percentage of cures follows this agent.

Theories of Action.—The therapeutic value of Beck's bismuth paste have been attributed to various factors, viz.:

1. Germicidal action of the bismuth.
2. Radio-activity produced by the action of the *x*-rays (ref. Beck, E. G., J. A. M. A., Mar. 14, 1908).
3. Mechanical, by squeezing out the pus and preventing the ingress of air-carried bacteria. (Ridlon and Blanchard).
4. Liberation of nitric acid when bismuth subnitrate comes in contact with organic acids (ref. Don, A., Edinburgh, M. J., Feb., 1909).

(3) *Bier's Hyperemic Treatment.*—Bier thus describes his treatment of tuberculous sinuses and fistulæ (ref. Bier, Text-book of Hyperemia, Transl., 1901, p. 263).

The cupping glass is at first applied three-quarters of an hour daily to all forms of open and fistulous tuberculosis which have not been treated heretofore. The rule laid down for acute inflammation, that the cupping glass should be removed for three minutes after it has been applied for five minutes, holds good here also. The patients are given daily treatment until the indolent, pale, tuberculous granulations become red and hard and until the immediate vicinity of the sinus becomes hard. It is then time to increase the intervals between the treatments, at first every second, later every third and finally every eighth day. In the vicinity of tuberculosis with sinuses which have been treated with the cupping glass, one often sees ulcers, which must be regarded as inoculated tuberculosis. To avoid this, Klapp suggests the following method: After removal of the dressing, and previous to suction, the vicinity is cleansed with benzine, and a large surrounding area is covered with fat (lanolin, vaselin āā). After suction, the first fat is removed with benzine and freshly applied.

(4) *Wright's Treatment.*—On account of its bacteriotropic powers, Wright utilizes the body lymph, bringing it into contact with the diseased tissues of the sinus. He introduces into the sinus a solution of 0.5 per cent. sodium citrate and 5 per cent. sodium chlorid. The former prevents coagulation of lymph within and around the sinus, while the sodium chlorid induces osmosis and a free flow of lymph.

7. **Special Forms of Treatment.**—(*a*) *Trypsin.*—This has been employed therapeutically on the principle that the proteolytic ferment favors resolution of the tuberculous granuloma. It is administered subcutaneously in the region of the bone lesion, as a 60 per cent. solution of trypsin in glycerine and in a dose of 1 to 2 c.c. diluted with 1 to 10 parts of normal salt solution, and given every two to seven days. The local reaction disappears in twenty-four to forty-eight hours but the swelling at the site of the injection persists about five days. Hyperemia, cellular infiltration and proliferation of the tuberculous tissue are said to ensue.

Batzner (Practitioner, 1913, xc, p. 213) reported 4 cases of tuberculosis of the ankle all cured by trypsin within fourteen months to two years, with improvement in the general condition.

(*b*) *Allyl Sulphide.*—This is the active principle of garlic. A report of its use as an ointment was made by Minchin in 1912 (Brit. Med. Jour.). It is said to be efficacious in superficial bone lesions (such as dactylitis) with associated tuberculosis cutis, if applied directly to the part.

4. Tuberculin Therapy

The term tuberculin is applied to the products of B. tuberculosis, either the soluble products of its growth, or the insoluble fragments of the bacilli themselves, or a combination of the two. To the former has been given the name "extract tuberculins" and to the two latter "vaccine tuberculins."

Space forbids an enumeration of these various extract and vaccine tuberculins, or a description of their modes of preparation; for which the reader is referred to special works on immuno-therapy.

Result of Inoculation.—A healthy person is unaffected by the injection of even an enormous dose of tuberculin. In the tuberculous subject, however, a minute dose causes a disturbance which is exhibited by the so-called "tuberculin reaction" and is indicated by three phenomena, viz:

(*a*) *Local Reaction.*—Redness, swelling and induration at the point of inoculation, indicating slow absorption.

(*b*) *Focal Reaction.*—Hyperemia at the site of lesion with accompanying serous exudation.

(*c*) *General Reaction.*—Fever, malaise, body pains and headache due to the circulation of tuberculous toxines.

Wolff-Eisner's theory explains these reactions as an attack by the individual's specific anti-bodies upon the tuberculin with the liberation of toxic products. This phenomenon is called "tubercular sensitiveness." The individual subsequently develops a *tolerance* to tuberculin, evidenced by the failure of subsequently repeated doses to elicit this sensitiveness.

Method of Administration.—The practical use of tuberculin as a therapeutic agent involves two objects, viz.: (*a*) the elimination of the individual's hypersensitiveness to the products of B. tuberculosis, by means of minimized doses of tuberculin gradually increased; and (*b*) the stimulation of the individual immunizing machinery to produce the maximum amount of antibodies by the administration of the maximum amount of tuberculin consistent with that individual's hypersensitiveness.

The method of administration employed by Dr. Ellis Bonime appeals to the author as particularly efficacious, and is here given in detail (ref. N. Y. Med. Journ., Apr. 15, 1916).

"Treatment is begun by giving 0.10 c.c. of a certain dilution of the tuberculin. This dose is increased by 0.02 c.c. for each of the two following injections, giving 0.12 c.c. and 0.14 c.c. respectively. Subsequently the increase is made by 0.04 c.c., then by 0.06 c.c., thus increasing the amount of increase by 0.02 c.c. at every second injection until 1 c.c. of that dilution is reached, when the next dilution is begun and given in the same routine as the former. This method allows of the maximum tuberculin compatible with the tolerance of each individual case being given, and if a reaction is reached, it will not be severe, as it is produced by the minimum of tuberculin necessary in that particular case.

"When the first dilution, or the dilution representing 10 per cent. tuberculin, is used, the increase of the increase may be at every injection instead of every other injection.

"It is evident from this scheme of doses that a mild reaction will be reached in every case, and since a constitutional reaction simply means the waiting of a full week for the next injection, treatment is then resumed with an amount equal to the third last injection, and increased subsequently as at the beginning of treatment. No two patients ever react to the same amount of tuberculin; the divergence in the schedule of doses will occur accordingly, and automatically the treatment applies itself to each individual case.

"*Method of Making Dilutions.*—Dilutions are made in multiples of ten and this is done in a Record tuberculin syringe, subdivided into 0.02 of a c.c. The diluent is half of 1 per cent. carbolic in normal saline. The first 0.90 c.c. diluent is drawn in, followed by 0.10 c.c. tuberculin. An air bubble is then drawn in, the syringe is shaken, and the contents are put in a receptacle, and labeled solution No. 1. It is of the strength of 1 in 10. Then 0.90 c.c. diluent is drawn into the syringe with 0.10 c.c. solution No. 1; this is well shaken, and labeled solution No. 2; 0.90 diluent is drawn in, followed by, 0.10 c.c. solution No. 3, and this is well shaken and labeled solution No. 4 and No. 5 is prepared in similar fashion by using No. 4.

"In most surgical conditions we begin treatment with the fourth dilution, except in an acute joint tuberculosis, particularly the knee, where the fifth dilution should be chosen. . . . . "

Autogenous Tuberculins.—Some authors (ref. Krause, Zeitschr. f. Tuberkolose, xiv, S. 73) have advised the preparation of an autogenous vaccine

(tuberculin) from the specific bacillus generating in the individual's tissues. Others (ref. Fraser and Macgowan, Lancet, June, 1912) prepare a tuberculin from the actual diseased tissue.

Conclusions.—Tuberculin has a definite therapeutic value in the treatment of osseous tuberculosis. Unfavorable results are often due to the ill-advised methods of its administration. It is particularly beneficial in cases complicated by sinus formation, administered in conjunction with an appropriate autogenous vaccine.

Antituberculous Sera.—(*a*) *Marmorek's Serum.*—This consists of the serum of horses immunized by repeated injections of filtered young cultures of B. tuberculosis. The serum is given hypodermically or by rectum. Several writers, Hoffa (Berl. Klin. Wochenschr., 1906, No. 44), Van Huellen, (Centralbl. f. chir., 1907, No. 3), and others have reported distinct improvement in cases of surgical tuberculosis following its use.

(*b*) *Spengler's I. K. Serum.*—This is obtained from the tuberculosis-immune blood of immunized sheep and rabbits. It is reputed to contain one million lytic and antitoxic units per cubic centimeter. Porter and Quinn (Chicago Med. Rec., 1912, xxxiv, 84–91) and Eversole (Amer. Jour. Orth. Surg., 1912–13, x, 234–242) obtained satisfactory results from its use.

(*c*) *Mehnarto's Serum.*—To this preparation the name contratoxin has been given. It is the serum of warm-blooded animals naturally immune to tuberculosis. The serum is sensitized or corrected with other sera to counteract any hemolytic or anaphylactic tendencies it may possess. The results of its use are too few to be conclusive.

5. Operative Treatment

Conservative treatment takes priority over operative interference as a general rule in osseous tuberculosis (except in the case of tuberculous vertebræ where an early bone-graft or fusing operation is indicated in every case) in contradistinction to the treatment of monarticular joint tuberculosis, in which condition the reverse is true, especially in children. Operative measures should, however, be undertaken before bone destruction, secondary infection with abscess and sinus formation have occurred and when lardaceous disease is threatened, especially in adults. In deciding the question of operation, the following factors should be considered:

(1) **Age.**—Operation offers as a rule unfavorable results in the first two years of life on account of the attendant shock and the tendency to dissemination of the localized process.

(2) Operation is indicated in a destructive joint lesion in an adult.

(3) **Location of the Lesion.**—A focus near a joint indicates removal before the joint is endangered or actually infected.

(4) **Social Position.**—From an economic standpoint, children of the very poor incline the surgeon to operate if advisable in an endeavor to shorten the period of treatment and lighten the burden of prolonged, expensive treatment.

(5) **Family History.**—An indication for operation is a strong family history of tuberculosis. A predisposition to tuberculosis favors dissemination and progression of the localized lesion.

(6) **Multiple Lesions.**—If dissemination is occurring from a bone focus, it should be eradicated.

(7) **Clinical History.**—The following features in the clinical course of the disease demand operative intervention:

(*a*) If after a considerable lapse of time there has been no improvement, but, to the contrary, extension of the lesion, under conservative treatment.

(*b*) Abscess formation—not an indication *per se*, but as an index of the extent of the local process.

(*c*) Cachexia and lardaceous disease.

Preliminaries to Operation.—(1) **Local Preparation.**—The general preparation is the same as that required for any major surgical procedure. The local preparation should be generous in its extent and by the iodin method, which should be carried out both the night before and the day of the operation in the most thorough manner.

(2) **Tourniquet.**—A tourniquet is *tightly* applied well above the site of operation and is not removed until the wound is closed, dressings applied and the plaster case entirely completed.

(3) **Opsonic Index.**—According to Wright, the time of election of operation is at the beginning of the positive phase following the administration of tuberculin.

Operative Procedures (When no Secondary Infection Exists).—1. *Gouging and Curetting.*—The point of election for the incision varies with the site of lesion and the bone involved. But in general, it should be placed in an intermuscular plane to avoid injury to important muscles, tendons, vessels and nerves. The periosteum is incised and elevated over the lesion. The medullary cavity is opened with osteotome and mallet. With a bone gouge all diseased bone is removed and the walls thoroughly scraped with a curet. The treatment of the resulting cavity is variously dealt with by different surgeons. Following are some of the most commonly employed methods:

(*a*) *Inlay Bone-graft.*—This is the treatment *par excellence* for replacing loss of bone substance from tuberculosis if there is no pyogenic infection. The presence of the tuberculous focus, strangely enough, interferes in no way with the union of the graft to its bed of healthy bone on either side of the focus. The details of the treatment will be found in other parts of this book. Other methods, not ordinarily used by the author, but commonly practised by others are:

(*b*) *Iodoform gauze* packed into the cavity to stimulate fibrosis and osteogenesis, and its use continued until the cavity is obliterated. This method can be used whether secondary infection has occurred or not.

(*c*) *Mosetig-Moorhof's Plug.*—This is a composition of the following:

Iodoform	60 parts
Spermaceti	40 parts
Oil of sesame	40 parts

heated to fluidity and poured into the cavity from which all blood has been removed and the cavity dried with a dentist's hot-air douche, or alcohol and ether, after which the skin is closed without drainage.

(*d*) *Neuber's Iodoform Starch. Composition.*—Ten Grams wheat starch mixed with minimum amount of water; 200 Gm. boiling 2 per cent. aqueous solution phenol; 10 Gm. powdered iodoform added after the above mixture has partially cooled. Used like the iodoform wax.

(*e*) *Murphy's Glycerogelatin-formalin Plug.*—This consists of 100 c.c. white gelatin boiled in 150 c.c. glycerin and 500 c.c. water, to which are added 1 to 2 per cent. formalin.

(*f*) *Beck's Paste.*—This is used in the same manner as the iodoform wax and Neuber's starch. Its composition has already been given under the treatment of sinuses.

The most favorable condition for resection is a sharply delimited bone focus involving the whole diameter of the shaft of a long bone which can be exactly determined by röntgenography.

The resected bone may be restored in various ways. In the case of the tibia, the upper part of the fibula may be moved over to a socket cut in the upper epiphysis of the tibia; or the whole shaft of the tibia may be replaced by transplanting the shaft of the fibula into its place. In any of the long bones the author's technic for the insertion of an inlay bone-graft taken from the tibia is the preferable method to be employed after resection. The prevention of shortening may be accomplished in two ways, either by a tongue and grooved joint at the end of the inlaid joint or by shaping the graft so that it is larger in diameter where it spans the bone hiatus and has mechanical shoulders at either end.

After-treatment.—After securing the graft and properly closing and dressing the wound, a carefully fitted plaster-of-Paris dressing, including the joints on either side of the bone grafted, should be applied, and allowed to remain for four to five weeks, when it should be replaced by a second plaster splint for two or three months, or until the röntgenograms and physical examination show that there has been a sufficient hypertrophy of the graft for it to be trusted without support.

TREATMENT OF JOINT TUBERCULOSIS

General Considerations.—After tuberculous disease of the synovial membrane and articular cartilages of a joint has once been established, there is very little hope of complete restoration of function especially in the adult. The best result which can be expected from any treatment, operative or palliative, is arrest of the process with as little destruction of joint structures as possible and with the minimum amount of shortening and deformity. More or less impairment of joint function is an inevitable sequel.

The treatment of joint tuberculosis will be considered under the headings of I. Conservative treatment, II. Radical treatment, and III. Correction of deformity.

I. **Conservative Treatment.**—This comprises the following:

1. Mechanical fixation.
2. Traction.
3. Counterirritation.
4. Injection.
5. Hyperemia.

1. *Mechanical Fixation.*—This is secured by braces or plaster-of-Paris bandages, applied after the manner described in Chapter XXIX on Plaster-of-Paris Technic. The joints immediately above and below the affected articulation should also be included in the bandage. The joint should be placed in the best possible functional position anticipating ankylosis.

After a varying length of treatment in this manner slight movement may be allowed by means of various splints. At a still later period, greater freedom of motion with gradual resumption of weight-bearing may be permitted.

2. *Traction.*—This has for its object partial fixation of the joint and separation of its contiguous articulating surfaces. It is often indicated by pain with muscular spasm and by deformity.

The best means of securing extension is by weight and pulley. The limb is shaved and two lateral strips of mole skin adhesive strapping further secured by circular strips, are applied. To their lower ends are sewed tapes between which is fixed a wooden stirrup. By means of a cord, weights are attached to the stirrup, and the cord passed over a pulley fixed to the bed-frame. The amount of weight required depends upon the age, location of lesion, muscular development of the individual and the state of the lesion

The weight must be applied in the actual axis which the limb occupies *i.e.* line of deformity, whatever it may be—correction of position may be

secured later. Too great weight must be avoided, otherwise it may increase instead of lessen the joint pain, and may stretch the ligaments and weaken the joint.

Counterextension is frequently necessary. It may be secured by the body-weight (as by elevating the foot of the bed in traction on the legs). At other times *indirect* counterextension is indicated (as in hip-disease, unopposed direct extension forces the lower part of the femoral head against the rim of the acetabulum); it may be obtained by lateral traction by a weight over the side of the bed (as in the case of the shoulder or elbow).

3. *Counterirritation.*—The actual cautery, heated to black heat and applied to the point of vesiculation will sometimes relieve acute pain. Tincture of iodin, although extensively used, has no effect on the fundamental pathological process. Neither of these counterirritants is curative to an important degree.

4. *Injection of Medicaments.*—Various medicaments are injected by some authors in and around the joint. The potency of this practice is questionable.

5. *Passive Hyperemia.*—Bier's treatment as described in the treatment of osseous tuberculosis may be applied to tuberculous joints, the congestion being induced for one to three hours daily.

II. **Radical Treatment.**—The operations of arthrodesis, arthrotomy and cureting, synovectomy, arthrectomy and excision, and amputation, have with the exception of arthrodesis (with bone-graft), as their underlying principle, operative eradication of the disease bearing tissues.

1. *Arthrotomy and Cureting.*—This consists of opening the joint by a suitable incision and excising or cureting the diseased tissue. In the case of a small isolated focus, this procedure may entirely eradicate the disease.

2. *Fixation. Operative Fixation by Bone-graft.*—This may be preceded by removal of the articulating surfaces of the contiguous bones to produce an arthrodesis, or may be performed by an inlay, peg or other form of graft described in Chapter III. The technic of the operative procedures will be found in the appropriate chapter devoted to the joint under discussion.

3. *Synovectomy and Arthrectomy.*—*Synovectomy* consists of a removal by scissors and knife dissection of the synovial membrane.

Arthrectomy comprises removal of the articular cartilages as well as the synovial membrane. Although not always followed by ankylosis, this is the desired result. Hence the wisdom of supplementing this procedure by the inlay bone-graft for the purpose of insuring and hastening bony ankylosis.

4. *Excision.*—Removal of all the joint structures, together with the contiguous ends of the bones is still performed. The operation is ill-advised, as it causes considerable shortening of the limb, and unless supplemented by the fixative and osteogenetic bone-graft is likely to result in an unfortunate non-union.

5. *Amputation.*—In extreme cases, as a last resort, this procedure is occasionally adopted. Probable indications are profound constitutional disturbance from waxy disease and cachexia, and steady advance of the local process with mixed infection and sinus formation. Care must be taken to make the incision well beyond the diseased area, to avoid inoculation of the flaps with tuberculous disease.

III. **Correction of Deformity.**—Deformed positions are due primarily to strong muscular contraction usually in the direction of more flexion. At a later period, adhesions between the joint surfaces make the altered position more permanent.

Correction is obtained by conservative or operative measures.

Conservative Correction.—This may be performed gradually or immediately.

(*a*) *Gradual Correction.*—Gradual correction is recommended where possible, and is attained by extension of the limb in various ways, viz.:

1. Head extension.
2. Foot extension.
3. Horizontal extension (in hip and knee deformities).
4. Frame extension for kyphotic spines.
5. Plaster-of-Paris bandages.

(*b*) *Immediate Correction.*—This is accomplished by anesthesia and straightening the deformed joint with the aid of tenotomy or myotomy when necessary.

Operative Correction.—This consists of the division of restraining muscles and tendons and of the various types of osteotomy.

REFERENCES

PATHOLOGY OF TUBERCULOSIS OF BONE

CADBURY, W. W.: "Tuberculosis of Bones and Joints." Reports, Henry Phipps Institute, 1906–7, iv, 203–233.

PAOLI, A.: "Due Casi di osteoperiostite tubercolare guariti coi raggi." Clin. Mod., Firenze, 1907, xiii, 1085–1004.

LORTAT, J. L., AND ANBOURG: "Malformations squelettiques d'origine tuberculeuse," Bull. et Mém. Soc. Med. des Hôp. de Paris, 1908, 3 S. xxv, 266–274.

MILLER, M. B.: "Caries Sicca." Ann. Surg., 1908, xlviii, 151.

CONE, S. M.: "Bone Pathology in Relation to General Pathology." Amer. Jour. Orth. Surg., Phil., 1908–9, vi, 607–615.

RIDOLFI: "La Tuberculosi ossea ed articolare nelle case di pena." Ann. di Ippocrate, Milano, 1908–9, iii, 87–90.

VOGELMANN, R.: "Isolierte tuberkulöse Knochenherde." Fortschr a. d. Geb. Röntgenstrahlen, Hamburg, 1908–9, xiii, 80–89.

MASSINI, G.: "Tuberculosi ossea ed articolare." Tommasi, Napoli, 1908, iii, 352–354.

COWDEN, C. H.: "Tuberculosis of Bones." South, M. & S., Chattanooga, 1908, ix, 189–193.

VAN METTE, B. F.: "Tuberculosis of Bone." Kentucky M. J., Bowling Green, vi, 272–275.

TIXIER: "Ostéomalacie tuberculeuse limitée." Rev. de Chir., Paris, 1908, xxxvii, 722.

MAUCLAIRE: "Maladies des os." Ballière et fils, Paris, 1908.

BRADFORD, E. H.: "Tuberculosis of Bones and Joints." South. Med. J., 1909–10, ii, 613–619.

EWING, W. G.: "Tuberculosis of Bones and Joints." Wash. Med., 1909–10, viii, 383–387.

GIMÉNEZ, L. H.: "Artritis tuberculosa abierta de la rodilla derecha." Med. de nos Ninos, Barcel., 1909, x, 83.

BATUT: "Syphilis et tuberculose craniennes." Marseilles Med., 1910, xlvi, 290–300.

LENTAIGNE: "Multiple Bone Tuberculosis Two Years after Treatment." Tr. Royal Acad. Med., Ireland, Dublin, 1910, xxviii, 209.

MARFAN, A. B.: "Maladies des os." Ballière et fils, Paris, 1910.

BROWN, E. M.: "Tuberculosis of Bones and Joints." New York M. J., 1910, xcii, 905–912.

TOEPEL, T.: "Tuberculosis of the Bones and the Joints." Atlanta Jour. Rec. Med., 1910–11, lvi, 239–244.

GOLDTHWAIT, J. E., PAINTER, C. F., AND OSGOOD, C. B.: "Diseases of the Bones and the Joints." Boston, 1910.

BROWN, E. M.: "Tuberculose inflammatoire du squelette, l'ostomalacie d'origine tuberculeuse." Bull. Acad. de Med., Paris, 1911, 3 S. lxv, 22–28.

PONCET, A., AND LERICHE, R.: "Tuberculose inflammatoire du squelette." Gaz des Hôp., Paris, 1911, lxxxiv, 3–5.

JOUON, E.: "Pièces de tuberculose osseuse." Gaz. Md. de Nantes, 1911, xxix, 33.

FRASER, J.: "Observations on the Situation of the Lesions in Osseous Tubercle." Edin. M. J., 1912, N. S. ix, 430–441.

FRASER, J.: "The Pathology of Tuberculosis of Bones." J. Path. and Bact., 1912–13, xvii, 254–277.

JONES, R.: "Tuberculous Disease of Bones and Joints." Pract. London, 1913, xc, 182–189.

VIGNARD AND MOUGUAND, E.: "Tuberculose diaphysaire spina des grands os longs." Rev. d'orthop., Paris, 1908, 2e S. ix, 481–504.

CHARITONOFF, S.: "Ein Beitrag zur Schafttuberkulose dergrossenrohren Knochen." Berlin, 1909, C. Siebert.

Broca, A.: "Spina ventosa des grands os longs." Rev. gén. de clin. et de thérap., Paris, 1910, xxiv, 353–355.
Benet, A., and Vacorand, H.: "Spina Ventosa du péronée." Ann. Med., Paris, 1910, xxi, 107.
Smoler, F.: "Zur chirurgischen Behandlung der Spina Ventosa." Beitr. zur. klin. Chir., Tübingen, 1910, lxvii, 79–95.
Peters: "Spina Ventosa." Münch. med. Wochenschr, 1911, lviii, 221.
Tourneaux, J. P.: "Sur deux cas de tuberculose diaphysaire." Archives med. de Toulouse, 1912, xix, 151–155.
Matthews, F. S.: "Tuberculosis of the Shaft of the Long Bones." Am. Surg., 1913, lvii, 133–135.
Melchoir: "Über symmetrische Diaphysentuberkulose." Berl. klin. Wochenschr., 1913, l, 513.
Alamantine and Langeron: "Tumeur de l'extrémité supérieure du tibia chez un tuberculeux." Lyon méd., 1913, cxx, 1177–1179.

PATHOLOGY OF TUBERCULOSIS OF JOINTS

Arce, J.: "Tuberculosis articular." Rev. Soc. Med. Argent., Buenos Aires, 1907, xv, 377–465.
Moro, G.: "Tuberculosi articolare." Boll. d. r. Accad. Med. di Genova, 1907, xxiii, 251–267.
Gangolphe: "Arthrites tuberculeuses." Ballière et fils, Paris, 1908.
Legg, A. T.: "The Cause of Atrophy in Joint Disease." Amer. J. Orth. Surg., 1908–9, vi, 84–90.
Treboulet, H., Rebadean, Dumas and Boye: "Apropos d'une observation de polyarthrites tuberculeuses." Bull. Soc. de Pediat. de Paris, 1908, x, 285–295.
Reinhardt, A.: "Die primar sklerosierende Tuberkulose der Schleimbeutel." Deutsche Zeit. f. Chir., Leipzig, 1900, xcviii, 63–74.
Ely, L. W.: "Joint Tuberculosis with Special Reference to Its Pathology." Med. Rec., New York, 1909, lxxvi, 551–554.
Keith, J. R.: "Acute Tuberculosis Arthritis." Brit. Med. Jour., London, 1909, ii, 205.
Tik, V. A.: "Diseases of the Joints Etiologically and Pathologically considered, and their Rational Classification." Kherurg. Arkh. Velyaminova, St. Petersburg, 1910, xxvi, 926–960.
Daniel, P. L.: "Arthritis; A Study of the Inflammatory Diseases of Joints." J. Bale, & Danielsson, London.
Finberg, A. H., and Wolley, P. G.: "Osteochondritis Dessicans, Concerning Its Nature and Relation to the Formation of Joint Mice." Amer. J. Orth. Surg., Philadelphia, 1910–11, viii, 477–494.
Ely, L. W.: "The Pathology of Tuberculous Joints." J. Am. M. Assoc., Chicago, 1910, lv, 1283.
Ely, L. W.: "Further Observation on the Pathology of Joint Tuberculosis and Practical Deduction therefrom." Med. Rec., New York, 1910, lxviii, 147–149.
Ely L. W.: "Observations of the Pathology, Diagnosis, and Treatment of Joint Tuberculosis." New York State Med. Jour., New York, 1910, x, 273–278.
Nichol, A. G.: "Tubercular Arthritis." South. M. J., Nashville, 1910, iii, 317–322.
Nott, J. J.: "Tuberculous Joint Diseases." Jour. A. M. A., Chicago, 1911, liv, 178.
Ridlon, J.: "Joint Diseases from the Orthopaedic Standpoint." Illinois M. J., Springfield, 1911, xix, 4–8.
Broca, A.: "Ostéoarthrites tuberculeuses procedées de type bacillose-tuberculose osseuse à foyers multiples." Rev. de la tuberculose, Paris, 1911, 2 S. viii, 1–19.
Albert, Maurin: "De la pyarthrose tuberculeuse d'origine synoviale sans lésion osseuse." St. Etienne, 1911.
Anzilotti, G.: "Ricerche sperimentali sulla pathogenesi delle artropatie tubercolari." Path. riv. quindecim., Geneva, 1911–12, iv, 709–716.
Lancial, D'Arras.: "Péri-arthrite fongeuse chez un enfant, etc.," J. des. sc. méd. de Lille, 1912, ii, 481.
Peltesohn, S.: "Über tuberculöse Gelenkdeformitäten der unteren Extremitäten und ihre paraartikuläre Korrektur." Charel's Ann., Berk., 1912, xxxvi, 526–544.
Wyn Koop, E. J.: "Observations Relating to the Early Recognition and Treatment of Tuberculous Bone and Joint Disease in Children." Post-Graduate, New York, 1908, xxiii, 608–613.
Courmont, P.: "Rhumatisme tuberculeux de Poncet." Lyon méd., 1908, cx, 210–212.
Alusandre, G.: "Sul valore della ophthalmoriazione di Calmetti." Gaz. di Höp., Milano, 1908, xxix, 400–403.

PONCET AND RHEUTER: "Un cas de rhumatisme tuberculeux." Bull. Soc. Méd. de l'hôp. de Lyon, 1908, vii, 151.
PONCET, A.: "Rhumatisme articulaire tuberculeux." Bull. et Mém. Soc. Méd. des hôp. de Paris, 1908, 3e S. xxv, 711–715.
GENEVIER: "Un cas de rhumatisme peut-être tuberculeux." Ann. de méd. et de chir. inf., Paris, 1908, xii, 487–490.
STRANGEWAYS, T. S. P.: "The Conjunctival Reaction to Tuberculin in Arthritic Diseases." Bull. Com. Study Spec. Dis., Cambridge, 1908, ii, 125–130.
ESAU, P.: "Rheumatismus tuberculosus;" Poncet. Münch. med. Wochenschr., 1908, lv, 300–302.
JACK, H. P.: "Diagnosis and Treatment of Tubercular Bone and Joint Disease." Ann. Gynec. and Pediat., Boston, 1908, xxi, 498–504.
ARNAUD, L.: "Rhumatisme tuberculeux." Rev. d'orthop., Paris, 1908, 2 S. ix, 510–522.
PAQUET, A.: "Diagnostic précoce des tumeurs blanches." Bull. méd. de Québec, 1908–9, x, 105–112.
COLVIN, A.: "Diagnosis of Joint Disease." St. Paul M. J., St. Paul, Minn., 1909, xi, 81–95.
BARBIN: "Notes sur les erreurs de diagnostic, etc." Ann. de chir. et d'orthop., Paris, 1909, xxii, 43–76.
COLVIN: "The Diagnosis of Joint Disease." Jour. Minn. Med. Assn., Minneapolis, xxix, 171–178.
DAVIDSON, J. T.: "The Importance of the Early Recognition of Bone Tuberculosis." Med. Rec., New York, 1909, lxxvi, 60–62.
WALDERSTRÖOM: "Early Diagnosis of Tubercular Disease of the Bones and the Joints." Hygiea, Stockholm, 1909, 2 f. ix, 270–275.
SUBBLEY, E. F.: "Tuberculin Diagnosis of Bone and Joint Tuberculosis." New York State J. M., 1909, ix, 423–425.
MELCHIOR, E.: "Die tuberkulose Gelenkrheumatismus," Centralbl. f. d. Grenzgeb. d. Med. und Chir., Jena, 1909, xii, 801–818.
CALDWELL, C. B.: "Diagnosis in Suspected Joint Disease." Lancet Clinic, Cincinnati, 1909, cii, 448–451.
O'REILLY, A.: "A Plea for an Early and more Complete Diagnosis in Joint Tuberculosis in Children." Jour. Miss. Med. Assn., St. Louis, 1909–10, vi, 615–623.
BREDI, C. S.: "The Early Diagnosis of Tuberculosis of the Bone." West. Med. Review, Omaha, 1910, xv, 70–75.
HORWITZ, A. E.: "Differential Points in the Character of the Bone Lesion in Tuberculous and Acute Osteomyelitis, Rhachitis, and Syphilis." Weekly Bull., St. Louis Med. Soc., 1910, iv, 362.
PRIVAT, T.: "Tuberculose externe, syphilis et scrofulate de vérole, diagnostic et traitement." Rev. gén. de clin. et de thérap, Paris, 1910, xxiv, 249–231.
MEHANS: "Die Rolle der isolierten Muskelatrophie als diagnostisches Symptom zu Lokalisation von tuberkulösen Knochenherden." Zentralbl. f. Chir., Leipzig, 1910, xxxvii, 852.
OGILVIE, C.: "The Early Diagnosis of Tuberculous Joint Disease." Post-Graduate, New York, 1910, xxv, 60–66.
HOLMER, B.: "Diagnosis and Treatment of Osteal Tubercle without Abscess Formation." Med. Rec., New York, 1910, lxviii, 1003–1005.
SWETT, P. P.: "The Diagnosis and Treatment of Tuberculous Joints." New York Med. Jour., 1910, xcii, 912–915.
HORWITZ: "Differential Points in Bone Lesions in Tuberculous and Acute Osteomyelitis, Rickets, and Syphilis." Interstate Med. Jour., St. Louis, 1910, xvii, 515–520.
SCHWARTZ, A.: "Examen d'une articulation malade." Progrés méd., Paris, 1910, 3e S. xxvi, 465.
BRACKETT, E. G.: "The Diagnosis of the Tuberculous Character of Joint Disease." Boston M. and S. Jour., 1913, cxviii, 673–676.

RADIOGRAPHY

SKINNER, E. H.: "A Röntgenological Discussion of Bone Lesions." Interstate M. J., St. Louis, 1908, xv, 431–438.
DIEFFENBACH, W. H.: "Differential Diagnosis by Means of X-rays of Diseases of the Osseous System." Jour. Advanced Therap., New York, 1908, xxvi, 283–296.
EWALD, P.: "Fusswurzel Tuberculose und ihre Diagnose mittel Röntgenstrahlen." Fortschr. a. d. Geb. d. Röntgenstrahlen, Hamburg, 1908, xii, 30–35.
GRANGER, A.: "Röntgen Ray Diagnosis of the Diseases of the Bones and Joints." Jour. Advanced Therap., New York, 1908, xxvi, 501–506.
JACOBSOHN, E.: "Die chronischen Gelenkerkrankungen im Röntgenbilde." Mitt. a. d. Grenzgeb. d. Med. und. Chir., Jena, 1909, xx, 758–813.

YOUNG, J. K.: "X-ray Diagnosis of Tuberculous Hip-Joint Disease." Penn. M. J., Athens, 1909, xii, 714.
FORSSEL, G.: "X-ray Diagnosis of Tubercular Diseases of Bones." Hygiea, Stockholm, 1900, 2 f. ix; Svns. Läk. Sällsk. Forhandlung, 258–270.
HARRIS, L. H.: "Röntgenography in Disease of Bone." Australasia M. Cong. Tr., Victoria, 1909, iii, 175–183.
RUCHMANN, M.: "The Diagnosis of Bone Lesions by Means of the Röntgen Rays." Illinois Med. Jour., Springfield, 1909, xvi, 118–120.
FREUND, L.: "The Treatment of Tuberculous Osteo-arthritis by Röntgen Rays." Arch. Röntgen Ray, London, 1908–9, xiii, 89–98.
CUSHWAY, B. C.: "Differential Diagnosis of Pathological Conditions of the Bones and Joints by Means of Röntgen Rays." Quart. Bull. Northwest, Univ. M. Sch., Chicago, 1909–10, xi, 105–115.
PFAHLER, G. E.: "Diseases of Bones and their Differentiation by Means of the X-ray." Amer. Jour. Surg., New York, 1910, xxiv, 377–381.
PIRIE, G. A.: "Diseases of the Bones and Joints as Shown by X-rays." Edin. Med. Jour., 1910, N. S. iv, 427–30.
SKINNER, C. H.: "The Röntgen Diagnosis of Bone Lesions." Oklahoma M. News Journal, 1910, xviii, 143–152.
BROCA, A., AND PHILBERT: "Radiographies de tuberculose diaphysaire des os longs." Paris mèd., 1912–13, ix, 578–582.

TREATMENT OF BONE TUBERCULOSIS

HYGIENIC

WALLACE, C.: "The Effect of Imperfect Hygiene in the Production of Bone Tuberculosis." Amer. Jour. Orth. Surg., Philadelphia, 1907–8, v, 335–338.
GILETTI, A. J.: "The Importance of Caring for, and how the State of Minnesota cares for its Indigent Children Suffering from Tuberculosis of the Bones and Joints." St. Paul M.J., St. Paul, Minn., xi, 1–9.
TAYLOR, R. T.: "The Care and Treatment of Crippled Children." Virginia M. Sem. Month., Richmond, 1910–11, xv, 513–517.
M'NURTEN: "The Permanent Betterment of the Crippled Child." New York, 1911, 11 pp.; Lancet, London, 1912, i, 4–7.

CLIMATIC

VARIOUS AUTHORS: "L'Influence du climat marin, de l'altitude, et de la campagne sur l'évolution de la tuberculose osseuse." Rev. des mal. de la nutrition, Paris, 2e sér., 1910, viii, 256–266.
LOZANO, R.: "Impressions de un viage á Berck-sur-mer; tratamiento de las artrites tuberculosas." Clin. Mod. Zaragoza, 1910, ix, 752–761.
HORWITZ H. S.: "Berck-sur-mer: a City of Hospitals for the Treatment of Bone Tuberculosis." J. Missouri Med. Assn., St. Louis, 1910–11, vii, 219–222.
VERNEUIL, H.: "La Cure marine en général et le traitement de la tuberculose osseuse en particulière." Clinique, Brux., 1911, xxv, 529–536.
FRANZONI.: "De l'influence des rayons solaires sur les ankyloses consécutives aux arthrites tuberculeuses." Rev. méd. de la Suisse rom., Genève, 1911, xxxi, 39–44.
DOUMER, E.: "Traitement des ostéites tuberculeuses par l'air marin et par l'électrosation." Rev. de Thérap. méd. chir., Paris, 1912, lxxix, 758.
ROLLIER, A.: "Die Heliotherapie der Tuberkulose mit besonderer Berucksichtigung ihrer chirurgischen Formen, 1913.

HYPEREMIC

BENNET, W.: "Induced Hyperemia as a Means of Treatment with Special Reference to Tuberculous Joint Disease and Stiffened Joints." Brit. M. J., London, 1908, ii, 1533–1535.
WILREN, C.: "Les Traitements de Bier appliqués aux affections osseuses." Archives prov. de chir., Paris, 1910, xviii, 462–502.
ELY, L. W.: "The Bier Treatment in Tuberculous Joint Disease." Surg. Gyn. and Obst., 1910, x, 63–69.
CHAPUT: "Traitement des tumeurs blanches et des synovites tuberculeuses par la méthode de Bier." Bull. et mém. Soc. de Chir. de Paris, 1909, N. S. xxxv, 546–554.
THIERY, P.: "Le Traitement des tumeurs blanches par la méthode de Bier." Bull. et mém. Soc. de Chir. de Paris, 1909, N. S. xxxv, 597–600.

Treatment of Cold Abscesses

Dalla Vendova, R.: "Del trattamento della tuberculosi osteoarticolare mediante le iniezioni di soluzione jodoioduata." Bull. d. r. Accad. Med. di Roma, 1907, xxxiii, 105–114.
Nove-Josserand: "Plombage iodoformé dans les résections articulaires." Lyon chirurg., 1908–9, i, 299-301.
Viguard, P. and Grüber, G.: "Du plombage des articulations." Lyon chirurg., 1908–9, i, 93–114.
Redard: P.: "Modifying Injections in the Treatment of Tuberculous Osteoarthritis." Amer. Jour. Orth. Surg., 1909–10, vii, 508–511.
Mayet: "Les injections intra-articulaires d'ether iodé dans les tumeurs blanches," Par. chir., 1910, ii, 103–233.
Loewy: "Les injections intra-articulaires dans les tumeurs blanches." Par. chir., 1910, ii, 111–115.
Belhant: "Injections antiseptiques dans les ostéoarthrites tuberculoses." Ann. de. chir. et d'orthop., Paris, 1911, xxiv, 65–70.

Tuberculin Treatment

Painter, C. F.: "Experiences with Opsonins and Bacterial Vaccines in the Treatment of Tuberculous and Non-Tuberculous Arthritis." Med. Communicat. Mass. M. Soc., Boston, 1907, xx, 613–633.
Dunne, F.: "Tuberculous Joint Disease Treated with Deny's Tuberculin." Med.-Press and Circ., London, 1908, N. S. lxxxv, 430.
Miller, H. B.: "Opsonic Therapy in Tuberculosis of Bones and Joints." Univ. Penn. M. Bull., xxi, 64–67.
Freiberg, A. H.: "The Treatment of Joint Tuberculosis with Marmorek's Serum." Am. Jour. Orth. Surg., Philadelphia, 1908–9, vi, 69–78.
Ogilvy, C.: "A Contribution to the Study of Orthopædic Practice." Amer. Jour. Orth. Surg., 1908–9, v, 35–47.
Nutt, J. J. and Hastings, T. W.: "Tuberculin in Orthopædic Practice." Amer. Jour. Orth. Surg., 1908–9, vi, 48–68. Trans. Am. Surg. Assn., Philadelphia, 1910, xxxiii, 359–373.
Smith, M.: "The Inoculation Treatment of Tuberculous Arthritis." Brit. Med. Jour., London, 1909, ii, 1046–1049.
Ochsner, E. H.: "The Effects of Vaccine Therapy in Joint Tuberculosis." Illinois Med. Jour., Springfield, 1909, xv, 137–141.
Ridlon, J.: "Investigations as to the Value of Tuberculin in the Treatment of Tuberculous Joint Diseases." Trans. Amer. Assn. Genito-Surg., N. Y., 1910, v, 328–339.
Willard, Def., and Thomas, B. H.: "Therapy by Bacterins and Tuberculins in Mixed Suppurative Bone and Joint Disease." Ann. Surg., 1910, li, 261–267.
Ochsner, E. H.: "Vaccine Therapy in Joint Tuberculosis." St. Louis Clinique, 1909, xxii, 256–264.
Socrdat, P.: "La Réaction locale à la tuberculin dans les tuberculoses ostéo-articulaires." Clinique, Paris, 1910, v, 760.
Ridlon, J.: "Investigations as to the Value of Tuberculin in the Treatment of Tuberculous Bone Disease." Amer. Jour. Orth. Surg., 1910–11, viii, 565–577.
Plimmer, W. W.: "The Vaccines in Operative Treatment of Tuberculous Joints." Amer. Jour. Orth. Surg., Philadelphia, 1910–11, viii, 525–537.
Painter, C. F.: "The Uses and Limitations of Vaccine Therapy in the Management of Arthritis." Amer. Jour. Orth. Surg., Philadelphia, 1910–11, viii, 538–564.
Packard, G. B.: "Results Obtained from the Use of Tuberculin in Joint Tubercle." Amer. Jour., 1911–12, ix, 17–24.
Porter, J. L., and Quinn, L. C.: "The Treatment of Tuberculous Joint Disease with Karl Spengler's I. K. Serum." Chicago M. Record, 1912, xxxiv, 84–91.
Silver, D.: "Vaccine Therapy in Tuberculous Bone and Joint Disease." Penn. M. J., Athens, 1912, xvi, 219–223.
Eversole, H. O.: "The Use of Karl Spengler's I. K. Serum in the Treatment of Tuberculous Joint Disease." Amer. Jour. Orth. Surg., 1912–13, x, 234–242.
Gillespie, E.: "The Results of P. T. O. in Tuberculous Bone and Joint Lesions." Jour. Vaccine Therapy, 1913, ii, 91–101.
Prevost and Depos: "Traitement de la tuberculose osseuse par les paratoxins." Rev. Mod. de med. et de chir., Paris, 1912, x, 55–58.

Treatment of Bone Cavities

Codet-Boisse: "Le Traitement des cavités osseuses par la méthode de Mosetig." Jour de méd. de Bordeaux, 1908, xxxviii, 821–824.
Collenet, A.: "Contribution à l'étude de l'oblitération des cavités osseuses par le mélange de von Mosetig-Moorhof." Lyon, 1908.
Hill, R.: "The Treatment of Bone Cavities." Mobile M. and S. Jour., 1908, xii, 41–48.
Walton, A. J.: "Cases of Bone Cavities Treated by Stopping with Paraffin." Lancet, London, 1908, i, 155–157.
Wetherill, H. G.: "Bone Cavities and Interspaces and their Treatment." Colorado Med., Denver, 1908, v, 9–15.
Le Breton, P.: "Some Experimental Work with Materials for Plugging Sinuses and Bone Cavities." Amer. Jour. Orth. Surg., 1909–10, vii, 464–468.
Sherman, H. M.: "Salt Solution as a Filling for Bone Cavities." Surg. Gyn. and Obst., 1911, xiii, 147–151.
Machard: "Traitement des cavités tuberculeuses ostéo-articulaires par le procédé de Mosetig." Rev. méd. de la Suisse rom., Genève, 1912, xxxii, 797–802.

TREATMENT OF JOINT TUBERCULOSIS

Le Moniat: "Du danger des interventions sanglantes dans les tuberculoses articulaires." Bull. Soc. Sci. et Méd. de l'Ouest, 1907, xvi, 108–112.
Martens, W.: "Die Behandlung Gelenktuberkulose." Therap. d. Gegenw., Berlin, 1907, xlviii, 481–493.
Wilson, H. B.: "Modern Tendencies in the Treatment of Bone Tuberculosis." Trans. Lehigh Valley Med. Assn., Easton, Pa., 1907, ii, 51–58.
Rudes-Jiccinsky, J.: "Tuberculosis of the Joints and its Modern Treatment." Iowa, M. J., 1908–9, xv, 257–261.
Schäffer, K.: "Om recidiverendé tuberkulos polyarthroitis." Hosp. Tid. kjobenh., 1908, 5, R. i, 642–649.
Ochsner, E. H.: "The Treatment of Joint Tuberculosis." Illinois M. J., Springfield, 1908, xiv, 31–37; Tr. Mich. Med. Soc., Detroit, 1908, vii, 389–396.
Primrose, A.: "The Treatment of Tuberculous Arthritis." Canad. Jour. M. and S., Toronto, 1908, xxiii, 13–22.
Todd, C. E.: "Treatment of Tubercular Diseases of Joints." Australian M. Gaz., 1908, xxvii, 166.
Swift, H.: "The Treatment of Tuberculous Joint Disease by Open Cut and Exposure to Sunlight." Australian Med. Gaz., Sydney, 1908, xxviii, 221–223.
Mencière, L.: "Phénolization et phéno-puncture dans les tuberculoses osseuses et articulaires." Clinique, Paris, 1908, iii, 616–621.
Calot: "Ce qui doit être le traitement des tumeurs blanches." Gaz. des. hôp. de Paris, 1908, lxxxi, 1551–1554.
Kantor, M.: "Die Behandlung der Kniegelenktuberkulose in der Königl. Chir. Klinik zu Berlin von 1888 nach 1903." Berlin, 1908, G. Shade.
Müller, W.: "Über Knochengelenkresektionen." Deutsche med. Wochenschr., 1908, xxxiv, 1129–1131.
Painter, C. F.: "The Place of Operative Surgery in the Treatment of Chronic Arthritis." Amer. Jour. Orth. Surg., 1908, v, 413–424.
Neil-Philippe: "Contribution à l'étude de l'arthrectomie." Paris, 1908, 86–366.
Peollett and Godernel: "Sur les résections des grandes articulations dans les ostéo-arthrites tuberculeuses." Contr. méd. et pharm., Gaunat, xiv, 1908, xiv, 104–139.
Adams, G. E.: "The Treatment of Tuberculous Joints from the Standpoint of the General Practitioner." Texas State Jour. Med., Fort Worth, 1909–10, v, ii.
Pengree, H. A.: "The Conservative Treatment of Tuberculous Joints." Amer. Jour. Surg., New York, 1909, xxiii, 194–198.
Hagbena, P.: "The Modern View in Regard to the Treatment of Tuberculous Diseases of the Bones in Children." Hygica, Stockholm, 1909, 2 f. ix; Svens. Läk. Sallsk. Forhandlung, 241–258.
Guermonpiez: "Sur le traitement des tumeurs blanches." Jour. des. sc. méd. de Lille, 1909, i, 615–619.
Jiminez: "De las osteoartritis tuberculosas y suyo tratámiento." Bol. d. Inst. Patol. Mexico, 1909–10, 2 cp. vii, 224–234.
Crespolti, L.: "La Resezione del genocchio per osteomyelite tuberculare." Bull. d. sc. med. di Bologna, 1909, 8 S. ix, 42–44.
Cilley, A. H.: "Report of Work done on Tuberculous Joints at the City Hospital." Post-Graduate, New York, 1909, xxiv, 840–844.

MacEwan, Sir W.: "Discussion on Modern Methods in the Treatment of Tuberculous Disease of Joints." Brit. Med. Jour., London, 1909, ii, 949–956.
Stern, W. G.: "The Treatment of Tuberculous Joint Disease in Children." Ohio M. Jour., 1909, v, 250–254.
Hoeftman: "Die Behandlung der Gelenktuberkulose." Deutsche Med. Wochenschr., Leipzig, 1910–11, xxxvii, 1723.
Lange, F.: "Die orthopädische Behandlung der Knochen- und Gelenktuberkulose." Monatsschr. f. d. phys. Diatet., Hellmeth, 1910.
Strauss, M.: "Die Karbolsäurebehandlung der Knochen- und Gelenktuberkulose." Klin. therap. Wochenschr., 1910, xvii, 99–102.
Shands, A. R.: "The Prevention and Correction of Deformities in Chronic Joint Disease." Internat. Jour. Surg., New York, 1910, xxiii, 97–102.
Porter, J. L.: "The Modern Treatment of Tuberculous Joints." Lancet Clinic, Cincinnati, 1910, ciii, 485–489.
Baden, C.: "Le traitement des exudates inflammatoires et de la tuberculose osseuse par isolation." Clinique, Paris, 1910, c, 218.
Wilson, H. A.: "Treatment of Bone Tuberculosis." Therap. Gazet, Detroit, 1910, 3 S. xxvi, 391–397.
Lederet, Q.: "Les idées directrices dans le traitement del'hydrarthrose." Scalpel, Liége, 1910–11, lxiii, 151–154.
Lauwers: "Synovitis tuberculosa." Geneisk. Tijdschr. v. Belgie, Amsterdam, 1910, i, 55–57.
Hauser: "Jothim Behandlung tuberkulösen Gelenkenzündungén." Med. Klin., Berlin, 1911, vii, 1006.
Ely, L. W.: "Joint Tubercle in Children." Amer. Jour. Orth. Surg., 1911–12, ix, 31–36.
Ely, L. W.: "Joint Tuberculosis." 1911, Wood & Co.
Ely, L. W.: "Joint Tuberculosis." Interstate Med. Jour., St. Louis, 1913, xx, 334–342.
Ely, L. W.: "Gelenktuberkulose." Berl. klin. Wochenschr., 1913, l, 256–260.
Ely, L. W.: "Diseases of Joints and Bone-marrow, etc." Amer. Jour. Surg., New York, 1913, xxvii, 179–184.
Perthes, G.: "Über die Behandlung der Knochen- und Gelenktuberkulose." Therap. d. Gegenw., Berlin, 1912, liii, 529–533.
Peterka, H.: "Zur Behandlung der kindlichen Kniegelenktuberkulose." Beitr. zur klin. Chir., Tübingen, 1912, lxxxi, 721–727.
Marshall, H. W.: "Causes of Failure in Treatment of Chronic Joint Disease and how greater Success can be Obtained." Boston M. and S. Jour., 1912, cxlvi, 759.
Burguet, P.: "Contribution à l'étude du traitement conservateur dans les arthrites tuberculouses." Paris, 1912.
Calvé, J.: "Articular and Bone Tuberculosis." Amer. Jour. Orth. Surg., Philadelphia, 1912–12, x, 468.
Menard, V.: "Introduction à l'étude des ostéoárthrites tuberculeuses." Gaz. des. hôp. de Paris, 1913, lxxxvi, 165.
Vulpius, O.: "Knochen- und Gelenktuberkulose." Zeitschr. f. Tuberk., Leipzig, 1913, xx, 105–107.
Garri, C.: "Die Behandlung der Knochen- und Gelenktuberkulose." Arch. f. klin. Chir., Berlin, 1913, ci, 376–397.
Barbarin, P.: "Le traitement des tuberculoses ostéo-articulaires chez l'enfant." Clinique, Paris, 1913, viii, 290–292.
Chalier and Maurin: "Pyarthrose tuberculeuse primitive sans lésions osseuses." Rev. d'orthop., Paris, 3 S. iv, 41–54.
Lozano, R.: "Artritis tuberculosas poco frecuentes en la practica profesional." Clin. mod. Zaragoza, 1913, xii, 2–33.
Doumer: "Le traitement des ostéites tuberculeuses par l'air marin et par électrisation." Ann. de la Policlin. de Fechner, 1913, xxiv, 35–38.
Pohl, F.: "Über Phenolkampferbehandlung verschiedener auch tuberkulöser Gelenkerkrankungen und kalter Abszesse." Zentralbl. f. Chir. Leipzig, 1913, xl, 814–818.
Doche, J.: "Immobilisation des arthrites tuberculeuses et héliothérapie." Jour. de méd. de Bordeaux, 1913, xliii, 402.
Porter, J. L.: "The Treatment of Tuberculous Joints." Surg. Gyn. and Obst., 1913, xvi, 334–339.
Oberst, Adolf: "Die herdiförmige Tuberkulose der grossen Extremitäten Knochen." Deutsche Zeitschr. f. Chir., September, 1913, S, 431.
Garri, C.: "Die Behandlung der Gelenktuberkulose." Tubingen, 1913.
Bonime, Ellis: "Tuberculin in Surgical Tuberculosis." N. Y. Med. Jour., April 10, 1916.
Bonime, Ellis: "Tuberculin Therapy, with special Reference to the Therapeusis used in Combination with or immediately following Tuberculin Administration." Jour. Med. Soc. of New Jersey, 1916.

CHAPTER II

TUBERCULOSIS OF THE SPINE

Synonym.—Pott's disease; spondylitis tuberculosa.

ETIOLOGY

Pott's disease was so called from the fact that Percival Pott, in 1779, was the first to describe accurately this slowly developing deformity, accompanied by pain and at times by paralysis. He did not, however, ascertain its cause and it was not until 1882 when Robert Koch made his discovery of the tubercle bacillus that its etiology was definitely determined.

At the present time the term, instead of including the various causes of angular deformity, such as may be the result of fracture, malignant disease, erosion of an aneurism, syphilis or other pathological process, is confined to those cases of kyphosis where the deformity is due to a tuberculous infection of the bodies of the vertebræ. The compression and disintegration of these vertebral bodies produce the characteristic angular deformity of Pott's disease.

Age.—Taking a broad view of statistical reports, the incidence appears to be commonest at the age of five. That it is essentially a disease of very early childhood is evident by a glance at the two following tables, both of which show that more than 85 per cent. of the cases occur under ten years of age:

1259 cases (Whitman)

Less than 1 yr.	38	3.1 per cent.
Between 1 and 2 yrs.	176	14.2 per cent.
Between 3 and 5 yrs.	627	50.2 per cent.
Between 6 and 10 yrs.	234	18.3 per cent.
Between 11 and 20 yrs.	89	7.2 per cent.
Between 21 and 50 yrs.	43	3.5 per cent.
Between 31 and 50 yrs.	32	2.6 per cent.
Over 50 yrs.	11	0.8 per cent.

180 cases (Lannelongue)

Less than 2 yrs.	7	per cent.
Between 2 and 5 yrs.	50	per cent.
Between 5 and 10 yrs.	32	per cent.
Over 10 yrs.	10	per cent.

Sex is of no importance as an etiological factor, although boys are slightly more often affected than girls.

Relative Frequency.—The spine is more often the seat of tuberculous disease than any other single bone or joint, viz.:

HOSPITAL FOR RUPTURED AND CRIPPLED, N. Y., 1885 to 1904

	Cases	Per cent.
Tuberculosis of spine	4,299	39.6
Tuberculosis of hip	3,329	30.7
Tuberculosis of other joints inclusive	3,222	29.7
	10,850	

BOSTON CHILDREN'S HOSPITAL, 1869 to 1888

	Cases	Per cent.
Tuberculosis of spine	1,864	50.1
Tuberculosis of hip, knee, ankle, shoulder, elbow, wrist combined	1,856	49.9
	3,720	

Predisposition.—*Heredity.*—As a predisposing factor, this element can be only estimated. Statistics vary, Gibney finding 76 per cent. of his series with tuberculous parents, while Jaeger and Waterman (Trans. Am. Orth. Surg., 1901, Vol. xiv, p. 287) obtained a positive family history in only 10 per cent.

A previous history of one of the exanthemata immediately preceding the onset of spinal symptoms is occasionally obtained, while in many cases there is evidence of tuberculosis elsewhere.

Injury.—In a certain percentage of cases there is a history of trauma, particularly a fall from a small height. Too often, however, the history of injury is more imaginary than real or the injury is noticed because of sensitiveness from tuberculous disease already existing.

NORMAL ANATOMY

The Spine as a Whole.—The spine or vertebral column consists of 26 superimposed bones or vertebræ of which 7 are cervical, 12 thoracic, 5 lumbar, the sacrum and the coccyx.

Viewed in profile, the normal spine has four anatomical curves, two with their convexities forward in the cervical and lumbar regions, and two with their convexities backward in the thoracic and sacral regions. The upper three curves merge imperceptibly into one another, but the lumbosacral junction presents a marked angle prominent on the anterior surface of the column at the sacral promontory. Viewed from behind, the vertebral column is vertical.

Pathological exaggerations of these anteroposterior curves and deviations from the normal vertical plane constitute:

Scoliosis—lateral deviation.
Kyphosis—exaggerated posterior convexity.
Lordosis—exaggerated anterior convexity.

Individual Vertebræ.—A typical vertebra is composed of a *body* with a *neural arch* behind it, completing the *spinal foramen*, the articulated series of which constitutes the *vertebral canal*.

The *neural arch* has 2 *pedicles*, 2 *laminæ* and 7 *processes* (4 *articular*, 2 *transverse* and 1 *spinous*).

The *pedicles* have above and below, *vertebral notches*, which with those of the vertebræ above and below, form the *intervertebral foramina*.

The *laminæ* are broad expansions from the pedicles, fusing behind in the middle line and at their junction prolonged into the *spinous process*.

The *transverse processes* are outward projections from the points of junction of pedicles and laminæ.

The *articular processes* comprise an *upper* and a *lower pair* from the roots of the transverse processes, and articulate with those of the vertebræ above and below.

TABLE SHOWING THE CHARACTERS OF TYPICAL VERTEBRÆ OF EACH GROUP

(From Gerrish's Anatomy)

	Cervical	Thoracic	Lumbar
Bodies:	Small, transversely elongated, sloped downward and forward, lipped laterally. No costal facets.	Heart-shaped. Deeper behind. Nearly equal transversely and antero-posteriorly. Costal facets.	Large. Elongated transversely. No costal facets.
Pedicles:	Pass outward and backward. Notches above and below nearly equal.	Pass backward. Inferior notches deeper than superior.	Pass backward and slightly outward. Inferior notches deep.
Laminæ:	Long, slender, flattened.	Broad, short, imbricated.	Short, deep and thick.
Spinous processes:	Short, strong, bifid and nearly horizontal.	Long, projecting downward and overlapping.	Quadrate, horizontal, of medium length.
Transverse processes:	Short, slender, directed outward and forward.	Long, strong. Projecting outward and backward. Articulate with tubercles of ribs.	Rudimentary, as "accessory process."
Costal process:	Slender, flat, ossified to the vertebra and transverse process.	A separate bone (*i.e.*, a rib).	Ossified to vertebra. Flat, thin, "transverse process."
Superior articular processes:	Flat, directed upward and slightly backward.	Flat, directed backward and slightly outward.	Slightly concave, directed inward and slightly backward.
Inferior articular processes:	Flat, directed downward and slightly forward.	Flat. Directed forward and slightly inward.	Slightly convex. Directed outward and slightly forward.
Spinal foramen:	Large, triangular, wide.	Smaller, circular.	Larger than in the thoracic. Triangular. Wide.

Articulations of the Vertebral Column.—There are 2 sets of articulations, (*a*) those between the bodies and (*b*) those between the *articular processes*, connected by *ligaments*.

(*a*) *Bodies.*—The articulations are amphiarthrodial.

1. *Intervertebral disks* between the bodies consist of an external fibrous portion and an internal pulpy, elastic portion with a central synovial cavity.

2. The *anterior common ligament* is a strong band lying over the anterior portions of the vertebral bodies and extending the entire length of the spinal column, being continued above as the *anterior occipito-atlantal* and *anterior atlanto-axial ligaments* and below as the *anterior sacrococcygeal ligament*. Its function is partly to limit extension of the spine.

3. The *posterior common ligament* lies on the dorsal surfaces of the vertebral bodies and extends the length of the spinal column, being continuous above with the *posterior occipito-axial ligament*.

(*b*) *Articular Processes.*—The joints between the articular processes are *arthrodial* (gliding) joints, each having a synovial cavity.

The ligaments uniting the neural arches are:

The *ligamenta subflava* connect the laminæ of adjacent vertebræ from the axis to the sacrum.

The *interspinous ligaments* extend between the adjacent borders of the spinous processes.

The *supraspinous ligament* is a continuous ligamentous band over the tips of the spinous processes—above, it is continued as the *ligamentum nuchæ*.

Blood Supply.—The *arteries* of the vertebral bodies and their neural arches are the *spinal branches* of the vertebral arteries.

The *veins* form complicated plexuses situated within and without the spinal canal.

Fascia.—The vertebral fascia is an extension downward of the posterior portion of the cervical fascia. It stretches from the spinous processes of the thoracic vertebræ to the angles of the ribs, covering in the deep vertical muscles of the back, passing in front of the serratus posterior superior and becoming continuous below with the lumbar fascia.

PATHOLOGY

Localization of the Disease.—The dorsal region of the spine is the part most frequently affected and the 8th to 12th dorsal vertebræ are those most often involved in the tuberculous process.

Of 1355 cases of tuberculous spondylitis analyzed by Whitman ("Orthoped. Surg." 1907, page 23) from statistics of the Hospital for Ruptured and Crippled, the following distribution is noted, based on the location of the most prominent spinous processes:

Cervical vertebræ	100 cases.
Dorsal vertebræ	854 cases.
Lumbar vertebræ	317 cases.
Lumbosacral vertebræ	13 cases.
	1284 cases.
No deformity	55 cases.
Disease in two regions	16 cases.
	1355 cases.

Judging by this prominence of the spinous processes, the number of cases steadily and progressively increases from the 1st cervical vertebra (with 3) to the maximum number (120) at the 12th dorsal vertebra, after which the incidence of involvement progressively decreases.

Varieties.—The infectious material, borne by the blood-stream, finds lodgement and sets up the tuberculous process practically always in the cancellous tissue of the body, but rarely in one or more component parts of a vertebra.

1. *Central Variety.*—Tuberculosis of the body is by far the commonest variety encountered.

2. *Epiphyseal Variety.*—The infection may begin at the epiphysis of the body, close to the intervertebral disk, whence it extends into the body or to the disk.

3. *Anterior* or *Peripheral Variety.*—The primary focus may be located in the anterior part of the body beneath the anterior common ligament.

4. *Appendiceal Variety.*—Very rarely the appendages (especially the transverse processes) are the seat of involvement.

Structural Changes.—In all varieties the essential pathological process is very much alike. As the central variety is the form usually met, it will be described as the typical picture of the process.

As a result of obliterating endarteritis consequent upon tuberculous toxemia, the primary change is a disturbance of nutrition of the vertebral body. The marrow changes from red to a pale, myxomatous structure, making an ideal soil for the growth of the tuberculous follicle. These follicles increase in size, coalesce and central caseation occurs. The grey myxomatous marrow of early malnutrition has now a different aspect; the central yellow caseous area is surrounded by a grey zone limited by a thin peripheral shell of red congested marrow.

The lamellæ become rarefied, and varying degrees of absorption occur. If they become isolated before absorption is completed, they form sequestra.

A striking phenomenon during the elaboration of the tuberculous focus is the constant tendency of the marrow to become fibrous. There is practically *never* any subperiosteal new bone laid down except in the later stages; tuberculosis seems to inhibit its formation in contrast with the formation of subperiosteal new bone in all other infections.

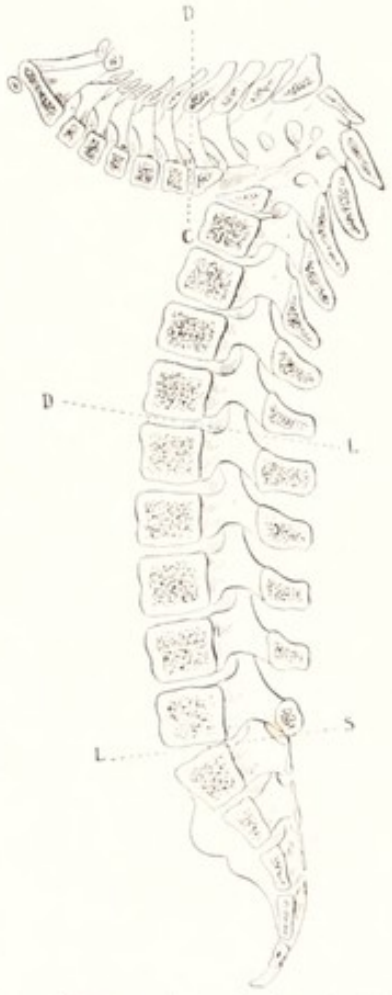


FIG. 9.—Destruction of the bodies of the third, fourth, fifth, sixth and seventh dorsal vertebræ; partial destruction of three others. (Ménard.)

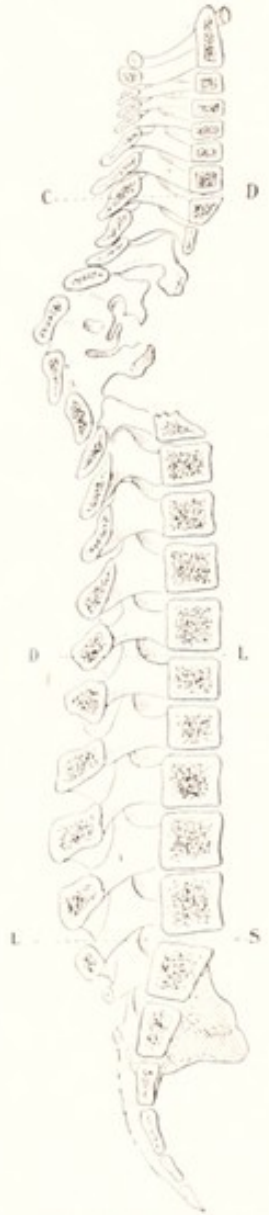


FIG. 10.—The deformity corrected, showing the area of the destructive process. (Ménard.)

With the centrum of the vertebral body caseous, the superimposed weight of the spinal column is now borne by the fragile peripheral shell of compact bone. With the fulcrum (articular processes) and the long arm of the

lever (pedicles, laminæ and transverse processes) intact, and the short arm (body) diseased, the latter gives way and descends, while the long intact arm ascends, causing the tips of the spinous processes to be widely separated and produces the angular deformity prominent in the back as a *kyphosis*. This leverage action is aided and the deformity increased by overaction of the irritated anterior muscles lying on each side of the spine (Figs. 9 and 10).

ASSOCIATED CHANGES

In addition to the essential deformity, kyphosis, there are compensatory curvatures and lateral deviations of the vertebral column as a whole and



FIG. 11.—Tuberculosis of the spine and of the right hip, of unusual character. Flexion deformity of the hip gave rise to lumbar lordosis of such severity that the skin over the gluteal muscles was brought into firm contact with that over the kyphosis of the lower dorsal spine from the point indicated by the arrow backward to the tip of the kyphos.

mechanical changes in the thorax and pelvis and frequent abnormalities of the heart and great vessels and occasionally of the spinal cord and its membranes.

1. **Vertebral Column as a Whole.**—(*a*) Kyphosis is the essential deformity of Pott's disease, produced in detail as given above. The amount and character of the kyphosis depends upon two factors, the number of vertebræ affected and the location of the disease. When a single vertebra is involved the angularity is sharp and the deformity slight. When several vertebræ are diseased the dorsal prominence is rounded, and the deformity great. A rounded kyphosis always indicates chronicity.

The degree and character of the kyphosis in the different regions of the spine are as follows:

Cervical Region.—Deformity very slight. Inflexion of the spine is prevented by the roots of the pedicles. Hyperextension is possible on account of the very considerable space between the posterior arches.

Dorsal Region.—The greatest deformity of all occurs with involvement of this part of the spinal column (Fig. 11), the reasons being that the physiological curve is posterior, the location of the pedicles in the posterior surface of the vertebræ and the close approximation of the laminæ and spinous processes preventing hyperextension (Fig. 12).

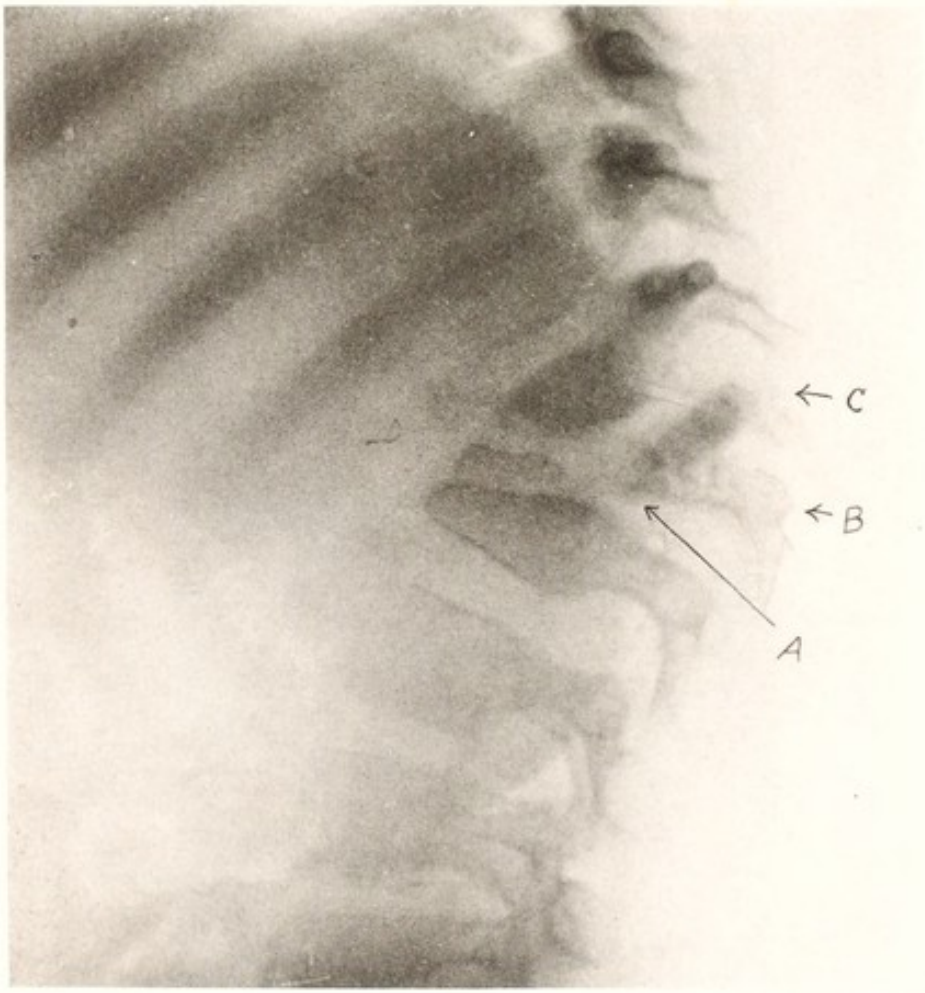


FIG. 12.—Rontgenogram of the dorsolumbar spine showing the bodies of the vertebræ *B* and *C* completely obliterated and one directly above and below thinned and wedge shaped due to the tuberculous process.

The resulting kyphotic angle of the spine thus produced should be noted.

The principal feature, however, of this rontgenogram is that no repair by bone proliferation is shown, although the destructive lesion in this case had existed for not less than three years. The need of the implantation of bone is apparent.

Lumbar Region.—Deformity is never marked in this locality. The large intervertebral spaces between the bodies and the wide intervals between the laminæ and spines of adjacent vertebræ readily permit of hyperextension. Therefore, kyphosis is slight, although there is some vertical shortening of the spine.

(*b*) *Compensatory Curves.*—Compensatory spinal curvature takes place as follows:

1. *In Cervical Disease.*—A backward curve with alteration in the axis of the skull.

2. *In Dorsal Disease.*—Cervical and lumbar lordosis.

3. *In Lower Lumbar Disease.*—Hyperextension of the hips.

(*c*) *Lateral Curvature of the Spine.*—This condition very often resembles a simple, non-tuberculous scoliosis. It is found complicating kyphosis in some cases and is caused by two factors: (*a*) In the collapse of the diseased vertebræ, when the upper do not fall true upon the underlying vertebræ, and (*b*) unilateral disease of the vertebral bodies.

2. **Spinal Cord and Meninges.**—Pressure symptoms are rare even in the presence of very great deformity. *Compression paraplegia* may be caused by disease of the vertebræ, the meninges or the spinal cord.

(*a*) *Vertebral Causes.*—It is very rare for bony compression by the vertebræ to occur. When such an event materializes, it is occasionally due to partial dislocation, or to the pressure of sequestra. Most commonly it is due to the encroachment of tuberculous granulations or an ichor pocket.

(*b*) *Meningeal Causes.*—By extension of the disease, tuberculous perimeningitis may occur, followed by pachymeningitis and subsequently by leptomeningitis.

(*c*) *Spinal Cord Causes.*—Direct infection of the cord by tuberculosis is rare. Infection is usually secondary. The cord may become constricted by pressure. When affected, there are local edema, subacute myelitis and softening.

3. **Heart and Great Vessels.**—The heart is particularly affected in Pott's disease of the middorsal region. Its base is displaced downward, its apex upward, and it is rotated on its horizontal transverse axis. Hypertrophy occurs as a result of kinking of the aorta with its consequent constriction; dilatation of the left ventricle follows.

The aorta becomes kinked in two localities, (*a*) at the center of its transverse portion, and (*b*) opposite the kyphosis. The *vena cava* undergoes distortion similar to that of the aorta.

4. **Thorax.**—To quote Tubby's excellent description (Deformities, incl. Dis. of the Bones and Joints, vol. 11, page 95):

"In the chest three varieties of deformity are seen: (*A*) If the curve is *high up* in the *dorsal* region, the true ribs are held at an angle greater than the normal, the sternum is displaced downward, and the antero-posterior diameter of the thorax is diminished. In fact, the chest is in an expiratory position. (*B*) If the disease is *low* down in the *dorsal* region, the ribs and sternum are raised, the anteroposterior diameter of the chest is lengthened, and the chest is barrel-shaped, and is in the position of inspiration. Therefore, the breathing is diaphragmatic and the patient is short of breath. (*C*) When the *lumbar region* is affected the whole thorax sinks downward and forward, the lower ribs override the pelvis, the ensiform cartilage approximates the symphysis pubis and the abdominal wall is thrown into folds." (Pain may be produced by actual telescoping of ribs and pelvis.)

5. **Pelvis.**—Compensatory to the angulation of kyphosis in the lumbodorsal and lumbosacral regions, pelvic deformity occurs as follows:

(*a*) *In Lumbodorsal Disease.*—Rotation of the sacrum—its upper half backward, its lower half forward. Flaring of the iliac crests. Increase of the antero-posterior and transverse diameters of the pelvic inlet. Diminution of the pelvic outlet by encroachment of the lower one-half of the sacrum. Approximation of the ischia. Pelvic cavity funnel-shaped.

(*b*) *In Lumbosacral Disease.*—Rotation of the sacrum on its transverse axis occurs and the pelvic outlet is diminished because of the encroachment of the lower half of the sacrum on its cavity; coincidently, the normal obliquity of the pelvis is greatly diminished in certain cases, *i.e.*, there is a marked

decrease in the normally acute posterior lumbosacral angle, so that the long axes of lumbar spines and sacrum are more nearly in the same vertical plane.

ICHOR POCKETS (ABSCESS FORMATION)

Although the term "abscess" is the one commonly used it must be borne in mind that the circumscribed collection of tuberculous detritus (from disintegration of bone and soft tissues and exudate from granulation tissue) bears no resemblance to the pyogenic product of the same name.

An **ichor pocket** (cold abscess) is the commonest complication of Pott's disease, occurring in 20 per cent. of cases (Townsend, Tr. Am. Orth. Assoc., iv, 164). This name was first suggested by Dr. Achilles Rose of New York and first used by Dr. H. L. Taylor. It is employed to designate fluid débris.

Origin.—Arising from disintegration of bone and soft tissues adjoining, the ichor pocket is formed by (*a*) *perforation* of the investing shell of bone or (*b*) *dissemination* following collapse of the vertebral bodies (Fig. 13).

Course.—From its point of origin, the course of the ichor is directed by the planes of fascia and other anatomical structures in its vicinity. For purposes of description, the ichor pockets of Pott's disease are arranged by spinal regions, and following are the determining factors and locations of the varieties in each region:

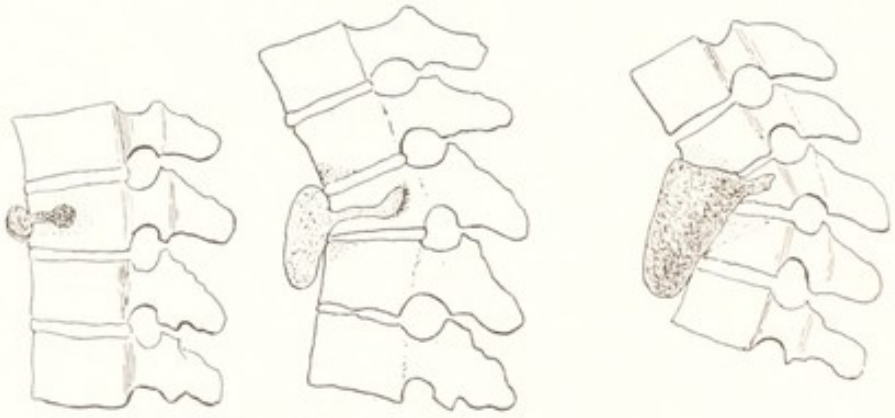


FIG. 13.—Tuberculosis of the spine, showing the progressive disintegration and collapse of the vertebral body primarily affected, the infection of the contiguous vertebræ by contact, and the mode of production and growth of a prevertebral ichor pocket (cold abscess). (After Calot.)

(*A*) *Cervical Spinal Ichor Pocket* (Cold Abscess).—Its course is directed entirely by the disposition and arrangement of the deep cervical fascia, for an anatomical description of which the reader is referred to the proper authorities.

1. Collecting between the anterior surface of the cervical vertebræ and the prevertebral fascia, it may bulge forward as a retropharyngeal ichor pocket, or it may spread laterally to the posterior edges of the sternomastoid muscles.

2. Penetrating the prevertebral fascia, the ichor pocket may appear *high* (in the mouth) or *low down* (in the visceral compartment of the neck, around the esophagus and trachea), but frequently gravitates downward to the mediastinum or axilla or may enter the esophagus.

3. It may lie between the spines and ligamentum nuchæ on the inner side and the posterior cervical muscles on the outer side.

(*B*) *Dorsal Spinal Ichor Pocket* (Cold Abscess).—An ichor pocket in this region is nearly always small and is usually retained *in situ*. Its varieties and locations are as follows:

1. Retained between the vertebral body and the anterior common ligament (*prevertebral* ichor pocket).

2. Perforating the anterior common ligament it invades the *posterior mediastinum*.

3. By extending laterally, it may lie beneath the pleura or penetrate its cavity to form a tuberculous empyema.

4. By gravitating downward it may appear as a *lumbar ichor pocket*.

5. Backward between the transverse processes, thence by way of the blood-vessels or posterior primary divisions of the nerves.

6. Forward with the intercostal vessels.

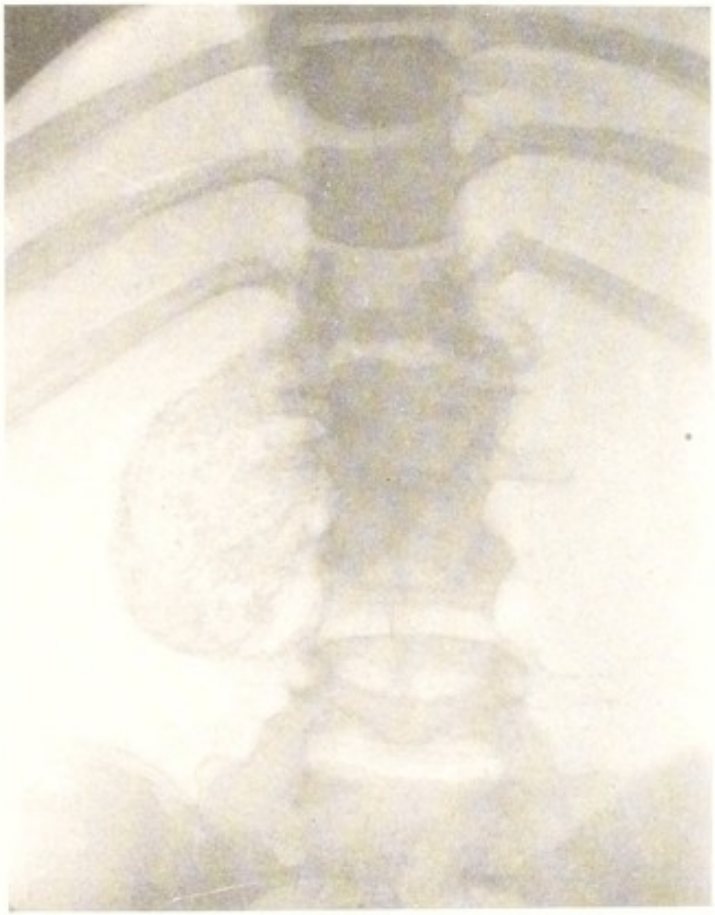


FIG. 14.—Old tuberculous abscess with calcareous deposit, complicating Pott's disease of spine.

7. Following the nerve trunks along the external or internal branches of the posterior primary divisions.

8. An ichor pocket from the upper four dorsal may follow the same course as given for pockets from cervical vertebræ.

(C) *Lumbar Spinal Ichor Pocket* (Cold Abscess).—An ichor pocket arising in the lumbar vertebræ is directed in its course by the psoas, iliac and lumbar fasciæ, lumbar arteries and nerves, for a detailed description of which the reader is referred to a standard work on anatomy.

Following are the principal routes and focalizing points of lumbar ichor pockets:

1. Following the sheath of the psoas muscle, beneath Poupart's ligament, appearing at the inner or outer side of the femoral vessels (Figs. 15 and 16).

2. Following the sheath of the psoas muscle for a short distance, thence

passing outward under the fascia iliaca to appear as an iliac ichor pocket (Fig. 17).

3. Into the sheath of the quadratus lumborum, thence above the iliac crest, pointing in Petit's triangle (Fig. 18).

4. Forward, behind the aorta, downward with the great vessels, thence following the external iliac artery to point in the thigh, or the internal iliac artery to point in the pelvis, opening into the rectum or through the great sacrosciatic foramen.

5. Forward between the planes of the abdominal muscles, to appear in the anterior abdominal wall.

6. Along the dorsal branches of the lumbar arteries, appearing close to the spines and the last rib.

7. Along the nerve-sheaths, pointing at some distance from the middle line of the neck.

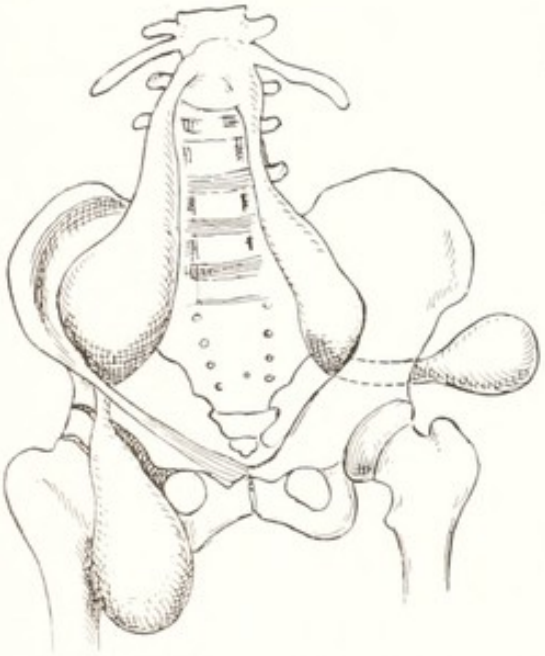


FIG. 15.—Disease of the lumbar spine with cold abscesses (ichor pockets), gravitating downward under Poupart's ligament on the right and posteriorly through the great sciatic notch.

AMYLOID INFILTRATION

Amyloidosis (lardaceous disease, waxy degeneration) is a common com-

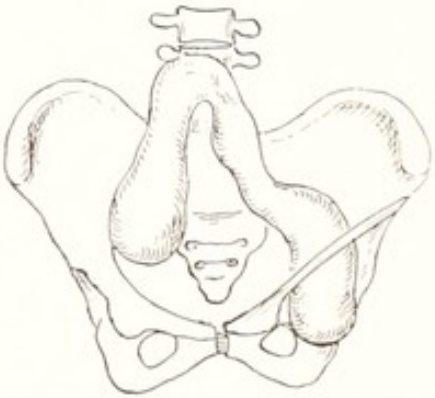


FIG. 16.—Psoas abscesses (ichor pockets), originating from lumbar Pott's disease and granulating downward in the psoas muscle-sheaths. (After Calot.)

plication. Tuberculosis with secondary infection is the cause of about 50 per cent. of all cases. The condition is an *infiltration* (not a degeneration) characterized by the deposit of amyloid (a glycoprotein) *between* the cells, in the interstitial tissues of the viscera, particularly the liver, spleen, kidneys and blood-vessels of the mucosa—especially that of the intestines. The common condition under which it occurs is prolonged suppuration, hence osseous and joint tuberculosis, complicated by secondary pyogenic infection and often followed by amyloidosis.

NATURAL METHOD OF CURE

Healing by spontaneous, natural means is preceded by preliminary absorption of detritus, is hastened by contact of the diseased bones (hence the only salutary effect of kyphosis) and is dependent upon these factors, viz.: (*a*) cessation of the disease and (*b*) consolidation of the spine.

Fibrosis is Nature's method of cure, and *not* regeneration of bone. This is a phenomenon in striking contrast to the process of repair in the

osseous lesions of the other infections (typhoid, pyogenic, etc.). This has been abundantly shown by *x*-ray and offers one of the chief arguments in favor of immobilization by operative means.

RARE FORMS OF TUBERCULOSIS OF THE SPINE

The preceding discussion of the pathology of the disease referred to that of the vertebral *body*, the predominating lesion.

Other unusual involvements are:

(*a*) *Spondylarthritis*, tuberculous disease of the occipito-atloid and atlo-axoid articulations, with peculiar pathological features. The affection is one of early years (15 to 25) as a rule. It begins as synovial tuberculosis but spreads to adjacent bony structures.

Other still more uncommon sites are:

(*b*) *Transverse processes.*
(*c*) *Spinous processes.*
(*d*) *Costovertebral articulations.*
(*e*) *Joints of the articular processes.*

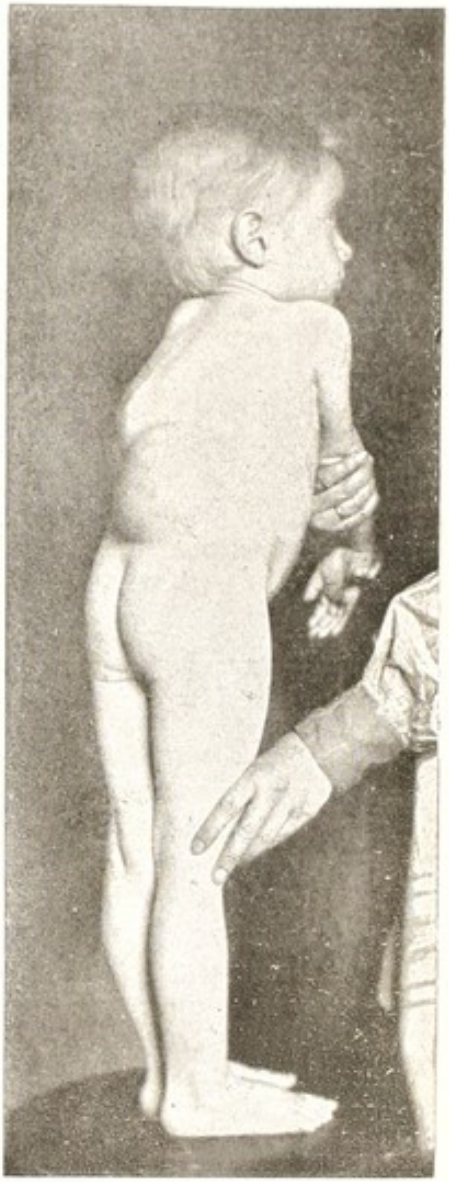


FIG. 17.—Lumbar abscess. (Bradford and Lovett.)

SYMPTOMS AND PHYSICAL SIGNS

When a patient presents himself for treatment, careful inquiry should be made into (1) his *family history*, in a search for hereditary tendencies to tuberculosis; (2) into the minutest details of his *present illness*, noting symptoms in the order of their appearance; and lastly, (3) a complete *physical examination* must be made.

SYMPTOMS

Occasionally the first intimation of spinal disease is kyphosis or beginning paralysis. Usually, however, a more or less extensive complex of *subjective symptoms* precedes these physical signs.

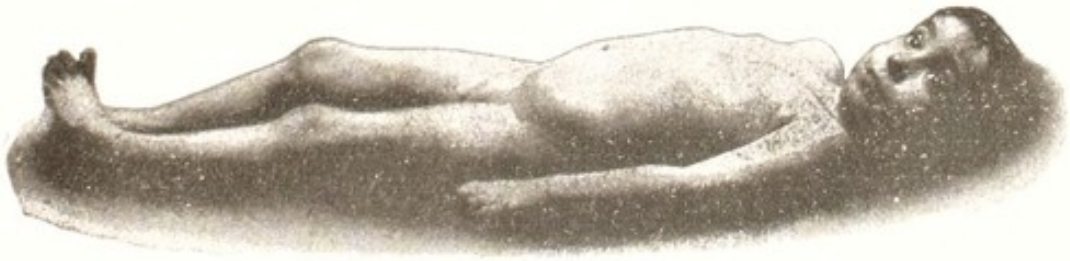


FIG. 18.—Psoas abscess. (Bradford and Lovett.)

1. **Latent Period.**—Sometimes during convalescence from one of the exanthemata indefinite symptoms of debility are noted, or their advent is gradual and independent of any tangible cause. There may be lassitude,

poor appetite and slight loss of weight with slight nocturnal rise of temperature. This "incubation" period may occupy several weeks or months.

2. **Pain.**—This is either (*a*) *local* or (*b*) *referred*.

Local pain may be subjective or elicited. In character it is sharp and stabbing and often corresponds to the location of the diseased vertebræ. If real pain is present, pressure on the spinous processes of the vertebræ may excite it.

Referred pain (felt at a distance from the lesion) follows the distribution of the sensory nerves and is usually subacute, with exacerbations. Its referred areas are, in the various spinal lesions, as follows:

(*a*) *Cervical* disease: occiput and arm.

(*b*) *Dorsal* disease: sternum, or intercostal neuralgia.

(*c*) *Dorsolumbar* disease: epigastrium and girdle pains.

(*d*) *Lumbar* disease: hips and legs.

The skin of all these regions is hypersensitive. Referred pains are frequently the cause of mistakes in diagnosis in early Pott's disease, as in case of epigastric pain, "indigestion" is often the diagnosis.

3. **Night Cries.**—They are not so common as in the case of the larger joints; are usually evident in cervical and dorsal disease and disappear under appropriate treatment.

4. **Paralytic Symptoms.**—Tripping, stumbling, difficulty in going up and down stairs and shuffling gait suggest the beginning of paralysis the nature of which is spastic without involvement of the sensory nervous system. (The physical signs of paralysis will be later enumerated.

5. **Symptoms Due to Ichor Pocket** (Cold Abscess).—In certain locations, pressure symptoms may occur, viz.:

(*a*) *Cervical* (retro-pharyngeal ichor pocket): produces dyspnea, hoarse voice and dysphagia.

(*b*) *Upper dorsal* (ichor pocket pointing anteriorly) from pressure on the recurrent laryngeal nerve; dyspnea, change in character of the voice.

(*c*) *Lower dorsal and lumbar* (psoas ichor pocket with psoas contraction); difficulty in walking.

6. **Miscellaneous Symptoms.**—A peculiar grunting respiration is not unusual. In addition, cough is not uncommon, also, dyspnea, gastric disorders, flatulence, obstinately recurrent vomiting and disorders of the bladder.

Physical Signs

As in all other phases of orthopedic practice, a definite routine method of examination should be employed, beginning with keen observation and a record of the patient's facial and general appearance, his attitude and gait, minute examination of the spine and pelvis and *in every instance* concluding with an *x*-ray examination of the vertebræ.

1. **Attitude and Gait.**—The attitude is, in a general way one of expectation (from fear of sudden jarring of the sensitive spine). The patient almost unconsciously flexes all the joints of the body in anticipation of an unexpected movement; his attitude is of the so-called "spring" type. Observation as to the above should be made before and after stripping the child.

Tuberculous disease of a particular region of the spine is characterized by a specific attitude so typical that an experienced observer can almost locate the disease by noting the attitude. Following are the spinal regions with their specific postures:

Location of Disease	*Attitude*
(*a*) *Upper Cervical*	Resembles wry-neck, but there is usually no rotation of the face (Fig. 19).
(*b*) *Lower Cervical*	Head thrown back and to one side. Chin forward (Figs. 20 and 21).
(*c*) *Upper Dorsal*	Shoulders raised. Shoulders and arms thrown back, "military" style. Upper chest flat. Lower chest prominent.



FIG. 19.—Tuberculosis of second cervical vertebra. (Dr. Reginald H. Sayre.) Marked distortion and extreme torticollis.



FIG. 20.—Attitude of head in cervical Pott's Disease. (Bradford and Lovett.

(*d*) *Mid-dorsal*	Spinal rigidity and early deformity. Arms appear longer and hang down lower than normal. Globular thorax. Ribs tilted up. Sternum forward.
(*e*) *Dorsolumbar and Upper Lumbar*	Typical attitude: head and upper body back—abdomen prominent—patient stands on a broad base with feet wide apart—"alderman's gait" (belly out, chest and shoulders back—waddling) (Figs. 22 and 23).

Location of Disease	*Attitude*
(*f*) *Last Lumbar Vertebra*.....	Condition, tuberculous *spondylolisthesis* (destruction of body of last lumbar vertebra with displacement forward and downward of the lower part of the spine). Attitude, very marked lordosis of the back with projection of the abdomen. Thorax depressed—last rib nearly touches iliac crest, deep transverse abdominal fold at level of umbilicus.



FIG. 21.—Cervical disease. A characteristic attitude. (Whitman.)

2. **General Appearance and Physical Condition.**—The patient, as a rule has the facies of tuberculosis in general but with the added element of pain causing an anxious expression. Poor nutrition and low weight are the rule.

3. **Irregularities of the Spine.**—To detect these the patient should be standing and stripped, at least as far as the waist. The commonest irregularities are (*a*) dorsal angularity (kyphosis); (*b*) lateral curvature (scoliosis); (*c*) obliteration of the normal anteroposterior curves ("boarding"); (*d*) increased anterior curvature (lordosis); (*e*) perivertebral thickening; (*f*) yielding of the spine on pressure.

(*a*) *Kyphosis.*—This has been thoroughly described in the section on pathology.

(*b*) *Scoliosis.*—Lateral curvature frequently complicates kyphosis and is often mistaken for an ordinary scoliosis.

(*c*) "*Boarding.*"—The normal curves are obliterated, the vertical axis of the spine being nearly straight. This phenomenon is due to muscular rigidity and is one of the earliest clinical signs. It represents an attempt of nature to immobilize the spine and is simulated by very few conditions.

(*d*) *Lordosis.*—This is nature's method of compensating for the kyphosis and varies in location according to the segment of spine affected by the disease, viz., in cervical disease, lordosis is absent, being represented by a decrease in the amount of normal dorsal kyphosis.



FIG. 22.—Lumbar Pott's disease; the posture indicates that disease is still active. (Taylor.)

In *dorsal* disease, the compensatory lordosis is found in the lumbar region.

In *lumbar* disease, inasmuch as no lordosis is possible below the affected region, hyperextension of the hips occurs.

(*e*) *Perivertebral Thickening.*—By running the thumb and forefinger down the vertebral column on either side of the spinous processes, a distinct thickening may sometimes be felt at the site of lesion.

(*f*) *Yielding on Pressure.*—Pressure on the spine in the affected region is accompanied by a degree of yielding which varies with the age of the disease

process, being marked in early cases and extensive in areas when several vertebræ are involved, while in cases where healing is in progress it is diminished or absent. Some writers advise against the employment of this test because of the possibility of lighting up a quiescent focus of disease.

4. **Recording the Deformity.**—For future reference, to compare the degree of deformity from time to time a graphic record should be made. The easiest, and a satisfactory method, is to use a strip of malleable lead tape (18 inches by ½ inch by ⅛ inch), moulding it to fit the kyphosis and tracing the result on paper (Fig. 24).

Possibly a more accurate and more rapid record can be made with Young's apparatus. The instrument consists of a wooden bar with a slot in which a number of wooden uprights of equal lengths play. By means of an adjust-



FIG. 23.—Beginning Pott's disease in a boy of three; slight projection at first lumbar; characteristic posture. (Taylor.)

able screw fixed in one end of the bar, the wooden uprights can be released, and, when their ends are placed against the spine, adjust themselves to the outline of the deformity, when, by tightening the screw, this outline is retained and can be transferred to paper.

To record a lateral curvature, Fraser ("Tuberculosis of the Bones and Joints," page 138) describes a convenient method: "A long strip of netting about 18 inches long and 4 inches wide is used. The netting has a ½ inch mesh, and running lengthwise along its center a colored line is marked. The material is held along the spine in such a way that the median line lies exactly in the center of the body, as judged by the seventh cervical vertebra and the natal cleft. The line of the scoliosis is marked upon the netting with ink."

5. **Muscular Rigidity.**—Of all the physical signs of Pott's disease, muscular rigidity is the most characteristic. Normal movements of the vertebræ are four, flexion and extension (with considerable hyperextension), in the vertical plane, lateral flexion and rotation. As a result of tuberculous toxemia and of nature's efforts to guard the diseased vertebræ, muscular rigidity is produced, restricting the normal movements in a manner, more or less peculiar to the three spinal regions, as follows:

(*a*) *Cervical.*—Normal movements: free flexion, extension and lateral flexion throughout this region; "nodding" at the occipito-atlantal articulation and rotation at the atlanto-axial joint. Restriction of these movements is tested in children thus:

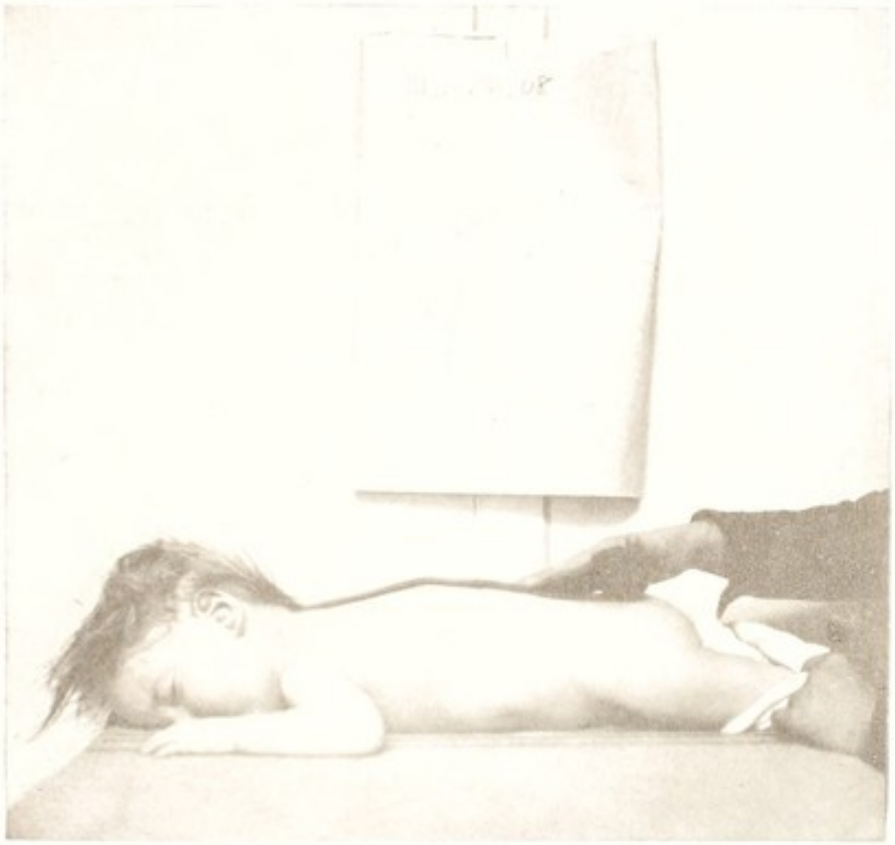


FIG. 24.—Early Pott's disease at ninth dorsal in child of two taking contour for record with lead tape. (Taylor.)

1. *Active Movements.*—With the child prone on the table or the lap, face down, limitation of normal flexion is observed by failure of the child to "hang" its head forward. Limitation of extension is tested by turning the child on its back and observing its inability to "drop" the head backward. In very young children, suddenly attract the patient's attention to a bright object at some lateral point to observe rotation.

2. *Passive Movements.*—These may be performed by manipulating the head, care being taken because of the danger of tearing the transverse ligament of the atlo-axial articulation in disease very high up.

(*b*) *Dorsal.*—Normally all four movements are readily made.

1. *Active Movements.*—The flexion test is the most important. With the patient standing erect, mark the tips of the spinous processes with a blue pencil; on subsequently bending forward, there is no increase of the interval between these processes such as normally occurs, the diseased vertebræ being

held *en masse* as may be appreciated with the palms on the affected segment during the movement. Attempts to pick up an object from the floor are slow and deliberate. The back is held rigid, the joints of the legs being bent instead (Fig. 25). Both hands are placed on the knees in stooping, while on rising, the child "climbs up its own legs" as in pseudohypertrophic paralysis. With the patient sitting with legs extended, attempts to touch the toes are significant.

2. *Passive Movements.*—With the patient prone upon the examining-table, elbows flexed and arms at the side, raise the legs by grasping the ankles. The exaggeration of lordosis normally produced by this maneuver is obliterated, the back remaining stiff and the trunk lifted with the legs to prevent movement at the intervertebral articulations at the site of disease (Fig. 26).

(*c*) *Lumbar.*—The maneuver mentioned above is accompanied by the same stiffness of the back as well as marked "boarding" (obliteration of the normal lordosis) in the lumbar region, due to spasm of the psoas muscle.



FIG. 25.—Attitude assumed in picking up an object from the floor in the case of a patient with tuberculosis of the lower dorsal and lumbar vertebræ.

6. **Sinuses and Ichor Pockets ("Cold Abscesses").**—Careful inspection should be made, particularly in the following regions, for the scars of old fistulæ and sinuses and for the presence of ichor pockets: the posterior wall of the pharynx, the triangles of the neck, the iliac fossæ, the loins, Scarpa's triangles and the neighboring inguinal regions, the gluteal regions. Suspected prevertebral and mediastinal ichor pockets may be detected only by the *x*-ray, while psoas ichor pockets must frequently be inferred, when impalpable, by rigidity of the psoas muscle.

7. **Paralysis.**—"Pott's paraplegia," so-called, appears, from the perusal of a large mass of statistics, to occur in about 5 to 6 per cent. of cases of tuberculous spondylitis, being most frequently observed complicating the disease in the upper and middorsal segments of the spine, possibly on account of the relatively small caliber of the spinal canal at that level (Fig. 27).

The palsy is *motor* in type and usually affects the legs, hence the term "Pott's paraplegia." The bladder and rectum are occasionally involved, and sensory disturbance unusual. The initial paralysis is spastic, but becomes more or less complete depending upon the degree of degeneration of the cord. The extent and nature of the paralysis also depends somewhat upon the situation of the disease, viz.:

Low Dorsal and Lumbar Disease.—The lower limbs and sometimes the sphincters.

Dorsal Disease.—Spastic paralysis of legs; no involvement of the sphincters.

Cervical Disease.—The arms are involved earlier than the legs.

High Cervical Disease.—The diaphragm is involved, also the spinal accessory and hypoglossal nerves.

All nerve functions should be investigated, viz.:

Motor Disturbances.—Awkward, jerky movements, ataxic gait, stumbling, dragging of toes.

Sensory Disturbances.—Pains in the body and limbs, disturbances of

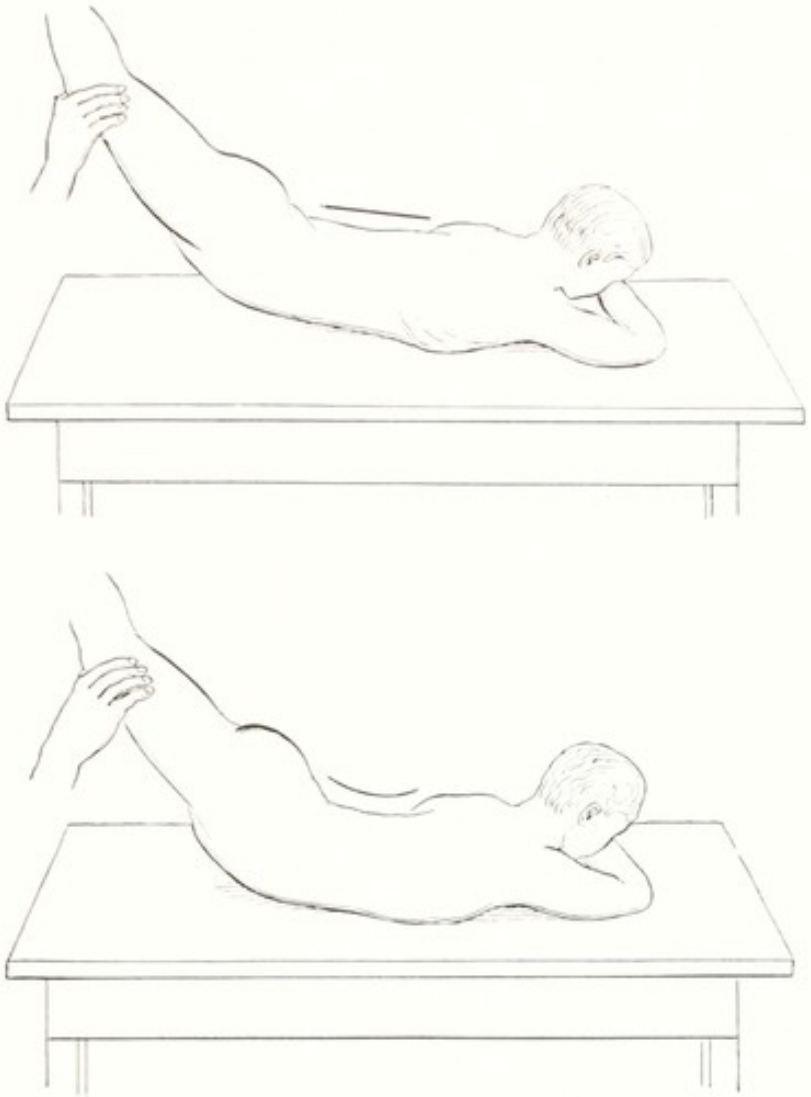


FIG. 26.—Shows extensibility of the spine in a normal individual. Upper figure illustrates the muscular rigidity ("boarding") of the back on passive extension of the spine.



(*a*) (*b*) (*c*)

FIG. 27.—The three usual causes of paralysis in Pott's disease. (*a*) Dislodgment of a disintegrated fragment of vertebral body and pressure therefrom upon the cord; the same effect would be produced by posterior dislocation of the entire vertebral body (both causes rare). (*b*) The escape of an ichor pocket into the epidural space and compression of the cord between it and the neural arch. (*c*) Pachymeningitis caused by extension of infection from the subjacent osseous lesion. (After Calot.)

cutaneous sensibilities. Reflexes all exaggerated, particularly the deep reflexes of knee and ankle; if the cord has undergone degeneration, the reflexes are absent.

Other Phenomena.—Incontinence of urine and feces, muscular atrophy, pressure sores, arthropathies, vasomotor disturbances (persistently cold skin, free perspiration) and signs typical of special nerve involvement (dilatation or contraction of the pupil, flushing of the face, etc.).

The presence of paralysis having once been determined, its cause should be accurately sought.

8. **Cranium, Thorax and Pelvis.**—Note any abnormal position of the head, shape of the thorax and direction of the ribs, and any deformity of the pelvis (see section on Pathology).

9. **Heart and Great Vessels.**—The usual clinical methods of inspection, palpation, percussion and auscultation should be employed for the detection of dilatation, hypertrophy and displacement of the heart and to ascertain the condition of its valves.

10. **Roentgenography.**—After completing the physical examination, an *x*-ray plate should be made in every instance, not only to confirm the diagnosis, but to determine the degree and the extent of the disease, the presence of an ichor pocket, and the progress of healing, as well as to act as a guide in the event of operation for ingrafting the spinous processes.

In addition to an anteroposterior view, a lateral, stereoscopic or oblique lateral view must be made, particularly in cervical Pott's disease, because the upper cervical vertebræ are concealed by the lower jaw in an anteroposterior picture.

Summary of Signs and Symptoms Grouped by Regions.—(*A*) *Upper Cervical Disease.*—1. Difficulty in moving the head. Muscular spasm.

2. Local pain over the spine.

3. Referred pain in back of head, and along the upper cervical nerves.

4. Pain on pressing the vertex.

5. Limitation or abolition of "nodding" and rotation of head.

6. Deformity resembling wry-neck.

7. Obliteration of the suboccipital hollow.

8. Head supported in hands on account of the great pain.

9. Ichor pockets: retropharyngeal or suboccipital.

10. Cord symptoms: dislocation of head, if odontoid process is disintegrated, is followed by sudden death. The usual paralysis is of the arms and then of the legs.

11. Ankylosis at the site of lesion usually follows a cure.

(*B*) *Cervical and Cervicodorsal Disease.*—1. Marked *rigidity*, associated with *wry-neck*, *shortening*, and *angular kyphosis*.

2. *Thorax:* ribs vertical, anteroposterior diameter reduced.

3. Pain: follows branches of the cervical or brachial plexuses.

4. Ichor pocket: retropharyngeal, supraclavicular or mediastinal.

5. Cord symptoms: not so common as elsewhere; arms first, then legs.

6. *Nerve Pressure Symptoms.*—(*a*) *Pupillary* symptoms (*myosis* or *mydriasis*) from pressure on sympathetic.

(*b*) *Recurrent laryngeal* and *vagus* symptoms (cough, slow pulse, vomiting, etc.).

7. Characteristic *attitude*, head and body turned as one, to look at an object.

8. Grunting breathing from pressure on intercostal nerves.

(*C*) *Dorsal and Dorsolumbar Disease.*—1. Characteristic kyphos. Muscle spasm.

2. Localized *vertebral thickening*.
3. *Pelvic deformity* (funnel-shaped in children).
4. *Pain*, radiating to outer side of thighs.
5. *Neuritis*, affecting individual groups of muscles.

(*D*) *Lumbosacral Disease.*—1. Deformity slight (rarely spondylolisthesis).
2. Vertebral thickening.
3. Deformed pelvis (funnel-shaped in children).
4. Pain referred to outer side of thighs.
5. Neuritis, local distribution.

DIAGNOSIS

(*a*) *Absolute.*—With a marked *kyphosis* present, no difficulty in diagnosis should be encountered. The most puzzling cases are those of compression symptoms without vertebral deformity.

A history of *referred pain* (in arms or legs or in the anterior midline), particularly *sternal* or *epigastric* pain, are especially suggestive.

In the physical examination, this aggregation of signs is strongly indicative of Pott's disease:

1. Muscle spasm (active or passive).
2. Ichor pocket formation (possibly sudden, occasionally overnight, and often one of the first signs.)
3. Early spastic paralysis (may be the initial sign of the disease).
4. The indisputable *x*-ray evidence.

(*b*) *Differential Diagnosis*

CERVICAL REGION — Reflection

Disease	Points of resemblance	Points of difference
Torticollis.	Abnormal posture of head and neck.	No pain on motion. Shortened sternomastoid muscles, rotation of face to opposite shoulder, hematrophy of face. *X*-ray. Cervical spine flexible.
Torticollis due to acute arthritis of cervical spine following acute infection.	Abnormal posture of head and neck, rigidity, pain on movement, etc.	Acute history. Rapid subsidence under treatment. *X*-ray. Metastatic infection from tonsillitis, etc.
Round shoulders, with stiffness.	Stiffness causes restricted motion. Absence of pain (adolescent tuberculous spondylitis.)	No muscle spasm. *X*-ray negative. Long duration. Postural history. Absence of neuralgic pain.
Fracture or fracture dislocation, cervical vertebrae.	Torticollis. Kyphotic deformity with stiffness and weakness. Pain. Paralysis.	History of the injury with acute symptoms following. *X*-ray.
Typhoid spine.	Pain, weakness and stiffness of the neck.	Typhoid history with onset in its later stages. *X*-ray.
Arthritis deformans, with or without cervical kyphosis.	Pain and stiffness in neck.	Chronicity. Relief from recumbency at night. Marked difference in *X*-ray findings.
Sarcoma.	Local pain. Paralysis. Deformity.	Rare in childhood. All symptoms more severe. Palpable tumor. Paralysis frequent early and rapidly progressing. *X*-ray.
Hysteria.	Pain and stiffness in back and neck.	Pain does not follow nerve distribution, with several points of intensity—anesthetic areas. Other hysterical stigmata. *X*-ray.

Region	Disease	Points of resemblance	Points of difference
DORSAL REGION	Rhachitic kyphosis.	Kyphotic deformity.	General rachitic stigmata. Sits erect without discomfort. Kyphos rounded and reducible. Absence of muscle spasm. Pain slight or absent. *X*-ray.
	Scoliosis.	Distortion of the spine.	Absence of muscle rigidity and pain. Typical posterior rib hump. Ribs rotate backward on convex side. *X*-ray.
	Syphilitic kyphosis.	Local deformity and local symptoms.	Rare. General manifestations of syphilis. *X*-ray shows marked bone proliferation.
	Spinal neuralgia.	Pain in the back.	Pain more diffuse and over a large part of vertebral column, is more superficial and more acute. Rigidity entirely absent. Subjects are neurotic young girls. *X*-ray.
	Anatomical anomalies.	Abnormal prominence of one or more vertebral spines, resembling a kyphosis.	Physical examination negative except for the pseudo-kyphos. *X*-ray.
	Typhoid spine.	As in cervical region.	
	Arthritis deformans.	As in cervical region.	
	Sarcoma.	As in cervical region.	
	Hysteria.	As in cervical region.	
	Gonorrheal spondylitis.	Pain, weakness, stiffness of back.	Rare. Ankylosis common. Urethral discharge stops when spinal involvement begins. *X*-ray.
	PARALYSIS — Diphtheritic.	Attitude. Localized. Muscular weakness.	History of diphtheria with symptoms following. Absence of symptoms of spinal caries.
	PARALYSIS — Cerebral spastic paraplegia.	Spastic condition of the muscles. Gait. Reflexes increased.	Absence of pain. History. Mental impairment. Absence of symptoms of spinal caries.
	PARALYSIS — Cerebrospinal meningitis.	Contractions, weakness and pain. Reflexes increased.	History of the case. Meningitis with symptoms following.
	All the preceding dorsal spinal affections.		
LUMBAR REGION	Hip-joint disease.	Limp (psoas-contraction). Flexion of the thigh.	Limp usually late symptom. No spinal symptoms. Pain on functional use. All motions at hip limited.
	Sacro-iliac disease.	Pain and sensitiveness of lower spine.	Pain and tenderness *localized* at joint. Movements of spine not restricted. Uncommon in childhood. Great restriction of motion of hip.
	Perinephritic and perityphlitic abscesses.	Motions of spine restricted. Swelling in inguinal region. Contraction of psoas muscle.	Acute onset. Constitutional disturbances. Local tenderness. Voluntary spinal restriction. Preceding history. Positive findings on spinal, abdominal, urinary and *x*-ray examination.
	Strain of back.	Stiffness and pain on motion.	Sudden onset. Cause known. Pain localized at point of injury. Relieved by rest. Restriction of motion voluntary.
	Pseudo-hypertrophic muscular dystrophy.	Attitude. Weakness or lordosis.	Absence of pain, kyphosis and muscular rigidity. Extremely slow onset. Gait waddling; awkward. Years. Knee jerks diminished or lost.
	Lumbago.	Stiffness and pain.	Sudden onset. Local pain. Sensitive *muscles*. Uncommon in childhood.
	Sciatica.	Pain referred to legs (both).	Pain *unilateral* and confined to distribution of the nerves which are sensitive to pressure. Movements of legs painful, spine painless. Uncommon in childhood.

PROGNOSIS

General.—As regards life, the outlook is good with the exception of infants under two years of age, in whom the immediate prognosis is very grave.

Causes of death are meningitis (although in fewer instances than with hip disease), pulmonary or acute miliary tuberculosis, amyloid infiltration of spleen, liver and kidneys, and exhaustion.

Expectation of Life.—The age limit has been found to average forty-nine and one-half years by Neidert (Inaug. Dissern., Munich, 1886), limitation being due to intrathoracic conditions, usually cardiac (hypertrophy, dilatation and valvular disease) with distorted aorta and other great vessels.

Deformity.—The extent of permanent deformity depends on the state of the vertebral bodies when first seen, and the promptness and character of the treatment. If the kyphos is plastic and malleable, early and complete fixation by direct inlay bone-graft almost invariably prevents further deformity, and, in many instances, that already existing may be obliterated in young subjects.

Paralysis.—Gibney found 77 per cent. of the paralyses complicating Pott's disease to have been cured or improved by conservative methods. The prognosis in this respect is more favorable after *operative* treatment. Recurrence after real or apparent cure is not infrequent in cases not operated upon.

Duration of Treatment.—The outlook for length of treatment varies greatly with the procedure adopted. The great length of time consumed by treatment under the old conservative regime of mechanical external supports is in sharp contrast to the brevity of treatment under the author's method of inlay bone-graft, as evidenced by a glance at the author's statistical study[1] on page 119 of this book.

TREATMENT

(*A*) **General Treatment.**—The cardinal principles of general treatment in all cases of osseous tuberculosis are applicable in Pott's disease. Heliotherapy should be employed to the fullest extent which the case permits, following Rollier's directions as far as possible (see Chapter I). An abundance of nourishing food and the free use of cod-liver oil and tonics should be employed.

(*B*) **Local Treatment.**—*General Considerations.*—From time immemorial, the object of all local treatment of tuberculous vertebræ has been to secure immobilization of the affected region of the spine, to the end that Nature might repair the lesion by substituting fibrous connective tissue for the carious vertebral bodies. In the past, attempts were made to secure this result by various mechanical supports whose name is legion. Principally because of the large size of the trunk and the fact that it includes within it two groups of important functionating organs (the respiratory and gastro-intestinal organs) which are in constant motion and causing a continual change in the diameter of the thorax and abdomen, no effectual immobilization of a part of the spine is possible of attainment by means of indirect supports (plaster jackets, frames, braces, jury-masts, etc.).

By recognizing the absolute necessity of complete localized fixation of the affected vertebræ directly at the site of the disease, and by devising and

[1] "A Statistical Study of 530 Cases of Pott's Disease Treated by the Bone-graft" (F. H. A., Am. Jour. Orth. Surg., 1916, xiv, No. 3, pp. 134–142).

elaborating a method of securing it, the author believes that he has revolutionized the treatment of Pott's disease, and has substituted for external supports a rational, scientific surgical procedure which effectually locks the involved segment of the spine, allowing Nature to relieve the situation in a comparatively short time and in favorable cases without the production of deformity.

As the structure of the bodies of the vertebræ is made up almost entirely of spongy bone, and as tuberculous disease in bone is confined almost entirely to this cancellous bone structure, it follows that this portion of the vertebra is involved to the exclusion of the denser or vertical portion, *i.e.*, the lateral masses and spinous processes.

As the action of each vertebra in the spinal column is for the most part a leverage action, and as the superincumbent body-weight is borne in very large measure by the individual bodies of the vertebral column with their interposed intervertebral cartilaginous disks, it follows that as respiratory action and involuntary contraction of the abdominal muscles, together with the activity of the tuberculous focus, weaken the resistance of the bodies to weight-bearing, these bodies are crushed and disintegrated, and unless measures are taken to prevent this crushing and transfer the weight-bearing more upon the articular processes and lateral masses, this crushing effect continues and the vertebral column collapses forward at the expense of the anterior arms of the levers (the vertebral bodies), causing a separation of the posterior arms of the levers (the spinous processes), thus producing the increasing angular deformity, or kyphosis, so noticeable in these cases.

The author's procedure has been devised on the basis of this principle of the leverage action of the vertebræ, in order to prevent the increase of this posterior angular deformity. The arrest of the tuberculous process depends largely upon the ability to check this increasing kyphosis and prevent further collapse of the vertebral bodies. As can be readily seen, any external fixation applied to the series of levers of the spine as a whole cannot be so exact in its control of any segment thereof, as fixation applied directly can control the leverage action of the particular vertebræ involved. Thus, we may compare the inexactness of the plaster jacket with the direct fixation of the bone-graft.

The means adopted to bring about this arrest of increasing deformity, also relieve the other symptoms accompanying the disease—pain, involuntary muscle-spasm, general weakness, and the characteristic awkwardness of attitude. The methods heretofore employed to accomplish this have been:

1. *Recumbency*, which removes one of the chief exciting factors, namely, the superincumbent weight of the body. This must be maintained during the activity of the destructive process. (2) *The application of plaster-of-Paris jackets or braces*, either as a further means of fixation during or following the months of compulsory recumbent treatment on a gas-pipe frame or, as it is employed by many, in conjunction with a certain amount of rest in the recumbent posture from the time the lesion is discovered—the so-called ambulatory treatment.

Nature, in her endeavor to protect the spine when attacked by tuberculosis, resorts to immobilization of the diseased area by the means at her command, and, by fixing the attached spinal and abdominal muscles in involuntary spasm, accomplishes this immobilization to a certain degree, but in so doing usually increases, in spite of external supports, the crushing effect of the diseased vertebral bodies with increasing collapse of the spine, which, together with the added influence of respiratory motion, usually results in extensive kyphosis and disability.

As Nature has taught us that immobilization is the prime factor in arresting tuberculous osteitis, we have endeavored to substitute for Nature's method our artificial fixation in an attempt to prevent the disfiguring and crippling angular deformity and progress of the disease; but as conservative brace methods offered the means to accomplish this end only approximately, many cases continued to develop increasing deformity and complete invalidism, and succumbed to this debilitated state.

It is the exception and not the rule, for cases of Pott's disease treated by the conventional methods of externally applied fixation to produce a solid bony union between the partly destroyed vertebral bodies and when actual firm bony fixation is not accomplished, the case cannot be considered, as a rule, permanently cured.

As has been pointed out by many men dealing with tuberculous osteitis of the adult knee it is always essential to secure a strong bony ankylosis in order to arrest and cure permanently tuberculous lesions where actual bone destruction has taken place. This rule applies more strongly to the vertebræ than to other articulations.

With such examples of ineffectual control of this progressive tuberculous disease constantly in evidence, further efforts were made to provide more accurate fixation of the tuberculous spine. Appreciating the leverage action of the vertebræ and failures to arrest the disease by external appliances, actual surgical intervention by wiring together the spinous processes (posterior lever arms) of the diseased vertebræ with silver wire was tried; but as the fixation for the cure of this condition must continue for a long period of time and as silver wire, being a foreign material, causes absorption of the bony structures in which it is placed and pulls through and drops out by its own weight, especially in the presence of constant respiratory motion, the resulting fixation is sure to be soon lost.

Lange in 1910 presented, before the American Orthopedic Association, a method which he had tried, which consisted of placing a metal bar on either side of the spinous processes, secured by metal or silk sutures. This method has not been adopted, undoubtedly because of reasons similar to those given for the failure of the silver wire fixation of the vertebræ. Nevertheless, the suggestion was offered that if some means could be provided for rendering the posterior arms of the vertebral levers more accurately fixed, a consequent arrest of the increasing deformity and disability could be rendered more certain.

In the folder of the American Orthopedic Association published May 15, 1911, and distributed to its members, and in several publications since that time, the author described a method of ankylosing together the spinous processes of tuberculous-infected vertebræ by autogenous osteoplasty which seemed to offer advantages over the methods previously employed, whether conservative or operative.

The technic employed upon 4 cases consisted of splitting the spinous processes longitudinally in halves, fracturing these halves at their bases, freeing them of ligamentous and muscular attachments, throwing one-half down to contact with the fractured base at the fractured half of the spinous process below, and turning up the other half to contact with the base of the fractured half of the spinous process above, and so on until a sufficient number of spinous processes had been so dealt with as to include the entire area of the diseased vertebræ, and one or two healthy vertebræ above and below.

In these cases, which were all children, this ligamentous covering, together with what periosteum was found, was separated from these spines and sutured over and about the arranged split fragments of the spinous processes. In this

way an attempt was made to ankylose together the posterior segments of these vertebræ and thus actually to prevent all intervertebral motion from respiration or muscular action, and, finally, to stop the further crushing together of the diseased bodies of these vertebræ. (It should be noted that practically the whole spinous process is covered with ligamentous and muscular attachments, consequently there is very little actual periosteum obtainable.

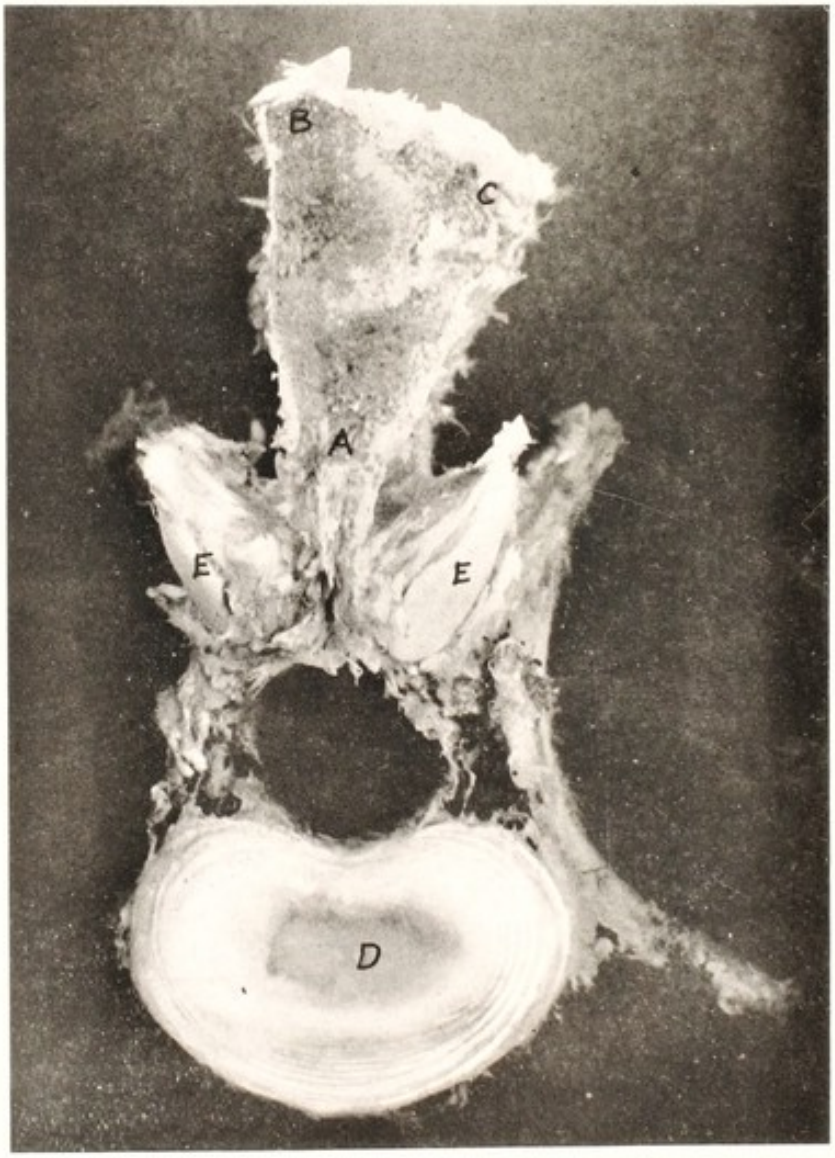


FIG. 28.—View of a dog's vertebra into the spinous process of which a portion of his ulna had been ingrafted by the author six months before; *A*, *B*, and *C* indicate the outlines of the graft, which has become firmly grown into the split spinous process. *E* is articular facet.

Since this method consumed much operative time and involved dealing with a number of small pieces of bone which had to be secured in a position favorable to final bony ankylosis, and as there was an element of uncertainty (on account of constant uncontrollable respiratory motion) in bringing about this desired ankylosed condition of all these segments of bone—a failure to produce this ankylosis between any two given vertebræ necessarily producing a failure in the ultimate result—the author was further influenced to change the method on account of the meager amount of osteogenetic bone present

in the spinous processes (especially in children where it is largely in a cartilaginous state) and to adopt the much simpler bone-graft method now employed, which has given extremely satisfactory results.

This consists of the implantation of one continuous strip of bone (removed preferably from the tibia) sufficiently long to span the diseased vertebræ and include one lumbar or two healthy dorsal vertebræ above and below



FIG. 29.—Photomicrograph of section through the long axis of spinous process of a dog with a cross-section of an autogenous ulnar graft (*abc*) thoroughly united by new bone two months after the graft was inlaid into the split tips of three spinous processes. The analogy to the technic of the tree graft (Fig. 71) is apparent. A careful microscopic study of this section has failed to disclose dead bone-cells. The corners of the graft are indicated by *a*, *b*, and *c*. *d* indicates base of spinous process. The author's surgical experience in over 1000 cases, as well as a large amount of animal experimental work, has convinced him that the inlay method of insertion affords by all means the most favorable graft environment, as this and many other miscroscopic sections have proved.

those involved in the tuberculous infection. The tibial bone-graft is implanted in a gutter previously made by splitting the ligaments and spinous processes to receive this long graft of bone between their split halves.

In conjunction with the above-mentioned observations, the increased trustworthiness of the bone-graft (especially in small children) as compared

with the previous osteoplasty, is still further emphasized by the facts that broken or incised cartilage tends to heal by the formation of bony callus and that the implantation of a bone graft into cartilage also influences the transformation of the cartilage to bone.

Therefore, in view of the foregoing desiderata, Pott's disease must now be regarded as a distinctly surgical affection, and operative treatment as *sine qua non*, to be given precedence over all other therapeutic measures. Mechanical treatment must now occupy a minor position, to be employed only as a postoperative adjunct or in patients who refuse surgical intervention or are not good surgical risks.

Local treatment, therefore, will now be considered in four main divisions:

Operative treatment.
Mechanical treatment.
Treatment of deformity.
Treatment of complications.

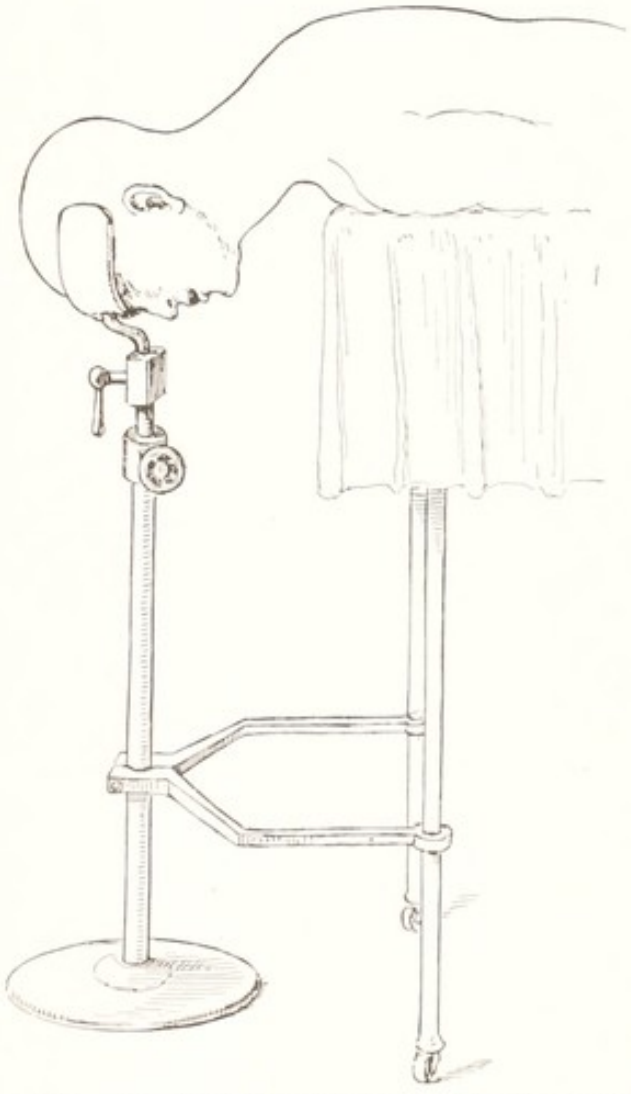


FIG. 30.—Position of patient and adjustment of head-rest for insertion of spinal graft for Pott's disease of cervical region.

OPERATIVE TREATMENT

ALBEE'S BONE-GRAFT FIXATION OF THE VERTEBRÆ

The detailed steps of the author's technic of preparing the graft bed, together with the removal of a suitable graft and its implantation, is as follows. In every instance the patient is in the prone position with head overhanging the table and held by a special rest (Fig. 30).

Incision.—This is semilunar in shape, usually about 6 to 8 inches in length, begins well above the site of lesion, swerves in a wide sweep to one side of the midline, at the level of the diseased vertebræ, and returns to the midline where it ends well below the diseased area. By having the free edge of this semilunar skin-flap away from the site of operation, the engrafted structures are guarded from contamination in the event of skin or suture infection.

Exposure.—After dissecting up and reflecting the skin-flap, the tips of the spinous processes lie directly exposed. Hemorrhage, usually slight, is best controlled by compression with towels wrung out of hot saline solution. A small amount of serous exudate and blood is considered advantageous to early nourishment of the graft.

Preparation of the Graft-bed.—The supraspinous ligament is split into halves, longitudinally over the tips of the spinous processes with a scalpel.

The interspinous ligaments are treated likewise. Muscular and ligamentous attachments to the spinous processes must not be disturbed.

With the author's broad, thin, sharp osteotome (Fig. 31), (1½ inches wide), its cutting edge parallel with their tips, the spinous processes are split in halves to a depth of ⅓ to ⅔ of an inch or nearly down to the neural arches. One-half of each spinous process, always on the same side, is fractured completely at its base (Fig. 33), and set over a distance varying according to the thickness of the graft which is to be implanted. Care is taken not to

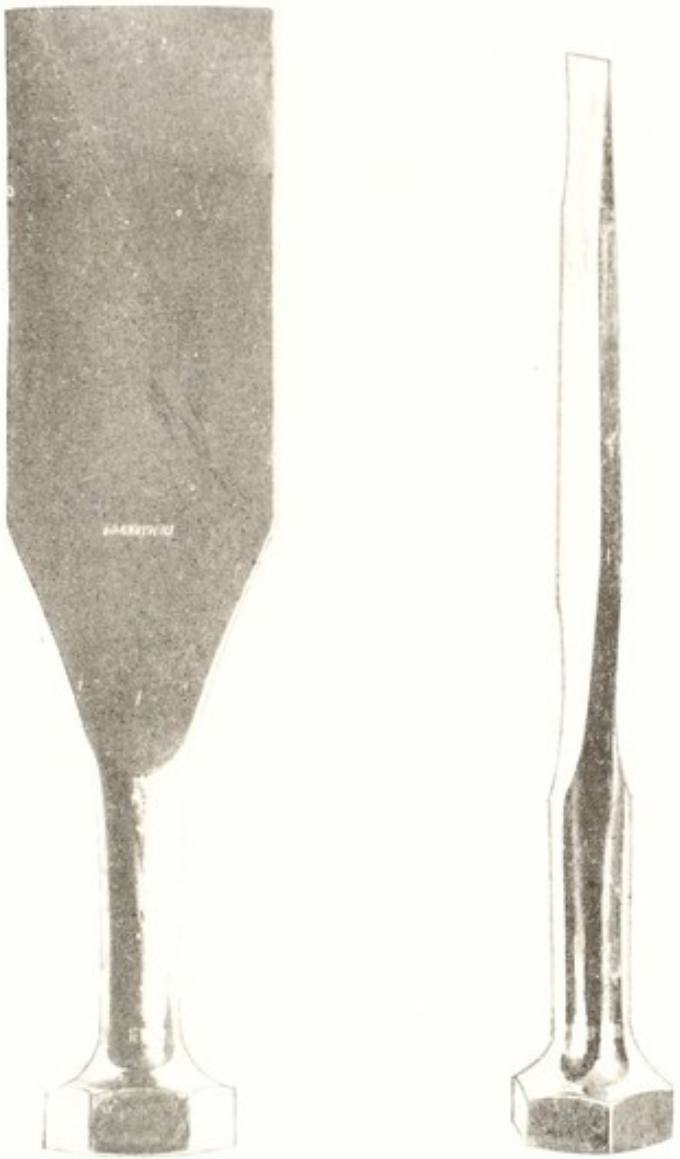


FIG. 31.—Author's broad thin osteotome for splitting the spinous processes of the spine in preparing the graft bed.

break the remaining spinous process halves and to preserve their full leverage action. Bleeding should be checked by ligatures or hot saline compresses.

The graft-bed thus prepared presents a median longitudinal gutter on one side of which are the cut surfaces of the *unbroken* halves of the spinous processes (with the cut surfaces of the bisected supra- and interspinous ligaments with their osseous attachments undisturbed), and on the other side the cut surfaces of the *fractured* halves of the spinous processes (with their corresponding bisected ligaments attached). It is to be noted that the muscular and ligamentous attachments are undisturbed save for the split

ting, fracturing and spreading incidental to bisection of the spinous processes. This leaves the anteroposterior diameter of the spinal column undiminished and unweakened and preserves the full leverage activity of the spinous processes as posterior arms of the vertebral levers.

It should be constantly borne in mind that the spine is a composite of a series of levers each one of which has its short (anterior) arm, the vertebral body, and its long (posterior) arm, the spinous process (Fig. 32).

The length and shape of the required graft is determined by calipers and a flexible probe applied to the gutter bed (Figs. 34, 35 and 36), and the latter protected by a hot saline compress tightly packed, awaiting the preparation of the graft.

Removal of Graft.—The patient being in the prone position, the prepared leg is raised and flexed to an acute angle with the thigh. A skin incision is made along the antero-internal surface of the tibia sufficiently long to allow a generous exposure of the tibia for the removal of the graft, and so placed that its closure will not bring the skin sutures over the bone cavity produced by removal of the graft. The skin is dissected up from the periosteum (but the latter is not disturbed), and the muscles freed from their attachments to the outer side of the tibial crest.

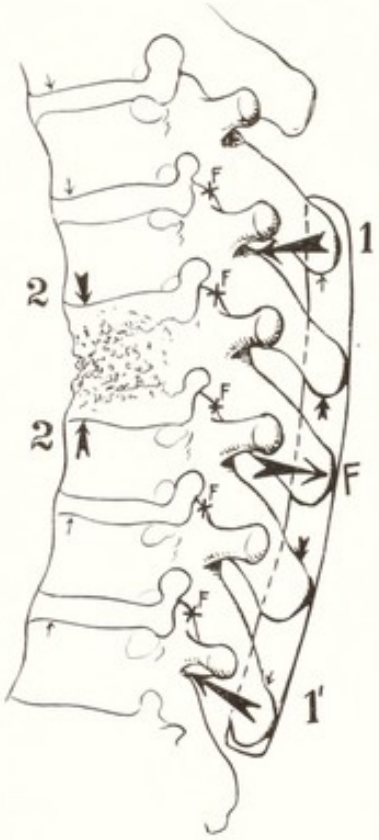


FIG. 32.

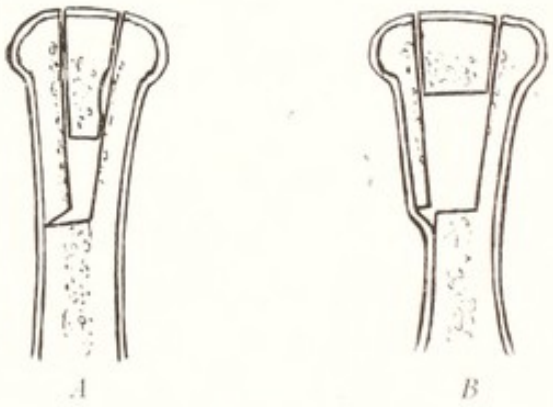


FIG. 33.

FIG. 32.—Each vertebra is a lever with its fulcrum point at small *F*. The arrow on the vertebral bodies at 2, 2, indicates lines of force from weight bearing, involuntary muscle spasm, etc., influencing crushing of vertebral bodies and progress of deformity by the approximation of the anterior lever arms which is associated with an equal separation of the spinous processes or the posterior lever arms this is prevented by a pull lengthwise on the graft as indicated by the small arrows situated at each spinous process. The graft in respect to this direction of force is under a great mechanical advantage.

FIG. 33.—*A* illustrates a cross-section of a spinous process split in half and fractured at its base. The deep, thin graft in cross-section has been removed from the crest of the tibia having its periosteum attached to two sides. The side in contact with the unbroken half of the spinous process is the saw cut or the medullary surface of the graft.

B illustrates a cross-section of a spinous process which has been split and one-half has been set over to produce a gap sufficient to receive a broad graft removed from the antero-internal surface of the tibia having periosteum on one surface only; the medullary surface of the graft lies nearest the base of the spinous process in the gap.

The size and thickness of the graft required depend upon the segment of the spine to be immobilized and the amount of strain required of the graft. In general, it should include the total thickness of the tibial cortex (periosteum, endosteum and marrow), and its width should be three to four times this amount.

Using the moulded probe as a pattern rod, the required graft is outlined by incising the periosteum with a scalpel. The lower three-fourths of the antero-internal surface of the tibia is selected on account of its strong dense cortex.

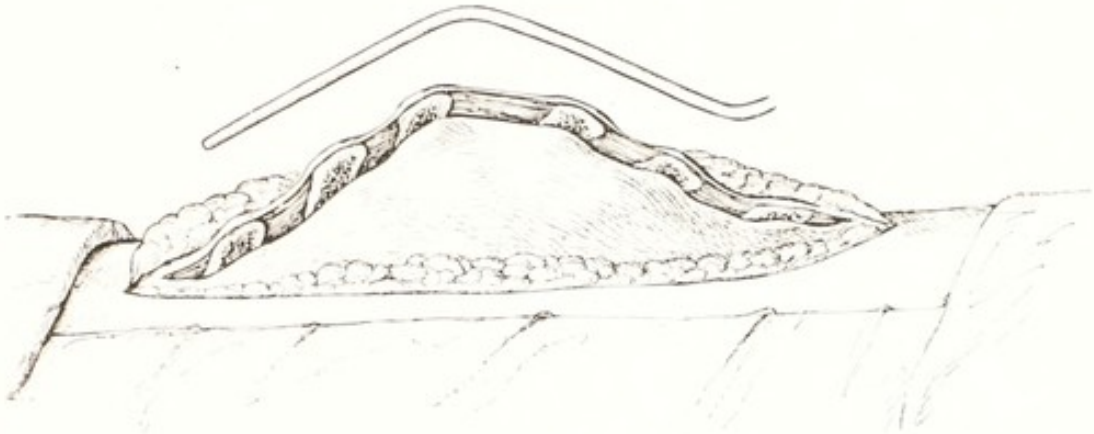


FIG. 34.—The flexible probe bent to conform to the spinal kyphosis and used as a pattern in removing the curved graft from the antero-internal surface of the tibia if the spine is not suitable to be straightened.

If the graft is to be straight, it is best removed from the crest, wide enough to encroach upon the antero-internal surface, so as to furnish the width required. If it is to be moulded for a moderate kyphosis, the central



FIG. 35.—To illustrate method of applying force to straighten spine, at the same time that the contour of the corrected kyphosis is obtained with flexible probe for purpose of pattern for removal of graft from tibia. (See Fig. 37.)

or fulcrum portion of the curved graft includes the crest of the tibia and from this portion each end is cut obliquely upward and downward on the antero-internal surface of the bone (Fig. 37). The advantage of this graft lies in

the dense thick cortical bone which forms its fulcrum portion, and which constitutes the strength of a lever (graft).

Sharply angular kyphoses, and those of short duration, particularly in children, are amenable to varying degrees of correction. In moulding the graft, its pattern should be the shape of the gutter-bed *after* correction has been applied by manual pressure on either side over the lateral masses when the probe is then bent into the clefts of the split spinous processes.

To obtain the straight graft, the tibial cortex is cut through to the marrow cavity with the motor circular saw, following the periosteal outlines of the pattern; this includes a saw-cut just to the outer side of the tibial crest and at a right angle to the one previously made on the antero-internal surface. This cut must be made the whole length of the graft, if a straight one; and if a moulded one, only to include the middle or fulcral portion. At either end, beyond this central or crest portion, the graft overlies the marrow cavity and the saw-cuts, therefore, need only be made on the antero-internal surface to free the graft.

The graft is freed by cross cuts at either end, made with a very small motor saw. It is then loosened and pried out by a thin osteotome introduced into the longitudinal saw-cuts. Although a thin chisel and a mallet may be used to remove a bone-graft, the motor saw has very distinct advantages, particularly in the case of very dense brittle bone in adults, where the tibia or the graft is easily cracked with mallet and chisel. Other disadvantages of the latter method are traumatism of the graft, inaccuracy of moulding it and postoperative pain in the leg.

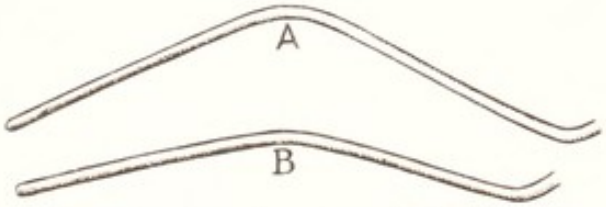


FIG. 36.—Actual contour of flexible probes, bent into tips of spinous processes before and after forcible correction. *A* is before correction. *B* after correction. (See Figs. 34 and 35.)

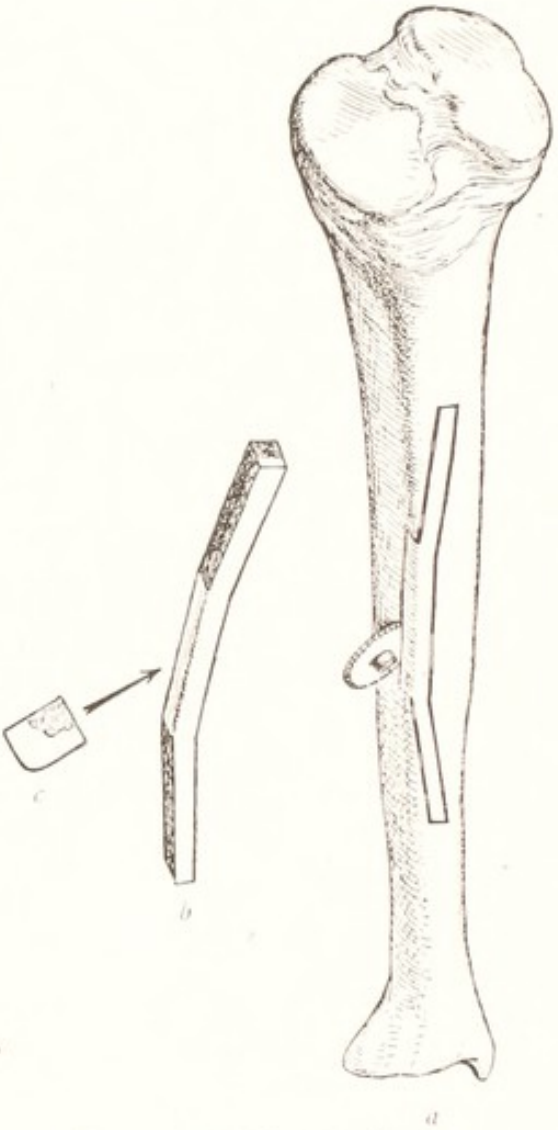


FIG. 37.—(*a*) Saw-cuts in the antero-internal surface of the tibia for obtaining a moulded graft; (*b*) a longitudinal view, and (*c*) a cross-section of the same at its strong central portion.

The graft is immediately transferred from the tibia to its spinal bed, all unnecessary handling being avoided, and clamps are used instead of the operator's fingers for its transference.

The cutaneous incision in the tibia is at once closed by an assistant with

a continuous suture of No. 1 plain catgut, and the wound properly dressed while the operator proceeds at once to mould and implant the bone-graft.

Inlaying the Graft.—In case the graft is straight, it is held in place by a strong suture of kangaroo tendon, passed through one-half of the split supraspinous ligament at one side of the gutter, thence up over the graft at its central portion and out through the opposite split half of the supraspinous ligament. Upon tightening and tying this suture, the two halves of the split supraspinous ligament are approximated over the central portion of the graft. The extremities of the graft are then secured in like manner. The sutures should be passed deeply enough to get a firm hold upon the ligament and close to the spinous processes (either above or just below them) to obtain the most intimate contact possible between the graft and the raw surfaces of the bisected spinous processes.

In some instances, in order that the supraspinous ligament may yield and completely cover the graft, it is advisable to place the sutures in the ligament midway between the spinous processes or at a varying distance to

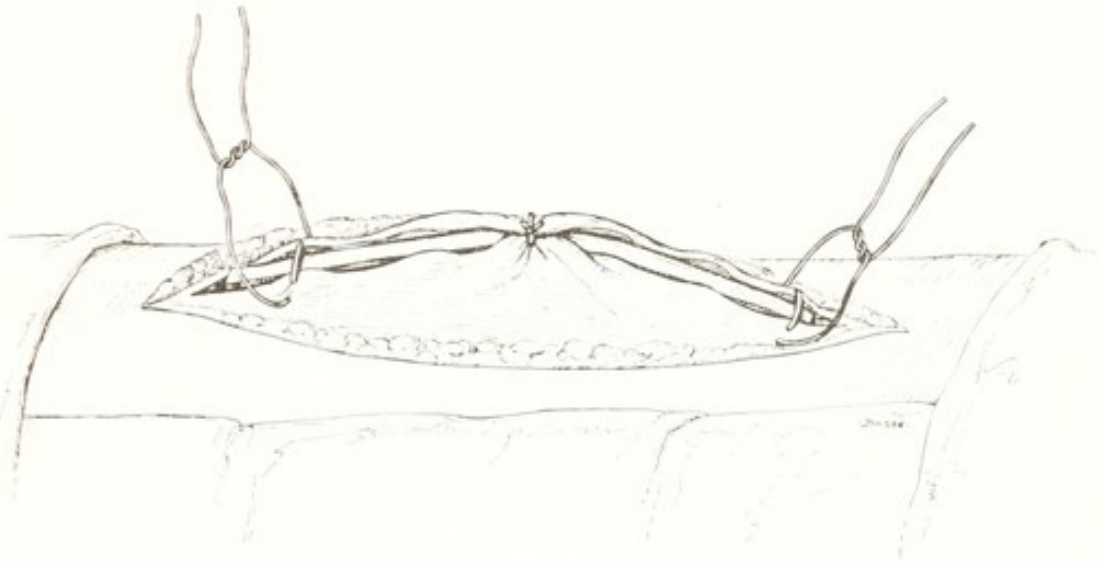


FIG. 38.—Moulded graft for Pott's disease in place with the kangaroo-tendon sutures in process of being inserted.

the side of them. This ligament in the lumbar region especially (particularly in adults) may be so dense and tense as to require incision of the vertebral aponeurosis on either side just external to the line of sutures to allow of its being drawn together to cover over the thick graft.

The graft must, in every instance, be long enough to include the spines of two healthy vertebræ above and two below the diseased area. It must be constantly borne in mind that on account of the natural obliquity of the spinous processes in certain regions (particularly the dorsal), the fact that their tips are well below the horizontal planes of their corresponding bodies (*x*-ray appearance) may mislead the operator into cutting the graft too short to include the requisite number of healthy spines or placing it too low in the spine. A satisfactory radiogram should always be obtained, not so much to confirm the diagnosis as to serve as a guide in inserting the graft.

Before fixing the ends in position, their sharp corners are removed by rongeur forceps and the fragments placed about and under the graft ends before the latter are secured with sutures. The removal of these bone fragments from the ends of the graft on its posterior edge-surface with a rongeur cutter causes it to be roughened so that it is better held and thus prevented

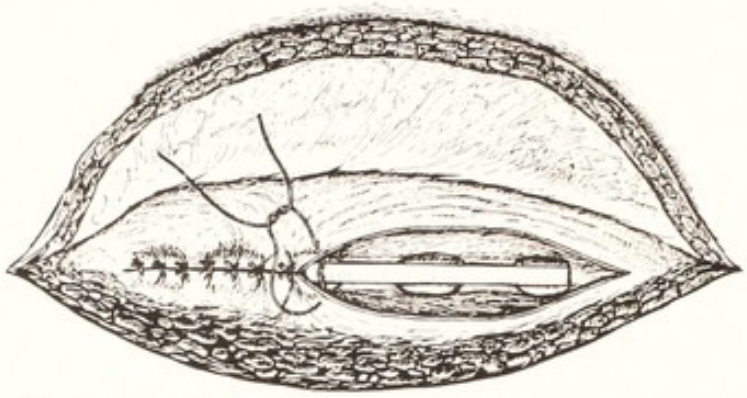


FIG. 39.—To illustrate method of drawing the split supraspinous and interspinous ligaments posteriorly over the graft. These ligaments are not separated from the split spinous processes.



FIG. 40.—*A*, the manner of holding the graft while making the transverse saw-cuts to increase its flexibility.

B, transverse saw-cuts at equal intervals and over three-quarters through the diameter of the graft on its marrow surface.

C, testing for the desired amount of curve in the graft obtained by making the transverse saw-cuts before applying it to the kyphosis of the spine.

from springing backward by the ligaments sutured over it. These fragmented particles furnish added foci for bone proliferation and enhance the amalgamation of the graft ends and the contracted spinous processes, on the principle that the osteogenetic power of the bone-graft is in inverse ratio to its volume, as emphasized by Macewen. That is, the smaller the graft, the greater is its relative surface and the more active its bone-growing ability. It has been further demonstrated that, because of their size, small grafts obtain their nourishment more readily from the surrounding serum or blood.

The rest of the graft is then secured with kangaroo-tendon sutures placed at $\frac{1}{2}$-inch intervals throughout its length, passed and tied in the manner above described.

In case the graft has been cut on the *curved* pattern, it must be placed *on edge* in its bed in order to fit the kyphos; its periosteal surface lies to one side and its marrow surface to the other. It should be so placed that the

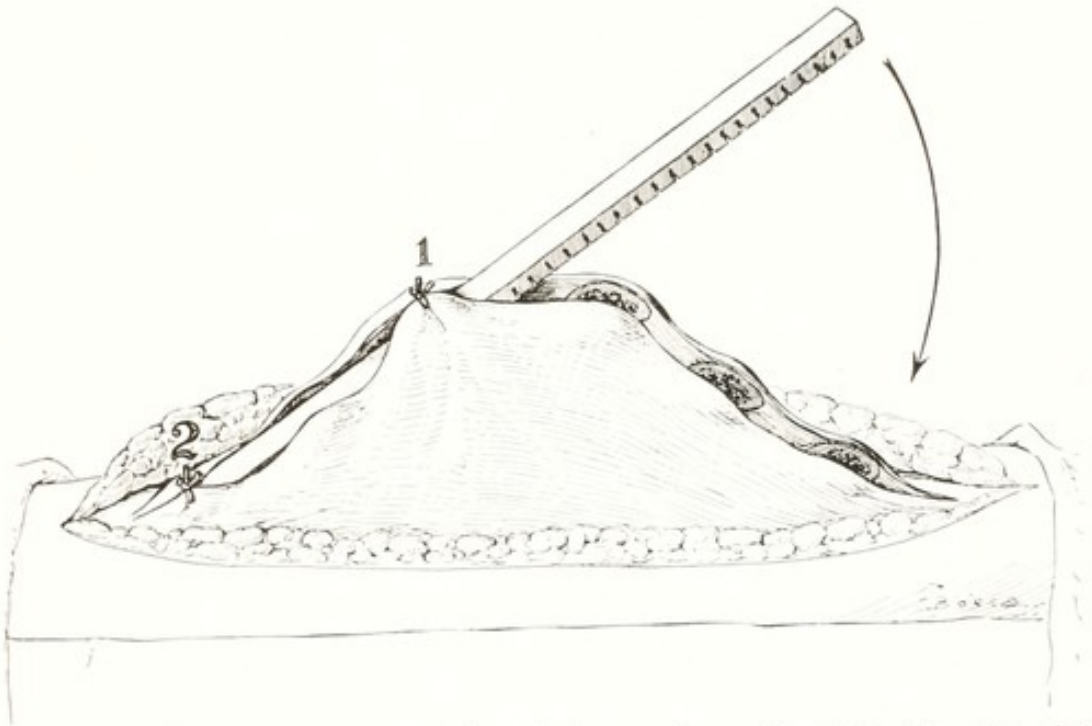


FIG. 41.—Method of securing the bent-in bone-graft to adapt it to the curve of the kyphosis. (1) First fixation suture. (2) Second fixation suture. The arrow indicates the direction which the graft is to be bent to fit over the kyphosis.

marrow surface lies in contact with the side of the gutter formed by the unfractured halves of the spinous processes; the *periosteal* surface contacting with the *fractured* halves. The endosteal (marrow) surface, being more actively osteogenetic, is thus in contact with the more virile unfractured half of its host. The curved graft is secured exactly as the straight graft.

If a straight graft with transverse saw-cuts (made on its marrow surface two-thirds to three-fourths through its thickness) is to be bent, it should be obtained from the lower two-thirds or three-fourths of the antero-internal surface of the tibia where the cortex is thick and includes the crest or not, at the discretion of the operator. If the graft does not include the crest, the twin saw hastens its removal and insures its uniform width throughout. If it includes the crest, cuts at right angles to each other on each side of the crest are necessary. The graft in the latter case includes two periosteal surfaces, and is therefore more active osteogenetically and stronger mechanically. It is again emphasized that *every graft should include all bone elements, namely*

periosteum, compact bone, endosteum, and marrow substance. This is the author's bent-in graft, and, as the saw-cuts naturally weaken it, the moulded graft previously described should always be used instead, when possible.

In making the transverse saw-cuts to allow the graft to bend (as a carpenter cuts a board to cause it to bend about a curved surface) the graft is held securely by the operator with two strong clamps, one at either end. An assistant holds the motor firmly on the instrument table with the saw overhanging its edge (Fig. 40). The current (under the operator's control by means of the foot-switch) is turned on. The operator presses the graft up from below against the rapidly revolving saw. By holding the graft in this way, he can regulate the spacing and depth of the cuts along the marrow surface, and can test its flexibility and judge very accurately when he has rendered it sufficiently flexible to conform to its bed and span the deformity, without being obliged repeatedly to place the graft in its bed to determine this point. The proper guard (washer) adjusted to the saw regulates the uniform depth of the cuts and, by eliminating the danger of entirely severing the graft, permits operative speed.

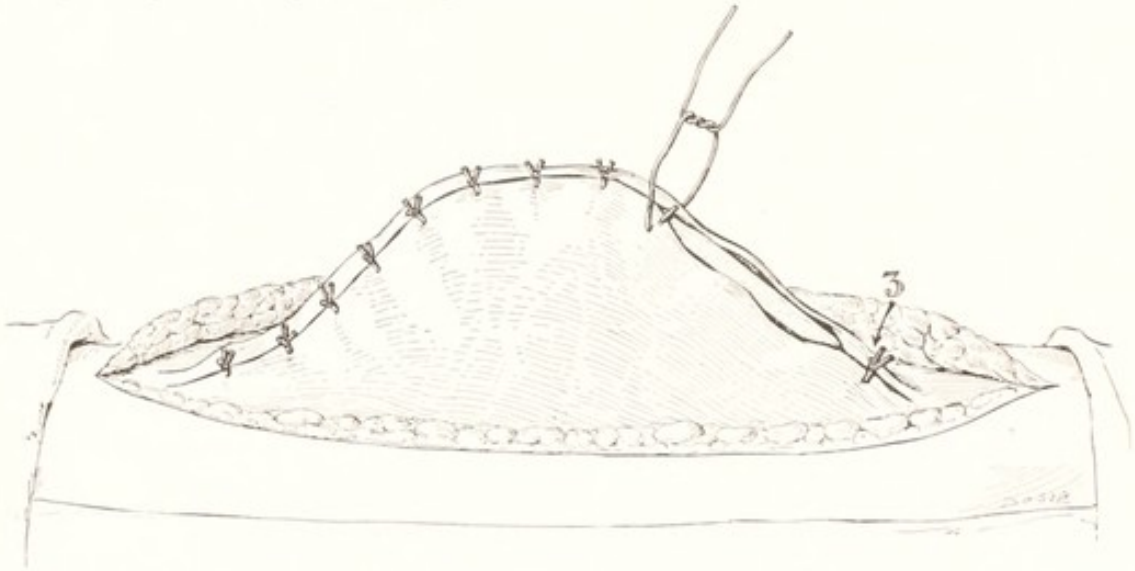


FIG. 42.—The bent-in graft in position, with the interrupted kangaroo-tendon sutures being placed to secure it and enclose it beneath the supraspinous ligament.

The bent-in graft is laid in its bed with the medullary surface (containing the saw-cuts) downward (anteriorly), its periosteal surface upward (posteriorly), and its edges in contact with the cut surfaces of the gutter side and the split spinous processes. In other words, the bent graft is not placed between the split spinous processes edgewise, but with its wide diameter laterally.

Suturing is performed as in the case of other grafts, except that the bent-in graft is firmly sutured first at one end and the middle, the other end projecting free (Fig. 41). This freely projecting half is slowly bent by consecutive suturing from the central point of the graft to its projecting end, thus obviating the danger of fracture if it were first held bent in place by one embedding suture at each end while the other sutures were added (Fig. 42). Whether or not fracture occurs, it is well to reinforce this graft by placing along each of its sides, at the maximum point of curvature, thin strips of cortical bone cut with the motor-saw from the tibia where the graft was obtained.

Closure.—The skin wound is closed in the usual way and sterile dressings are applied. Thick pads of gauze and cotton, varying in thickness

according to the degree of the kyphosis, are placed on each side of the grafted area to prevent pressure sores on the apex of the grafted kyphosis.

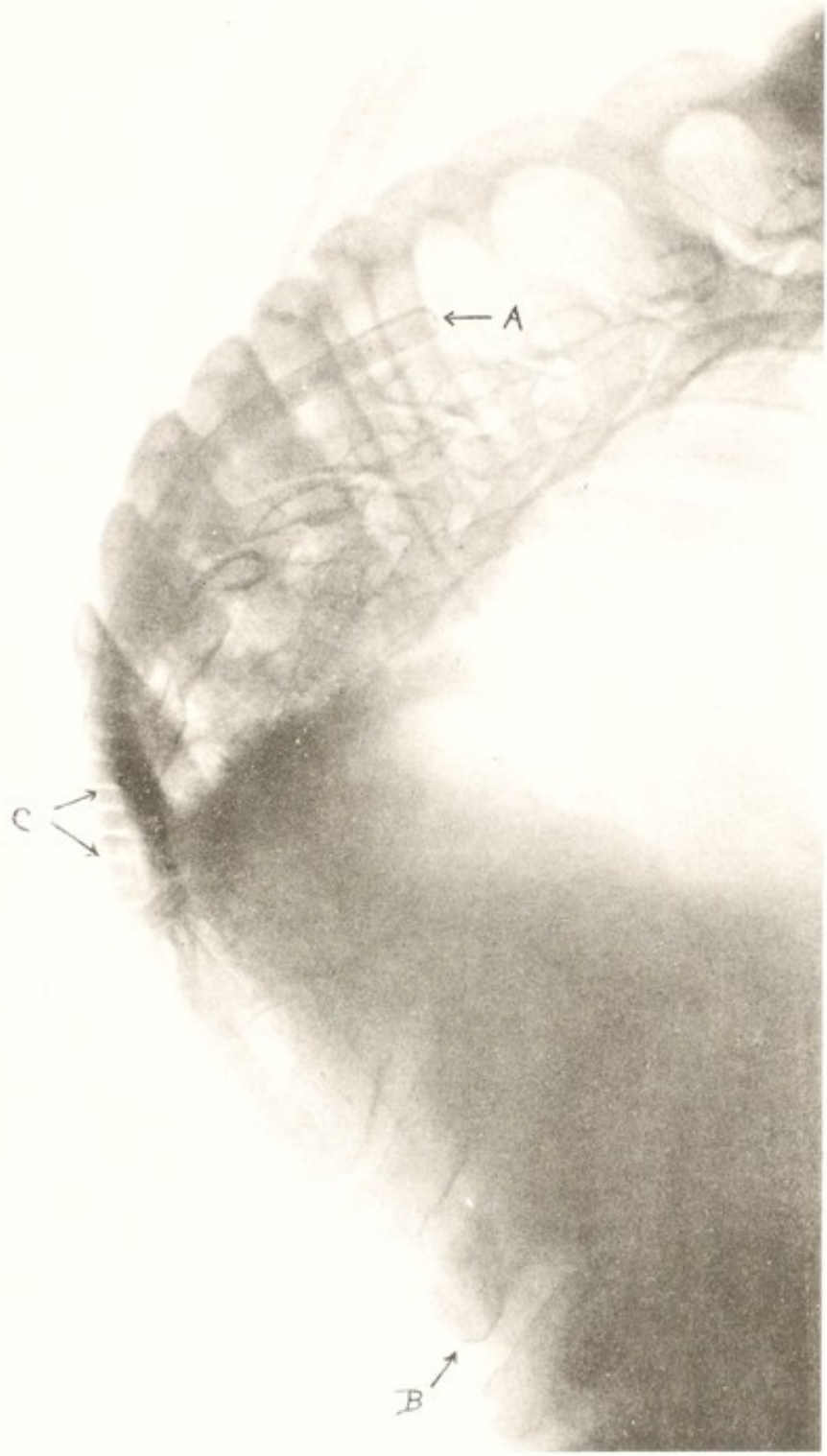


FIG. 43.—Lateral rontgenogram of a spine of a man twenty-two years old, which is illustrative of the extreme degree to which an adult tibial bone-graft can be bent. *C* indicates the saw-cuts in the marrow side of the graft. This case had been under conservative treatment seventeen years as a private case by two very competent orthopaedic surgeons; nevertheless, a relapse with paraplegia occurred after that period of treatment. The result after the insertion of the bone-graft was excellent.

The dressings and pads are then secured in place by broad strips of zinc oxide adhesive plaster. It is not safe, even with this dressing, to allow pa-

tients with prominent kyphosis to lie upon the back; they must be restrained upon the side or obliquely on the back during the postoperative recumbent period.

Author's "Bent-shingle" Technic of Spinal Inlay Bone-graft.—In the case of a very sharply angular kyphosis, or one of great extent—in both of which instances it would be manifestly impossible either to cut from the tibia a graft of sufficient angularity or to bend a straight graft to conform to the mechanical requirements—the author has devised the following procedure:

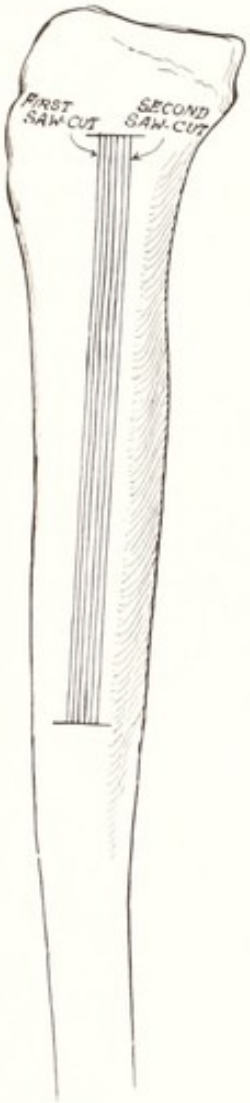


FIG. 44.—To show grafts obtained for the author's "bent-shingle" method of placing grafts over a large kyphosis. The saw-cuts labelled first and second are made first so as to produce nerve blocking (Crile's anoci-association) of the intervening strip of bone before it is sawed into 5 or 6 strips of bone 1/32 to 1/8 inch thick and 3 to 5 inches in length.

The graft-bed in the spinous processes is prepared as has already been described. The leg is given the customary preparation, and the incision in it is made in the usual manner. With the single motor-saw, two cuts (each about 6 inches in length) are made in the antero-internal surface of the tibial cortex—one close to the external, the other close to the internal limit of the medullary cavity, to produce anoci-association (Fig. 44). With the single saw, the intervening cortex is now cut into strips, each about one-sixteenth to one-eighth of an inch in breadth (Fig. 44). These strips are released by the small cross-cut saw. One of the strips is cut in equal halves, one of which is laid (on the flat) in the spinal gutter at the lower extremity of the kyphos. One of the long thin strips of bone is then placed, its lower half being exactly superimposed on the short piece, the remainder projecting (Fig. 45). Upon this projecting end another long thin strip is placed in a similar manner, and this procedure is repeated with each of the strips, just as a carpenter shingles a roof (Fig. 46). Care must always be taken that each succeeding "shingle" overlies not only the projecting end of the preceding one, but also about one-third of the undermost one—in other words, so that there will be three thicknesses of bone strips at each point of junction (see Fig. 47). When the upper extremity of the kyphos has been reached, the short half piece of bone strip (its other half having been used to start the "shingling" process) is slid beneath the last two shingles" that were laid.

Sutures of small-sized kangaroo tendon are passed through the spinal ligaments at the points of junction of three "shingles" and at such other points as seem to be indicated. The remainder of the technic and the postoperative treatment are the same as in the author's spinal inlay operation previously described.

Remarks.—The technic above described is applied to the bone-graft implantation into all segments of the spine. The anatomical variations of the spinous processes of the different segments must be borne in mind (see p. 74 of this chapter), as well as the increased strain and leverage action of the different segments. For instance, in the cervical or upper thoracic region, the strain placed upon the graft is much less than lower down, from the mid-thoracic region to the sacrum. The strain and leverage action of the

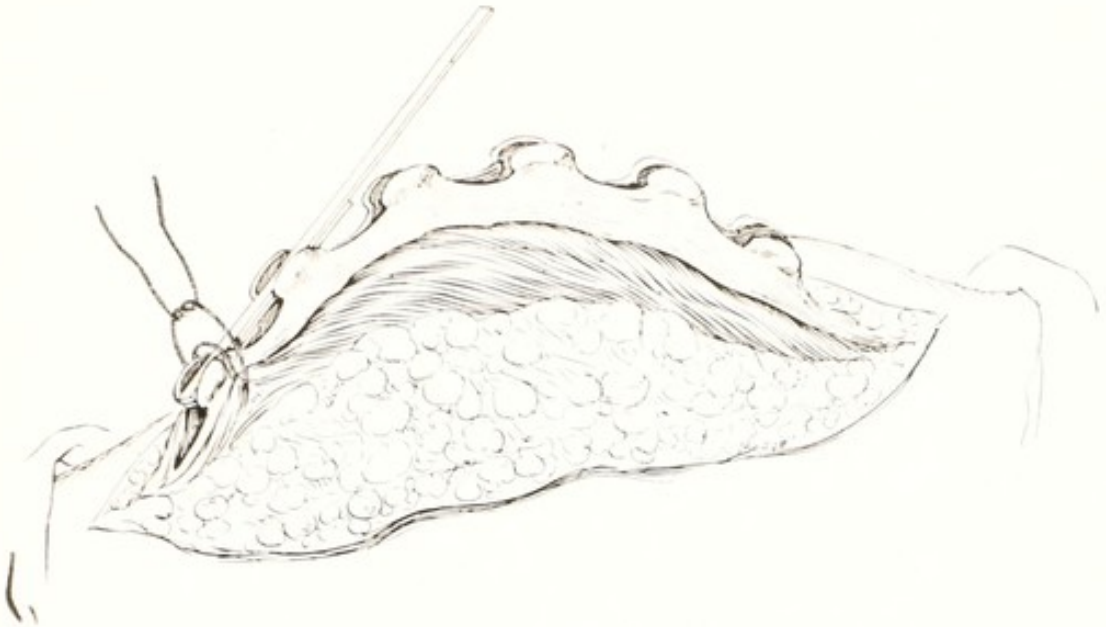


FIG. 45.—A half length graft with one of complete length is placed in the clefts of the two inferior vertebræ and the split inter- and supra-spinous ligaments drawn over them. The ligamentous structures are not separated from the sides of the spinous processes as might be inferred by this drawing in which the ligaments have been purposely shown retracted to give a better view of the arrangements of the grafts.



FIG. 46.—Ligature has been tied over first spinous process. First long graft is being held down by assistant. Second long graft is being inserted on top of first and into cleft of second spinous process. Second ligature is about to be tied to hold second long graft in place. The process is repeated until all clefts are filled.

column as a whole increase materially toward the sacrum. In the act of flexion, side-bending or rotation, the farther away from the general center of the long axis of the total lever a graft is implanted, the less is the strain placed upon it; so that a graft implanted into the lumbar region will have a greater



FIG. 47.—Diagram showing how grafts are disposed in completed operation. ("Bent-shingle" technic.)

amount of strain to resist than one at any segment above, not only for this reason but because of the increased flexibility of this segment of the spine. In this region, the general leverage that will have direct bearing upon the graft includes not only the weight and force applied through the entire length

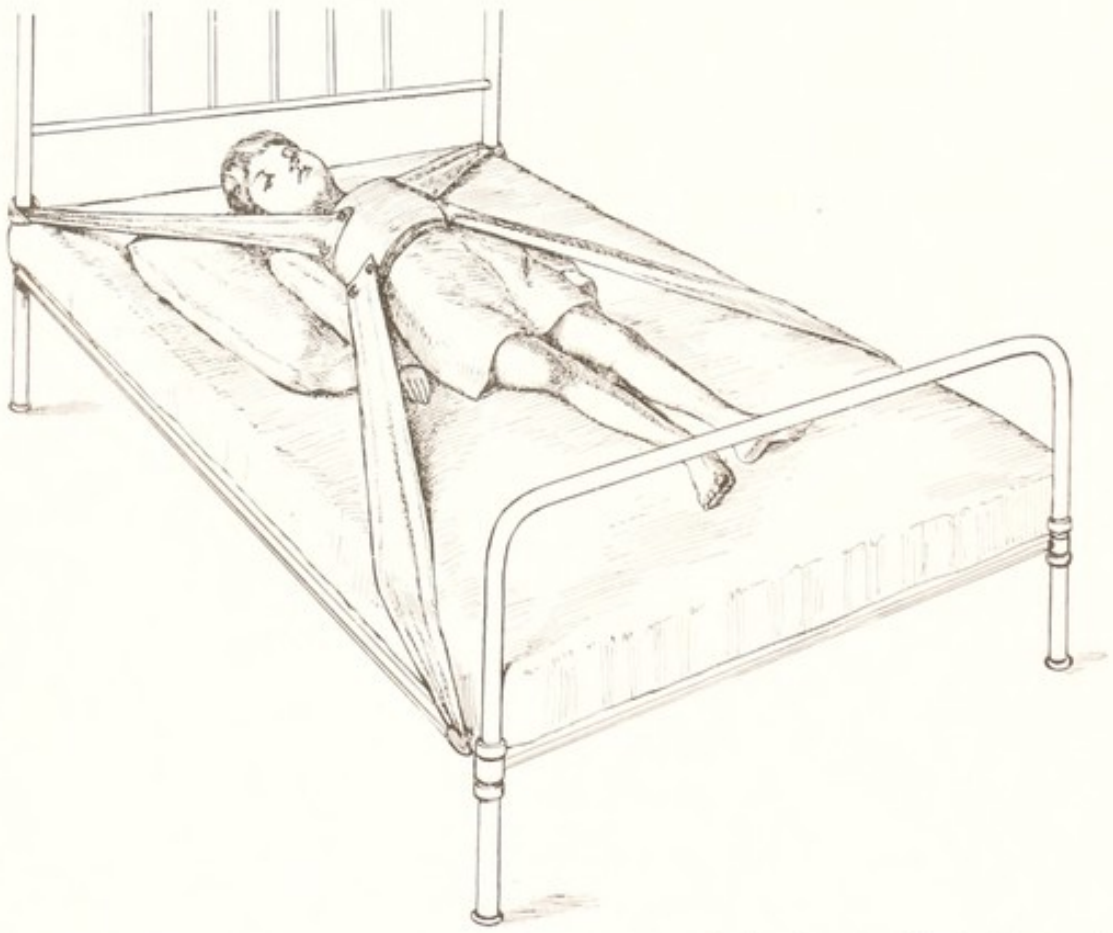


FIG. 48.—Method of fixation in bed after the bone-graft implant for Pott's disease has been applied.

of the spinal column above the implanted graft, but also includes the force of the leverage action from muscle pull of that portion of the trunk and lower limbs which extends below the graft.

Immediate Postoperative Treatment.—In the most favorable cases, recumbency upon the back on a fracture bed is maintained for a minimum of five weeks in adult cases and six weeks for children. Immobilization is furnished in the case of the latter by a towel pinned about the thorax and fastened to the bed and constitutes the immediate after-treatment. Four broad muslin bandages are attached by one end to the binder and by the other to the four corners of the mattress, to prevent the patient's sitting up or rolling from side to side and they are usually necessary only with children (Fig. 48).

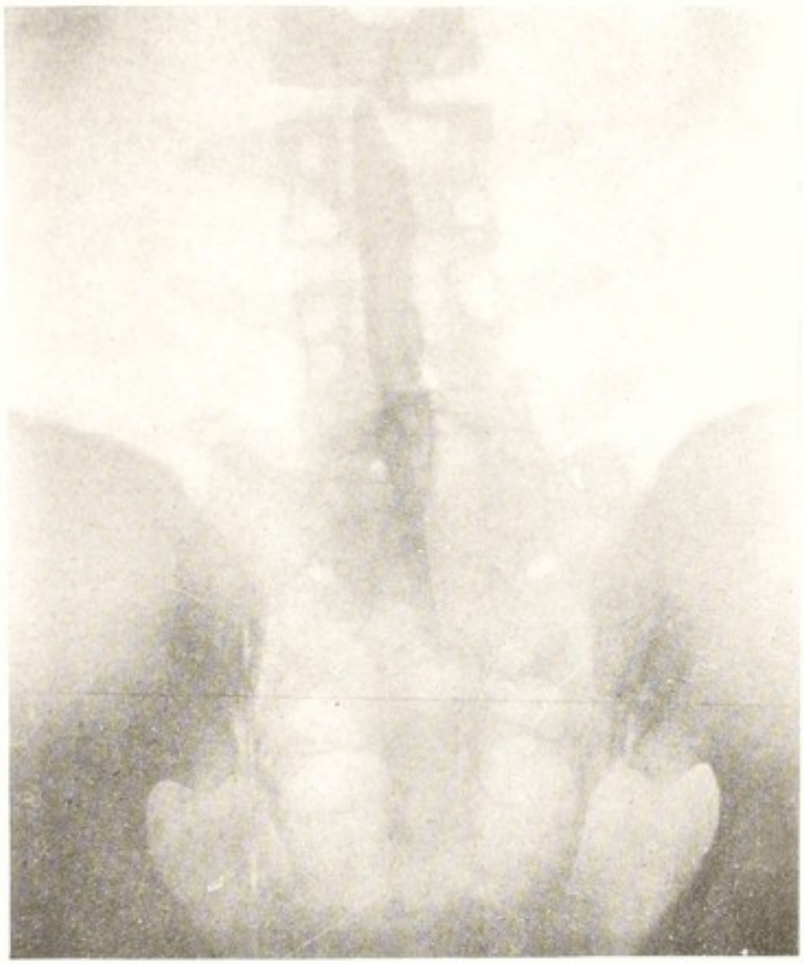


FIG. 49.—This radiograph shows the satisfactory proliferation of a bone-graft inserted six months previously for tuberculosis of the fifth lumbar vertebra. The graft was contacted with the third and fourth lumbar vertebræ above and the first and second sacral segments below the lesion.

If a marked kyphosis is present, it is best, in addition to the thick pads already in position, to secure the patient in the lateral oblique position, to obviate undue pressure on the grafted area, thus preventing necrosis of the skin flap. For the same reason it is unwise to employ the gas-pipe frame with its rigid canvas covering or a plaster-of-Paris jacket, immediately following the operation. The slight amount of motion produced by respiration is not considered detrimental to the adhesion of the graft, but rather to stimulate proliferation of callus between the contacting cut surfaces of bone and thus hasten the fixation of the graft.

General Postoperative Treatment and Convalescence.—It should be observed that, while this operation does not directly remove the diseased focus (an anatomical impossibility), it not only accomplishes the long-

sought-for immobilization of the affected intervertebral joints, but in many cases causes a separation of the diseased vertebral bodies, thus eliminating active causative elements in the extension of the disease.

Convalescence.—Although immediate relief from symptoms and evidence of arrest of active disease are often enjoyed, nevertheless the patient for a long period should have the general careful régime of bodily rest, wholesome feeding, sunlight and fresh air, that has heretofore been found of so great



FIG. 50.—Lateral view of the same case shown in Fig. 49.

importance in these cases as well as in cases of pulmonary and glandular tuberculosis.

Adults should refrain from heavy work for six months or more after the operation. (In numerous instances in the author's practice, however, patients have, by force of necessity, resumed their former occupations within eight to ten weeks after operation, against advice, without apparent interference with their convalescence.)

Children should have one year or more of restraint with daily rest periods and out-of-door life.

External Supports.—External support to the spine is employed in the following instances.

(*a*) When a patient is obliged to be moved from his bed prior to the expiration of the six weeks' postoperative period.

(*b*) When a graft is bent or weakened by the transverse saw-cuts necessary to mould it to a marked kyphosis.

In these two exceptional cases, a plaster jacket is applied and worn for a few months, as well as in other cases where it is indicated.

Summary.—Following this operation, the full and natural leverage action of each vertebra is not only preserved but is utilized to the fullest extent in preventing the crushing together of the bodies anteriorly (due to respiratory motion, superincumbent body weight, contraction of abdominal muscles, and other attempts at normal movements) by a pulling of the ankylosed spinous processes on the ankylosing graft posteriorly. The change from the

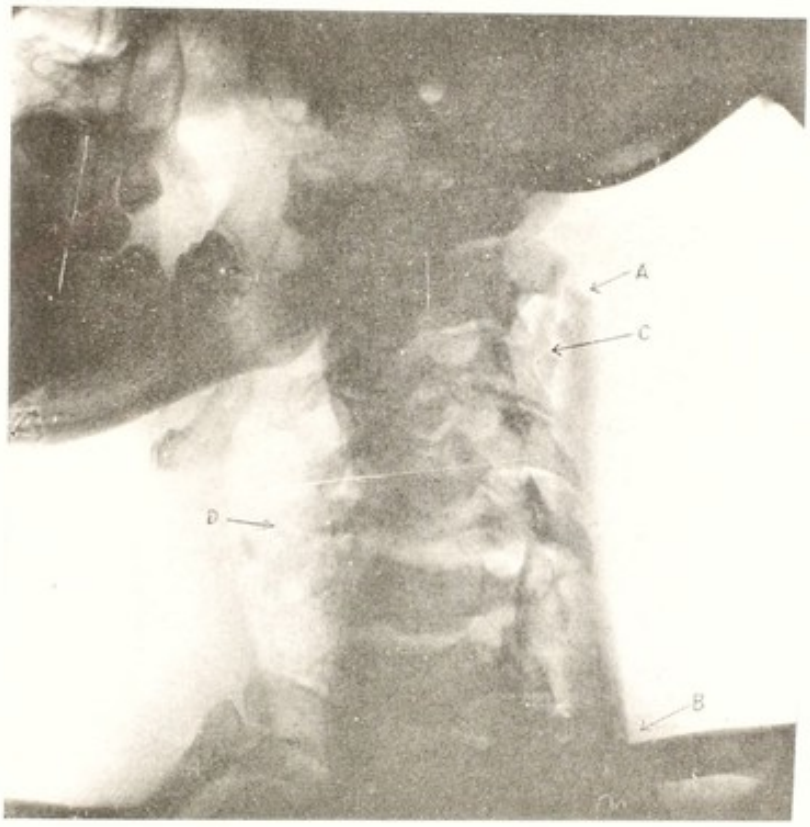


FIG. 51.—Pott's disease of third and fourth cervical vertebræ (at *D*) with almost complete paralysis of the right arm. The graft *AB* was inserted with immediate relief of all symptoms, including the paralysis of the arm, in ten days time. *C* indicates small grafts.

crushing effect taking place in the bodies by the approximation of the anterior arms of the levers to a traction effect on the graft implanted in the ends of the posterior arms of the levers (preventing separation of the spinous processes) is obvious. The fulcra of these levers remain constant, because this portion of the vertebræ (the lateral masses) is not involved by the disease. In comparatively early cases of sharply angular anteroposterior deformity of the spine, further progress of the kyphosis can be prevented and actual correction (in young subjects) maintained by this bone-graft implantation. Besides accomplishing this, the accurate immobilization of the involved segment of the spinal column is secured without interference with body activity or digestive or respiratory function, and without resorting to pro-

tracted recumbency, fixation on a gas-pipe frame, plaster-of-Paris jacket, or brace.

Indications for Operation.—The inlay spinal bone-graft is indicated in *all cases* and at *all ages* in which pain or muscle spasm demand it. The earlier the operation, the more favorable the prognosis.

Special Indications.—1. The prevention and correction of an *increasing deformity.*

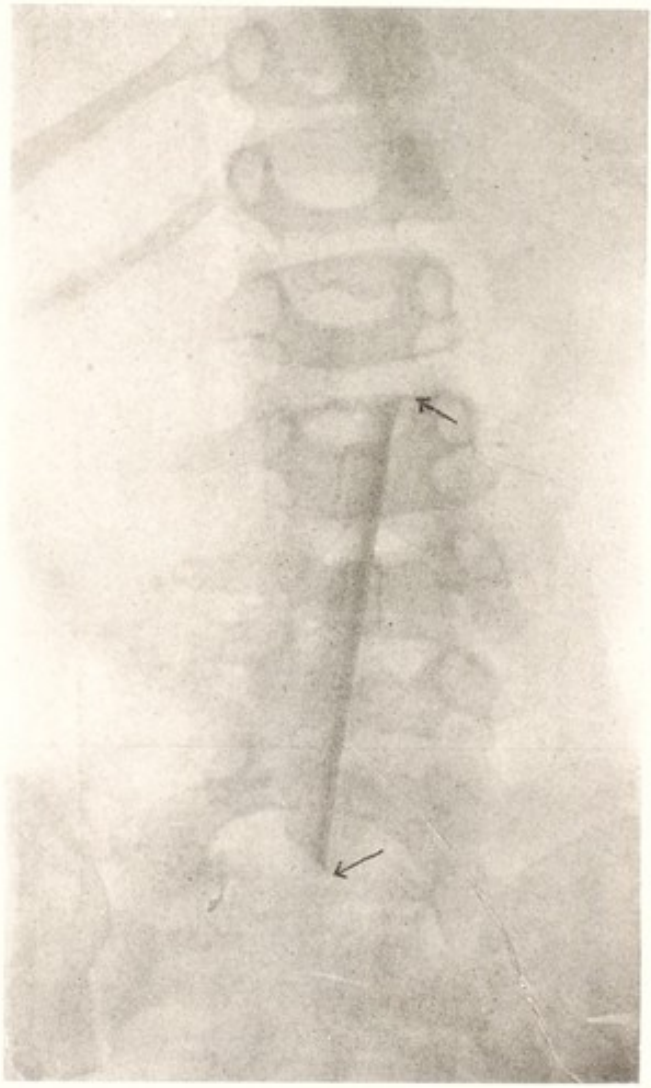


FIG. 52.—To demonstrate a bone-graft inserted for Pott's disease with a lateral deviation of the spine. The spinous processes are split in as straight line as possible and then the graft is moulded to meet the condition.

2. Complications.

(*a*) Psoas spasm.
(*b*) Ichor pocket (cold abscess) or a sinus.
(*c*) Paraplegia.

Contra-indications.—The only contra-indications are high temperature (bacteremia), and inability to secure a clean operative field. The presence of a simple ichor pocket (a rare event in the region of the spinous processes) is no bar to operation. The author has often spanned through a simple ichor pocket without untoward result to either the graft or the subsequent union.

A *secondarily infected* (pyogenic) ichor pocket is a *real* contra-indication to operation only when it is situated directly in the field of operation.

Prognosis Following the Bone-graft Operation.—The outlook is most favorable for the *relief of all symptoms* and *decrease* of the deformity. The most brilliant results are in the early cases in adults, but even in chronic cases where the kyphosis is sharply angular or mobile, a certain amount of *correction* is possible in addition to the almost constant relief of symptoms and arrest of the pathological process.

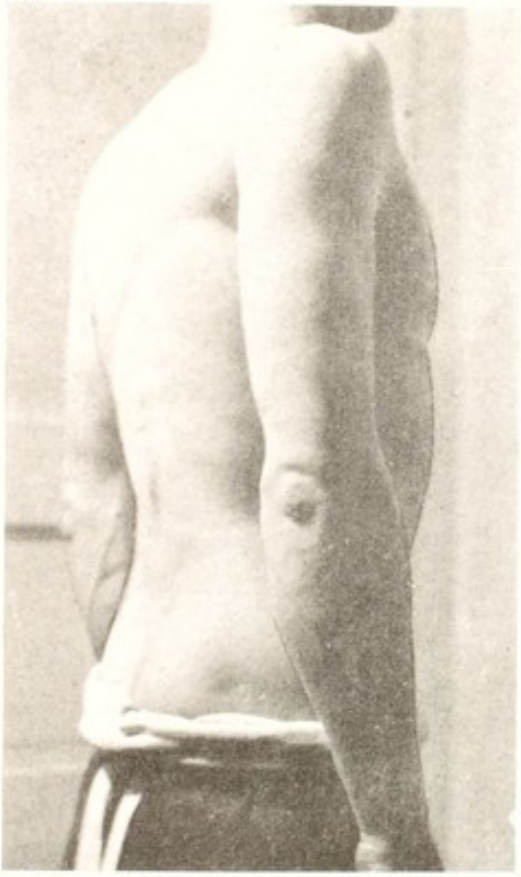


FIG. 53.



FIG. 54.

FIG. 53.—Acute Pott's disease of the lower thoracic region with large psoas abscess, four years after the insertion of a tibial graft. The abscess immediately disappeared and the patient has not lost a day's work on account of his back since seven weeks after the operation.

FIG. 54.—Case of acute Pott's disease operated during the first year of the disease when there was a very small kyphosis.

In refutation of one argument against the inlay spinal graft, namely, that it may render the spine more or less inflexible, it is to be noted that fixation by bone-graft rarely involves more than five or seven spinous processes, and when it is borne in mind that there are twenty-five spinal joints, immobilization of one-fourth of these is not only theoretically insignificant, considering the benefit conferred by relief from a terrible malady, but is also negligible from a practical standpoint, as is evidenced by a glance at Fig. 55.

Abundant and reliable evidence is available to invalidate the contention of those (if any still persist) who assert that "the inlay bone-graft operation is inadvisable in the case of children because healing takes place by cartilage; that the operation produces deformity, etc." The first assertion is falsified by the radiographic postoperative evidence; the author has in his possession numerous *x*-ray plates of children which show a distinct bar of bone extending between the graft and the spinous processes in cases in which the bone-graft had become "sprung" from the spinous processes. That the operation does not cause increase of the deformity by "locking" the involved segment of the spine is attested by innumerable clinical and radiographic observations which demonstrate that the growth of the graft proceeds *pari passu* with that of the rest of the spine. Furthermore, any tendency which the graft might have to favor increase of the kyphosis is outweighed by its inherent tendency in the opposite direction, that of lordosis.

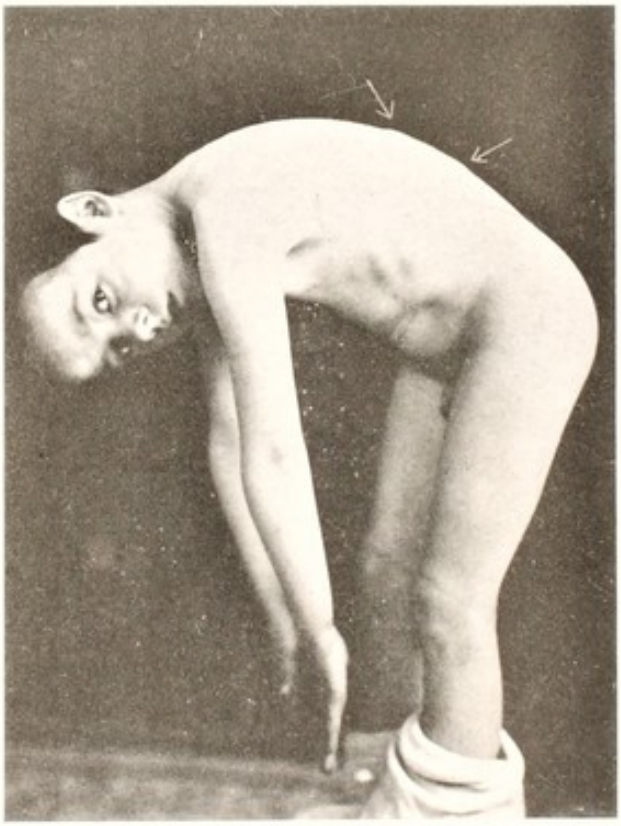


FIG. 55.—Same case as Fig. 54. Shows function of spine, two years after operation. The arrow indicates location of graft.

The prognosis is still further influenced by the patient's postoperative environment and his régime of living (rest, fresh air, forced feeding and sunlight).

Combining the author's results with those obtained by certain other surgeons in this and in foreign countries, the following data on 532 operations with the inlay bone-graft in Pott's disease are herewith presented:

(There have been only 3 of the 532 cases who died of tuberculous meningitis, and in no case was there any serious trouble with the tibia from which the graft was removed.)

(*a*) *Ages.*—The patients varied in age from twenty months to sixty-five years.

(*b*) *Duration* of the *disease prior to operation.*

Duration of the disease	Number of cases
Less than 1 year	58
More than 1 year	71
More than 2 years	62
More than 3 years	71
More than 4 years	56
More than 5 years	36
More than 6 years	33
More than 7 years	21
More than 8 years	16
More than 9 years	13
More than 10 years	10
More than 11 years	8
More than 12 years	8
More than 15 years	5
More than 19 years	3
More than 21 years	5
More than 26 years	2

(*c*) *Location* of the *disease.*

	No. of cases	Percentage
Cervical	6	1.33
Cervicodorsal	42	9.33
Dorsal	168	37.33
Dorsolumbar	78	17.33
Lumbar	122	27.10
Lumbosacral	34	7.55

(*d*) *Results of the Operation.*

Results	Total series 532 cases		Author's series 198 cases to June 1915*		292 results of 31 surgeons		14 of the 31 surgeons		8 of the 31 surgeons	
	No.	Per cent.	No.	Per cent.	No.	Per cent.	No.	Per cent.	No.	Per cent.
Disease arrested	449	84.40	184	92.9	222	76.0	.....	100.0	.....	100.0
Improved	59	11.00	2	1.0	59	20.0				
Unimproved	9	1.69	0	0.0						
Died:	15	2.81	12	6.0	12	4.0				
Soon after operation	9	1.69	6	3.0	4	2.0				
Long after operation	6	1.12	6	3.0	8	2.0				
No external spinal support used	.....		198	100.0	.....		.....		.....	100.0

*Only those cases in which one year or more had elapsed since the operation was listed (June, 1915).

†Dead: 6 were entirely relieved of their Pott's disease and died from some intercurrent disease, viz.:

One, six years of age, in poor general condition, after *five years* of *conservative treatment* died the day following operation, cause unknown. (The graft in this case was removed with chisel and mallet at operation.)

One case, in four days, from *acetonuria.*

One case from *status lymphaticus.*

One case from middle-ear disease, complicated by *suppurative meningitis*, two years after the spinal operation. (Autopsy showed *complete cure* of the *tuberculous spine.*)

One case from *pneumonia*, one week after operation.

Causes of death of others: amyloidosis of viscera; tuberculosis of the lung; acute abdominal condition.

HIBBS' OPERATION

Hibbs (N. Y. Med. Journ., May 27, 1911) conceived the idea of removing the peri-osseous structures from the spinous processes, dividing the latter at their bases and so placing them longitudinally in the interspinous spaces that their ends touched the bases from which the processes had been removed. The soft structures were then brought back and sutured, the desired result being ankylosis of the vertebræ at the site of operation. Hibbs at first supported the spine by a plaster spica from knees to axillæ, but on account of discomfort later abandoned its use for a modified spinal assistant (light brace) with perineal straps.

Hibbs' technic (Hibbs, R. A., Jour. Am. M. Ass., Aug. 10, 1912, lix, No. 6, pp. 433–435) is as follows:

A longitudinal incision is made directly over the spinous processes through skin, supraspinous ligament and periosteum, to the tips of the spinous processes. The periosteum is split over both the upper and lower borders of the spinous processes and the laminæ, and stripped back from them to the base of the transverse processes. The spinous processes are then transposed after partial fracture, so that they make contact with fresh bone, the base of each with its own base and the tip with the base of the next below. The adjacent edges of the laminæ being absolutely free from periosteum, a small piece of bone is elevated from the edge of the laminæ and placed across the space between them, its free end in contact with the bare bone of the laminæ next below it. The lateral walls of periosteum and the split supraspinous ligament are brought together over these processes by interrupted chromic catgut sutures. The skin wound is closed by silk, and a steel brace applied with the space between the uprights increased somewhat at the site of the wound so as not to make pressure on it. In some cases the gaps in the periosteum removed from the spinous processes and laminæ have been closed by suture, thus establishing at once a continuous periosteal wall. Hibbs advises that rest in bed be absolute for eight to ten weeks; that during the next four weeks sitting-up be permitted and at the end of the twelfth week, walking. The brace is continued for another month when it is removed for a part of each day until gradually left off entirely; in the case of children under five, it is to be worn for six months.

Dobrotworski (Zeitschr. f. chir., Aug. 12, 1911) has recommended that, for grafting purposes, a portion of rib be used in preference to tibia.

CONSERVATIVE (MECHANICAL) TREATMENT

As previously stated, operation by direct immobilization of the affected vertebræ by the author's inlay bone-graft should be performed *in all cases, at all ages, and at the earliest possible moment* after a diagnosis has been made.

When the patient refuses to submit to operation, a conservative attempt to secure immobilization is the only alternative. It is also indicated when operation has to be postponed in the event of pyogenic infection (bacteremia, infected sinuses, etc.) or any infection other than tuberculous or in the event of hyperpyrexia from *any* cause with the single exception of that due to the tuberculous process itself. The temperature from spinal caries (if other causes can be eliminated) is not only not a contra-indication but a very strong indication for operation.

The indications for conservative, mechanical treatment, as opposed to operative intervention may therefore be summarized as follows:

1. Refusal of operation by the patient.

2. General infection and bacteremia.
3. Exanthemata and other complications. } temporary.
4. Infected field of operation.

General Principles of Mechanical Treatment.—The desideratum of all local treatment is to remove weight, pressure, and movement from the focus of infection and to fix and hold the diseased portion of the spine in the desired position. This is attempted by external mechanical means.

In order to better understand the fundamental mechanical principle involved in the treatment of tuberculosis of the spine, it must be appreciated that the disease is wholly in the vertebral bodies, and that the progress of the condition is that of a crushing, telescoping, and destruction of this part of the vertebra. This is caused not only by the *superincumbent weight* of the body above the point of disease but also in a large measure by *muscle spasm* and constant *respiratory motion*. The last factor is more potent in the dorsal region, but its influence is considerable in any region of the spine.

From this standpoint, it is evident that the mechanical conditions for effective splint support are unfavorable in any region of the spine, and it is apparent also that the conditions are more favorable in some parts than in others, *i.e.*, the external splint is more efficient in the lower dorsal and upper lumbar regions on account of the focus of disease being in the central portion of the spine, thus affording a maximum of leverage above and below.

The opposite or unfavorable condition is found in the upper dorsal region, where the leverage above is short, and the superincumbent weight of head and shoulders, together with the physiological curve, favors an anteroposterior kyphosis. The poor leverage below the focus of disease is even more marked in the last few lumbar vertebræ.

With the disease in these regions, recumbent horizontal fixation is by all means the most efficient conservative treatment.

Mechanical treatment is administered in (*A*) the *recumbent* posture (in the stage of acute symptoms or complications) and thereafter by the (*B*) ambulatory method.

(A) RECUMBENT TREATMENT

This is indicated in all cases for postoperative fixation or in the event of refusal of operation, on the part of the patient, or of a contra-indication to operation; also under the following conditions, viz.:

1. Acute symptoms.
2. Paralysis (actual or impending).
3. Psoas spasm or contracture.
4. Lateral deviation of the spine.
5. Abscess formation.

The beneficial effects of recumbent fixation of the spine are due to the fact that more complete immobilization is secured by this method than by any ambulatory method; hence the more complete relief of symptoms.

Appliances.—Of the many appliances for securing recumbency and fixation, only those used by the author in his practice will be described in detail, the remainder being merely mentioned, and the reader being referred to the older text-books and to special monographs for a more complete description of them.

The Bradford-Whitman gas-pipe frame is the appliance of choice in securing recumbency fixation in Pott's disease of all regions of the spine, being supplemented by special appliances for the cervical and upper dorsal regions and in disease of the last lumbar vertebra. This apparatus is used as the fixative agent in cases upon whom, for some reason, operation is not performed, and may also be used for postoperative fixation.

1. *Bradford-Whitman Frame* (Figs. 56 and 57).—This is an effective and convenient horizontal support, and consists of a rectangular frame of gas-pipe, a foot and a half longer than the patient and in width equal to the inter-axillary distance. Over this frame a cover of strong canvas is stretched by means of corset laces on its under surface. The canvas can be made in 2 sections with an interval between to allow for the bed-pan. Two felt pads, about 7 inches long and $\frac{3}{4}$ inch thick, are sewed to the canvas to relieve the tip of the kyphosis from pressure and thus prevent excoriation. The patient is



FIG. 56.—Whitman frame with head traction. This patient is making a good recovery from tuberculosis of the spine, hip, and wrist tendons. (Albee's case.)

held in place by a front piece or apron secured to the sides of the frame by straps and buckles. As soon as he becomes accustomed to the restraint, the hyperextension of the spine is increased from time to time by bending the frame upward beneath the kyphos. This tends to separate the vertebral bodies, relieving them partially for the time being from friction and pressure.

The patient is kept constantly upon this frame, the clothing, in case of children, being made large enough to include the apparatus, thus assuring better fixation and avoiding removal of the child from the frame for the



FIG. 57.—The stretcher frame on which the patient is replaced while the jacket is hardening. (Whitman.)

purpose of changing the outside clothing. The patient should be removed once a day, inspected, bathed with alcohol, and powdered with talcum or stearate of zinc, etc., after which the apparatus is re-applied. Great care must always be taken in handling the patient, who should never be allowed to assume the vertical position.

2. *Sayre Halter and Sling* (Fig. 58).—In disease of the cervical region, and in acute stages of dorsal disease above the ninth dorsal vertebra traction by means of a Sayre halter and sling is desirable to give greater fixation and hyperextension, whether the child is on the frame or in a plaster-of-Paris

jacket or a spinal brace. This halter is attached to a cross-bar at the upper end of the frame.

3. *Traction—Plaster Jacket or Back Brace.*—In cases of disease of the last lumbar vertebra, traction is made on the limbs by weights attached to the legs by adhesive strapping and ropes playing over pulleys at the foot of the bed.

In very acute cases, a light plaster-of-Paris jacket or a back-brace may be necessary to supplement the fixation of the frame, for the relief of symptoms. If a brace is to be used, that devised by C. F. Taylor (described below) is preferred.

Remarks on Frame Treatment.—Pain and discomfort usually disappear within a few days after the patient is fixed on the frame. The treatment of all acute cases, if conservative treatment is to be followed, should be begun by the immobilization of the patient on the horizontal frame. This is not an absolute fixation, but it is the most effective of any of the methods of conservative treatment. So long as respiration continues, perfect fixation is not possible by external means. But there are individual cases where this does not apply, and pain persists in spite of the recumbent treatment.

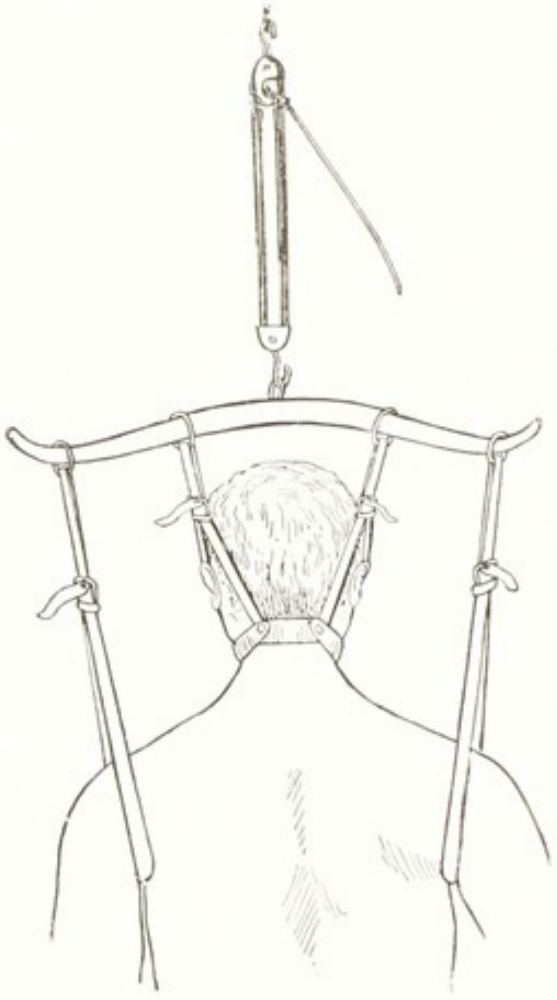


FIG. 58.—Sayre headpiece for suspension in Pott's disease. (Bradford and Lovett.)

Recumbent fixation is not a complete method of treatment in that, sooner or later, ambulatory fixation becomes necessary in the form of either plaster-of-Paris jacket or a brace.

Duration of Frame Treatment.—The duration of the frame treatment varies from six months to three years. The indications for its discontinuance in favor of ambulatory treatment are relief of all symptoms and apparent arrest of the local disease, as indicated by physical examination and *x*-ray findings, also the increased freedom of motion and restlessness of the patient when removed from the frame for sponging, evidently fretful from long-continued confinement. At such a time it is advisable to begin ambulatory treatment. Other indications to terminate horizontal fixation are:

1. Disappearance of pain.
2. Deformity stationary or absent.
3. Absence of evening rise of temperature for some months.
4. Increase of body-weight.

Other Appliances for Recumbent Treatment.—Space will permit only an enumeration of the more important of the many other methods for securing fixation in recumbency. A detailed description of them can be obtained by consulting the text-books and monographs of their authors.

1. A simple bed prepared for recumbency, with board under mattress.
2. Tubby's spinal pillow.
3. Fisher's bed-frame.
4. Double Hamilton splint.
5. Double Thomas splint with headpiece.
6. Plaster-bed (Hoffa; Phelps).
7. Gauvain's spinal board.
8. Gauvain's back-door splint.
9. Gauvain's wheel-barrow splint.
10. Phelps' box.
11. Rollier fixation straps.

(B) AMBULATORY TREATMENT

When the patient is judged to be able to get about, the spinal column must be supported and immobilized by some type of apparatus.

The most commonly used ambulatory supports are of 2 types, the plaster-of-Paris jacket and the steel brace, with the addition of some variety of head support in the case of disease above the ninth dorsal vertebra. The selection of either of these depends upon a number of factors, chiefly the following:

1. The individual experience of the surgeon.
2. The co-operative inclination and intelligence of the family.
3. The age of the patient.

The plaster jacket is best adapted for use in children of the poor and ignorant class, being less likely to be tampered with. As a rule, the brace is best suited to the adult and to children of intelligent families.

Essentials of Efficient Spinal Supports.—To avoid being a useless encumbrance, and to be at all serviceable, a spinal support must satisfy the following requirements:

1. A fixed point from which pressure may be exerted, preferably the pelvis.
2. Pressure should be exerted along the transverse processes of each side, especially in region of kyphosis.
3. No compression of the lateral chest walls.
4. Compensatory pressure on the upper portion of the anterior chest wall and the pubic and pelvic regions.
5. If the disease is located between the eighth and tenth dorsal vertebræ the support must extend above and in front of the shoulders.

If above the eighth dorsal vertebra, the support must include the head and neck.

1. **The Plaster-of-Paris Jacket.**—All that can be expected of the brace or plaster jacket is to hold the spine in general alignment. The latter is a simple splint to the whole spine and only partially fixes the individual segments. Its efficiency depends upon accurate and smooth application over the body's irregularities, and upon its leverage above and below the diseased focus. It should be applied with the spine held in the most favorable hyperextended position which, as a rule, is obtained by the Sayre or Calot suspension apparatus (Fig. 59) or Robert's extension jack appliance.

After the skin is prepared by bathing with alcohol and dusting with talcum powder, a seamless jersey shirt or stockinet is applied. This should be of sufficient length to allow of its being turned up to form an outer cover to the jacket. The patient is then placed upon a stool and the halter of a Sayre or Calot suspension apparatus adjusted about the head. The arms are extended above the head and grasp the suspending straps on either side.

The patient is then suspended by sufficient traction to raise the heels off the stool. The anterior superior spines and the crests of the ilia and the sternum are protected by piano felting. The spinous processes of the kyphosis are protected by a strip of saddler's felt placed on either side to prevent them from chafing, and to allow the application of greater pressure and fixation at the point of disease. In adolescent and adult females the breasts are protected by cotton, which may be removed later if there is undue pressure. No "dinner pad" is used except in thin adults.

The selection of a proper plaster bandage is essential, and the details of its preparation will be found in Chapter XXIX on "Plaster-of-Paris Technic."

The bandages are wound smoothly about the patient, and while the jacket is being applied, an assistant sits in front, holding the patient's thighs to prevent swaying and rotation. A second assistant, standing to the side, rubs each layer of plaster bandage thoroughly as the turns are made by the surgeon, who stands at the back of the patient, and also rubs in each layer thoroughly.

Care should be taken that the jacket is made of uniform thickness throughout, $\frac{3}{16}$ to $\frac{1}{4}$ inch. It should extend above the sternal notch and below the anterior superior iliac spines, sufficiently to afford plenty of length for trimming.

Before the plaster sets, it is moulded so as to increase its leverage, and trimmed. It should be left as long as possible and should permit flexion of the thighs and motion of the shoulders.

The patient should be placed in a recumbent position, for not less than one hour after the application of the jacket, in order to insure sufficient hardening and firmness before strain is brought to bear upon it by the patient's assuming the erect posture.

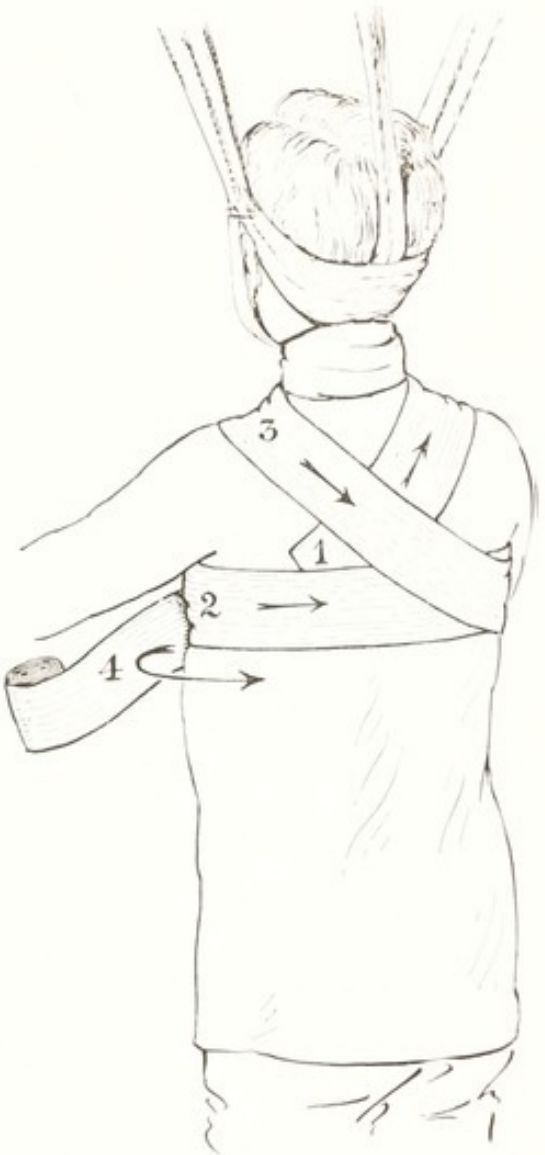


FIG. 59.—Applying the Calot "military" plaster jacket.

If the disease is above the ninth dorsal vertebra, a jury-mast or head support, incorporated in the plaster, is necessary to lengthen the leverage above the point of disease and aid in holding the upper portion of the spine in hyperextension.

Modifications of the Plaster Jacket.—The jacket may be changed to meet the various individual requirements, viz:

1. The plaster may be carried *over the shoulders*, to secure more efficient hyperextension.

2. The *head may be included* in the plaster as a substitute for the *jury-mast*.

3. *One* or *both thighs* may be included for acute and painful disease low down, or for psoas spasm.

4. *Calot's method* (modified).

A very efficient method is that of the modified Calot, where a corrective jacket is worn in recumbency for one to two years, followed by the *military* style (Fig. 60) for all cases below the ninth dorsal vertebra, and the so-called *grand* style for all cases above that level (Fig. 61). In the hands of the author



FIG. 60.—The Calot military plaster-of-Paris jacket for immobilizing the lower dorsal and lumbar spine.



FIG. 61.—The Calot "grand" plaster-of-Paris jacket for immobilizing upper dorsal and cervical spine.

it has been found preferable to use the American plaster-of-Paris roll in applying this jacket instead of the technic of cream plaster and pattern crinolin method of application advised by Calot and so dexterously used by him.

In applying the military and grand types of the Calot, the Sayre suspension apparatus is used, excepting the leather halter. As a substitute, portions of 3-inch muslin bandages have been adjusted about the chin and occiput, and held by means of large safety pins, so as to be easily removed.

The military jacket is applied in a way very similar to the ordinary jacket, except that the shoulders are padded and included in the plaster with a military collar above. The "grand" differs in that the head is hyperextended and held by including the chin and occiput.

In the case of either type of jacket a square window is made over the kyphos, sufficiently large to admit a layer of thick felt with a hole in the center to allow periodical increase of pressure on the spinous processes of the kyphos. This is placed in contact with the stockinet, and the corrective force is established by forcing in layers of cotton after which the square of plaster removed is fastened in place again, under pressure, by a few layers of plaster-of-Paris bandage. A large triangular window with its apex upward is made



FIG. 62.—Plaster-of-Paris Minerva jacket being applied. The moulding about the pelvis and sacrum, shoulders and neck is important. (After Calot.)

in the front of the jacket in such a position as to allow the thorax and spine to be forced forward at the level of the kyphosis. A constant corrective pressure is maintained by removing the posterior plaster window and adding to the cotton padding at intervals of two weeks, as the kyphosis recedes.

5. *Gauvain's method* may be briefly mentioned. He employs two types of plaster jacket, the "*Minerva*" and the "*Fillet.*" The former extends so high as to be below the jaw, the mastoid and the occiput, and completely encases the head to the supra-orbital ridges (Figs. 62 and 63).

In the "Fillet" a narrow band (fillet) of plaster is carried around the forehead in such a position as to keep the head extended.

6. *Hammock Frame Method.*—Whereas in the previously described methods, application of the jacket has been made with the patient standing

with suspension added, in this method, the patient lies prone or supine on a strip of cloth stretched over a frame. The advantages claimed for this method are the comfort of the child during application, the absence of any tendency to syncope, and the correction by hyperextension which may possibly be obtained.

On the above principles, there have been developed the following methods each with its special apparatus for applying the jacket:

(*a*) Goldthwait's method (Figs. 64 and 65).

(*b*) Brackett's method.

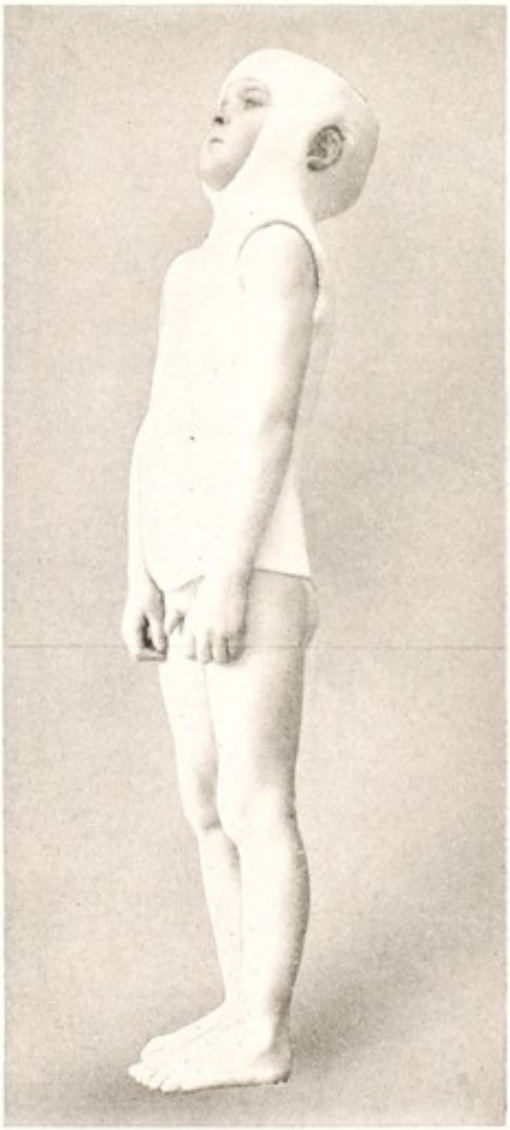


FIG. 63.—Plaster jacket including head and neck. (Starr and Gallie.)

(*c*) Lovett's method.

(*d*) Taylor's method (Fig. 66).

II. The Spinal Brace.—The other type of spinal support is the spinal brace, the best type of which, and the one used and recommended by the author, is the steel brace of Dr. C. F. Taylor which has been largely used since its introduction by Taylor in 1863.

1. *The Taylor Brace.*—This consists of two paralled steel uprights, $\frac{1}{2}$ inch wide, gauge 8 to 12, one on each side of the spinous processes, extending from

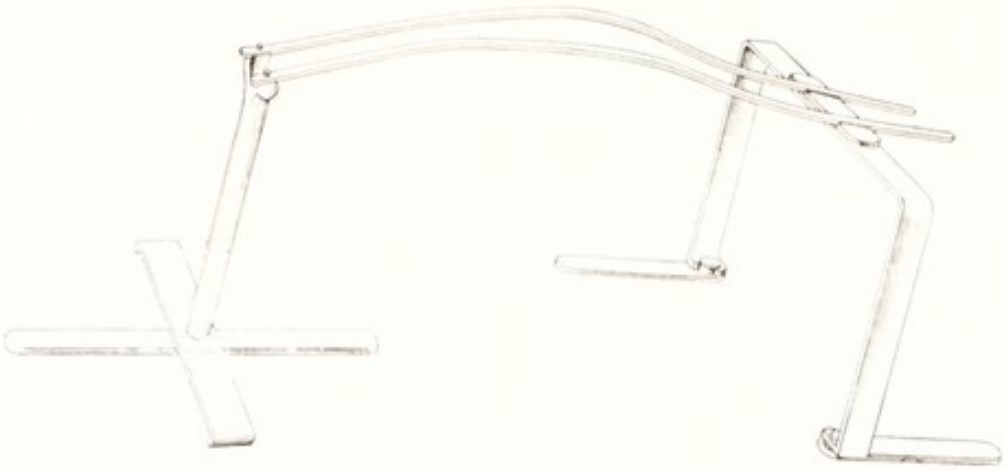


FIG. 64.—Goldthwait's portable frame for applying the plaster jacket. (Whitman.)

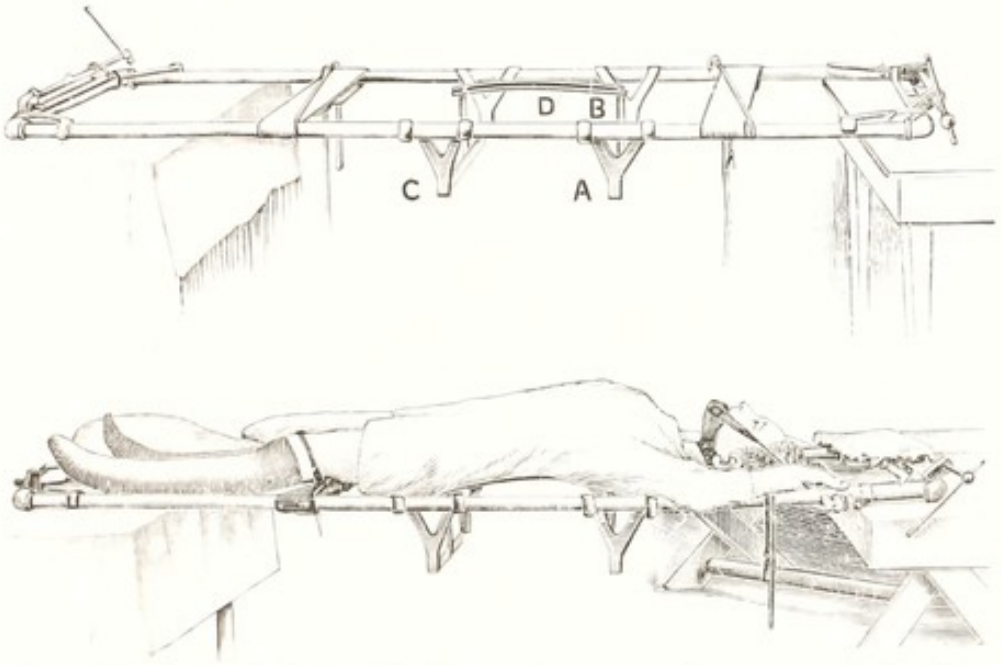


FIG. 65.—The plaster jacket applied in supine posture by means of the Metzger-Goldthwait apparatus. (Whitman.)

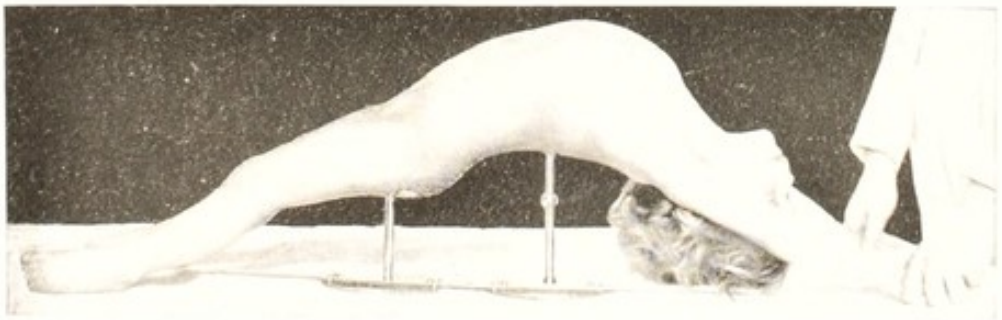


FIG. 66.—The Taylor appliance in use, showing the hyperextension of the spine. The plaster jacket having been applied, the back rest is removed by pressing the bandages from side to side by enlarging the opening. If desirable, the defect is then concealed by a turn of plaster bandage. (Whitman.)

the buttocks to the seventh cervical vertebra. Pressure pads of ground cork or soft leather are adjusted on the under surface of the uprights. These allow greater pressure for fixation and correction of deformity at what is the fulcrum of the brace lever when the upper and lower ends are fixed to the shoulders and pelvis. To the lower ends of these uprights is fastened a pelvic band of sheet steel, 1½ to 2 inches wide, with average gauge 18, and reaching from one iliac spine to the other. Opposite the second dorsal vertebra, 2 shoulder pieces of lighter metal extend over the shoulders to about the middle of the clavicle. These are padded, and from their ends padded shoulder straps are continued around and under the arms, and then buckled to the uprights at about the level of the angle of the scapula. Additional fixation is had by applying an apron covering the abdomen and fastened below by a strap sewed to its lower border to buckles at the ends of the pelvic band. The upper border is similarly arranged with straps and buckles to the uprights at a level with the axilla.

To measure for the brace, have the child face-down on a firm flat surface. A lead tape is then applied along the spine over the lateral masses and an exact outline is then transferred to a piece of cardboard, and trimmed with scissors for use as a pattern in shaping the uprights. Modifications and changes can be made to adapt this brace to special indications.

In cases where the disease is above the ninth dorsal vertebra, a hard-rubber chin cup or jury-mast attachment to the brace is necessary. (These head supports are described below.)

Space will permit of only an enumeration of some of the other spinal supports more or less commonly used, viz.: (2) Schapp's brace. (3) Davies' quadrilateral brace. (4) Thorton's back brace. (5) Tubby's spinal support. (6) Leather jackets. (7) Celluloid jackets. (8) Knight's spinal brace.

It should be appreciated that the correction obtained by plaster jackets, steel braces, or other external appliances, is most difficult to maintain, owing to an irreparable loss of substance in the diseased vertebral bodies, and also because there is so little osteogenesis.

Mechanical support can never be removed without great apprehension of a relapse of the deformity or of the disease, and should be discarded with the greatest conservatism. It is in this particular, among others, that operative treatment is so much to be preferred, in that bone support is quickly and directly supplied, the simplicity of the operation being indicated by the short time in which it can be performed. (The author has prepared the graft-bed, inserted and secured the bone-graft and closed the skin wound in nine minutes.)

III. **Head Supports.**—If the disease is above the ninth dorsal vertebra, a jury mast or other form of head support, incorporated in the plaster (Fig. 67) is necessary to lengthen the leverage above the point of disease and aid in holding the spine in hyperextension.

1. *The Jury Mast* (Fig. 68).—This is the commonest adjuvant of the plaster jacket in cervical and high dorsal disease. The jury mast should be made of tempered steel. It consists of a base formed of a flat steel bar about 3 × 1½ inches. From the extremities of this bar flat steel bars curve downward and outward, and to the extremities of these are fastened lateral plates of perforated tin. The base-piece is incorporated in the plaster jacket, the transverse bar crossing opposite the second dorsal vertebra, and the lateral pieces passing over the scapula of each side.

The "mast" proper passes from the center of the base-bar upward to below the occiput, where it curves backward, conforming with the outline of the skull, but about 1½ inches distant from it. It ends over the center of

the vertex but about 2 inches above it. To its extremity is rivetted a narrow steel cross-bar, extending laterally the length of the biparietal diameter. A halter is slung from the two ends of this cross-bar and by leather bands is attached to a chin-piece in which the occiput and chin are supported. As much tension as can be borne should be applied. The chin should be tilted upward to get hyperextension; this is best accomplished by shortening the halter-strap passing to the chin.



FIG. 67.

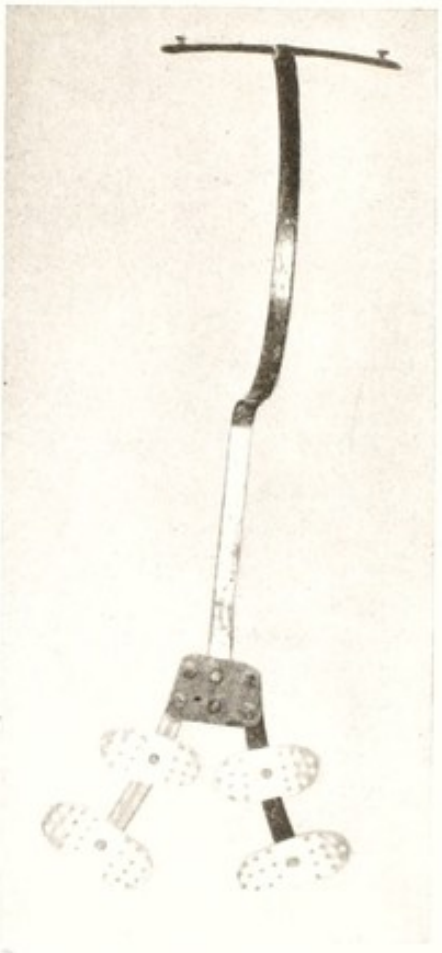


FIG. 68.

FIG. 67.—Plaster jacket with jury mast, just applied. Note tilting back of head. The stockinet hanging down will be turned up over the jacket and sewed to itself at the top. (Taylor.)

FIG. 68.—Jury mast. (Taylor.)

Other forms of head-supports less commonly used may be briefly mentioned.

2. *The Thomas Collar* (Fig. 69).—This consists of a poroplastic felt, plaster-of-Paris or other material, and is cut wide enough to reach from the sternum to the chin, and from the back of the neck to the base of the occiput. If made of thin sheet metal, the edges are turned outward and the whole is properly covered with felt and fitted.

3. *The Taylor Ring.*—This is an attachment of the Taylor brace, and consists of an oval ring to support the chin and occiput, forged to a steel upright and pierced to admit the top of a spindle attached to the brace by a socket riveted to its upright. The one disadvantage of the Taylor ring is its tendency to produce recession of the chin by causing a luxation of the temporomaxillary joints.

4. *The Goldthwait Head Support.*

5. *The Davies Head Support.*

Correction of the Deformity

Although a kyphosis is merely a symptom, an attempt should be made to correct the deformity, if feasible, when it exists.

Corrective measures may be classified under two heads (*A*) operative correction and (*B*) gradual correction.

(A) Operative Correction

The various procedures, in the order of preference are:

1. Bone-graft correction and fixation. Albee method.
2. Correction under anesthesia (Calot).
3. Removal of spinous processes.
4. Wiring together of spinous processes (Hadra).
5. Internal steel splints (Lange).

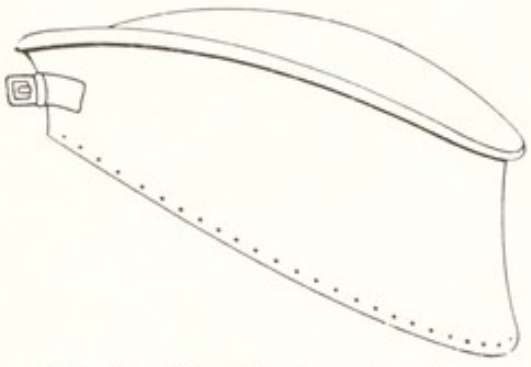


Fig. 69.—The Thomas collar for permanent use. A piece of thin sheet metal is cut wide enough to reach from the sternum to the chin, and from the back of the neck to the base of the occiput. The edges are turned out and the whole properly covered with felt and fitted. (Ridlon and Jones.)

1. **Bone-graft Fixation.**—Although the author's operation is designed primarily to cure the disease, it incidentally provides a means of correcting the deformity. If the spine is markedly kyphotic and angular, and the disease of short duration and in a young subject, fixation of the patient on a Bradford-Whitman frame for some time prior to operation will often largely correct the kyphosis before operation and enable the bone-graft to maintain the correction. With care, much correction can be accomplished at the operation by manual force and by using the graft as a lever as it is inserted under the dense ligaments.

The details of the author's operative technic have already been given in full.

2. **Rapid Correction under Anesthesia (Calot Method).**—The patient is anesthetized and suspended face downward in the horizontal position by five assistants, who exert traction upon each of the extremities and upon the head, while the surgeon gently presses directly downward upon the kyphosis. The deformity gradually yields and is overcome. The amount of pressure necessary varies from 30 to 80 pounds. The correction thus secured is maintained by applying a plaster jacket with the spine hyperextended. Recumbency is required for three to six months and a spinal support is necessary for at least one year thereafter.

This method has proved disastrous in a very large percentage of cases, not only in Calot's experience, but in that of all others, because nature's

efforts at fixation are largely destroyed, *i.e.*, the fixative influence of connective tissue and bone proliferation are broken up and destroyed, and the surgeon has been unable by his conservative appliances to immobilize the spine sufficiently to prevent relapse of the disease. For instance, a well-known surgeon reported a case of Pott's disease with kyphosis and paraplegia treated by Calot's method; the paraplegia subsided for some days following the manipulation, and the result appeared brilliant. However, in a few weeks relapse occurred, and the tuberculous process and the paraplegia returned, with marked symptoms of active Pott's disease. Largely because the surgeon was unable by the conservative means at his disposal to restore the fixation which he had broken up by his manipulation, the tuberculous process, irritated by unchecked respiratory motion, became more active than ever, and the result of the operative correction was lost. The insertion of the graft enables the surgeon not only to maintain the correction of the deformity, but to accomplish immediate fixation. The operative correction of a kyphosis, however, should be attempted with the greatest caution, and care should be exercised in the selection of cases.

4. **Wiring Together the Spinous Processes.**—Hadra, in 1891, advocated carrying silver wire through the interspinous spaces above and below the processes in a figure-of-8 fashion, and twisting their ends to produce fixation. The practice is reprehensible in view of the well-known destruction of bone by silver wire and by all other metallic substances.

5. **Internal Steel Splints** (Lange).—Splints of tin plated steel 10 cm. × 5 mm. were used by Lange to fix the affected vertebræ, being placed one on either side of their spinous processes. Aside from the incomplete fixation secured, the destructive action of metal when brought in contact with bone would serve to condemn this procedure.

(B) GRADUAL CORRECTION

1. **The Bradford-Whitman Frame.**—This has already been mentioned as a valuable preliminary maneuver prior to bone-graft fixation (see page 122).

2. **Calot's Plaster Jacket.**—After an ordinary plaster jacket has been applied, a small window is cut out posteriorly over the deformity and a large window in front. Several pieces of wadding are cut, each slightly larger in size than the posterior window, and about 1 cm. thick. They are introduced through the window between the jacket and over the deformity. Eight or ten layers of wadding are sufficient for the first compression. These compresses bulge out through the window and further compression may be obtained by replacing the cut-out piece of plaster over them and forcing it inward by a few turns of plaster bandage or adhesive straps. As the kyphosis diminishes more compression pads are added until 15 to 18 are introduced at the third or fourth insertion.

Other less used methods are:

3. *Goldthwait's horizontal traction and leverage.*

4. The Extension Couch and *Weight Traction.*

TREATMENT OF COMPLICATIONS

The two chief complications of Pott's disease are *ichor-pocket formation* (cold abscess) and *paralysis.*

(1) ICHOR POCKETS

That which has already been stated regarding tuberculous abscesses in general (see Chapter I, Tuberculous Disease of Bones and Joints) may here be profitably repeated.

The word "abscess" is a misnomer when applied to the primary circumscribed collection of tuberculous detritus formed from the disintegration of bone and soft tissue, plus granulation exudate. The term *ichor pocket* is more suitable, accurate and graphic. When secondary infection of this ichorous material has occurred, then the word abscess (a circumscribed collection of pus) is eminently appropriate.

Treatment may be grouped in two classes: (*a*) conservative and (*b*) operative.

(*a*) **Conservative Treatment.**—As a general rule an ichor pocket (cold abscess) *should be let alone.* The sterile, semi-fluid detritus is innocuous and as a rule causes no discomfort and disappears when its origin, the bone or joint lesion has been cured.

(*b*) **Operative Treatment.**—This consists of aspiration or incision. Indications for such operative interference are: (1) *Mechanical interference with function* (viz.: a psoas ichor pocket interfering with the application of a brace or splint or the extension of a limb). (2) Evidence of *pressure necrosis* and thinning of its wall, with danger of sinus formation. (3) *Discomfort from tension.* (4) Evidence of *secondary infection* (the cardinal signs of inflammation).

I. *Aspiration.*—If interference with an ichor pocket (cold abscess) is essential, aspiration is far preferable to incision. A *thick portion* of the wall should be selected and the needle introduced *gently* and *obliquely.* No disturbance of the granulations lining the wall of the ichor pocket should be occasioned, because we are dealing with a large cavity which may fill with blood-clot (a more favorable culture medium for bacteria than the innocuous tubercular ichor). The *recumbent treatment* should precede aspiration, to allow the ichorous material to return to its point of origin.

II. *Incision.*—The only occasion for incision is the necessity for removing fibrous clots not removable by aspiration. Remember that if infection occurs after incision, which may happen despite the utmost care in technic of operation and subsequent dressings, it spreads into the extensive recesses and ramifications produced by the tracking of the hitherto sterile tuberculous ichor and deep infection, profound toxemia, amyloidosis and death may ensue.

General Rules for Aspiration and Incision.—1. Recumbency and gravitation prior to operation.

2. Rigid *asepsis.*

3. In evacuating a large ichor pocket pointing in two *locations* (viz., loin and hip in Pott's disease), to avoid disintegration of the line of suture from force of gravitation, it is preferable to aspirate or incise the one on a *higher plane* (with the patient standing) rather than the dependent one.

4. Select the *thicker portion* of the *wall.*

5. *Avoid injuring* the *granulations* lining the cavity, as this minimizes the danger of a postoperative hematoma. Hence, *express* the *contents gently.*

6. The incision should be long enough to allow fibrous clots to be expressed.

7. *No instrument* should be introduced into the ichor cavity.

8. *Suture* the incision carefully in *layers,* using *absorbable material.*

9. Dressings should be large and should exert firm, even *compression* to prevent the ichor pocket from *refilling* with exudate or blood clot.

10. *Recumbent position* for *two weeks* or more *after operation* to prevent breaking-down of the wound from gravitation.

11. *Heliotherapy* after operation.

Special Spinal Ichor Pockets (Abscesses).—Vertebral ichor pockets pointing in localities requiring special treatment are:

1. Retropharyngeal or prevertebral cervical ichor pocket.
2. Supraclavicular ichor pocket.
3. Prevertebral thoracic ichor pocket.
   (*a*) Rib resection.
   (*b*) Costotransversectomy.
4. Lumbar ichor pocket.
   (*a*) Subcostal ichor pocket.
   (*b*) Ichor pocket in Petit's triangle.
5. Iliac ichor pocket.

1. *Retropharyngeal* or *Prevertebral Cervical Ichor Pocket* (Cold Abscess).—Incision should never be made through the mouth; the danger of secondary infection is too great.

The incision follows the upper third of the posterior border of the sterno-mastoid muscle. Avoid the spinal accessory nerve emerging from the posterior border of the muscle. Retract the muscle forward, securing freer exposure if necessary by partially severing it near the mastoid. The splenius and levator anguli scapulæ are now exposed. The ichor pocket lies in front of the transverse processes; access to it is obtained by the finger passed inward along their anterior surfaces, displacing forward the jugular vein which lies in front of the abscess.

If the ichor pocket extends across the neck to the opposite side, a second opening should be made behind the opposite sternomastoid.

These cases should be watched carefully, as edema of the glottis occasionally occurs.

If dyspnea and dysphagia are urgent symptoms an incision may be made through the mouth. The head is allowed to hang well over the edge of the table (to avoid inspiration of pus) and the jaws held apart with a mouth-gag. After opening the ichor pocket the patient is quickly turned upon his face and kept in this position until the ichor pocket has been completely evacuated. It is advisable to freely use an antiseptic mouth wash after this procedure.

2. *Supraclavicular Ichor Pocket* (Cold Abscess).—In disease of the middle cervical vertebræ, tuberculous ichor passes between the trapezius and sternomastoid muscles, and points in the posterior triangle of the neck, above the clavicle. Incision should correspond with the lower two-thirds of the posterior border of the sternomastoid muscle, care being taken to avoid the spinal accessory nerve. Retract the sternomastoid inward, until the outer edge of the scalenus anticus is in view. Enlarge the interval between the scalenus and longus colli muscles with fingers, forceps or scissors to evacuate the ichor pocket.

3. *Prevertebral Thoracic Ichor Pocket* (Cold Abscess).—A collection of tuberculous ichor in this locality, between the mediastinal pleura and the vertebral bodies, usually presents no objective signs, or subjective symptoms. Occasionally pressure symptoms on esophagus, trachea, left recurrent laryngeal nerve or spinal cord demand operative intervention. Relief is obtained by one of two procedures, rib resection or costotransverse excision.

(*a*) *Rib Resection.*—With the patient in a semiprone position, healthy side downward, make an incision parallel with the spinous processes of the affected vertebræ, about 1½ inches from the middle line, exposing the articulation of rib and transverse process. Divide and elevate the periosteum over the posterior surfaces of 1 or 2 ribs, and divide and remove 1 or 2 inches of the latter. Incise the anterior costal periosteum, pass the finger inward and forward along the anterior surface of the transverse processes and in front of the vertebral body and open the ichor pocket. The disadvantages of the

operation are the inaccessibility of the lesion, the imperfect drainage obtainable, and the danger of injuring the pleura.

(*b*) *Costotransversectomy* (Costotransverse Excision).—A straight vertical incision is made close to the spine and the soft tissues separated outward as far as the tubercle of the rib. First resect the transverse process of the affected vertebra, then the head and neck of the rib. Introduce the finger, strip the pleura from the side of the vertebra and penetrate the ichor pocket. Instead of the vertical incision, Kocher begins at the most prominent spine and follows the rib to be resected downward and outward.

4. *Lumbar Ichor Pocket* (Cold Abscess).—Ichor pockets from tuberculous lumbar vertebræ appear in the loin and point in one of two common localities, (*a*) between the erector spinæ muscles and the last rib or (*b*) above the iliac crest, in Petit's triangle.

(*a*) *Subcostal Ichor Pocket* (Cold Abscess).—For an ichor pocket in this locality, make the incision along the lower border of the last rib, from the outer edge of the erector spinæ. Divide the latissimus dorsi and serratus posticus inferior, and (at a deeper level) the outer fibers of the quadratus lumborum and the middle layer of the lumbar fascia. After evacuation, close the wound at once.

(*b*) *Ichor Pocket* (Cold Abscess) *in Petit's Triangle.*—Extending into the sheath of the quadratus lumborum the ichor pierces the lumbar fascia and points above the iliac crest. Make an oblique incision passing downward and outward, exposing Petit's triangle. The ichor pocket usually lies in front and to the outer side of the transverse processes of the fourth and fifth lumbar vertebræ.

5. *Iliac Ichor Pocket* (Cold Abscess).—Make the incision parallel with and about 1 inch above Poupart's ligament and of a length commensurate with the size of the ichor pocket. Split the fibers of the external oblique, internal oblique and transversalis. Dissect close to the anterior superior iliac spine, exposing the transversalis fascia close to its junction with the iliac fascia but exposing the ichor pocket behind the latter. If the pocket is prolonged downward into the thigh it may be necessary to make a second incision just below the anterior superior iliac spine and along the outer border of the sartorius which is retracted and the pocket entered through the fascia over the iliopsoas internal to the tendon of the rectus femoris. The point of election, however, should be the less dependent location near the anterior superior iliac spine. All incisions should be carefully closed.

(*c*) Paralysis

Paralysis as in the case of the ichor pocket (cold abscess) is merely a symptom and not an independent affection; its primary treatment, therefore, is the treatment of the condition producing it. Absolute fixation of the spine in its affected segment being the desideratum, the method most effectually securing this is selected, and the author's bone-graft fixation operation is the procedure of choice.

(*a*) **Bone-graft Fixation** (Albee).—The operative technic has already been fully described in this chapter.

It is desirable, in cases of remediable deformity, that preliminary treatment by hyperextension on the Bradford-Whitman frame be instituted prior to operation.

Trophic disturbance in the shape of bed sores must be guarded against by scrupulous care of the skin.

Deformities arising from muscular contractures are to be treated by weight extension.

Saturated solution of potassium iodide, in properly graduated dosage, appears to have a salutary effect in some cases in aiding in the resolution of tuberculous granulation tissue.

In cases treated by bone-graft fixation before permanent structural alterations in the spinal cord have become profound, the percentage of recovery from the paralysis is high.

Other operative procedures aiming at the relief of paralysis are laminectomy and costotransverse excision. Neither operation is in any way comparable in its results to bone-graft fixation of the affected segment of the spine in non-traumatic cases.

(*b*) **Laminectomy.**—Removal of portions of the laminæ has been practised for many years, but has given very unsatisfactory results in the treatment of paralysis from tuberculosis of the spine. The mortality following its use is large, and as the posterior part of the spinal cord is exposed rather than the site of the disease, it partially fails of its object, and removal of the laminæ further impairs the already weakened osseous structure of the spine unless hemilaminectomy is done and a bone-graft is inserted into the spinous processes. (See Chapter XII, Section on Fracture of the Spine.) Weakening of the spinal column by the usual laminectomy may contribute to a relapse of the tuberculous osteitis.

(*c*) **Costotransversectomy (Costotransverse Excision).**—This operation (the technic of which was given in the paragraph devoted to the treatment of prevertebral thoracic abscess, see page 135) has been performed for the relief of paralysis due to the pressure of a prevertebral ichor pocket, and may in some cases be justified, but it is believed that the cases of recovery from paralysis attributed to this operation would have enjoyed equal relief and a more reliable convalescence from bone-graft implantation, without the removal of rib and transverse processes.

(*d*) Removal of tuberculous sequestrum when causing paralysis by pressure on the cord.

REFERENCES

PATHOLOGY

Mattinesco, G., and Mivea, J.: "Changements morphologiques des cellules aux ganglions spinaux dans le mal de Pott." Compt. Rend. Soc. de Biol., Paris, 1908, lxiv, 512.

Angel, A. M.: "Forma miliar defusa de la tuberculosis de las vertebras." Rev. Ibero. Am. de Cien. Med., Madrid, 1909, xxii, 1–16.

Deloux and Chalier: "Trouble nerveux du mal de Pott, anatomie pathologique et pathogénie." Clinique, Paris, 1909, iv, 649–697.

Alquier, L. and Klarfield, B.: "Sur la lésion osseuse du mal de Pott." N. iconog. de la Salpétrière, Paris, 1910, xxiii, 310–312.

Brackett, E. G. "Study of the Relations between Clinical Evidences and Pathological Conditions in Spinal Caries." Amer. Jour. Orth. Surg., 1910–11, viii, 362–380.

Ardin, Deltart, Reynaud, and Pelissier: "Mal de Pott latent granulé." Bull. méd. de l'Algérie, Algiers, 1912, xxiii, 520–524.

Elsberg, C. A.: "Some Features on the Gross Anatomy of the Spinal Cord and Nerve Roots, and their Bearing on the Symptomatology and Surgical Treatment of Spinal Disease." Amer. Jour. Med. Sc., 1912, cxliv, 799–803.

SYMPTOMS AND PHYSICAL SIGNS

Gauthier, L.: "La Mort subite dans le mal sous-occipital et leimal de Pott." Méd. inf., Paris, 1906–07, iv, 505–509.

Chalier, A.: "La Scoliose d'origine tuberculose." Lyon med., 1907, cix, 777–782.

Virchow, H.: "Eine nach Forme zusammengesetze kyphothetische Wirbelsäule." Berlin klin. Woch., 1907, xliv, 1235–1278.

Bastianelli, R.: "La Cura della spondiliti tubercolare." Arch. di ortop., Milan, 1907, xxiv, 448–461.

Logan, G. K.: "Pott's Disease." New Orleans M. & S. J., lx, 995–1003.
Armour, D.: "Spinal Caries." Hospital, London, 1907–08, xliii, 389.
Buzzard, E. F.: "Disease of the Cervical Vertebræ with Pressure Symptoms." Proc. Roy. Soc. Med., London, 1907–08, i, Neur. Sect., 12–14.
Gauthier, K.: "La Mort subite dans le mal sous-occipital et le mal de Pott." Jour. de méd. de Paris, 1907, 2e sér. xix, 471–473.
Rieger (K. G. A. G.): "Beiträge zur Therapie der Compressionsmyelitis infolge von Spondylitis tuberculosa." Leipzig, 1908.
Touchot, F. H.: "Laminectomie dans le traitement des paralyses pottiques rebelles." Nancy, 1908.
Alquier, L., and Renard, L.: "Mal de Pott cervico-dorsal, paralysie flasque aux membres supérieures sans spasmodicité nette aux inferieurs; myelite incomplète." Rev. de neurol, Paris, 1908, xvi, 717–719.
Jouon, E.: "Mal de Pott cervical avec monoplégie brachiale." Gaz. méd. de Nantes, 1908, 2e sér. xxvi, 834–836.
Tissot, F.: "Mort subite dans un cas de mal de Pott silencieu." Progrés méd., Paris, 1908, 3e sér. xxiv, 309.
Guyot.: "Mal de Pott dorso-lombaire." Jour. de méd. de Bordeaux, 1908, xxxviii, 697.
Allen, H. P.: "Pott's Disease." Cent. States M. Monit., Indianapolis, 1908, xi, 448–453.
Johnston, R.: "Tuberculous Disease of the Spine." Clin. Jour., London, 1908–09, xxxiii, 64.
Dervaux: "Mal de Pott et accidents du travail." Méd. des accid. du travail, Paris, 1908, v, 8–13.
Boveri, P.: "Appunti semeiologci e clinici sul morbo de Pott." Corriere san., Milano, 1908, xix, 2.
Sarfels, C.: "Über Spondylitis tuberculosa." St. Pétersb. méd. brochure, 1908, xxxiii, 85.
Starr, C. L.: "Tuberculous Disease of the Spinal Column." Am. Pract. Surg. (Bryant & Black), New York, 1908, iv, 927–983.
Bencke: "Über primäre Tuberkulose der Zwischenwirbelscheiben." Münch. méd. Wochenschr., 1908, lv, 1105.
Foulatier: "Sur un cas de mal de Pott avec paraplégie." Nord. méd., Lille, 1908, xv, 195.
Tridon, P.: "Mal de Pott et doigts hippocratiques." Rev. d'orthop., Paris, 1908, 2e sér. ix, 347–356.
Calôt: "Le Mal de Pott." Rev. gén. de clin. de thérap., Paris, 1908, xxii, 425.
Wassiliew, M. A.: "Operative Behandlung der Paraplegien bei tuberkulöser Spondylitis." Arch. f. klin. Chir., Berlin, 1909, xxviii, 845–860.
Sable, J., and Foulatier, A.: "À propos de deux cas de paraplégie pottique, etc." Jour. des sc. méd. de Lille, 1909, i, 169–193.
Wallis, F. C.: "Chronic Tuberculous Abscess of the Spine." Clin. Journal, London, 1909–10, xxxv, 337–339.
Ferré: "Àpropos d'un cas de spondylolisthesis." Prov. méd. Paris, 1909, xx, 486–489.
Pic, A., and Bonnamour, S.: "Hépatite tuberculeuse subaiguë consécutive à un mal de Pott lumbaire antérieur latent." Lyon méd., 1909, cxii, 24–28.
Saxe, A.: "Spondylitis und Hernia Lumbalis." Wien. klin. Wochenschr., 1909, xxii, 18–21.
Von der Ostensarken, E.: "Über die Deformierungen des Unterkeifers durch Stietz-apparate bei Spondylitis." Zeitschr. f. Orth. Chir., 1909, xxiii, 353–367.
Gayet: "Spondylose chronique." Lyon chirurg., 1909, ii, 121–123.
Gallie, W. E.: "Caries of the Spine." Canad. J. M. and S., Toronto, 1909, xxv, 344–349.
Nyrop, E.: "Om Behandlung af spondylites tuberculosa." Ugesk. f. Laeger, Kjbenh., 1909, lxxi, 247–254.
Wholey, C. C.: "Pain and Pott's Disease, with Special Reference to Backache." Jour. A. M. A., Chicago, 1909, liii, 1914–1916.
Guseff, P. F.: "Laminectomy with Treatment of Tubercular Spondylitis." Khirurgia, Mosk, 1909, xxviii, 19–30.
Atherton, H. B.: "The Treatment of Spinal Abscess, with a Report of Some Cases of the Disease." Maritime M. News, Halifax, 1910, xxii, 76–82.
Casper, M.: "Pott's Disease in Infant Two Weeks Old." Kentucky M. J., Bowling Green, 1910, viii, 1784.
Traversier and Ternier: "Mal de Pott cervico-dorsal." Dauphiné méd. Grenoble, 1910, xxxiv, 101–114.
Latreille, E.: "Mal de Pott sans signes rachidiens." Union méd. de Canada, Montreal, 1910, xxxix, 273–275.
Edmunds, A.: "Tuberculosis of the Spine." Med. Press and Circular, London, N. S. xc, 218.
Broca: "La Gibbosité du mal de Pott." Pédiatrie prat., Lille, 1910, viii, 68–71.
Klarfield, B.: "Sur la méningite tuberculeuse spinale au cours du mal de Pott." Rev. neurol., Paris, 1910, xviii, 336.

Moon, R. S.: "Pott's Disease." Am. J. Obst., New York, 1910, lxii, 561–565.
Poncet, A.: "Tuberculose inflammatoire et scoliose; scoliose d'origine tuberculeuse." Bull. de l'Acad. de Méd., Paris, 1910, lxiv, 150.
Armour, D.: "Paraplegia in Connection with Pott's Disease." Hospital, London, i, 131.
Weil, A., and Roiderer, C.: "La Fréquence des abcés dans la maux de Pott dorsaux." Paris méd., 1911–12, ii, 467–470.
Balamie: "Un Nouveau dispositif de compression dans le traitement des gibbosités pottiques." Rev. gén. de chir. et de thérap., Paris, 1910, xxiv, 775.
Ascenze, E.: "Compression médullaire par le mal de Pott; étude clinique et anatomie pathologique." Encéphale, Paris, 1910, ii, 330–360.
Schlüseler, K.: "Ein Beitrag zur operativen Behandlung der Paraplegie bei tuberculosen Spondylitis." Archiv f. klin. Chir., Berlin, 1910, xvii, 555–557.
Young, J. K.: "Sacral Laminectomy for Tubercular Monoplegia." Am. Surg., 1911, liii, 116.
Cadwalader, J. K.: "The Sudden Onset of Paralysis in Pott's Disease without Deformity of the Vertebræ." Amer. Jour. Med. Sc., Philadelphia and New York, 1911, clxi, 540–558.
Gauvain, H. J.: "Muscular Spasm in Caries of the Spine." Lancet, 1911, i, 830.
Harris, W.: "Spondylitis in Progressive Muscular Contraction." Proc. Roy. Soc. Med., 1911, iv, 42–45.
Moore, G. C.: "Clinical Notes on Pott's Disease." Boston M. and S. Jour., 1911, clxv, 54.
Stuia, I. D.: "Tuberculosis of Spine." Internat. J. Surg., New York, 1911, xxiv, 202–208.
Steinar: "Mal de Pott." Clinique, Brux., 1911, xxv, 195–197.
Roederer, C., and Weil, A.: "La Fréquence des abcés dans les maux de Pott." Bull. Soc. de Péliat. de Paris, 1913, xv, 152–150."

DIAGNOSIS OF POTT'S DISEASE

Batier: "Pseudo mal de Pott lombaire hysterique." Echo méd. du nord., Lille, 1908, xii, 333–335.
Rauenbusch, Z.: "Die Spondylitis tuberculosa in Röntgenbilde." Hamburg, 1908 (Graefe and Sillenn).
Wallace, C.: "Early Diagnosis and Corrective Treatment of Pott's Disease; Analysis of 643 Cases." Pediatrics, New York, 1908, xx, 273–283.
Cotti, G.: "Scoliose et Tuberculose." Lyon méd., 1908, cx, ii, 67.
Hatel, E. S.: "The Diagnosis and Treatment of Pott's Disease." New Orl. M. and S. Jour., 1909–10, lxii, 576–580.
Neff, F. C.: "The Early Recognition of Pott's Disease in Children." Kansas City M. Index Lancet, 1909, xxxii, 40–44.
Parsons, W. B.: "Spinal Caries and Hip Disease; a Point in Differential Diagnosis." B. M. J., 1910, ii, 1126.
Dalchef, J.: "Le Diagnostic différential entre la scoliose et le mal de Pott en détail." Scalpel, Liége, 1910–11, lxiii, 331–337.
Ewart, W.: "Percussion of the Vertebra." B. M. J., 119 ed. ii, 1057.
Chlumsky, V.: "Betrachtungen über die differential Diagnose zwischen Scoliose und Spondylitis." Zeitsch. f. Orth. Chir., Stuttgart, 1910, xxvii, 87–100.
Matthews, J. G.: "Pott's Disease, Its Symptoms and Diagnosis." Hosp. Bull., Univ. Maryland, Baltimore, 1910, vi, 123–126.
Forbes, A. M.: "Enlarged Lymph Glands as a Symptom of Pott's Disease." Montreal M. J., 1910, xxxix, 343–348.
Roth, P. B.: "Muscular Spasm in Caries of the Spine." Lancet, 1911, i, 903.
Steinhardt, I. D.: "Tuberculosis of Spine, Diagnosis and Differential Diagnosis." Arch. Diagn., New York, 1911, iv, 276–280.

TREATMENT OF POTT'S DISEASE

Galeazzi, R.: "Trattamento mechanico della spondylite tubercolare." Arch. di ortop., Milano, 1907, xxiv, 430–448.
Openshaw, T. H.: "An Apparatus for Obtaining Extension of the Spine in the Treatment of Scoliosis and Caries." Proc. Roy. Soc., London, 1907–8, i, Clin. Sect., 190.
Berry, J. M.: "The Treatment of Lumbar Pott's Disease, Complicated by Psoas Contraction." New York State M. J., New York, 1907, vii, 440–448.
Epstein: "An Easily Constructed Sling for the Application of the Plaster Jacket." Am. Jour. Surg., New York, 1908, xxii, 311.

VOGEL, K.: "Zur Technik des Gypsverbandes." Zentralbl. f. m. Chir., 1908, xxxv, 1242–1244.
ALLISON, H.: "Apparatus for the Application of Plaster-of-Paris Bandages." Am. Jour. Orth. Surg., Philadelphia, 1908–09, vi, 699–701.
FORBES, A. M.: "The Treatment of Pott's Disease of the Lumbar Vertebræ." Montreal M. J., 1908, xxxvii, 877–879.
SCHULTHESIS: "I Tipi dell' affezione tubercolare della colonna vertebrale." Arch. di. ortop., Milano, 1908, xxv, 1–16.
VIGNARD: "De l'immobilisation en traction des maux de Pott." Bull. Soc. de Chir. de Lyon, 1908, xi, 34; Lyon méd., 1908, cx, 555–557.
LOVETT, R. W.: "La Cura della tubercolosi della spina coll' analisi di 1792 casi." Arch. di. ortop., Milano, 1908, xxv, 16–34.
WIENER, A. C.: "Zur Behandlung der Spondylitis." Zentralbl. f. Chir., Leipzig, 1908, xxxv, 252–254.
VIGNARD: "Immobilisation du mal de Pott par le corset." Rev. de chir., Paris, 1908, xxxvii, 721.
VIGNARD ET MONOT: "Corset plâtré avec traction céphalique pour le mal de Pott." Lyon méd., 1908, cx, 778.
CLARK, J. J.: "Some Practical Points in the Treatment of Tuberculosis of the Spine." B. M. J., 1908, ii, 914–916.
DAVIS: "A Sling for Head Extension." Am. Jour. Orth. Surg., 1909–10, vii, 234.
PANTON, K. D: "An Approved Method of Applying the Plaster Jacket." Jour. Am. Med. Assn., 1909, liii, 2155.
FRIEBERG, A. H: "A Suggestion for the Improvement of Plaster of Paris Technique." Am. Jour. Orth. Surg., Philadelphia, 1909–10, vii, 227–229.
CALOT: "Le Traitement du mal de Pott." Méd. inf. Paris, 1909, vi, 198–204; "Traitement du mal de Pott." Gaz. méd. de Paris, 1909, No. 44–8.
FRAZER: "An Inexpensive Suspensory Apparatus for Pott's Disease." Jour. Am. Med. Assn., Chicago, liii, 1637.
ELY, L. W.: "The Treatment of Pott's Disease at the Sea Breeze Hospital." Med. Rec., New York, 1909, lxv, 1096–1099.
LOVETT, R. W.: "The Modern Treatment of Tuberculosis of the Spine." Cleveland M. J., 1909, viii, 76–88.
CALOT: "Le Traitement du mal de Pott." J. de méd. de Paris, 1909, 2e sér. xxi, 273.
SELBY, C. D.: "Treatment of Pott's Disease." Toledo M. and S. Reporter, 1909, xxxv, 308–311.
GALLIE, W. E.: "The Treatment of High Dorsal Pott's Disease." New York Med. Jour., 1909, xc, 14.
STERN, W. G.: "Non-Inflammable Splints and Braces." Surg. Gyn. and Obst., 1910, xii, 77.
RICH, E. A.: "Newer Therapeutic Uses of Plaster of Paris." Med. Sentinel, Portland, Oreg., 1910, xviii, 404–9.
LANGE, B.: "Allmähliches Redressement des Pottischen Bückels." Strassburg med. Zeitung, 1910, vii, 10–14.
SABELLA, P.: "L'Intervento precoce nell' osteite tubercolare della colonna vertebrale." Policlin., Roma, 1910, xvii, sez. Chir., 250–259.
FRESS, O. H.: "The Advantages of Braces over Plaster Jackets in Pott's Disease." Amer. Jour. Orth. Surg., 1910–11, viii, 336–343.
WYETH, J. A.: "The Treatment of Caries of the Lumbar Spine by Continuous Extension." Jour. Am. Med. Assn., Chicago, 1910, liv, 1299.
WHITBECK, B. H.: "The Treatment of Pott's Disease." N. Y. State Jour. Med., New York, 1910, x, 404, 408.
LANGE, F.: "Die Behandlung der Spondylitis." Jahresb. f. ärztl. Fortbild., München, 1910, xxii, 432–437.
MASON, F. S.: "Treatment of Pott's Disease and Complications." Pediatrics, New York, 1910, xxii, 423–427.
BROM, L. T.: "A Portable Apparatus for Applying Jackets in Hyperéxtension." Am. Jour. Orth. Surg., 1910–11, viii, 404–426.
MONOD, G.: "De l'immobilisation des ostéoarthrites tuberculeuses (mal de Pott et ceralgia)." Paris méd., Paris, 1911, xix, 141–58.
ANDRIEU: "Traitement du mal de Pott cheles enfants." Gaz. des hôp., Paris, 1911, lxxxiv, 1351–1388.
MERGUET, H.: "Traitement du mal de Pott par la méthode de Lannelongue modifiée." Médicin prat., Paris, 1912, viii, 789–792.
FROELIEB.: "Considérations sur le mal de Pott." Rev. méd. de l'est, Nancy, 1912, xliv 721–736.
CALVÉ: "Traitement du mal de Pott." J. Méd. franc., Paris, 1912, vi, 516–527.

OPENSHAW, T. H., AND ROTH, P. B.: "The Treatment of Pott's Disease with an Analysis of 116 Cases." Lancet, London, 1912, ii, 1808.
GAUVAIN, H. J.: "The Use of Plaster of Paris in the Mechanical Treatment of Tuberculous Disease of the Spine." Pract., London, 1913, xc, 190–202.
GAUVAIN, H. J.: "The Use of Celluloid in the Treatment of Tuberculous Disease of the Spine." Brit. Med. Jour., June 7, 1913.
LELIÈVRE, H.: "Le Traitement orthopédique du mal de Pott." Paris, 1912.
ADAM, S. D.: "The Mechanical Treatment of Spinal Caries." St. Mary's Hosp. Gaz., London, 1913, xix, 42–44.
FROLIEB: "Considération sur le mal de Pott." Ann. de méd. et chir. inf., Paris, 1913, xvii, 47–49.
PARRY, L. A.: "The Treatment of Spinal Caries in Children." Antiseptic, Madras, 1913, x, 5–7.

Abolition of Deformity by Correction

HAYS: "Enquête sur le traitement actuel de la gibbosité du mal de Pott." Anjou méd., Angers, 1908, xv, 62–71.
REDARD, P.: "Della correzoine della gibbosità Pottica." Arch. di. ortop., Milano, 1908, xxv, 34–38.
GANGELE, K.: "Das Redressement altes Pottisches Bückels." Zeitsch. f. orth. Chir., 1908, xix, 437–444.
KOFMANN, S.: "Die Erfahrungen über die Behandlung spondylitisches Bückels nach Calôt." Zeitschr. f. orthop. Chir., 1908, xx, 433–439.
WOLLENBERG, G. A.: "Über die Resultate des Redressements des Pottischen Bückels." Berlin, klin. Wochenschr., 1909, xlvi, 2055–57.
LANGE, B.: "Allmächliches Redressement des Pottischen Bückels." Zeitschr. f. Orth. Chir., Stuttgart, 1910, xxv, 292–302.

Operative Treatment

ALBEE, F. H.: "Transplantation of a Portion of Tibia into the Spine for Pott's Disease." Jour. Am. Med. Assn., August, 1911, lvii, 885.
ALBEE, F. H.: "A Further Report of an Original Treatment for Tuberculosis. Arthritis Deformans, Old Fractures, etc." Post-Graduate, New York, 1912, xxvii, 1017–1021.
ALBEE, F. H.: "Bone Transplantation as a Treatment of Pott's Disease, etc." Post-Graduate, New York, 1912, xxvii, 999–1017.
ALBEE, F. H.: "Knochentransplantation bei tuberkulöser Spondylitis." Zeitschr. f. orth. Chir., Stuttgart, 1913, xxxi, 400–479.
KIRK, T. S.: "The Operative Treatment of Spinal Caries." Med. Press and Circ., London, 1908, lxxxvi, 603–605.
NEWMAN, W.: "Zur operativen Behandlung der Spondylitis tuberculosa." Beitr. zu klin. Chir., Tübingen, 1909, lxv, 446–461.
FIORAVANTI: "L'Intervento chirurgico nella cura dell' osteite tubercolare dei corpi vertebrali." Morgagni, Milano, 1909, li, 209–273.
WHITMAN: "Operative Treatment of Pott's Disease." Am. Surg., Philadelphia, 1911, liv, 841–847.
SACHS, B.: "Spondylitis and some other forms of Vertebral Disease, with Special Reference to Diagnosis and Operative Treatment." Jour. Nerv. and Ment. Dis., New York, and Lancaster, 1911, xxxviii, 488–491.
ALLISON: "Review of Literature on Ankylosing Operations in Pott's Disease." Interstate Med. Jour., St. Louis, 1912, xix, 450.
HIBBS: "Further Considerations of Operation." Am. Surg., Philadelphia, 1912, lv, 682–688.
BADRIS: "A New Operation for the Treatment of Pott's Disease." Médicin prat., Paris, 1912, viii, 229.
RUGH, J. T.: "The Treatment of Spondylitis (Pott's Disease) by Bone Grafting: Albee's Operation." Month. Cycl. and M. Bull., Philadelphia, 1913, vi, 78–82.
GALLANI, A. E.: "Hibb's Operation for Pott's Disease." Med. Rec., New York, 1913, lxxxiii, 684.

CHAPTER III

FUNDAMENTAL PRINCIPLES UNDERLYING THE USE OF THE BONE-GRAFT IN SURGERY

Cellular life may be quite independent of organic or somatic life and, under favorable conditions, tissue cells may retain their viability long after being detached from the living organism. "The remarkable viability of transplanted periosteum has been demonstrated by Grohe and Morfurgos the former showing that it is capable of preservation for 100 hours and yet able to be implanted and exert its osteogenetic powers. The latter (Morfurgo) has shown that the periosteum of a corpse kept at 15° can produce new bone when implanted after 168 hours"—Janeway. The duration of this cellular life depends largely upon the means of preservation of the detached parts or, in the case of organic death, of the whole cadaver, and also upon the amount of disintegration from the cause of death. It is on account of this phenomenon that detached portions of living tissues can be successfully transplanted from a corpse to a living organism. The higher the specialization of the cell, the less marked are its resisting and proliferating powers. This is especially well illustrated in the case of tissue grafts. The lower order of tissues, which need less nutrition, continue to live for days on their own substance which is contained in the serum that permeates them, but the more highly specialized tissues are liable to necrosis in a short time unless nourished by a blood circulation. This viability varies with the individual tissue, since the higher the development of the cell—such as the ganglion or parenchymatous cells—and the richer the tissue in blood-vessels, the less likely it is to survive.

The most favorable tissues for grafting purposes are the simpler connective tissues, such as bone, fat, fascia, etc., which are endowed with the capacity of extracting nutrition from the soil into which they are planted and at the same time are able to regenerate so that the portion of the graft that disintegrates is replaced. Muscles and nerves are most unfavorable.

Bone has been successfully transplanted since 1809, when Merrem obtained successful healing of bone plates in the skulls of animals after trephining. Subsequently, Walther, in applying this technic to the human subject, secured partial healing of the graft, in spite of the coincident suppuration. In 1858, Ollier, after extensive investigations of the use of the bone-graft in both animals and man, concluded that fresh bony tissue covered with periosteum remains viable. Autogenous grafts, or those derived from the same individual into which they are engrafted, are by far the most trustworthy. The fluids, albumins, and tissues of every individual vary in degree from those of every other, and while this incompatibility may be slight it is sufficient cause for using, whenever feasible, the individual's own tissue for the repair of his defects.

With primary union and the absence of infection, autogenous bone-grafts, properly contacted, are always successful, and even infection does not necessarily indicate failure. "The vegetative capacity of the bone-cell is as great as that of the epithelial cell, and if one grants not only the viability of the transplanted epithelium but also its power of extensive proliferation,

then, judging by analogy, the bone-cell ought to show, as it has shown in this instance, equal capability of living and growing when transplanted. In proportion to the size of the graft, the smaller the graft the greater the proliferation" (Macewen).

Fortunately, the knowledge of the exact histological rôle which the bone-graft plays is immaterial to its clinical usefulness—whether it serves as an osteoconductive scaffold or as an active osteogenetic force. The extensive experiments and histological studies of Ollier, Macewen, Frangenheim, Cotton, and Loder, MacWilliams, Mayer, Phemister, and the author have proved the viability and osteogenesis of the grafts when inserted by the proper technic.

Cotton states: "Our specimens show a practically uniform survival of the transplant when the technic is adequate. The articular transplant of the cartilage usually shows no gross change in color or texture from that of the surrounding undisturbed joint surface. *The fragment very rapidly becomes firmly fixed in place.* Histological preparations obtained at varying intervals show a series of changes in the bony portions of the graft, the more important of which are constant and very definite. The essential picture shown is, briefly: (1) the early disappearance of the bone corpuscles in the transplanted trabeculæ and in the trabeculæ of the host bone for a short distance from the wound surface; (2) without any loss of substance in (or any marked foreign-body reaction around) the bone from which the corpuscles have disappeared, this bone was rapidly and completely covered by a layer of new endosteal bone, which unites with the endosteal bone of the host; (3) the new bone is laid down by the activity of endosteoblasts in all portions of the grafts, center as well as periphery. It has not yet been proved that some of the endosteoblasts which are active in the graft may not have originated from the endosteum of the host and extended, or even emigrated, from it to the graft; but no one after study of our sections can doubt that in part, at least, these osteoblasts represent the actively proliferating covering membrane of the transplanted trabeculæ; (4) practically no changes, either of degeneration or proliferation, in transplanted articular cartilage, at least up to four weeks."

MacWilliams concludes in a recent publication: "Living bone-grafts have life inherent in themselves, and the theory that contact with living bone is necessary for subsequent life of the graft must be given up."

"As important as the properties of the transplant are the qualities of the 'wound soil' which serves the function of supplying as quickly as possible nutrition to the graft. The first step in the establishment of the lymph flow and the circulation is the early adhesion between wound edges and the transplant. The more quickly and surely this takes place, the more promptly is nourishment assured. Should the cells of the wound be injured because of antiseptic applications or should they be abnormal because of the presence of scars or hematoma, or the seat of previous disease, as tuberculosis, necessary nutrition will be delayed. Very important contributing factors to failure are errors in operative technic, causing infection with a very slight transudate which is instrumental in destroying the first intimate contact, thus partially or absolutely preventing nutrition and predisposing to partial or total necrosis due to suppuration. By means of strict asepsis, this element of failure can be eradicated. Most important, however, is a second factor, which prevents the early intimate adhesion of the wound edge, namely, imperfect hemostasis. The presence of the slightest amount of blood is dangerous, as it interferes with the nutrition. That this factor has heretofore been disregarded is apparent from the literature. It is the general belief that a smooth uninfected wound is a sign of perfect technic. This is

not true in connection with transplantation. In this instance, perfect technic is recognized by a complete gumming and coaptation of the wound edges. For this reason, every experimenter in recording the results of his transplantations should convince himself that the transplant is really grafted as it should be, in order that his operation be perfect" (Lexer).

Homoplastic grafts are those which are derived from another individual of the same species, and when composed of the lower order of tissues, such as bone or fascia, they may be employed successfully, though not with the same certainty as autogenous grafts. When they consist of the more highly specialized tissues, they result in failure. Homoplastic grafts are often difficult to obtain, and there always exists the danger of transmitting disease from the donor to the host even when the greatest care has been exercised. Fibrous encapsulation occurs more frequently in homoplasty than in autoplasty. This, as Lexer has pointed out, is probably due to the irritation of a foreign proteid which varies most with difference in race, next with distant relatives, near relatives, and least with the individuals of one family. This variation prevents proper nourishment of many tissues and, as a result, substitution in the regenerative process occurs very slowly, while degeneration takes place rapidly.

Heteroplastic grafts are those which are obtained from an individual of another species. Living grafts from different species may die when implanted into man or animals of a higher grade. In such cases the graft acts as a foreign body, and if there is even mild infection it is liable to ulcerate out. In the event of no infection, it either becomes encapsulated or disappears, and is slowly substituted by the proliferation and migration of the tissues in which it is embedded. This process may require months in the case of the bone-graft, and thus it follows that the graft may be a success clinically although histologically it undergoes partial or even complete absorption; in other words, it acts as an osteoconductive scaffold.

The principal difficulty with homoplastic grafts is that the albumins of different individuals are not alike. Successful experiments are reported as being under way in Lexer's clinic, with the object of changing the blood by preliminary treatment. Kuttner has been partially successful in grafting tissue from the ape to man. The cellular mass necroses, as it may in homoplasty. Clinical success in the repair of large denuded bony cavities can be secured only by the use of living autogenous bone covered with periosteum.

In the author's experience with both human beings and animals, perfect union of the autogenous aseptic bone-graft with the bone into which it was placed has been secured in 100 per cent. of cases.

The subject of the bone-graft has been widely discussed, and the men who have been studying the problem were divided into two schools, those who claimed that a certain portion of the cells in the graft live and that the graft is a distinct and separate osteogenetic force; and those who claimed that the cells do not *per se* have any osteogenetic power and that the graft merely serves an osteoconductive-purpose.

The ultimate fate of the bone-graft has been practically determined in the past few years as a result of the mass of experimental work which has been performed, not only in this but also in other countries. The old theory concerning the osteoconductive nature of the graft has been abandoned in favor of the *osteogenetic theory*. The most favorable graft may act *entirely* in an osteogenetic capacity, although this is very difficult of proof by histological methods; less favorable grafts, and these constitute the great majority, vary within wide limits with respect to the ratio between their osteogenetic and their osteoconductive properties. That portion of a graft which acts in

an osteoconductive manner may receive its migrating cells either from the host-bone or from that portion of the graft itself in which the bone-cells retain their viability. The foregoing deductions are the result of the extensive experimental bone and joint work on dogs, sheep, and rabbits performed by the author in the years 1910, 1911, and 1912 (Ref. Albee; Jour. Am. Med. Assoc., April 5, 1914). Most of those, if not all, who clung to the osteoconductive hypothesis have been convinced that their theory must be abandoned in favor of the osteogenetic (Fig. 70).

One should not be too dogmatic concerning the exact rôle that every graft must play. Individual conditions or individual environment determine the exact rôle of each particular graft. There may be a considerable blood-clot or tissue shreds which interfere with the nourishment of the graft, preventing immediate and perfect union; or there may be a slight or severe infection or other disturbances to deal with, and these conditions determine the exact histology in each individual case or, in other words, how many of the graft cells have received sufficiently early nutrition and remain viable, and how much of the graft dies and serves in an osteoconductive rôle.

As far as the result goes in favorable cases, it does not matter how much of the bone-graft lives and remains or becomes osteogenetic and how much acts as an osteoconductive element. However, in more unfavorable cases, where periosteum and active bone-forming elements are lacking, it is most important that the graft should be osteogenetically active: in fact, success or failure may depend upon this very feature. It is known that an autogenous bone-graft always "takes" and becomes permanent if it is put in under aseptic conditions, and if it has a function to perform it stays there and adapts itself to the new environment in structure, size, and contour.

Years ago, boiled bone was used by Kausch and others as a substitute for the bone-graft. From a recent discussion of this matter, one would gather that this material had never been



FIG. 70.—Rontgenogram of two grafts, each 3 inches long, inserted by the author for a tibial defect from the removal of two-thirds of its shaft for sarcoma. It was necessary to amputate the leg just four weeks after the insertion of the grafts, on account of the recurrence of the sarcoma, and in this short time the grafts had become firmly united (at C) by solid bone, although the diameter of the grafts both above and below the union remained the same as when implanted. These proliferating callus bone-cells could have originated from no other source than the two graft ends, thus proving conclusively the active osteogenesis of these free grafts. The efficiency of the bone-graft could not be better demonstrated than by this specimen. *A*, indicates where firm union has occurred between the upper graft and the upper remaining end of the tibia; *B*, where the lower graft has become united to the lower fragment of the tibia; *C*, indicates firm bony union between the two graft ends which were contacted in the center of the leg far away from any other possible source of new bone.

used before. Boiled bone is far inferior to autogenous bone-graft, and in 1910 Kausch, from an extensive experience, prepared a table illustrating the scale of value of different materials for bone substitution, and made the following statement: "Boiled bone and bone from the cadaver are not adapted for implantation in a bed free from periosteum, and foreign substances are still less suitable for this purpose."

KAUSCH'S TABLE OF VALUE OF DIFFERENT MATERIALS FOR BONE TRANSPLANTATION

1. Pedunculated soft parts with periosteum-covered bone flap.
2. Free transplanted periosteum-covered autoplastic bone.
3. Free transplanted periosteum-covered homoplastic bone.
4. Fresh boiled bone.
5. Fresh preserved bone.
6. Cadaver or fetal bone, obtained under sterile conditions.
7. The same bone boiled.
8. Ivory.
9. Foreign bodies, such as metal.
10. Fresh animal bone, living or boiled.

Lexer states: "Boiled bone, obtained from a cadaver, or fresh bone which has been sterilized, acts as does a foreign body which slowly undergoes substitution; it is rapidly destroyed by vigorous granulations. Foreign-body suppuration with extrusion of the dead graft, long after primary union, occasionally occurs."

Barth (Verhandlung der Deutsch. Gesell. für Chir., xxxviii, 1909) makes this statement: "Personally, I have had nothing but failures. Absorption follows in these cases, or secondary suppuration if the patients are allowed to use their limbs, and the bone must be removed. I therefore believe that it would be going backward to make use of dead bone as a routine measure in osteoplastic work. Accordingly it can no longer be doubted that in the substitution of very large defects, only the living bone covered with periosteum furnishes trustworthy results."

Baum reported five cases of intramedullary graft for ununited fractures. Four were homoplasty grafts (taken from amputated limbs and fetal bones). The fifth graft was an autogenous graft and was the only one which resulted in solid union, thereby proving the value of live autogenous bone-grafts—and possibly the disadvantage of the intramedullary technic.

In this connection, Bier claims that most bone regeneration comes from the endosteum and bone-marrow, and that no regeneration occurs in a scraped (or reamed-out) medullary cavity. This undoubtedly explains in part, at least, failures from the intramedullary technic of inserting the graft in ununited fractures.

Implanted ivory is merely absorbed, without any substitution formation of new bone.

Autogenous live bone is the only material which can be inserted with safety in a bed free from periosteum.

Laewen made histological studies of bone-grafts that had been transplanted eleven weeks, and by injecting the blood-vessels of the amputated arm found that there had been complete vascularization of the transplant which had been obtained from the tibia of the same patient. The graft was being gradually absorbed and replaced by new bone that proliferated from the osteogenetic bone-cells in the periphery of the Haversian canals of the graft itself; also, the periosteum lived and was active in proliferating new bone from its deep osteogenetic layer. The new bone always took on the contour of the part which it replaced.

After extensive experimental investigations and a large amount of human work, the author is convinced that the best transplant is a live piece of autogenous bone including all its elements—namely, periosteum, compact bone, endosteum, and marrow substance; that the periosteum which is separated from attached muscles should be incised in numerous places to provoke a greater stimulation and also a freer blood supply—it lets out osteogenetic cells and lets in nourishment; that the bone is best taken from the same individual or, if this be impracticable, from another individual of the nearest kin, preferably a brother or sister; that the bone should never be obtained from an animal—because its viability or replacement is uncertain or, at best, delayed, and according to Axhausen its periosteum does not proliferate.

Certain fundamental rules should always be observed in the transplantation of all tissues. These rules must be adhered to as closely in the animal as in the vegetable kingdom. The science of grafting in the plant kingdom is centuries old. The most important rule of the process of grafting in the vegetable kingdom is the contacting of the alburnum of the scion or graft (which in a way corresponds to the periosteum) to the alburnum of the stock, or the part grafted (see Fig. 71). The contacting of the corresponding histological layers is not of such paramount importance in the grafting of bone as it is in vegetable life, but the importance of its observance is unquestionable.

The more closely these rules are adhered to, the greater will be the percentage of clinical successes. In the case of the bone transplant, nature is confronted with the following problems: (1) the rapid establishment of cellular nutrition and blood supply; which is brought about by the extension of blood-vessels and by the cellular assimilation of the serum in which the graft is immersed; (2) the union of the graft to the contacted bones or fragments of bone by osteogenesis on the part of the graft or recipient bone, or both; (3) Wolff's law, which is the adaptation in form and increased strength of the graft to its mechanical requirements. If nature is to succeed in accomplishing this, it is quite essential that both the graft and the recipient bone should be favorable to cellular life and proliferation.

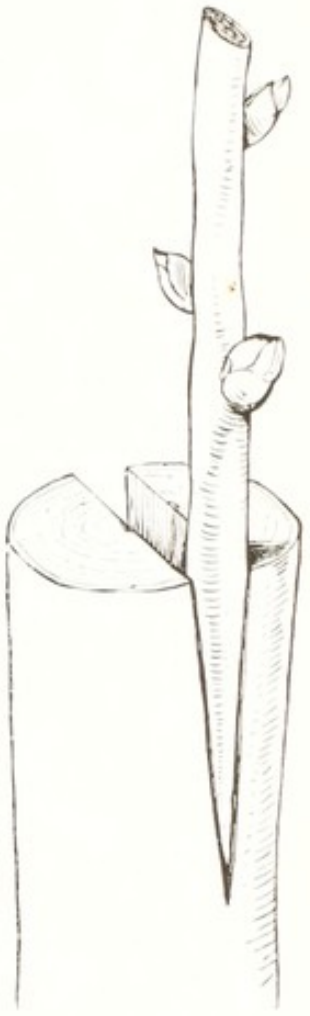


FIG. 71.—A diagram illustrating the method used most frequently in grafting fruit trees. It will be noted that it is an inlay graft and that the three elements of the graft or scion (namely, the bark, alburnum (sap) and wood) are closely coapted with their corresponding elements of the stock or recipient branch. This contact of individual tissue layers is most essential in tree grafting, and it is believed to be analogous to bone or other animal-tissue grafting.

The surgeon can do much in aiding nature by strict asepsis; by minimizing the trauma to all the tissues involved; by avoiding cellular death through either bruising or comminuting with hand tools or by frictional heat from motor-driven instruments; by the avoidance of traumatism—thus guarding against necrosis of portions of the graft and lessening the danger of wound infection; by the proper protection and preservation of the graft bed and the graft itself from drying and possible infection; by so arranging the skin in-

cision that it will not come directly over a superficially placed transplant, as this lessens the danger of skin necrosis and infection; by excising, if possible, extensive scars from the field of operation, since their poor blood supply is likely to interfere with the establishment of nutrition to the graft; by closely fitting and contacting bone surfaces which should, whenever possible, include the accurate coaptation of periosteum of graft to periosteum of recipient bone, of cortex to cortex, of endosteum to endosteum, and of marrow to marrow; by properly suturing muscle origins and insertions to the suitable mechanical locations of grafts which replace skeletal bones or portions of them (this is important if muscle control is to be re-established); by securing sufficient hemostasis in the graft bed by means of repeated applications of hot saline solution and by careful tying of blood-vessels (a hematoma not only favors the development of infection, but also interferes with the early nutrition of the transplant by the permeating serum; a small amount of blood-clot, however, may be desirable); by including in the graft the periosteum, endosteum, and marrow, which not only contain active osteogenetic elements but on account of their loose structure are more favorable than compact bone to a rapid re-establishment of the blood supply with the recipient tissues of the graft bed, from whence nourishment rapidly reaches the compact part of the graft through the numerous blood-vessels passing from these enveloping membranes into the compact bone. In other words, a bone-graft consisting of all its elements approaches more closely a complete physiological unit—not only in its osteogenetic function but also with regard to nutritional distribution.

Stöhr, in his text-book on Histology, states: "The blood-vessels of the bone, the marrow, and the periosteum are in the closest connection with one another and also with the surrounding structures. Small branches (not capillaries) of the numerous arteries and veins of the periosteum enter the Haversian and Volkmann's canals, which on the inner surface of the bone are in communication with the blood-vessels of the marrow. The latter is supplied by the nutrient artery, which on its way through the compact substance gives off branches to the same, and in the marrow breaks up into a rich vascular network."

The bone contact should be of generous extent and always with healthy vascular osteogenetic bone, the less favorable the bone, the greater should be the area of contact. Careful suturing as well as accurate coaptation should be secured when early use is to be made of the part, in order to obtain the benefits of functional irritation. In many instances where close contact and exact coaptation cannot be secured, early bony union may be accelerated by the interposition of numerous small grafts or fragments of bone which, for purposes of emphasis and description, the author has in his writings and teachings termed "bone-seed," their analogy to vegetable seed being almost perfect. In early ununited fractures, it is the practice of the author to remove most of the fibrous union and substitute for it (after the inlay has been fixed in position) numerous bone-chips between the ends of the fragments. These coalesce with each other and also with the graft and recipient fragments.

The proper contact of these bone elements can be secured only by the employment of the author's inlay procedure, which should always be carried out as carefully as circumstances permit. Examples of the various modifications of this principle are the inlay spinal graft for Pott's disease, the bone-graft wedge for the correction of deformities, and the inlay bone-graft for fresh and ununited fractures. In many of the latter type of cases, the callus formation is so meager that it may be compared to the cabinet maker's glue

PLATE I

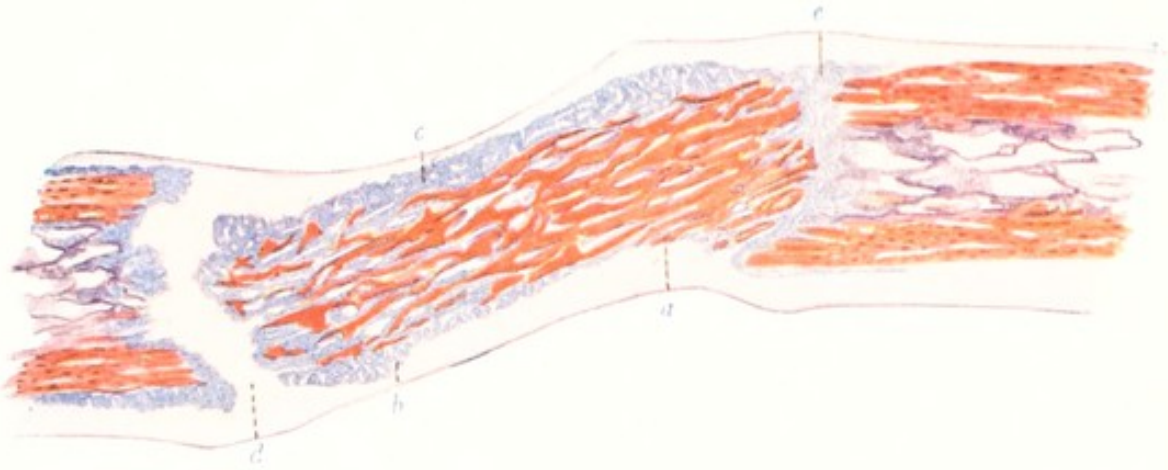


FIG. 1.—Sixty-four day Exp. No. 153. One-half of the shaft split longitudinally; periosteum and endosteum on: *a*, Old dead cortex; *b*, new bone from periosteum; *c*, extensive new bone from endosteum; *d*, fibrous intermediary callus above; *e*, bony union lower end. This specimen emphasizes the importance of the endosteum in the production of new bone.

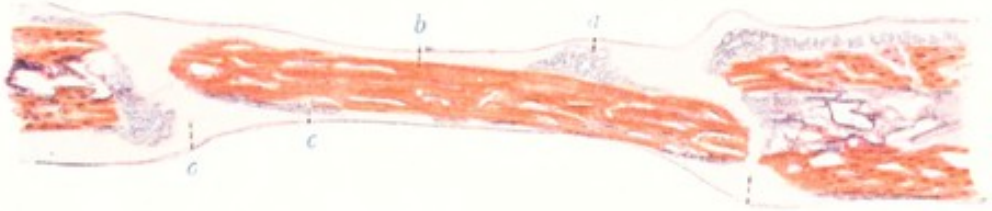


FIG. 2.—Forty-six day Exp. No. 176. Periosteum and endosteum both removed: *a*, Callus formed on transplant from surviving cells; *b*, dead cortex; *c*, fibrous intermediary calluses. This specimen proves that a cortical bone transplant will produce new bone from its "marrow canals," although all its periosteum and endosteum has been removed.

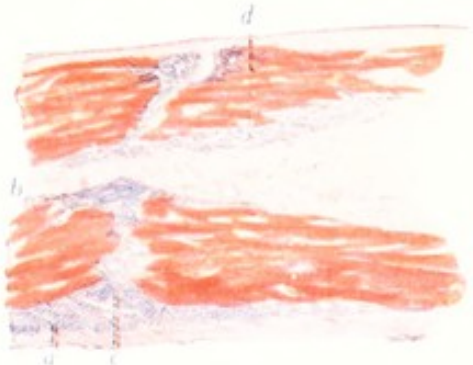
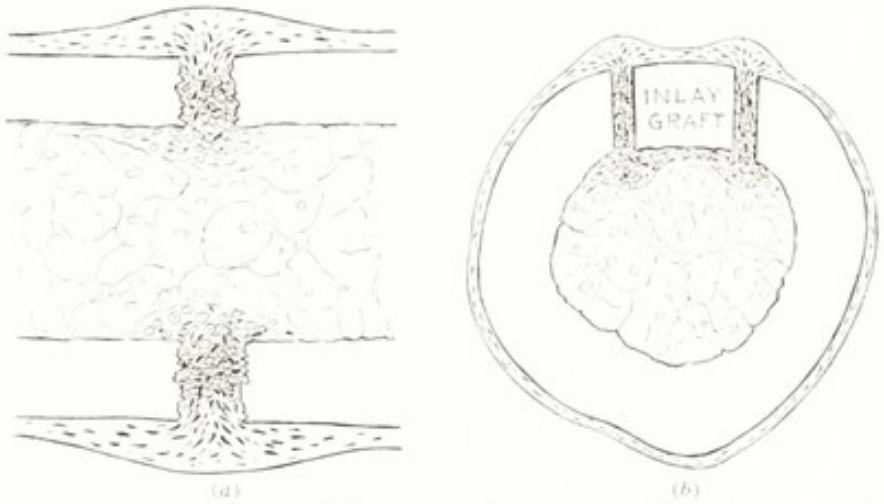


FIG. 3.—Forty-six day Exp. 161 R. Showing rapid bony union—a fracture through a transplant with periosteum and endosteum on: *a*, Bony periosteal callus; *b*, bony endosteal callus; *c*, bony intermediary callus; *d*, cortex with cells dead. The rapid bone formation and union in this specimen emphasizes the importance of coaptating like layers of bony parts, whether they are fracture fragments or bone-grafts. There is an important correlation between these layers (viz., periosteum, compact bone, endosteum, and marrow) in the formation of bony callus, and a bone-graft should always, when possible, be inserted by the inlay method, which brings all its layers in coaptation with the corresponding ones of the host bone. According to Ely the periosteum furnishes connective tissue from which the osteoblasts of the marrow tissue build new bone.

(D. B. Phemister in "Surgery, Gynecology and Obstetrics.")

which will not hold unless the wood is exactly fitted and coaptated. It will not bridge space. The same holds true in a long-existing ununited fracture. The surgeon must execute cabinet bone work in order to approximate 100 per cent. of successful results, and this can be accomplished only by employing the inlay method with the author's bone mill.

Bone-grafts have been successfully applied by other means but the following are some of the obvious advantages of the author's inlay method, besides the approximation of corresponding elements of graft to recipient bone which this procedure makes possible. In the repair process, especially in fractures, new bone appears from both the periosteum and the endosteum on both sides of the cortex, possibly more markedly on the concave side of the fracture. The space between an inlay graft and its host bone becomes filled by cells arising from both the endosteum and the periosteum. Cotton and Loder consider the endosteum as the more important factor in the formation of bone about the transplant. In view of these facts, the advan-



(*a*) (*b*)

FIG. 72.—(*a*) represents a so-called greenstick fracture with perfect apposition of the corresponding bone layers (periosteum, compact bone, endosteum and marrow substance) of one fragment to the other. Bone growth is thus under the most advantageous condition and is the product of the co-ordination of all these layers. Therefore the conditions, in this respect, in a greenstick fracture, are ideal for a rapid union. The histological conditions and coaptation of like bone layer to like bone layer are the same in the instance of the inlay-graft (*b*).

tage of the inlay method is apparent, in that it affords the coaptation of both these structures of the graft to the corresponding ones of the host bone. Furthermore, the author wishes to emphasize the fact that physiological bone-growth results not from the independent activity of one or more bone layers, but from the synchronous interaction of all the bone layers lying in their proper relationships to each other, *i.e.*, such relationship as obtains in a greenstick fracture in which there is no displacement of fragments and in which the different layers of one bone fragment lie in close approximation with the corresponding layers of the other bone fragment (Fig. 72). Under these conditions, each bone layer is enabled to co-operate in its osteogenetic activities with all other bone layers, viz., according to Ely, we can compare the production of bone to that of the building of a masonry wall—the brick and mortar corresponding to the fibrous tissue produced by the periosteum, while the osteoblastic cells of the marrow and the endosteum are likened to the mason. In this instance, as long as the mason (marrow and endosteum) and the brick and mortar (periosteum) are not brought together in their proper relationship, no masonry wall (bone-union) will result. It may like-

wise be true that so long as the proper coaptation of periosteum to periosteum, marrow to marrow, and osteoblastic cell to periosteal fibrous tissue is not observed and the several layers do not co-operate with each other in a physiological manner, no bony union will take place. The histological and mechanical conditions obtaining in the author's inlay bone-graft are every bit as favorable as those in a green-stick fracture, and the requirements of Ely's postulate are fulfilled.

The modifications of the inlay technic meet practically all mechanical requirements; it is as applicable to fracture of the small bones of the forearm as of the tibia or femur; it controls the deformity of the foot as well as of spinal caries; its inherent mechanics favor the fixation of the graft as well as the immobilization of the fragments into which it is inserted; its technic is not difficult, because it has to do with plane surfaces. Moreover, the technic is far more simple and easy of application than that of the intramedullary graft. The inlay method allows the highest efficiency of Roux's postoperative functional irritation. To increase the potency of this factor, Roux advises frictional dressings during the after-treatment, which consists of pressing or weighting the bones and stretching the tendons.

That it is not absolutely necessary for the success of the graft that it be contacted with a host bone, has been proved by Carter, who states (Med. Record, Feb. 7, 1914): "Bone-grafts either covered by periosteum or bare, but accidentally separated from the living periosteum-covered bone (host bone) appear to be osteoconductive and very likely osteogenetic." He reports 20 cases where the bone-graft was used to elevate the bridge of the nose. In many of these cases the graft was not contacted to the bone of the face but was (usually) embedded in soft tissue, nevertheless the transplants are still in place and some are larger than when they were implanted two or three years before.

Chiari has succeeded experimentally in grafting portions of bone marrow into the spleen of the same animal. The grafts survived and increased in size from that of a hemp-seed at the time of transplantation to the size of a pea five months later. Histological examination of the grafts in the spleen showed that the growth was actually due to an increase in bulk of the specific bone-marrow tissue.

A thorough understanding of the *modus operandi* and theory of Wolff's aw is imperative. The influence of this law upon the success of grafting procedures of all kinds cannot be too strongly emphasized. It not only influences the graft to proliferate and strengthen to an almost unlimited degree if the new mechanical environment of the graft requires it, but the action of this law also causes the bone from which the graft was removed to be restored to its original strength (see Fig. 73). This same influence also causes internal reconstruction of not only the trabeculæ, as the mechanical forces demand, but also of the general histological character of the bone, *i.e.*, cortical bone ultimately becomes spongy bone if implanted in or contacted with bone of that character, and *vice versa* (see Fig. 74).

A brief statement of Wolff's law is as follows: "Every change in the form and position of the bones or of their function is followed by certain definite changes in their internal architecture and by equally definite secondary alterations of their external conformation, in accordance with mechanical laws."

The question as to what factors control the growth and development of a transplanted bone or fragment of bone and later on cause it to take the size and shape of the bone which it replaces, is a most interesting one. It is undoubtedly intimately connected with the corresponding problem of the

factors concerned in the development of normal bones. Museum specimens and Nichols' cases (reported in Jour. Am. Med. Assoc., Feb. 3, 1914) demonstrate that when a new bone casing or involucrum is thrown out around the necrotic shaft of a long bone, it is thicker opposite the middle of the shaft than at the ends.

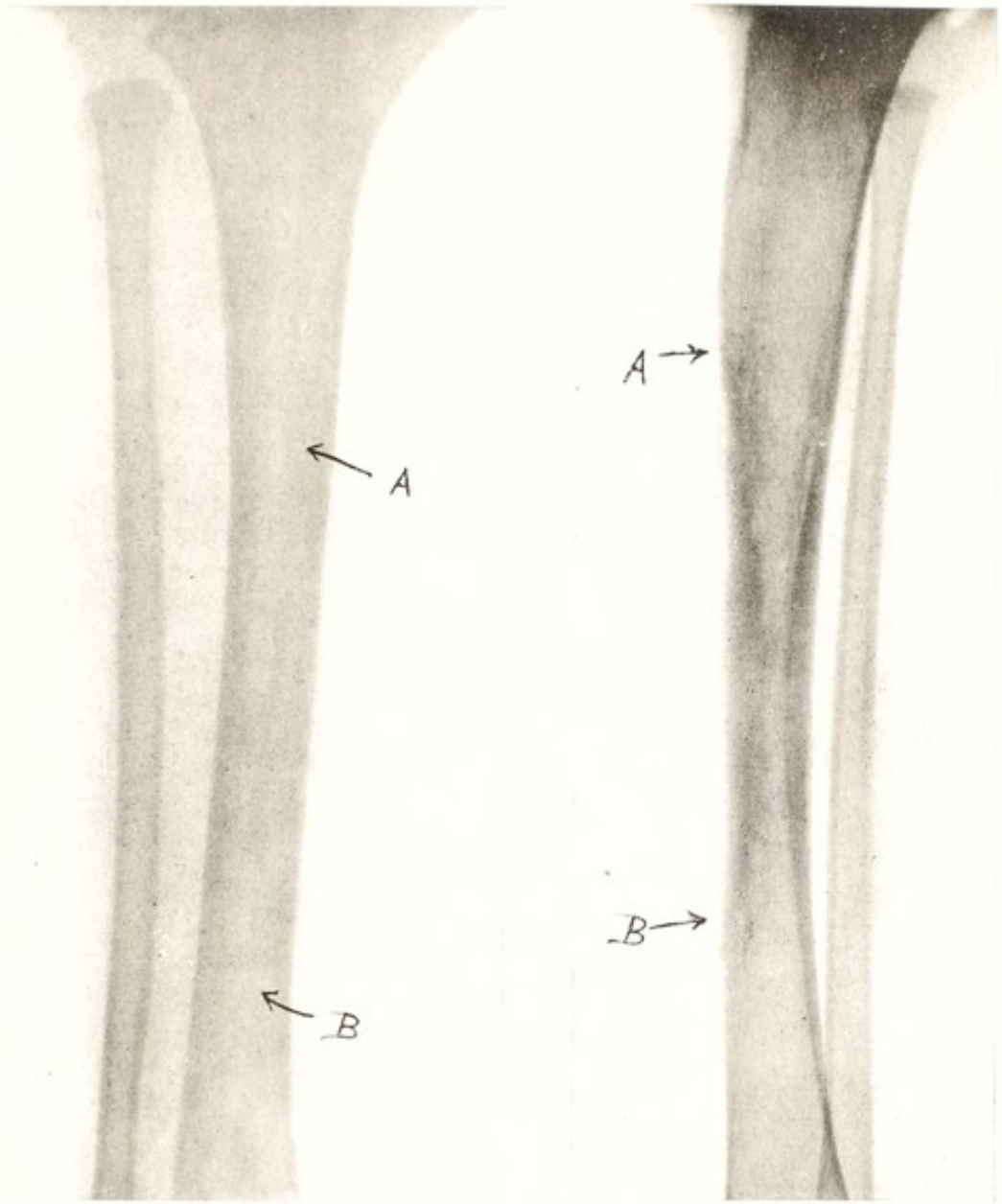


FIG. 73.—Anterior posterior and lateral roentgenograms of a tibia from which a graft had been removed for Pott's disease twelve weeks before. *AB* indicates location from which graft was removed. The cavity has filled in and under influence of Wolff's law the tibia has become nearly if not as strong as it was before the graft was removed.

The physiological repair of badly reduced fractures, with a wide separation of fragments and the restoration of the original contour of the shaft of that bone from the two overlapping broken ends, demonstrates clearly what can be done by diaphyseal osteoblasts, apart from the aid of the epiphyseal cartilage, in restoring not only the external contour but also the medullary canal of the original bone. The osteoblasts will not only restore the outlines of a fractured fibula or form a new fibula shaft but, as has been demon-

strated by Huntington, Stone, Bond, and others, they will transform a transplanted fibula into a new tibia. Skiagrams show that not only does bone deposit on the outside of the shaft but that the medullary canal is enlarged and the fibula thus approximates the structure, size, and contour of the normal tibia. Bond believes that: "This must be the outcome of original hereditary capacity on the part of the osteoblast concerned, as well as the result of new pressures and strains experienced by these bone-cells during their growth under altered conditions. This must mean that although a considerable amount of young bony material may have been supplied by osteoblasts from the shaft and ends of the fibula—when used to replace the

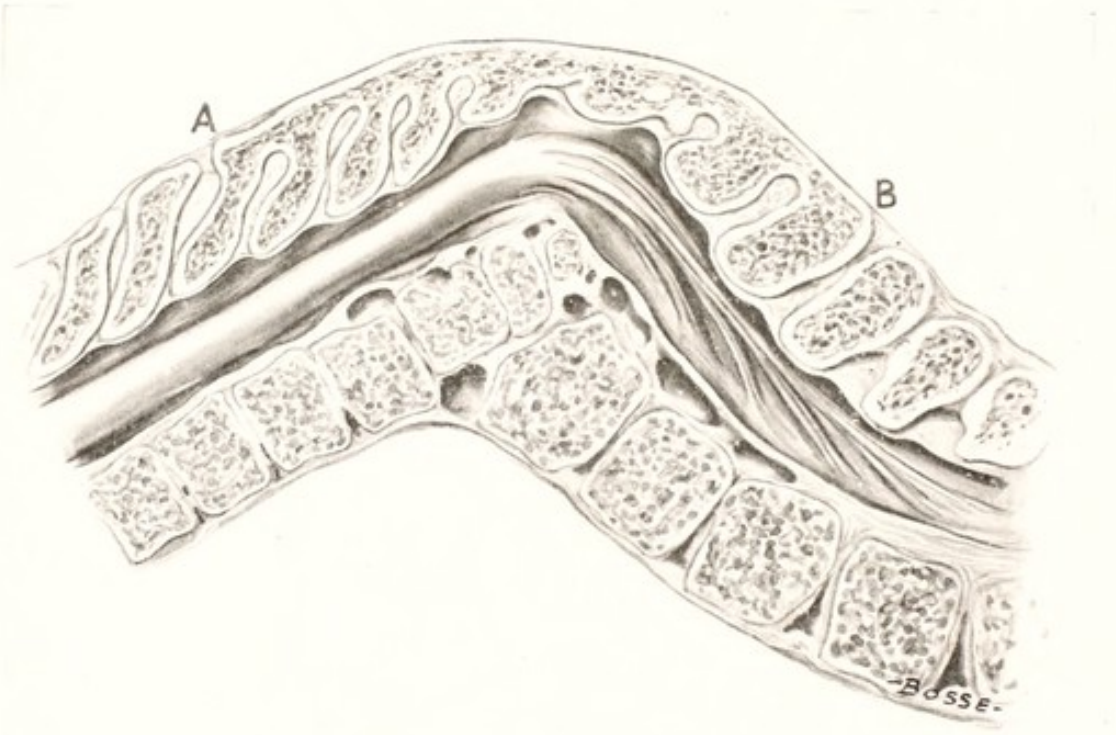


FIG. 74.—An anteroposterior longitudinal section of a spine two years after the tibia bone graft had been implanted into its split spinous processes to ankylose the tuberculous infected vertebræ present between *A* and *B*.

The drawing was made from an actual specimen and represents the alteration which has taken place in the character of the graft and its bed.

The area *A* to *B* has been so changed that it presents the characteristics of a single bone with a distinct cortex enclosing cancellous bone structure throughout or in other words it has become identical in its anatomical structure to the spinous processes to which it has become amalgamated.

This is a fortunate characteristic of the bone-graft, *i.e.*, it adapts itself to its environment.

tibia—yet the real task of remodelling the new bone thus thrown out and of depositing it in the right situations must fall upon the osteoblasts of tibial ancestry, upon bone-cells which are thrown out by the tibial extremities after these have been rejoined by the interposition of a new shaft."

The way in which osteoblasts derived from separate bones may work in co-ordination to build up bony trabeculæ in situations of stress is well illustrated in a case of excision of the knee, with ankylosis of the femur and tibia at a right angle to each other. Under the mechanical disadvantage of the two longest bones in the body being united into one at a right angle, the bony trabeculæ have arranged themselves to carry the weight of the body and this result has been attained by osteoblasts of femoral and tibial origin,

each having taken part in the formation of the new bone. "The key-note of all bone development seems to be a co-ordinated arrangement of bone-cells in lateral and end-on relations to each other under the stimulus of pressure and strain within certain limits of innate capacity" (Bond).

This, in brief, is Wolff's law, which always requires a bony connecting medium if its influence is to be potent. In the same way, a shaft seems to be essential to the proper growth of all epiphyses—all of which is in confirmation of Murphy's statement that "the amount of growth in a bone depends on the



FIG. 75.—This is a rontgenogram of a case of loss of the lower one-third of the tibia one year before from osteomyelitis. The remaining periosteum attempted to reform the shaft and a small interrupted thread of bone can be seen. It, however, either became broken in two places or a complete bridge of bone was never produced; therefore, the influence of Wolff's law did not operate to stimulate bone proliferation for the tibia at A, as it would have if there had not been a solution of continuity. The potency of this same Wolff's law, however, could not be better demonstrated than it is in this same rontgenogram, as shown by the enormous hypertrophy of the fibula, which has become the size and strength of a normal tibia. This is a physiological property of bone, and shows itself as strikingly in bone-grafts under functional stress as it does in complete skeletal bones. Therefore, as stated elsewhere, at the same time the graft is proliferating, in order to be of sufficient strength for its new environment, the tibia from which it was removed proliferates under the stimulus of function until it has returned to its normal strength and size.

need for it." The bone-cell colony has its investing and limiting membrane, the periosteum, just as the liver has its capsule, and, as Macewen has shown, this periosteum or bone-capsule serves to keep the bone-cells within circumscribed limits and prevents them from invading neighboring tissues. The fact that the transplanted fibula shaft develops into a bone of the size and shape of the tibia, shows that the failure to do so in some cases is not due primarily to the fact that the transplanted bone is naturally a smaller bone,

but to the fact that it is not mechanically taken over sufficiently or that its growth is not sufficiently stimulated by osteoblasts of tibial origin.

Bond has suggested the following theory: "It may not be entirely useless to regard for a moment an individual bone as an organ, to think of it as a mass of bone-cells of definite ancestry whose activities are exercised in becoming adapted to a physical environment of definite stress and strain." If this supposition be true, the selection of bone from which the graft is to be used becomes of the greatest importance, as the degree of possible cellular proliferation of grafts or fragments of bone would be determined by the size and strength of the bone from which they were removed. This would argue in favor of obtaining grafts from a large and active bone, such as the tibia, when they are to be placed in an environment where it is necessary for them to proliferate actively and withstand a large amount of functional stress. Under this supposition, a graft obtained from a rib would not have the mechanical possibilities of a tibial graft but would be suitable for the correction of facial bony defects, as has been so well demonstrated by Carter, or for any purpose where excessive mechanical strain is not required, and this principle has been applied by the author in his experience with more than 1600 bone-graft cases. He has always employed the bone-graft of tibial origin, or at least a graft whose cortical structure is satisfactory for all environments in which mechanical stress must be borne by the graft. On many occasions he has removed remnants of rib-grafts which had become disintegrated into bundles of bone in cases where they had been inserted to restore defects in long bones or in the jaw. He believes that the rib-graft has a very limited field of usefulness and should be employed only for cosmetic purposes; and even in such instances it is probable that a cortical tibial graft is more constant in its activity and therefore preferable—in other words, it tends neither to proliferation on the one hand nor to overabsorption on the other.

The external shape of the bone is the result of functional adaptation. The bone is strengthened and thickened at those points where most stress and pressure come upon it, and is weakened at the opposite points. Such transformations have the object of enabling the bones or grafts in their altered positions and relationships to meet the new and abnormally directed stress.

A good illustration of Wolff's law occurs where a portion of the tibia has been destroyed by osteomyelitis and removed. Without the support of the tibia, the use of the leg causes an abnormal amount of stress from both weight-bearing and muscle-pull to be borne by the fibula, which hypertrophies to a strength commensurate with this added strain (see Fig. 75). The same thing happens to a graft which is not of sufficient strength to withstand the stress that comes upon it—it proliferates to an adequate size. Again, the tibia or bone from which the graft has been removed proliferates until it becomes of the same size and strength that it was before the graft was removed. This occurs in about two to four months, if the skiagrams can be trusted. Thus it is seen that Wolff's law has to do with function and is operable in fragments of bone as well as complete skeletal bones, and that it has an important bearing upon the plan of treatment and the progress of convalescence in a very large proportion of bone and joint work.

Local or general hypertrophy of a bone may occur. Local hypertrophy may occur in consequence of increased strain upon certain parts of a graft, either directly or through the muscle-pull. Schulze-Berge (Centralb. für Chir., No. 48, 1913, p. 1854) reports the removal of the knee-joint, including 8 cm. of head of tibia, for spindle-cell sarcoma and the substitution of a segment of the fibula from the opposite leg. Radiographs taken one year

later showed that the transplant had attained the strength and size of the diaphysis of the tibia.

The recognition and full appreciation of these important conclusions of Wolff constitute the foundation of the treatment of deformities and the application of grafts of all kinds. It is obvious that it is always advisable to allow the graft to functionate as early as possible by bearing mechanical stress within the limits of safety. This is highly favorable to osteogenesis, establishment of blood supply, and bony union. This functionating period should be preceded by the most efficient relaxation of the parts grafted during an interval of not less than eight weeks.

The Rôle of the Periosteum.—It is largely a question of what the periosteum is and what it includes whether or not it is to be considered actively osteogenetic. If by chance the cleavage is deep, as when the periosteum is removed with a sharp elevator and the underlying cortical bone scraped, the periosteum is sure to be actively osteogenetic, and it is only by this technic that the whole anatomical or histological periosteum is secured. On the other hand, if the normal periosteum is stripped off and removed with a blunt instrument, the cleavage is not likely to be deep enough to include the osteogenetic layer of cells on the periphery of the compact bone. In that case, the periosteum is incomplete and constitutes only a connective-tissue limiting membrane (Macewen), and slight or no osteogenesis occurs.

Every graft should have as large a covering of periosteum as possible, because it not only favors the establishment of blood supply to the graft but is also an important factor in influencing the permanency of the graft, as has been so well demonstrated by MacWilliams.

In the study of bone injuries and bone-growth, the three burning questions of the origin of bone callus, the rôle of the periosteum, and the rôle of the bone-graft have largely dominated the recent literature.

In 1692, Havers, whose name has been immortalized by association with the vascular canals of the bone, described the periosteum as a simple connective-tissue "limiting and vascularizing membrane," but his deductions were apparently largely speculative, as they could not have been based upon exact microscopic investigation.

Antoine de Heyde, in 1684, published the first experimental observations upon the repair of fractures—based upon work on frogs—and reached the conclusion that callus was formed by calcification of the blood which had extravasated around the broken ends.

Duhamel (1739 to 1743) brought forth the first systematic work on this subject and was the originator of the generally accepted modern theory of the reparative rôle of the periosteum. It was his belief that the periosteum proliferated and became thickened about a fracture and formed the callus by throwing out the new tissue. He was also the first to define the use of the term "cambium layer" of the periosteum.

Over a hundred years later, after the less important investigations of Troja and others, there appeared the great and important work of Ollier (1858 to 1867) which has stood the test of time and remains to-day the principal foundation of all our exact knowledge of bone-growth, although for a time it was thought that Barth and others had definitely refuted Ollier's views. These very men, however, have largely come back to Ollier's position. His work was so thorough and careful that his conclusions have attained an almost unassailable position. He proved the regeneration of bone from periosteum in every possible way, and ever since his day the periosteum has been regarded as the most important vital tissue of the bone. Nearly fifty

years have elapsed since Ollier's treatise appeared, and during this period practically the whole of modern surgery has developed. Very many works have been written dealing with fractures experimentally produced, but these have chiefly been concerned with the structure and origin of callus. More recently, the practical question of filling bone defects by grafts of dead or living bone obtained from various sources has absorbed the attention of workers who have sought to examine experimentally this method of bone reconstruction (Groves). Most important contributions on the subject have been made by Axhausen (1908), who showed that certain portions of transplanted living bone retain their viability and act as the centers of new bone proliferation. Groves states that: "Every practical worker on the subject has, moreover, endorsed the opinion that a living bone of the same species gives much quicker, stronger, and more certain results than dead bone or that taken from another species" (or individual).

In 1858, Ollier described his technic for subperiosteal resection, but, as far as the author is aware, he did not emphasize the importance of vigorous scraping with a sharp instrument in order to separate with the periosteum the embryonic layer of active osteogenetic cells which is situated on the periphery of the compact bone, although it is evident from the description of his work that he frequently practised this technic. It seems certain that osteogenesis on the part of the healthy periosteum removed from a healthy bone is largely dependent on the presence of these active embryonic cells from the outer surface of the cortical bone. Therefore the wisdom of the use of the sharp periosteum elevator in bone resection is apparent if a regeneration of bone from the periosteum is desired.

This statement, however, refers to normal periosteum removed from an uninfected bone. Infection of bone, especially of the marrow cavity in osteomyelitis, causes, according to Macewen, an immediate migration of osteogenetic cells from the Haversian canals of the underlying bone into the loose areolar tissues of the periosteum. The meshes of this layer become filled with osteoblasts, from which layers of bone form later. In this case, where the osteogenetic cells are driven into areolar tissue, it makes no difference what technic is employed in elevating the periosteum—whether a sharp periosteal elevator is used or not—the osteogenetic cells from the deep layer, having migrated outward, will be included, under any conditions, in the separated membrane. In the normal uninfected bone, this layer of osteogenetic cells, as stated above, is firmly attached to the periphery of the bone-cortex, and the tendency of cleavage is for this layer to remain adherent to the bone and not to be separated and come away with the periosteum. If the pyogenic infection be progressive, the diaphysis may be involved and die; but the osteoblasts in the periosteum, which have escaped before the necrosis occurred, avoid destruction. Occasionally the whole shaft necroses without reproduction of bone from the periosteum, because of early blockage or thrombosis of the nutrient blood-vessels. This arises from one of at least two causes.

It is in these cases, in which an involucrum fails to regenerate, that the bone-graft is of the greatest service. In fact, it is in many cases the only possible means of avoiding an amputation.

Davis and Hunnicutt, in Bulletin of Johns Hopkins Hospital, record the following findings: Free periosteal transplants did not produce bone, even though osteoblasts were adherent to the transplants. Pedunculated flaps of periosteum did not produce bone. Free and pedunculated periosteal flaps with bone shavings attached produced bone in each experiment. Autogenous

bone, both with or without periosteum, lived and was successfully transplanted to fill defects in bone.

Although not advisable, many liberties can be taken with the bone-graft without interfering with its success. It has certain bacteria-resisting properties.

The author's experimental grafts were kept in normal salt solution for varying periods up to one week, with successful results following their implantation. In other cases, sepsis occurred immediately after insertion of the graft (experimental); nevertheless, parts of the graft became united to recipient bone while the rest of the implant sequestrated.

Human autogenous grafts have been repeatedly so placed that at their middle portion they extend through tuberculous foci, and in no instance has primary union or taking of the graft failed. Likewise, grafts have been so placed as to span attenuated infected areas, and here the grafts have been equally successful, but the author recommends the greatest caution in selecting such cases and that as a rule the graft should not be implanted until complete healing has existed for several weeks or months.

To substantiate the author's previous statement—based upon animal experimentation and many similar surgical experiences—that many liberties may be taken with the bone-graft without interfering with its success (Albee, Experimental Study of Bone Growth and of the Spinal Bone Transplant, Jour. A. M. A., April 5, 1914), Galloway (Western Canada Med. Jour., April, 1914) cites the following experiences: "I have operated on four patients (bone-graft for Pott's disease) in whom a discharging lumbar sinus was present. Of course, extra precautions were taken, the mouths of the sinuses and the surrounding skin being thoroughly disinfected with iodin and then sealed with collodion on the day preceding the operation and before the regular pre-operative disinfection of the patient's skin was commenced. In all four cases, primary healing took place."

The author has found that experimental grafts taken from long bones, such as the tibia or ulna, showed evidence of greater osteogenesis than those taken from the vertebral spinous processes or neck of the femur. Bone from which the periosteum had been removed proved as satisfactory as bone-grafts on which the periosteum had not been removed. As stated elsewhere, it is deemed advisable to always include the periosteum and marrow substance on the graft when this is possible.

The bone-graft acts always as a stimulus to osteogenesis to the bone into which it is engrafted or with which it is contacted. This is a constant and important factor, and may be depended upon toward securing results. If the graft is placed in a location where there is no mechanical function for it to perform, its cells retain their vitality but nearly always there will be few or no proliferative changes in the transplant. On the other hand, if it is transplanted into a defect where there is demand for it to perform a mechanical function, proliferative changes are usually marked and it becomes rapidly united and similar in structure to the part into which it is grafted. This is the law of functional irritation, as laid down by Roux. The more perfect the technic of transplantation, the greater will be the effect of irritation.

The bone-graft, when well contacted, becomes immediately adherent to the recipient bone by newly formed tissue, which usually changes to solid bone within four weeks. In the author's opinion, this, together with the graft's bacteria-resisting property, strongly favors, whenever feasible, the employment of the bone-graft rather than any metal internal splints, especially when it is appreciated that metal has an effect opposite to that of a

graft in that it inhibits callus formation, produces bone absorption, and favors infection.

The dowel, the inlay, and the wedge bone-graft fulfill all mechanical requirements and afford a means of repairing and remodelling the skeleton which the surgeon has not hitherto possessed.

Preservation of the Bone-graft.—Various methods have been suggested for the preservation of bone-graft material, but in the experience of the author the following have proved most convenient and reliable. The temporary immersion in normal salt solution during the same operation is most satisfactory, and even this is usually not necessary, since, when possible, the graft bed should always be prepared prior to the removal of the graft, and the graft is immediately implanted in the prepared bed. The sequence of the operation is important; because (1) it assures an interval of time for



FIG. 76.—Example of bone-transplantation performed seven years previous to this radiograph. The material was obtained from an infant's cadaver, kept in cold storage forty-eight hours, and was used to replace congenitally absent cuneiform bones of the feet.

the more perfect hemostasis of the graft bed; (2) it enables the surgeon by means of calipers, bone wax model, and flexible sterile pattern rod or flexible probe, to obtain the exact size and contour of the required graft, thus avoiding unnecessary traumatization from holding forceps in re-shaping a graft after its removal. Even in grafts where drill holes are necessary, it is far preferable to drill them before loosening the graft from the bone whence it is obtained. A graft should always be used as soon as possible after its removal; but if it is necessary for any amount of time to elapse before it can be used, normal saline is not satisfactory as a preserving medium because of its evaporation and the consequent toxic effect. In the experiments of the author, sterile vaselin has proved a most satisfactory medium in which to keep the graft. It is not only perfectly non-toxic, but it is an effective preventive of drying. The graft should either be immersed in a jar of vase-

lin or wrapped in gauze smeared with the same and placed in cold storage at a temperature of 4 to 5°C. Freezing is not desirable, as the resultant contraction and expansion damage the cellular content of the graft. Human grafts removed from the living, as well as from a cadaver (Fig. 76), have been successfully kept by the author on different occasions for forty-eight hours. Emphasis should again, however, be laid upon the importance of using autogenous bone-grafts whenever possible, since they are the most reliable; and as they are always used immediately, no preserving medium is necessary.

The surgical status of the value of the bone-graft has now become so thoroughly established that the surgeon should be equipped and ready to make the best use of it in every individual case requiring osteoplasty. An unabridged enumeration of the indications for the employment of the bone-graft would be most difficult, and the following tabulation serves only as a suggestion of its broad field of usefulness.

GENERAL INDICATIONS

1. To immobilize and stimulate osteogenesis in certain tuberculous joints.
2. To repair traumatic bone injuries.
3. To replace bone destroyed by infection.
4. To supply bone congenitally absent.
5. To strengthen or replace bone weakened or destroyed by benign or malignant growths.
6. To correct congenital or acquired deformities of the face.
7. To establish joints congenitally absent and restore those destroyed by disease.
8. To fix in place certain dislocated joints (acquired or congenital).
9. To close bone foramina in neuralgias.
10. To correct congenital or acquired deformities of extremities or trunk.

More specific indications for bone-grafting are:

1. To immobilize, support, and stimulate repair in spinal vertebræ whose bodies are infected with tuberculous or other chronic infection where mechanical treatment is indicated. It is also applicable in cases of persistent non-union following fracture of the spine, presenting pain, disability, and increasing deformity, and should be inserted as for Pott's disease. Further indications are for certain fresh fractures of the spine; spondylitis traumatica (Kümmel's disease) and neuropathic spine (Charcot) where, on account of a rarefying osteitis, crushing of the vertebral bodies and increasing deformity is likely to produce cord compression.

2. In the support and immobilization of cases of tuberculosis of the sacro-iliac joint, in certain desperate cases of tuberculosis of the tarsus, and in the form of inlays to hasten or insure bony union in erasure or excision operations for adult tuberculosis of the knee or hip.

3. In certain cases of paralytic scoliosis to support the weakened spine and prevent lateral deviation due to superincumbent weight and unbalanced muscle pull.

4. To immobilize and support or replace bones of the tarsus destroyed or partly destroyed by tuberculosis.

5. To correct deformity or restore balance in congenital clubfoot and acquired deformity from local disease or paralysis.

6. As a substitute for all metal plates, screws, nails, spikes, and wires, as used in the internal fixation of fractures and other conditions. The graft, in the form of inlays and various sizes of nails or pegs, is employed by the

author in all types of fractures, such as fresh and ununited fracture of the long bones and of the neck of the femur.

7. To produce permanent closure of nerve foramina after nerve section for neuralgia (Kanavel).

8. As a preventive of luxation or slipping of the patellæ, by raising the low femoral condyle by inserting a graft in the form of a wedge.

9. To aid, by means of numerous small grafts, rapid bone union where joint resection has been done or where a large graft has been used.

10. To strengthen the spine and prevent lordosis or other deformity in cases of spina bifida, where a large amount of bone is congenitally absent.

11. To replace the head and neck of the femur when previously destroyed by disease, the head and neck of the astragalus being used as a graft (Roberts).

12. In congenital and paralytic dislocations of the hip where the acetabulum is shallow and the femoral head will not stay in place. The upper half of the meager rim of the acetabulum is separated with a chisel and forced out and down, forming a pronounced rim. The cuneiform cavity thus produced is filled with wedge grafts.

13. To produce ankylosis of the ankle-joint in severe paralytic cases or tuberculosis of the adult, by placing a bone-graft peg through the os calcis and astragalus into the lower end of the tibia (Lexer).

14. To replace bone removed for osteomyelitis, tuberculosis, and spina ventosa.

15. For deformities of the nose, by contacting graft with nasal bones. If the skin incision is made in the tip of the nose, the scar is not noticeable.

16. To replace or repair defects of the lower jaw; to fill in sunken defects of the face—in the forehead following operation, in bony defects due to tuberculous osteitis of the facial bones, in recession of the superior maxilla due to harelip; to replace a mastoid process removed by operation.

17. In intra-articular fracture-dislocations, the head of the humerus or femur, etc., should be replaced at an open operation, as a graft.

18. To repair cavities in the cranial bones by transferring from the immediate neighborhood one or two segments of the external table covered with periosteum. The cortex of the tibia or a portion of the scapula may likewise be used; the latter source is preferable, as both surfaces of the graft are covered with periosteum.

19. As an aid in arthrodesis operations, the use of fragmental grafts (bone-seed) and dowel pegs of bone has been found valuable.

SUMMARY

The bone-graft is a trustworthy surgical agent, as proved by the author's uniform success in its use in over 1600 surgical cases; also by a careful study of the results, in animal experimentation, microscopical, macroscopical, and radiological, even in the occasional instances where primary union was marred by mild sepsis. The field of usefulness of the cortical graft is distinctly enhanced because of its resistance to tuberculous and attenuated pyogenic infection. Its field is also enlarged by the employment of motor-driven instruments—circular saws of different sizes, the adjustable twin saws, and the lathe or dowel instrument with different adjustments for making, as conditions demand, various sizes of bone-graft inlays, nails, or spikes. By the use of this motor outfit and its products, in conjunction with kangaroo tendon, the author has been able during the past six years to avoid entirely the use of metal in the form of screws, nails, Lane's plates, wire, etc., for internal bone fixation purposes. This had been made possible, largely,

by utilizing the best of well-known mechanical devices hitherto rarely, if at all, used in surgery—such as bone inlays, wedges, dowels, tongue-and-groove joints, mortised and dove-tailed joints.

The importance of adequate fixation cannot be too strongly emphasized. The position of "neutral muscle-pull" has also been of the greatest service in every case.

CONTRA-INDICATIONS

The only contra-indications to the surgical use of the bone-graft are a markedly septic field of operation and excessive scar tissue as an environment. Syphilis should be cured before operation, although one case of syphilitic osteitis of the spine was unintentionally operated. The graft healed in and immediately controlled the spinal symptoms.

REFERENCES

Ollier: "Traité experimental et clinique de la régéneration des os, et de la production artificielle du tissu osseux." 2 vols., Paris, 1867.

Streissler: "Der gegenwärtige Stand unserer klinische Erfahrungen über die Transplantation lebenden menschlichen Knochens." Bruns' Beitr. z. klin. Chir., Tübingen, 1911, vol. lxxi, i. (Contains complete list of references to bone transplantation up to 1909.)

Axhausen: "Histologische Untersuchungen über Knochentransplantation am Menschen." Deut. Zeit. f. Chir., Bd. xci, 388.

Barth: "Untersuchungen über Knochenimplantation." Zeigler's Beitr., 1895, Bd., xvii, 65. Also Berl. klin. Woch., 1896, 8; and Archiv f. klin. Chir., 1897, Bd. liv, 471.

Macewen: "The Growth of Bone." Maclehose, Glasgow, 1912.

Schmidt: "Allgem. Pathologie u. pathol. Anatomie der Knochen." Lubarschostertag Ergebnisse, vols. iv, 1897, and v, 1898.

Albee, F. H.: "The Fundamental Principles Involved in the Use of the Bone-graft." Amer. Jour. Med. Sci., March, 1915.

Albee, F. H.: "The Inlay Bone-graft in the Treatment of Fractures, Joint Tuberculosis and Certain Deformities." The Lancet Clinics, April, 1915.

Albee, F. H.: "Original Uses of the Bone-graft" (condensed). Detroit Med. Jour., February, 1915.

Albee, F. H.: "Meine Verwendung der Knochentransplantation." Verhandl. d. deutsch. orthop. Gesellsch., 1915, xxxv, 112.

Albee, F. H.: "Bone-graft Surgery." W. B. Saunders Co., Phila., 1915.

EXPERIMENTAL FRACTURES; CALLUS FORMATION, ETC.

Biddler: "Zur Frage über d. Herkunft des sog. irneren Callus." Centralbl. f. Chir., 1876, Bd. iii, 657.

Borst und Riedinger: Sitzungsberichte d. phys.-med. Ges. zu Würsburg, 1908, 63.

Buchholz: Arch. f. Pathologie, Virchow, 1863, xxvi, 78.

Busch: "Exp. Untersuch. ü. Osteitis u. Nekrose." Arch. f. klin. Chir., 1877, Bd. xx, 237.

Foa: Gior. d. m. Accad. de med. di Torino, 1903, lxvi, 582.

Haas: "Regeneration of Bone from Periosteum." Proc. Soc. Exp. Biol. and Med., N. Y., 1913, xiii, 57.

Haab: Untersuch. aus. d. Path. Inst. z. Zurich, 1875, Hft. 3, 25.

Hanau: "Exp. Untersuch. über Callusbildung." Verhandl. d. Gesellsch. deutsch. Naturf. u. Aerzt., 1897, lxviii.

Herz: Deut. Zeit. f. Chir., 1901, lx, 398.

Hilty: "Der innere Callus, seine Entstehung u. Bedentung." Zeit. f. rationelle Med., 1853, Bd. iii, No. 7.

Koenig: Münch med. Woch., 1913, lx, 430.

Merlani: "Ricerche sperimentale sulla prod. di cartilagine nel processo di guarigione delle fratture." Policlinico, Rome, 1910, xvii, sez. prat., 355.

Matsuska: Deut. Zeit. f. Chir., 1903–04, lxx, 13.

Maas: "Wachstum, Regeneration, u. Callusbildung d. Rohrenknochen." Arch. f. klin. Chir., 1877, Bd. xx, 708.

Rost: "Exp. u. klin. Untersuch. über chronische Entzundungen des Knochenmarks." Deut. Zeit. f. Chir., October, 1913, 83.

RIGAL ET VIGNAL: "Recherches exp. s. l. formation du cal, etc." Ecole prat. d. hautes études: Lab. d'histol. du Coll. de France. Trav., Paris, 1881, vi, 107.
SORRENTINO: "Ricerche sperimentale sulla formazione del callo osseo." Arte med., Napoli, 1900, ii, 804.
ZIEGLER: Deut. Zeit. f. Chir., 1901, lx, 201.
ZONDEK: "Zur Transformation des Knochen Callus. Experimentelle Untersuch. u. ihre klin Bedeutung." Hirschwald, Berlin, 1910.

EXPERIMENTAL OBSERVATIONS BEARING UPON TREATMENT

LUCAS-CHAMPIONNIÈRE: "Traitement des fractures sans immobilisation chez le chien." Jour. de Med. et Chir. Prat., 1888, lix, 65.
ROSSI: "Exp. Beiträg. z. Frage der Behandlung v. Knochenfrakturen." Allg. Wien. Med. Ztg., 1901, xlvi, 27; klin. therap. Woch., Wien, 1900, vii, 1637; clin. Chir., Milano, 1901, ix, 6; Arch. di Ortop., Milano, 1901, xvii, 369.
RONCALI: "Contributo allo studio delle infezioni consecutive alle fractture esposte sperimentale." Policlin., Rome, 1895, ii, 383, 439, 514, 555.
POTÀRCHÀ: "Certetari experimentale a supra protesei metalice superiostale in tratamental imediat al unor fratturi osose." Spitalul, Bucuresi, 1895, 457, 481.

EXPERIMENTS UPON CONGESTION OR THE APPLICATION OF FIBRIN OR BLOOD-CLOT TO FRACTURES

BERGEL: "Callusbildung d. Fibrin." Arch. f. klin. Chir., 1910, xciii, 755.
BUM: "Experimentelle Untersuchungen über den Einfluss der Stauung auf die Entwicklung des Knochencallus." Centralbl. f. Chir., Leipzig, 1901, xxviii, 1153.
FORLINI: "Contributo sperimentale agli affeti dell' iperemia da stasi nella guarigione delle fratture." Clin. Vet., Milano, 1909, xxxii, sez. sc., 78.
POCHHAUMER: "Ueber periosteal Callusbildung, etc." Deut. med. Woch., 1910, xxxvi, 2120; and Archiv f. klin. Chir., 1911, xciv, 352.
SCHMIEDEN: "Experimentelle Studie z. Bier's Behandlung d. Pseudoarthrosen Mittells Bluteinspritzung." Sitzungsgericht d. Niederrhein Ges. f. Natur. u. Heilkunde z. Bonn, October, 1914; and Med. Klin., 1907, 197.

CHAPTER IV

ROENTGENOLOGY

The importance of the *x*-ray in the management of all bone and joint lesions, and particularly its importance in planning operations *before* submitting the patient to surgical interference, cannot be too strongly emphasized.

In order to make the best use of the *x*-ray one must have had large experience, not only in diagnosis but also in actually planning operations and studying their results, *e.g.*, in the case of fractures and fracture dislocations, to interpret the appearance of callus and the proliferation of bone in the case of the bone-graft by means of this most useful agent. The author cannot impress his conviction in this matter more strongly upon his readers than by stating that for some five years he labored in two of the largest *x*-ray laboratories in New York City with the sole purpose of familiarizing himself with Roentgenology.

Dangers of Misinterpretation.—The author wishes to emphasize the fact that these dangers of misinterpreting the *x*-ray are real. They can be partially accounted for by the very rapid increase in the use of the *x*-ray, necessitating the advent into this field of young and inexperienced workers. It is believed that a definite opinion from an *x*-ray examination is too often given in the fear that the radiologist's examination will be considered by the patient, or the physician referring the case, as unsatisfactory if the *x*-ray report is negative or incomplete. In the case of many pathological conditions of the bones and joints, it is very often unsafe and unwise to make positive deductions and assertions from *apparent* variations from the normal in one plate. It must be constantly borne in mind that, as a matter of routine, it is practically impossible to place the patient and the photographic plate in such relationship to one another that the coronal or frontal (side-to-side) plane of the former will lie exactly parallel with the flat surface of the latter or at a right angle to it. Any deviation of these relationships is bound to cause distortions in the *x*-ray shadows upon the plate; this is particularly true in comparing one side of the body with the other.

This matter is strikingly illustrated by an incident in the author's practice: a patient had travelled a long distance to New York, bearing with him a written opinion from a radiologist stating that "the lateral process of the fifth lumbar vertebra is impinging on the posterior wing of the ilium;" this opinion was endorsed by the family physician who accordingly sent the patient to the author for operative removal of the offending lateral process. Additional *x*-ray examinations taken with the rays passing obliquely between the lateral process of the lumbar vertebra and the wing of the ilium, showed that there was an interval of nearly one inch (see Figs. 77 and 78) between the two structures.

It should furthermore be appreciated that in many instances it is as unsafe to draw definite diagnostic conclusions from an *x*-ray examination alone, unsupported by clinical data, as it is to render an unqualified opinion on the unsupported evidence of any other single laboratory or clinical examination. That *x*-ray interpretation should always be supplemented by thorough

clinical study of the patient, is supported by much evidence. It will suffice to cite two cases, one of a patient with congenital dislocation of the hip who, with his corrective traction apparatus still applied, was sent to the *x*-ray room for examination; in due time the written report arrived from the radiologist: "Tuberculosis of the hip-joint." In the other case, on account of the obliquity of the rays as they passed through the normal fifth lumbar vertebra the following written opinion of the radiologist was stimulated: "Crushing of the body of the fifth lumbar vertebra: Diagnosis—Pott's disease."



FIG. 77.—Shows apparent impingement of last process of fifth lumbar upon ilium.

Patient traveled several hundred miles to have this process removed and the supposed impingement overcome and this radiographic error corrected. (See Fig. 78.)



FIG. 78.—Same case as Fig. 77 taken at different angle, shows no impingement of fifth lumbar on ilium.

The *X*-ray in Military Surgery.—The value of the *x*-ray in military surgery is inestimable and has been attested hourly behind the battle lines in Europe. Not alone in determining the presence and location of foreign bodies, but also the location and position of fragmented bones in swollen lacerated soft parts, is the *x*-ray of value. In these military cases, the portable *x*-ray apparatus can be taken to the fracture-bed, and is particularly useful in examining cases which are being controlled by traction in the Balkan frame in the position of neutral muscle pull.

I. INJURIES TO THE BONES AND JOINTS

The *x*-ray should be used in every case in which there is a possibility of fracture or dislocation—even in every obscure injury, particularly if it is in

the neighborhood of a joint. The importance of this is emphasized by the fact that severe sprains and contusions are frequently complicated by minute fractures which are impossible of detection by physical examination. Again, although the clinical picture is that of a single lesion, the *x*-ray frequently reveals the existence of more than one, *e.g.*, in a case in which the symptoms are those of uncomplicated dislocation of the shoulder, the *x*-ray will often reveal fracture of the neck or the greater tuberosity of the humerus or of the glenoid rim, complicating it.

On the other hand, as has just been said, the diagnosis should not be allowed to rest on the unsupported testimony of the *x*-ray alone in any case. The most thorough clinical examination is of primary and chief importance. To justly and intelligently revise or correct the results of treatment of old injuries or to offer a prognosis in these or in recent ones, requires thorough, painstaking, physical examination in addition to a careful radiological study.

A thoroughly good *x*-ray plate is *essential*. Blurred or under-exposed plates are worse than useless. They show only the gross lesions and mask minute pathology, such as cracks, greenstick fractures, small detached fragments of bone, early tuberculous or other pathological lesions, etc. It is also essential to be able to interpret the *x*-ray appearance of *normal* bones and joints from every angle.

Fluoroscopy is unreliable for the detection of any but advanced pathological lesions and all *fractures without displacement*, although it may be used to locate the position or fragments or the movements of broken bone. It cannot be used as a substitute for the skiagram.

Methods of Examination.—In examining a fracture, exposure should be made from two different angles and as near right angles as possible—laterally and anteroposteriorly. Stereoscopy is valuable and is often indispensable, particularly in cases of the shoulder which can be viewed from one side only. It is necessary to place the tube directly over the seat of fracture, otherwise distortion will be so great that there will be much error regarding the relationship of the parts. The plate for the normal side should be placed in exactly the same position as the other, for checking purposes.

If the fracture has already been "set," the *x*-ray examination should be made through the splints or other appliances; the presence of any metallic substance across the seat of fracture should be avoided. If the alignment is not satisfactory, it should be corrected, and other radiograms taken to confirm the correction. In pathological lesions with sinuses, the injection of bismuth paste and the use of the flexible probe or catheter before exposure may be of great service in locating the lesion. This is especially true about the pelvis and spine.

Fractures.—Careful scrutiny is necessary to detect any break in the outline of the bone or in the structure of the cancellous tissue. It must be borne in mind that minute lesions in the neighborhood of joints are the hardest to detect and the most important to diagnosticate accurately, from the standpoint of both diagnosis and treatment. This usually necessitates exposure from two opposite angles. Radiograms taken at subsequent periods of repair are important in following the convalescence. Calcification begins in two weeks to three months after fracture, and is hastened by perfect apposition of the fragments. Prior to the onset of calcification, the callus is tran-parent to the *x*-rays; it is first indicated by faint indefinite shadows in the angles between the fragments; later, the dense irregular mass of callus may give a shadow as deep as bone. Years after the fracture has occurred, it may be impossible to detect any evidence of its previous existence. Even spurs and angles become rounded off.

By means of the *x*-ray there can also be demonstrated impaction, nonunion, the position of a spur or fragment which may be causing pressure, and the pathological condition of the fragments. No operative procedure on bone should ever be undertaken without a thorough preliminary *x*-ray examination.

In spontaneous fractures the *x*-ray examination reveals, as a rule, unmistakable evidence of the contributing cause, such as faulty development, malnutrition, general or local bone disease (osteomyelitis, carcinoma, sarcoma, Charcot's disease, bone cyst, osteitis fibrosa, etc.).

Dislocations.—*X*-ray examination is imperative in these cases, especially to exclude the possibility of fracture. A second *x*-ray examination should be made after the dislocation has been reduced. In long-standing cases, *x*-ray examination is also essential before reduction is attempted, for the reason that advanced ossification of torn periosteum may completely fill the socket, preventing reduction and necessitating an open operation, etc.

Examination of Special Regions.—Certain standard positions for the limb and tube for each joint are necessary to avoid distortion. Since the shadows of the structures nearest the plate will be revealed with the greatest definition, those parts of the joint which it is desired to study most particularly should be placed in contact with the negative.

(*a*) *Spinal Column.*—An anteroposterior view (except in the cervical region) and made with the patient lying with his back on the plate is the most feasible in adults. The lateral or oblique view is of great importance in studying the vertebral body. In the case of the lower dorsal or lumbar vertebræ, the intestines should be thoroughly evacuated before the exposure is made. Careful scrutiny of the radiogram should be made for signs of injury, *e.g.*, fracture of the transverse processes, cracks in the bodies of the vertebræ; disease or crushing of the body (indicated by asymmetry of outline or diminution of the distance between two adjacent vertebræ on account of telescoping). Fractures and dislocations of the vertebræ are best shown by a lateral view.

(*b*) *Shoulder.*—An anteroposterior or the reverse position is the most satisfactory. The anticathode is placed over the center of the glenoid cavity, to avoid distortion. Misinterpretations: The acromioclavicular articulation in the anteroposterior view appears unduly large; notching of the scapula just below the glenoid (mistaken for fracture); the coracoid is not clear on account of foreshortening.

(*c*) *Elbow.*—Two views should be taken: anteroposterior with the arm fully extended, and another from the external surface with the forearm flexed to a right angle. Fissures in the lower end of the humerus often cause filling up of the olecranon or coronoid fossæ with callus, with resultant limitation of flexion or extension, and can be detected by lateral view.

(*d*) *Wrist.*—The best positions for this joint are dorsal, and lateral from each side. *Hand* is best taken with the palm laid on the plate, and a second exposure made in the lateral position.

(*e*) *Pelvis and Hip-joint.*—Here the exposure is best made in one plane, the patient lying either on the plate with the tube over him, or *vice versa*. For the hip, the feet must be symmetrically placed, parallel and with the inner borders of the feet in contact. In a radiogram of the hip, turning out of the foot foreshortens the shadow of the neck and simulates coxa valga. It is impossible to get an individual in a plane absolutely parallel with the *x*-ray plate, therefore in joints like the sacro-iliac or in certain portions of the spine, they will rarely seem entirely symmetrical, although radiologists often expect that such will be the case. In the normal hip-joint, a line following

the under surface of the neck of the femur and the upper border of the obturator foramen makes an unbroken arch, a very important point in diagnosis of fracture of neck of the femur.

(*f*) *Knee.*—Anteroposterior and lateral views should be taken; the lateral is the best view of the patella. One or more sesamoid bones normally present in the outer head of the gastrocnemius may be mistaken for detached fragments of bone or loose bodies in the joint.

(*g*) *Ankle.*—Lateral and anteroposterior views should both be taken. In the case of the latter, the patient lies on his back with the plate beneath the ankle. *Foot*, if the radiogram is to be taken from the dorsal aspect, the sole of the foot should rest on the plate.

Myositis Ossificans.—The radiogram shows a characteristic mass of irregular flaky shadows in the muscle substance. These shadows are much more flaky and more definite than those in periosteal sarcoma, and moreover they are not connected with bone. Similar shadows in ossification of torn periosteum (*e.g.*, after dislocations) may cause confusion in early cases.

II. DISEASE OF THE BONES AND JOINTS

Pathological changes in the bones are discernible by *x*-rays, and can be differentiated by changes in their contour and structure, many times very early.

Contour is affected by (*a*) disturbance of metabolism (*e.g.*, rickets); (*b*) local rarefaction or erosion (tuberculosis); (*c*) formation of new bone (*e.g.*, periostitis).

Structural Changes.—The chief of these is increased translucency to the *x*-ray; aside from the various bone diseases about to be considered, it is seen in old age, cachexia, alcoholism, and disuse (*e.g.*, after fractures and other injuries). Translucency is due to absorption of lime-salts. It may be so extreme, in extensive tubercular or paralytic lesions, that one can scarcely distinguish bones from soft parts. In addition to translucency, cancellous bone is "sketchy" in appearance.

1. **Simple Inflammatory Periostitis.**—Although *x*-ray evidence of periostitis and the formation of new subperiosteal bone are seen in the radiograms of numerous bone diseases (*e.g.*, osteomyelitis, syphilis, beneath the bases of chronic leg ulcers, varicose or syphilitic, and certain stages of tuberculous disease) simple inflammatory periostitis is usually of traumatic origin.

In acute cases of this lesion, the *x*-ray shows no change in the outline of the affected bone, even though considerable swelling is present clinically. In subacute and chronic cases, a faint shadow appears along the shaft, due to the deposit of lime-salts in the thickened periosteum. These appearances are noted in both the septic and the traumatic cases.

In septic cases early signs of osteitis of the underlying bone are indicated by increased translucency, which is later superseded by necrosis and abscess formation with their characteristic *x*-ray appearances.

2. **Septic Diseases of the Bone.**—(*a*) *Osteomyelitis.*—Increased translucency of the bone is very marked, together with evidence of necrosis and subperiosteal bone formation; the latter being indicated by irregular thickening of the shaft. The cortical bone is eroded and has a worm-eaten appearance. Advanced cases are characterized by clear spaces representing cavities. The walls of cavities in active cases are irregularly necrotic and pale (deficiency of lime-salts), while in quiescent cases the walls are more sharply delimited. It is often difficult to detect sequestra, because of rapid solution

of their lime-salts, and this difficulty is increased by disseminated lime-salts in the bone débris scattered through the pus in which the sequestra lie. In other cases, sequestra are discernible.

(*b*) *Localized Bone Abscess.*—Early evidence of this condition consists of local pain in the bone and later a distinct circumscribed clear space denoting a cavity.

3. **Tuberculosis.**—(*a*) *In tuberculous disease of the joints*, the picture varies in early cases with the position of the primary lesion. If the synovial membrane and cartilage are affected, the only change noticeable in the bones is an increased translucency due to halisteresis. The presence of fluid adds to the indistinctness, so that an ill-defined picture of the bones, provided the remainder in the radiogram is clear, is often pathognomonic of a tuberculous joint.

(*b*) When the *bones of the joint* are the seat of primary disease, erosion of the bony outline, or a focus within the bone (the latter as a light area with indefinite blurred boundaries), and in advanced lesions necrosis and in the presence of secondary infection, sequestra, are the characteristic features.

(*c*) *Shaft of Bone.*—When the tuberculous process is confined to the shaft of the bone (an extremely rare event in this country), there is usually localized focus with subsequent necrosis and periosteal thickening; in rare cases, periostitis only, with evidence of lime salts in the different portions. In the active stages of tuberculosis of bone, the limits of the lesion are ill-defined; the margins of the focus show necrosis, while the surrounding bone is more transparent. Pus impregnated with lime-salts within the cavities increases the blurred effect of the picture.

(*d*) *Quiescent or Healed Foci.*—Here the details are better defined, and the outlines more sharply limited. A clearly defined picture of a tuberculous focus indicates that the process is quiescent, because new bone formation occurs only under these conditions. Thickening of the cortex (particularly in old tuberculous disease of the carpus and tarsus) occurs to compensate for the destruction of cancellous bone. In such a case, the outlines appear penciled. The same condition is found in several other diseases in which atrophy of bone has occurred. *Tuberculous sinuses* are best defined in the *x*-ray picture after a preliminary injection with Beck's subnitrate paste, which acts in some cases also as a therapeutic measure (see Chapter I. Tuberculosis of the Bones and Joints).

4. **Syphilis.**—The *x*-ray picture is not distinctive of this disease. (*a*) The commonest appearance is a coarsely striated thickening of the cortex at the expense of the medulla, the thickening being localized or diffuse. (*b*) In other cases, the lesion is a periostitis, with a considerable formation of new subperiosteal bone. (*c*) Localized gummata and rarefaction, with the formation of new bone in the periphery, are evident in still other cases. Thickening of the periosteum also occurs beneath syphilitic ulcers.

5. **Posttyphoid Bone Lesions.**—Increased thickness of the cortex, with corresponding narrowing of the medullary lumen characterizes some cases. In other cases, there is evidence of primary infectious periostitis with necrosis of the underlying bone, which may go on to abscess formation. If the spine is the seat of disease, the vertebræ are blurred and indistinct, but the absorption of the intervertebral disks (such as appear in Pott's disease) is not extensive.

6. **Osteitis Deformans** (Paget's Disease).—The *x*-ray picture is that of a rarefying osteitis from absorption of compact bone, resulting in the formation of large, irregular and ill-defined Haversian canals filled with soft cellular tissue, with an overdeposit of calcium salts in certain areas. The radiogram

shows a uniform mortar-like appearance of the interior of the bone, with less density toward the center. There is no definite bone architecture. There may be some cystic formation, and fractures may be apparent. In far advanced cases, the mortar-like shadow of the bone is remarkably uniform.

7. **Osteitis Fibrosa.**—The essential change is replacement of the bone structure by fibrous tissue, which is indicated in the *x*-ray picture by longitudinal striæ containing cysts. There may be an actual increase in the length of the bone, indicated by bending of the shaft. The bone is expanded. The appearance of a well-defined cyst is characteristic. As a rule, only one bone is involved. The disease may be mistaken for sarcoma. Fractures are frequent.

8. **Osteomalacia.**—The most striking radiographic feature is extreme thinning of the bone. The shaft is narrowed, the compact layer reduced to a thin line, and the medullary canal disproportionately wide. The cancellous tissue is greatly rarefied, has a light sketchy appearance, and hence it is difficult to get a good impression of it in the *x*-ray plate. The extremities of the long bones are expanded, having a "drumstick" appearance.

9. **Newgrowths.**—(*a*) *Enchondromata.*—These tumors appear in early life, affect the fingers and toes principally, and are often multiple. In the *x*-ray examination, they appear as a relatively transparent mass, growing within the bone and causing its expansion. In fact, the bone may be reduced to a mere shell which may undergo rupture. Trabeculæ of bone may still be detected within the cartilaginous mass, causing the tumor to resemble a bone cyst; in fact, it may be impossible to differentiate the two in the *x*-ray picture. The location of these tumors near the epiphyseal cartilage is important.

(*b*) *Exostoses.*—These are easily recognized upon *x*-ray examination as spurs or irregular masses directly continuous with the shaft. The clinical diagnosis is often very obscure, but is conclusively established by the *x*-ray. When the exostosis is in the form of a spur, its free end is usually turned away from the nearest joint. They are frequently caused by gonococcus infection elsewhere and are usually located in the insertions of tendons or fascia, as the plantar fascia insertions into the os calcis.

(*c*) *Sarcoma.*—This neoplasm is more frequent than carcinoma. Its *x*-ray appearance differs according to the position and character of the growth. *Periosteal sarcoma* is characterized by periosteal thickening and blurred irregular shadows, indicating incomplete ossification radiating from the center of the growth; the appearance is wholly unlike the regular layer of new bone in chronic periostitis or the dense well-defined flaky masses in myositis ossificans, and is to the trained eye unmistakable. *Central sarcoma:* The *x*-ray picture varies according to the rate of growth. In a rapidly growing round- or spindle-celled sarcoma, the swelling which is clinically observable to the eye shows more or less complete disappearance of bony tissue in the radiogram. It appears eaten away or scooped out. The bone may be represented by a mere shell, and in such cases the picture is pathognomonic of sarcoma. The slower growing myeloid types have a cyst-like appearance, with irregularly placed spicules of bone. An outer shell surrounds the growth, and beneath it is a thin layer of compact bone. This shell expands greatly as growth proceeds.

(*d*) *Carcinoma.*—No such enlargement of bone is apparent in the *x*-ray as one might expect from the clinical picture. The bone is irregularly eaten away and there is no attempt whatever at new bone formation. Differentiation from sarcoma is usually easy.

Differential Diagnosis of Cystic Appearances in Bones.—Any pathological process producing this appearance of structure causes increased translucency to the *x*-ray. Radiograms of such conditions reveal only the extent of the lesion and the character of its walls, and give no information as to the contents of the clear space, whether it be fluid or solid, benign or malignant. This cystic appearance is commonest in septic and tuberculous abscesses and in round- and spindle-celled sarcomata. The diagnosis of these conditions is usually cleared by a combination of clinical and radiographic data, but there is the greatest difficulty in diagnosis in the less common conditions associated with cyst formation, viz., myeloid sarcoma and benign bone cysts. In both, the clinical history is inconclusive, while the *x*-ray picture in each is almost identical.

Myeloid Sarcoma.—This tumor is much less malignant than other forms of sarcoma and rarely metastasizes, but the growth in the bone increases until it breaks through and invades the surrounding structures. The expansion is gradual, in all directions, until there is merely a thin shell of bone left as a capsule to the tumor, which thus differs from the round- and spindle-celled types, in which erosion of bone occurs before expansion has had time to advance to any great extent. The growth of this tumor is very slow, and the first clinical evidence of its existence is usually spontaneous fracture. The *x*-ray picture is that of a cyst-like area, with trabeculæ traversing it, and a thin shell of bone surrounding it as a capsule.

Benign Bone Cysts.—The radiographic appearance of these cysts is very much like that of myeloid sarcoma. There is a translucent area in the bone into which project numerous trabeculæ, while a mere shell of bone covers the tumor. Differential diagnosis can be aided by radiograms taken at intervals of a few weeks to watch the behavior and progress of the lesion, but absolute diagnosis can be made only by an exploratory operation. In their radiographic appearances enchondromata may be mistaken for benign bone cysts, but their multiplicity, situation (near epiphyseal cartilages) and clinical features serve for their differentiation.

10. **Chronic Arthritis.**—The clinical classification of the various forms of chronic arthritis is still so confused that the basis for *x*-ray differentiation is likewise insecure. The best radiographic classification is a pathological one, since the bony lesions are clearly demonstrable in this way. The character and severity of the clinical symptoms are not reliable indications of the amount of bony change to be expected by radiography. For example: it frequently happens that in a chronic case of the proliferative type of arthritis, we may clinically have great pain and stiffness, or a creaking of the joints which is both audible and palpable, while the *x*-ray offers no evidence of erosion or the presence of osteophytes.

The following *x*-ray types of chronic arthritis can be differentiated:

(*a*) *Infectious arthritis*, in which the etiological infectious agent is known (*e.g.*, gonococcus). No change whatever in the bones is appreciable by *x*-ray, with the possible exception of slight osteoporosis from halisteresis, the result of disuse. In early cases it is impossible to distinguish this type from recent cases of proliferative and degenerative types of chronic arthritis.

(*b*) *Proliferative Type.*—The *x*-ray shows atrophy of the articular cartilage (narrowing of the articular space between the bone ends) and atrophy and erosion of the bones of the joint. The articular ends of the bones exhibit greatly increased translucency, and marked changes in outline may be present as the result of erosion.

(*c*) *Degenerative Type* (Osteo-arthritis).—The *x*-ray shows increased density of the articular ends of the bones, with lipping and the presence of

osteophytes. In this type, prominence of the radiographic changes may be greatly in excess of the clinical signs and symptoms.

Gouty arthritis cannot always be distinguished from the degenerative type by means of the *x*-ray alone. In all the types of chronic arthritis, a striking feature of the *x*-ray picture is the sharp, clear-cut outline and structure of the bones of the affected joints in contrast with the haziness characteristic of tuberculous joints.

Spondylitis Deformans.—The *x*-ray picture is the same as in other manifestations of the degenerative type of chronic arthritis. The vertebræ are asymmetrical in the early cases, chiefly at the corners of the bodies and in the transverse processes. In chronic lesions, bridges of bone which finally fuse, unite the vertebral bodies, giving a smooth, rounded outline to the spine in the radiogram.

11. **Pulmonary Osteo-arthropathy.**—Bythell and Barclay (*X*-ray Diagnosis and Treatment, Oxford University Press, 1912, p. 29) state that in the only example of this rare condition coming under their observation, the metacarpal, metatarsal, and certain of the long bones showed changes exactly similar to those seen in osteomalacia, and that *x*-ray treatment not only relieved the pain in the affected bone but appeared to completely arrest the disease.

12. **Neurotrophic Diseases.**—Atrophy of the cartilage with exposure of the articular ends of the bones is the initial joint change in these conditions, and in chronic cases eburnation of the ends of the bones with the presence of loose bodies due to osseous formation in the synovial membrane of the joint. In the fulminating types with rapid course, the *x*-ray reveals destruction of the articular ends of the bones and multiple fragments of bone within the joint. Absorption of lime salts and blurring from the presence of fluid in the synovial cavity frequently make it difficult to obtain a good *x*-ray plate.

Acromegaly.—The radiogram shows a uniform increase in the cancellous tissue of the affected bones of the extremities, an irregular thickening of the cranial bones, and, in some cases a lateral view shows increase in the size of the sella turcica, probably associated with hypertrophy of the pituitary body.

13. **Loose Bodies in the Joints.**—These foreign bodies are recognizable in the radiogram only if ossified, and therefore a negative report of their existence is not conclusive. In a certain percentage of cases, a sesamoid bone can be seen in the outer head of the gastrocnemius and may be mistaken for a loose foreign body.

14. **Cervical Ribs.**—The surgeon should make absolutely certain of his diagnosis by means of the *x*-ray before operation is undertaken. A very large transverse process of the seventh cervical vertebra may be mistaken for a cervical rib; a point of differentiation is the line of articulation which exists between the rib and the transverse process. However, a large transverse process may produce the same symptoms as a cervical rib. A cervical rib is rarely more than an inch in length. It has also been noted that owing to the forward curve of its extremity, it may appear shorter in the radiogram than is found to be the case at operation.

X-RAY EXAMINATION OF BONES AND JOINTS IN CHILDREN

The feature distinguishing *x*-ray examination of the bones and joints in children from that in adults, is the presence of the epiphyseal cartilages. By means of the *x*-ray, one can demonstrate not only local disease (*e.g.*, tuberculous epiphysitis) but also epiphyseal involvement in the general diseases of childhood (*e.g.*, rickets and achondroplasia). Delayed ossification and

abnormal types of growth are also demonstrable by *x*-ray, hence one can distinguish between lesions resulting from disease and those which are the result of developmental anomalies.

It is necessary to have an exact knowledge of the *x*-ray appearance of the normal epiphyses at different ages. The long bones are all cartilaginous until the end of the third month of fetal life, after which centers of ossification appear in the diaphyses at regular intervals, gradually merging into one another. The only epiphyses visible by means of the *x*-ray in the newborn are those at the lower end of the femur and upper end of the tibia. The dates on which ossification of the epiphyses are recognizable by radiography, and their union to the shafts of the bone are given in the following table by Bythell and Barclay (*loc. cit.*, p. 34).

	Date of appearance of epiphysis	Date of union with shaft
Clavicle	18th to 20th year	22d to 25th year
Humerus: head	3d to 4th month	20th to 25th year
great tuberosity	2d year	
lesser tuberosity	3d year	
lower epiphysis		
capitellum	End of 2d year	18th year
trochlea	10th to 13th year	
external condyle	12th year	
internal epicondyle	5th year	18th year
Radius: head	5th to 6th year	16th to 19th year
lower epiphysis	2d to 3d year	17th year
Ulna: olecranon	10th to 13th year	20th to 21st year
lower epiphysis	5th to 7th year	20th to 24th year
styloid process	4th year	20th to 24th year
Metacarpals: thumb (base)	7th to 8th year	16th to 20th year
other digits (heads)	4th to 6th year	16th to 20th year
Phalanges	4th year	18th to 20th year
Femur: upper epiphysis	Shortly after birth	18th to 22d year
great trochanter	4th to 5th year	18th to 22d year
lesser trochanter	13th to 14th year	17th to 22d year
lower epiphysis	9th fetal month	22d to 24th year
Patella	3d year.	
Tibia: upper epiphysis	9th fetal month	18th to 24th year
lower epiphysis	1st to 2d year	16th to 18th year
tubercle (if separate)	12th to 13th year	18th to 24th year
Fibula: upper epiphysis	4th to 5th year	20th to 22d year
lower epiphysis	2d to 3d year	21st to 23d year
Metatarsals	3d to 8th year	16th to 19th year
Phalanges	5th to 8th year	18th to 20th year
Epiphysis of os calcis	7th to 10th year	16th to 18th year

A zone of proliferation separates the epiphysis from the diaphysis as long as growth continues. The appearance of this zone is of the greatest importance in *x*-ray diagnosis. Growth and ossification take place here in very orderly fashion in a normal case, in which the edges are smooth and even (but not sharply defined as in achondroplasia) the zone clear and transparent, and the epiphysis evenly ossified, with a smooth and rounded articular surface.

Even in the absence of a definite pathological lesion, development of the epiphysis may be affected by several factors (*e.g.*, social and hygienic) so that radiograms of different children may vary under normal conditions.

The pathological lesions of the bones and joints in children may be grouped according as they are the result of local or general factors. The *x*-ray is especially useful in the latter group, because one can often detect the

presence of general disease by changes in the epiphysis before the symptom complex has become established.

A. **General Diseases.**—(1) *Chondrodystrophia Fetalis.*—This disease affects the fetal bones from the third to the sixth month of gestation, but only those in which ossification begins prior to the sixth fetal month. There is more or less osteoporosis with curvature of the shafts, while fractures are less common. Radiographic features: The zone of proliferation is very narrow, and the margins are sharply defined, due to the presence of a layer of dense bone on the surfaces of epiphysis and diaphysis. The outlines of all the bones are sharply marked. Subperiosteal bone formation is a feature of certain cases.

2. *Osteogenesis Imperfecta.*—This occurs in fetal life or early infancy. There are frequently multiple intra-uterine fractures if the affection is of fetal origin. The great tendency to fracture is due to extreme fragility and brittleness of the bones and is a leading clinical sign. Radiographic features: The bones are broader than normal. In structure they present a coarse-meshed cancellous tissue which frequently appears cystic in places. The compact layer is thin. Increased translucency to the *x*-rays is marked. Epiphyses are usually uninvolved. Bending of the bones may occur with fracture.

3. *Rickets.*—Radiography may reveal existence of the disease before any clinical symptoms make their appearance. The epiphyses and subperiosteal ossification are both abnormal. Asymmetry and increased activity are the characteristic features. Epiphysis: The cartilage cells form asymmetrical masses; there is no arrangement in orderly rows; the zone of proliferation is wider than normal and ill-defined on account of the irregular margins of epiphysis and diaphysis. Subperiosteal bone formation shows also asymmetrical overactivity, viz., the periosteum is thickened and hyperemic, the cortex thin, and the medullary spaces increased in size. Osteoid tissue replaces the bony trabeculæ of the medulla, due to the deficiency in lime salts and produces a cystic appearance. Swelling of the bone ends is due to the formation of irregular spongy bone. Deformities and fractures are common, the amount of callus in the latter being very great. Greenstick fracture is frequent and occurs from insignificant causes. After the acute stage has subsided, lime salts deposited in the osteoid tissue convert the bones into a dense structure which become deformed by fracture and curvature.

Radiographic features are characteristic: The epiphysis is small relative to the age of the child, while the end of the diaphysis is disproportionate to the size of the epiphysis. The epiphysis is ragged in appearance from irregular ossification, and the zone of proliferation is ill-defined, very wide, and its diaphyseal border irregular. The cortex is thin, but the periosteum is thickened in the shafts of the long bones. The medullary cavity is wide, very transparent, and may be cystic. In the event of curvature, the bone is thickened on its concave side. Coxa vara is frequent, while coxa valga occurs less often. Flat or beaked pelvis, due to upward and inward thrust of the femora, is a common distortion.

4. *Scurvy.*—Subperiosteal hemorrhage is the chief radiographic feature distinguishing it from rickets. A common site for the hematoma is the middle of the shaft of the femur. At later stages, organization of the clot and eventually the deposit of lime-salts increase the density of the shadow.

5. *Osteomalacia.*—This affection is very rare in childhood. The radiographic features are the same as those in the adult.

Differential diagnosis of the above-mentioned general diseases of childhood by *x*-ray usually presents no difficulty, but such diagnosis should be made

only in conjunction with thorough clinical examination. The points of differentiation are very clearly and concisely stated by Bythell and Barclay, as follows: (Ref. "*X*-ray Diagnosis and Treatment," Bythell and Barclay, p. 40).

"In *achondroplasia* the short limbs present a great contrast to the large body; the enlargement of the ends of the long bones is caused solely by the overgrowth of the subperiosteal bone, whereas in rickets it is partly due to epiphyseal activity; the zone of proliferation is narrowed, is straight and regular, and is bordered by a line of dense bone. *Osteogenesis imperfecta* occurs in early infancy, the bones give the appearance of being expanded; they are very translucent to the rays, and are composed of a coarse cancellous tissue. In *rickets* the distinguishing features are the ragged epiphysis and the broad and irregular zone of proliferation; the picture as a whole suggests a disorderly method of growth. In *scurvy* the diagnosis is established by the detection of subperiosteal hemorrhage; radiography in such cases may be very useful in eliminating fracture, tubercular disease, and sarcoma."

B. **Local Affections of the Bones and Joints.**—*Traumatic Lesions.*—It must be borne in mind that the epiphysis is not yet united to the shaft, and in the case of all injuries to children in the neighborhood of the joints it is essential to examine them carefully. Care must be exercised not to mistake the line of an ununited epiphysis for a separation resulting from fracture. Great confusion may be caused the amateur by the relations of the different centers of ossification in the lower epiphysis of the humerus. Another common mistake is to diagnose an ununited epiphysis of the os calcis as fracture of that bone.

1. *Separation of the Epiphysis and Juxta-epiphyseal Fracture.*—The first is a traumatic lesion of childhood, occurring more frequently in adolescence and the usual sites are the hip, the elbow and wrist. But of equal or even greater frequency as the result of trauma in the neighborhood of a joint is fracture just above the epiphyseal line, the detached epiphysis carrying with it irregular fragments of the diaphysis.

2. *Schlatter's Disease.*—This consists of enlargement of the tibial tubercle. It occurs only in children in whom a separate epiphysis has developed in the tibial tubercle. Pain and swelling result from insignificant traumata (such as a fall, kick, or even sudden strain on the ligamentum patellæ), or a succession of slight traumatisms. A mistaken diagnosis of tuberculosis of the tibial tubercle may be established unless radiographic examination is made.

Radiographic features: A separate epiphysis is noted in the tubercle. Irregular ossification is seen by comparison with the *x*-ray plate of the sound tibia. The tubercle is frequently displaced forward, and there is occasionally a deposit of lime-salts in the ligamentum patellæ.

3. *Tuberculosis.*—This is the commonest localized affection of the bones and joints in children. It is only when the bony components of the joint are involved that the *x*-ray is of particular value. This osseous involvement varies in the different joints, viz., in the knee the process occurs many months before the bones of the joint are sufficiently involved to show in a radiogram, while in the hip the bones very early show lesion. In the bones, tuberculous osteitis, although rare, may be mistaken for syphilis. Cavity formation and pronounced rarefaction are often marked in the advanced tuberculous bone lesions.

Tuberculous Spondylitis.—The diagnosis rests upon erosion, asymmetry, and collapse or telescoping of the vertebral bodies. Scant ossification in young children may obscure the diagnosis, but the presence of abscess formation offers aid, especially if the sinuses are injected with bismuth.

4. *Syphilis.*—The congenital form consists of acute epiphysitis and periostitis. The former is characterized by erosion and occasionally separa-

tion or dislocation. The latter, by thickening and the formation of dense layers of new bone.

The differential diagnosis between the osseous lesions of tuberculosis and syphilis, is as follows: Early tuberculous joints are characterized by increased translucency, a general blurred appearance of the bone ends and erosion; in such cases, there is no question of the diagnosis, but in rare instances of tuberculous periostitis there may be confusion in the diagnosis. In tuberculous disease, the periosteum is thickened slightly and there is little or no new bone along the shaft, caseation and erosion taking place before this can occur. In syphilis, there are great periosteal thickening and dense layers of new bone.

5. *Osteomyelitis.*—The only radiographic feature not noted in adults is the fact that the pathological lesion stops at the epiphyseal line. The disease almost never begins in the epiphysis, and never invades the epiphysis from a primary lesion in the diaphysis.

6. *Lesions of the Hip-joint in Children.*—The *x*-ray is of the greatest value in these cases. It may clear the diagnosis when the clinical picture is very confusing, *e.g.*, there may be only slight pain, limping, waddling gait, or a disconnected series of vague complaints, and yet the *x*-ray may at once show congenital dislocation or early tuberculosis. Traumatic lesions (the commonest being fracture, separation of the upper epiphysis of the femur or of the several parts of the acetabulum) usually offer no difficulty in *x*-ray diagnosis.

(*a*) A traumatic lesion to which the author has drawn particular attention in his writings, is traumatic epiphyseal coxa vara. The relatively slight etiological factor and the occasionally indefinite character of the symptoms may without the aid of röntgenology cause the lesion to be overlooked. The lesion consists either of a separation of the upper epiphysis of the femur or an impacted fracture extending through the neck and into the epiphyseal line.

(*b*) *Cervical Coxa Vara and Coxa Valga.*—These two conditions are immediately apparent in a radiogram in cases where the clinical picture is indefinite. Rickets is usually associated with these deformities, and its presence should be sought in other bones.

(*c*) *Congenital Dislocation of the Hip.*—Even though the clinical diagnosis is certain, a radiogram is indispensable in every case, particularly for the purpose of ascertaining the exact position of the head and the condition of the acetabulum and femur. Thin, underdeveloped and ill-formed head and neck are often seen, the result of arrested development of the upper epiphysis of the femur. Coxa valga of varying degree is almost uniformly present. The acetabulum is usually shallow and poorly developed, particularly the iliac portion of its rim. After the reduction of a dislocation, a radiogram should be taken within the first few weeks and before the plaster-of-Paris dressings have been removed to ascertain whether or not the head of the femur is still in place.

(*d*) *Tuberculosis of the Hip* (Fig. 79).—A definite diagnosis can often be made by means of the *x*-ray in very early cases in young children, even where the clinical picture is incomplete. However, in certain early cases the radiogram is of no particular diagnostic value. The initial lesion is usually an erosion of the upper epiphysis of the femur or acetabulum, although in some cases a large focus may exist in the femoral neck and develop to a considerable extent before the epiphyses of the joint are involved. Rarefaction of the bony elements making up the joint may be the only radiographic manifestation in a very early case.

After the joint has become involved, destruction of the rim of the acetabu-

lum follows the gradual shifting upward of the head ("travelling acetabulum"); again, a pathological dislocation or fracture may be found. In other cases the process may be confined to the cartilage or membrane in older children, in which case the radiographic picture is not so characteristic. Suggestive elements in the radiographic field are thinning of the bones of the joint and loss of definition from synovial effusion. In obscure cases



FIG. 79.—This radiograph illustrates the indispensable rôle of rontgenology in the diagnosis and treatment of bone and joint lesions. This case of very severe tuberculous disease of the hip is seen to be accompanied by such advanced osteoparesis of the bony elements of the joint that they are nearly as permeable to the *x*-ray as are the surrounding soft parts. The knowledge of this condition is of extreme value to the surgeon in planning his treatment—it means that the joint is liable to be crushed and mechanically disintegrated if it is not protected with extreme care from spasm and weight-bearing.

bismuth injection of the sinus will aid in localizing the primary tuberculous focus.

(*c*) *Syphilitic Disease of the Hip-joint.*—This is relatively uncommon in children. The radiogram frequently shows erosion of the upper epiphysis of the femur, periostitis of the shaft, and occasionally pathological dislocation.

CHAPTER V

THE ELECTRO-OPERATIVE BONE OUTFIT AND TECHNIC OF ITS USAGE. OTHER INSTRUMENTS

In view of the almost universal application of electric power to artisanship in all its wide fields of usefulness, the moulding of metal and wood, driving lathes, etc., it is a curious fact that its applicability to surgical procedures had apparently been rarely considered until the introduction by the author, in 1911, of his bone-grafting operation for Pott's disease. The speedy and accurate execution of this operation, as well as many other operations which he has devised, impelled him to develop the motor outfit which bears his name. Until that time, the bone transplant had been so infrequently employed as a surgical agent that no special technic had been developed for its removal and modelling. The electric motor circular single saw (Doyen) had been used for skull work—driven either by a flexible shaft from a motor on a near-by stand, or by the Hartley-Kenyon apparatus where the cutting tool is attached directly to the motor shaft—and it had not been used in any systematic way for the removal or the modelling of bone transplants or in plastic surgery of any kind, whether involving bone-graft or not.

The author began his spinal work by removing the graft from the tibia with chisel and mallet, and later made use of the Gigli saw. It was soon found that these methods were not only slow and grossly inaccurate but that they presented the dangers of bruising, cracking, or fracturing the graft or tibia, or both. This is especially true in adult patients, on account of the brittleness and thickness of the cortex. In the child, on account of the small diameter of the bone, the danger of fracture is evident, although the graft is obtained by means of hand tools with much less difficulty and much less likelihood of fracturing it.

Also in obtaining grafts 8 inches or more in length, it was found that the hand-tool methods were crude—requiring too much time, tiring the surgeon, and unnecessarily shocking the patient. In removing the graft with the chisel and mallet, the graft must be handled and shaped many times after its removal, whereas with the circular motor-driven twin saw a pattern marked in the periosteum with a scalpel can be followed accurately and the graft shaped *in situ* during its removal. In other words, "machine work" is employed and an automatic fit secured. The graft pattern is usually obtained by bending a flexible probe or leaden bar into the prepared graft-bed, whose shape is transferred to the tibial surface from which the transplant is to be removed.

In modelling the graft into dowels, wedges, and inlays, and in making use of the different well-known mechanical devices, such as tongue-and-groove joints, dove-tail joints, mortises, etc., the motor outfit is even more indispensable. An accurate cabinet-maker's fit may mean success in many instances where an ordinary crude coaptation would mean failure. Especially is this true in ununited fractures.

It is only when the most precise cabinet-maker's fit has been secured, that

the full influence of Roux' law of frictional stimulation to osteogenesis is obtained. This is a most potent influence in stimulating callus formation or securing union and when not employed often results in one of the most ugly tragedies of all surgery, *i.e.*, non-union either after fracture—Lane-plated or not—or after plastic bone procedures with or without the bone-graft.

The scepticism as to the value of the graft, with the difficulty in obtaining and moulding it, has undoubtedly delayed the development of the use of this most valuable surgical agent. It is difficult to give an adequate reason for the fact that in the rapid advance of general surgery the work of osteoplasty has, until very recently, stood practically at a standstill—especially in view of the fact that Ollier in 1858, from extensive animal experiments and surgical work, although working in the pre-antiseptic era, furnished abundant evidence that the autoplastic bone-graft survived and lived when consisting of cortex, periosteum, and endosteum, and when implanted into a bony defect where it had function to perform.

As in many other fields of endeavor, electric power has been an important factor in their development, and in this instance it has been the chief influence in placing this valuable agent (the bone-graft) at the disposal of the surgeon. In recent years the generalization of the use of electricity for lighting, heating, and power purposes in most hospitals, private dwellings, etc., has also been a potent influence, and has enabled the surgeon always to be in reach of the necessary power for operating his motor outfit, whether he is operating in the city, suburban hospital, or private dwelling. The electric automobile or storage battery can also be made to furnish a movable source of electric supply which can be utilized at any time or place.

The ideal electro-motor outfit should measure up to the following requirements:

1. It should permit of the thorough and rapid sterilization of every part which comes in contact with the surgeon or the field of operation, including the electric cable for transmitting the power.

2. It should permit of ready application to all types of osteoplasty, whether situated superficially or in a deep wound; whether the work to be done is the procuring of a graft, the preparation of its bed, the drilling of holes, the removal of bone for the correction of deformity or curing disease, or to allow the proper approximation and alignment of bone fragments in cases of fracture.

3. It should permit accurate control and guidance of the motor cutting tool in all wounds and at *all angles*.

4. It should permit easy and convenient control of the electric current.

5. It should be light in weight, small in bulk, and permit of easy transportation.

6. The motor should be universal and adapted to all types of motor current.

7. The motor instruments—saws of different types, drills, dowel-shapers, etc.—should be held in place in the motor by an automatic catch, favoring their speedy interchange.

8. The motor cutting tools should be constructed similarly to those long used by the artisan for working hard materials, and should be of sufficient variety to meet every requirement of bone carpentry or machine work, and should include all kinds of automatic tools. The twin-saw for inlay work should be so constructed that it can readily be adjusted—to the fraction of a millimeter—by the gloved hands of the surgeon at the operating table. Dowel-shapers should have interchangeable cutters of sizes varying sufficiently to meet all requirements.

9. The motor should furnish enough power to drive rapidly a saw or large drill through the thickest human cortex without tendency to stall.

The author's outfit described in this chapter has been carefully devised and perfected to fulfill all the above requirements. The motor has been devised and developed during its application in over 1600 bone-graft operations on the human subject in addition to many other plastic procedures and in extensive animal experimentation. The motor tool is attached directly to the motor shaft; the motor is covered by an adjustable sterilizable shell, enabling the surgeon to hold the motor in his hands while the tool is cutting; the weight of the motor itself (only 4 pounds) has been found to be an advantage rather than a drawback in its application. The weight of the entire outfit is so small that it can be packed in an instrument bag and carried conveniently, long distances, and it is believed that it completely fulfills every demand.

Description of Outfit (Fig. 80).—The author's electric operating bone set is run by a small universal motor, *i.e.*, one which will operate without re-adjustment on all types of electric currents, such as direct, alternating, or of varying cycles. If it is to be used on a 220-volt direct current, a 100-c.p. 220-volt lamp should be placed in series with motor. Electrical engineers have found it impossible to construct a light motor which will resist deterioration from repeated boiling of the motor itself or from any other safe type of sterilization. Both the insulating material and the carbon brushes are liable to disintegration from repeated subjection to heat. Therefore, the Hartley-Kenyon method of removable, sterilizable shells has been adopted, as it seemed by all means the most desirable.

The apparatus consists of the above-mentioned small portable motor with a sterilizable shell which is divided into two parts so that it can be removed for boiling. A guide handle, which can also be boiled, is adjusted at right angles to the small end of the motor over the shell. A foot switch is supplied to make and break the electric current. A long electroconducting cord is provided to transmit the current from the source of supply. In one end of the cable is a fitting, to be inserted into the electric supply, and on the other is a connection for the foot switch. Midway between the two terminals, a connecting block is mounted, into which is inserted the connecting cord leading to the operating motor. This connecting cord has fitted to one end of it a metal tube and connection for the motor, and is the only portion of the electric cable necessary to be boiled.

The foot switch is an important part of the outfit. It enables the surgeon not only to turn the current completely on and off, but by means of a rheostat-control he is able accurately to control the speed of the cutting tool. This is a valuable feature of the outfit in that it allows the surgeon to start the operation of his drill at a low speed, thus permitting him to drill hard cortical bone without difficulty. This low speed is of great advantage because it prevents the drill from wandering about over a wide area of the bone before it becomes fixed at the desired point of entry. The foot switch possesses many other evident advantages, but the author wishes to emphasize one in particular, *that the thin, rapidly revolving saw is the safest and best for bone work.* This statement is based on his use of the motor outfit in more than 2500 cases.

The slowly revolving saw is much more likely to catch and pull sideways in the soft tissues or bone. The heat generated by a rapidly revolving sharp saw with proper set, making 6000 revolutions per minute, has been proved by careful experimental work to be only about 5°F. higher than that generated by a saw revolving at 500 revolutions per minute.

The author wishes to take this opportunity to deprecate the efforts of certain individuals who in their endeavor to exploit a modification of his motor outfit have misled the profession by their claims that a slowly revolving saw will not produce destructive heat. Any surgeon can prove to his own satisfaction the danger of generating heat by means of any friction-producing tool, although it may be moving slowly.

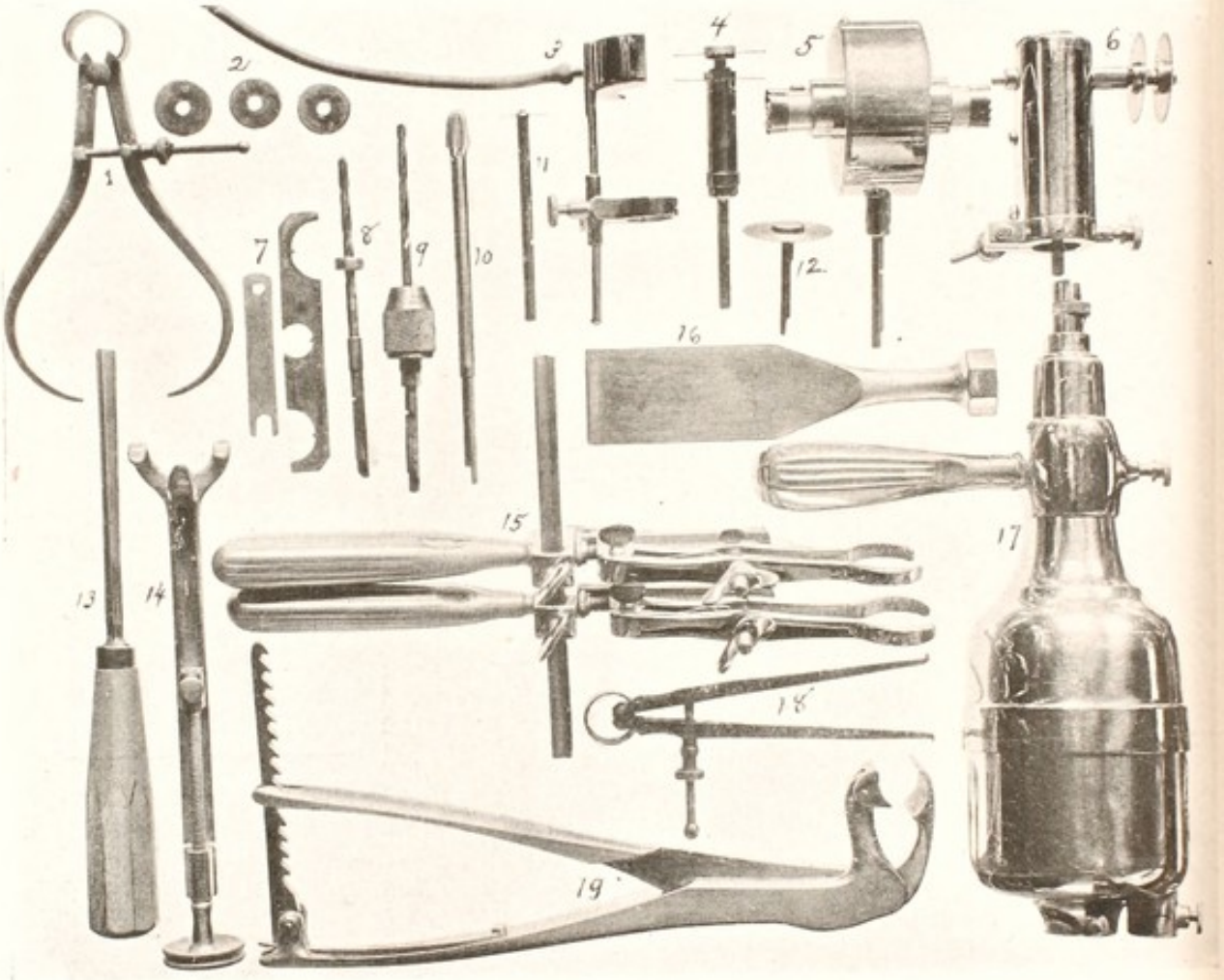


FIG. 80.—Author's armamentarium for bone work. 1. Calipers. 2. Doyen washers or guards for motor saw. 3. Spray and guard for saw. 4. Twin saw. 5. Dowelling instrument or lathe. 6. Right angle twin saw. 7. Wrenches for twin saw and drill chuck. 8. Drill with guard to prevent it penetrating too deeply. 9. Drill chuck and small drill in place. 10. Burr for drilling fractured neck of femur for peg graft. 11. Small circular saw. 12. Large saw. 13. Carver's gouge. 14. Lowman fracture clamp. 15. Berg fracture clamp. 16. Wide osteotome for splitting spinous processes for the insertion of bone-graft for Pott's disease. 17. Surgical electric motor. 18. Compasses. 19. Lambotte fracture clamp, large and small.

For example, if one will take a Gigli saw and rapidly cut a piece of hard cortical bone, it will be found that destructive heat can be readily produced; and yet in this instance the Gigli saw is moving much less rapidly than the motor saw, even when the latter is revolving as slowly as 500 revolutions per minute. Again, if the surgeon will perform the same experiment with a saline drip constantly flowing to the cutting portion of the Gigli saw, he will find that the saw not only cuts much more smoothly and readily, but that *heat is not generated*. It is a well-known fact that when cutting hard materials in machine shops, oil, water or some other fluid is kept in constant

contact with the edge of the cutting tool. For the same reason, in using the motor-saw, *the saline drip not only entirely prevents the generation of heat but it enables the saw to cut more smoothly and safely.*

Moreover, from a mechanical standpoint, we cannot see why a rapidly revolving saw should generate more heat than a slowly revolving saw, for this reason:

AD and $A'D'$ being of equal length, if the saw, S, making only 100 revolutions per minute takes ten minutes to cut the distance AD, the saw S', moving at rate of 1000 revolutions per minute would consume only one-tenth of the time, or one minute, in cutting an equal distance, $A'D'$; so that the frictional coefficient is the same in either instance.

Again, an additional advantage of the rapidly revolving saw may be found in certain phenomena, strikingly illustrated in the recent world war, viz.: the laceration of non-vital tissues by means of a slowly travelling (spent) projectile causes such a bombardment of the central nervous system by a storm of afferent noci impulses that the smitten soldier drops in his track in a profound state of shock; on the other hand, when these same tissues are severed by a projectile travelling at high velocity (providing the vital centers are uninjured), the soldier walks on with scarcely any evidence of vasomotor disturbance. In the latter contingency, the nervous end-organs are severed by a cutting agent travelling at such speed that the nerve filaments are unable to deluge the central nervous system with a wave of afferent noci impulses, because they are incapable of taking up such stimuli produced by a severing agent travelling at such speed. An analogous set of circumstances may be presumed to exist, to a certain degree, in the cutting of bone—which likewise involves a severance of nerve-endings—by a slowly revolving saw on the one hand and a rapidly revolving saw on the other.

The author by necessity began his early bone-graft operations with hand tools, and after he had developed his motor-driven instruments, he found that shock had almost entirely disappeared in the course of operations of reasonable length. He is uncertain as to whether this absence of shock is to be attributed to Crile's theory of anoci-association or to a shortening of the time of operation brought about by motor-driven tools.

Cutting Instruments.—The *single* (circular) *saw*, about $1\frac{1}{4}$ inches in diameter, with Doyen graduated washers or guards, is used more than any other of the cutting tools. These saws are made of the best steel and are very thin, and are held on the shafts by means of nuts which allow the saw-blades to be changed when they become dulled.

In the *single saw*, the type of tooth should always be that of a cross-cutting saw (*i.e.*, a tooth shaped like an isosceles triangle), and should have very little "set." An excess of "set" is as dangerous as a "rip-saw" tooth, because they both favor the *catching* of the saw in the soft tissues and in bone and allow the saw to pull sideways. Such an accident may not only cause laceration of important vessels and nerves, but in some instances has actually resulted in amputation of the surgeon's or the assistant's fingers.

The *twin-saw* is so constructed that it can be adjusted to any desired width, even to the fraction of a millimeter. It consists of two single saws, which can be used singly or together. Each is mounted on a separate shaft, one of which is hollow so that the other can be inserted into it and so bring them at any distance apart that may be desired, according to the size of the bone being operated upon and the width of the graft or gutter to be formed.

In determining the size of the inlay or gutter, the saw-teeth are placed on the exposed bone in the manner of a compass or calipers, in order to

determine the width of the inlay or gutter, and, with the saws undisturbed, the shaft of the proximal one is prevented from turning by placing the accompanying wrench or a heavy clamp on the flat-sided end of the small shaft while the operator locks the saws together by turning away from him the proximal saw, protecting his gloved right hand with a piece of gauze over the saw teeth. The distance between the twin blades may be increased after making the gutter and when removing the graft, if a tighter fit is desired.

The *dowel instrument* or *lathe* is fastened into the motor by the automatic catch, precisely as are the other cutting tools. The speed of rotation of the dowel cutter is reduced about 10 times by steel gears.

The size of the bone-graft dowel or nail is regulated by the size of the cutter which is adjusted in the lathe. The largest cutter is for turning out a bone spike for a fracture of the neck of the femur. The smallest one is for making pegs with which to hold inlay grafts in place. The medium-sized cutter is for making graft nails, such as are used for pinning the scaphoid to the head of the astragalus in an arthrodesis for advanced club-foot, or for

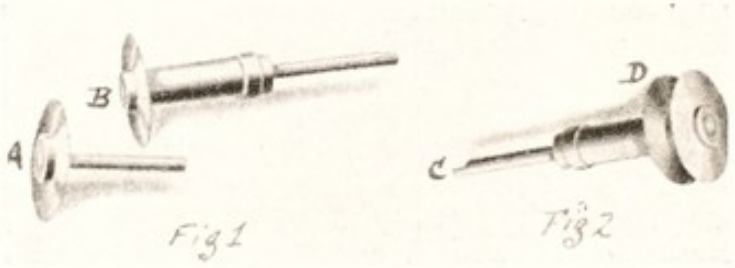


FIG. 81.—Fig. 1 is cut of author's adjustable twin-saw with the individual saws separated, either of which can be used as a single saw. When it is desirable to use them as a twin-saw, the shaft of the one to the left (*A*) is inserted into the hollow portion of the shaft of the saw to the right at (*B*), as represented in 2. The distance of the saws apart is adjusted as required by caliper measurements. The saws are then locked firmly together by placing the accompanying small wrench or a strong clamp on the flat end of the shaft at (*C*) and turning the saw (*D*) (covered with sterile sponge) with right hand. This is done quickly and causes the shaft of the distal saw (*a*) to be grasped by a compression ring in the hollow shaft of the proximal saw (see 2). The saws are released from each other by turning the proximal saw in the opposite direction. When the saws are in place in motor and in action they are covered with a spray-guard which not only furnishes a constant spray of salt solution on the saws to keep them from heating, but prevents the flying of the solution from the centrifugal action of saw. (Albee in American Journal of Surgery.)

pegging on a fractured tuberosity, or as a substitute for metal nails and screws in any situation where they might be indicated.

A cutter, after the pattern of a rotary pencil sharpener, has been added to the motor outfit for the purpose of fashioning a conical tip on a peg-graft of any size, so that it will engage in the drill hole with greater ease and to enable it to be driven through cancellous bone if desirable. These cutters can be rapidly interchanged, and slipped in and out in a moment's time. After the tip of the graft has thus been "sharpened" this conical cutter is removed and a dowel-shaper of the size desired is inserted and manipulated in the manner about to be described.

The dowel-shaper is used by first inserting it into the motor and then placing the apparatus parallel with and on the edge of the instrument table. While the assistant steadies the motor and lathe by gently pressing the same on the table, the operator, holding with a strong clamp the piece of bone to be shaped, pushes it into the dowel cutter. (A carriage to hold and direct the bone-graft into the dowel-cutter has been devised, but is omitted from the outfit to avoid unnecessary expense and because of the simplicity of

"feeding" the graft into the cutter in the manner shown). When withdrawn from the dowel-shaper, it is a perfectly round dowel and is ready to be driven into the drill hole formed by a drill of corresponding size. (The strip of bone from which the peg has been fashioned is obtained by means of the single or the twin-saw.)

The *small saw* is used for cutting the ends of the inlay graft or the strip of bone which is being removed to produce a gutter. On account of its small size ($^3/_4$ of an inch) the saw does not encroach upon the gutter walls while it is cutting across the inlay and therefore does not weaken the remaining portion of the tibia.

The *guard* with *spray* is rarely used because it obscures the surgeon's view of the saw. By extensive experience it has been found that in the majority of cases a few drops of saline solution constantly dripped from a

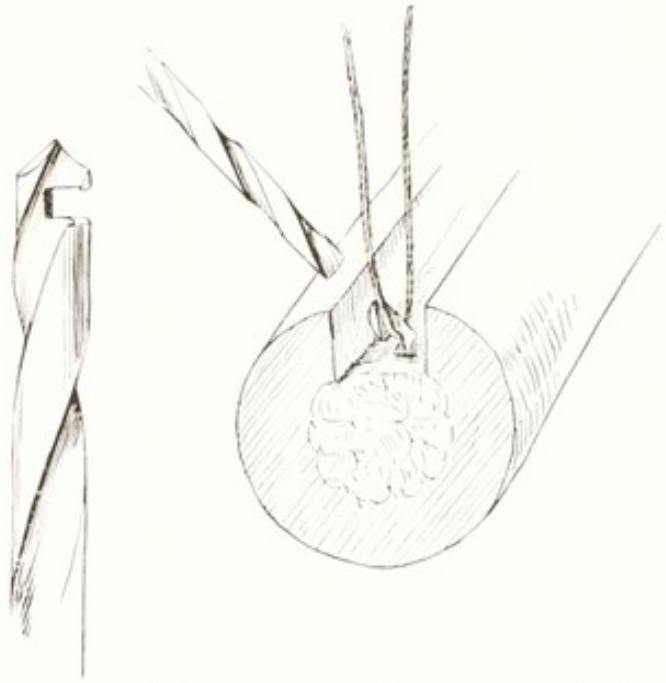


FIG. 82.—Author's motor-drill with hook to pull kangaroo tendon ligature through drill hole when the drill is withdrawn.

saturated sponge or spray syringe made for the purpose and held by an assistant serve every purpose. It is emphasized that the assistant should exercise the greatest caution in order to prevent the end of the gauze from becoming entangled in the saw, as such an accident would endanger asepsis. When employed, this guard is connected by a sterile rubber tube with a douche bag suspended over the operating table and maintains a constant spray of saline solution on the saw, preventing friction, heat, and the flying of the solution.

The *twist drills* are of the type used by the machinist for drilling metal.

The *notched drill* (Fig. 82) is a simple device but is very effective in saving time and labor. After the desired hole has been made, the motor is stopped and a ligature slipped into the notch. Upon withdrawing the drill, the ligature comes with it and thus avoids the subsequent use of a needle or other instrument for threading the ligature through the drill hole.

The author's *laminatome* (Fig. 165) facilitates cutting the vertebral arches in performing laminectomy for any purpose. The guard rests upon the dura of the spinal cord, thus preventing any possible laceration of the

membranes, while the rapidly revolving cutter, driven by motor power, removes the desired amount of bone in an incredibly short space of time.

Sterilization (Hartley-Kenyon Method).—The parts to be sterilized are first removed from the motor by releasing the plunger on the end of the electric cable so as to allow it to come out. This part of the electric cable, from the motor to the black rubber union on the connecting cord, is boiled. The handle is removed after first releasing the thumb-screw which locks it and the shell to the motor beneath, and the shells are removed and, together with the cutting tools, sterilized by boiling. The part into which the cutting instruments are inserted is removed from the motor, with the long part of the sterilized shell. This is the part which contains the automatic catch, and is sterilized with the shells. A little vaselin is placed in the shaft opening of the small end of the motor and it is then laid aside until the sterilizable parts are ready to be re-adjusted. The amount of vaselin should be no larger than the size of one-half of a split pea. The importance of avoiding an excess of vaselin cannot be too strongly emphasized because of the danger of the lubricant welling-up around the shaft and contaminating the field of operation.

After sterilization, the operator picks up the long part of the shell with his gloved hand and holds it with its large open end up. The nurse, holding the large end of the motor in the palm of her hand, inserts the other end into the recipient shell and turns the motor to the right as far as it will go, or until the arrow on the motor comes opposite the arrow on the shell. (This is the reverse of the former description of this procedure in the author's "Bone-Graft Surgery," *q.v.*, p. 58, and has been adopted because it is found to be simpler and easier of execution.) The operator can then manage the motor alone by grasping the sterile half shell which is firmly secured to the motor. The second half of the shell is placed over the other end of the motor and is locked in place to the first shell by a bayonet fitting (Fig. 83). The guide handle is placed over the neck of the motor and securely fastened by the set screw. The connecting plunger on the side of the electric cable is then inserted through the sleeve on the shell into the motor. This portion of the electric cable, with its metal tube and block connectors, is especially constructed to withstand sterilization by boiling. The corresponding connector is next inserted into the black connecting block in the central portion of the cable leading from the socket of electric supply to the foot switch, which the nurse has previously connected and arranged with the foot switch in a convenient position for the surgeon's controlling foot while he is operating. The motor is then ready for use. The saws or the cutting tools are inserted by turning them over a little to the right or the left while the knurled ring on the end of the shaft is pressed in by the operator's thumb or until the spring engages the slot on the side of the shaft of the instrument. The cutting tool is unlocked by pressing the knurled ring on the end of the shaft at the same time that the instrument is withdrawn. The action of the motor is controlled by the foot switch which makes and breaks the electric circuit, and thus the surgeon has the uninterrupted use of both hands and the most precise speed control of the cutting instruments.

This automatic control is a great improvement over the screw and screw-driver arrangement for holding cutting instruments as used previously. In certain plastic work, especially fracture work, it may be necessary at one operation to employ several different cutting tools, such as two sizes of single saws, twin-saws, different sized drills, and surgical lathe, and also to interchange these several times. The automatic catch permits of almost as speedy interchange of motor tools as of hand instruments and is a most im-

portant feature of the outfit. So far as the author is aware, this is the first automatic catch to be incorporated into an electric-motor surgical outfit, and it is almost indispensable to rapid work. Then, again, the screw-driver is a source of danger to the operator's gloved hand because while loosening or tightening the screw the motor shaft may turn, allowing the screw-driver to push by and puncture the surgeon's glove.

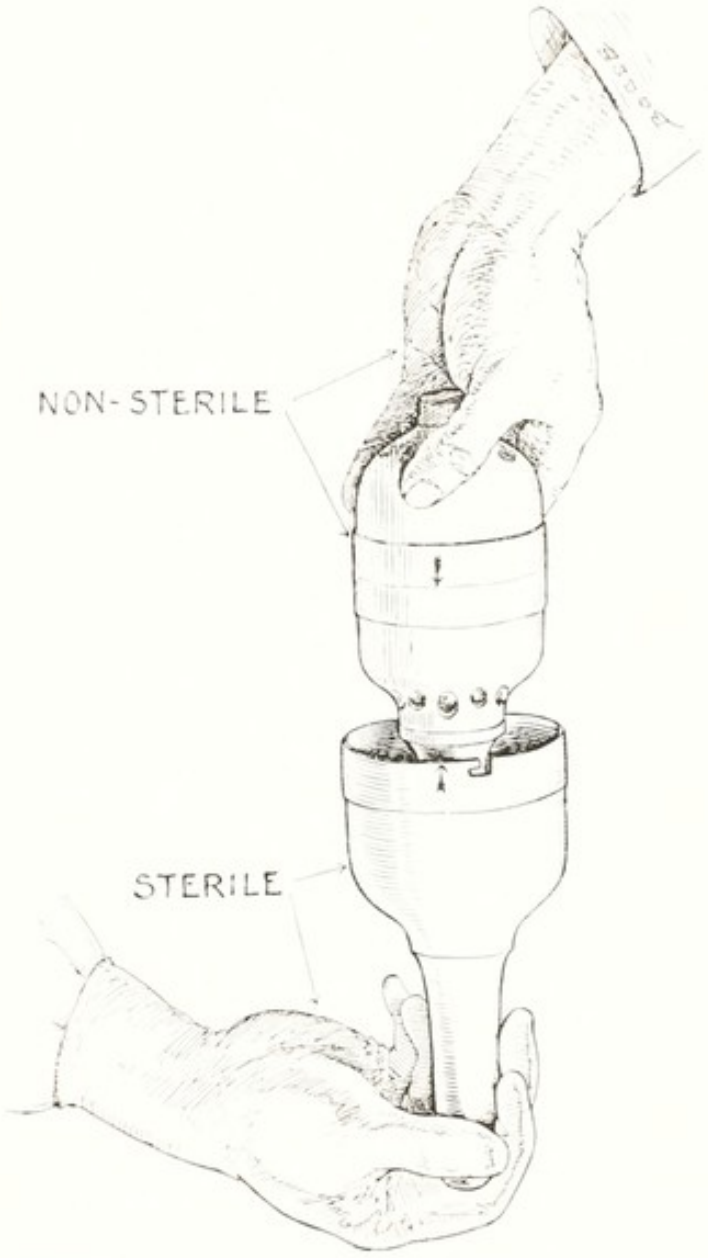


FIG. 83.—In assembling the motor, the surgeon holds the recipient shell (its orifice uppermost, like a goblet), both the shell and the surgeon's hand being sterile. An assistant (whose hands are non-sterile) inserts the shaft of the motor (which has not been sterilized) into the recipient shell and turns it to the right until it can be turned no further and the arrow on the shell comes in line with the arrow on the motor.

Technic of Using Motor.—When the motor tool is cutting, the handle, which is placed at a right angle to the long axis of the motor, is held in the operator's right hand; the base of the motor is grasped in the left hand, and the right foot manipulates the foot switch which is placed on the floor beside the operating table at a place convenient for the operator's foot. If found

necessary, the position of the motor and hands may be reversed. The various technical applications of the outfit will be illustrated in detail in the various special chapters.

The surgeon should, from the *very beginning* of his work with the motor driven instruments, *acquire the invariable habit of taking out the cutting tool from the shaft immediately upon the completion of a given maneuver, before laying the motor down upon the table.* This is very quickly and simply done by means of the knurled ring at the end of the shaft and consumes very little more time than that required to pick up and lay down any other instrument.

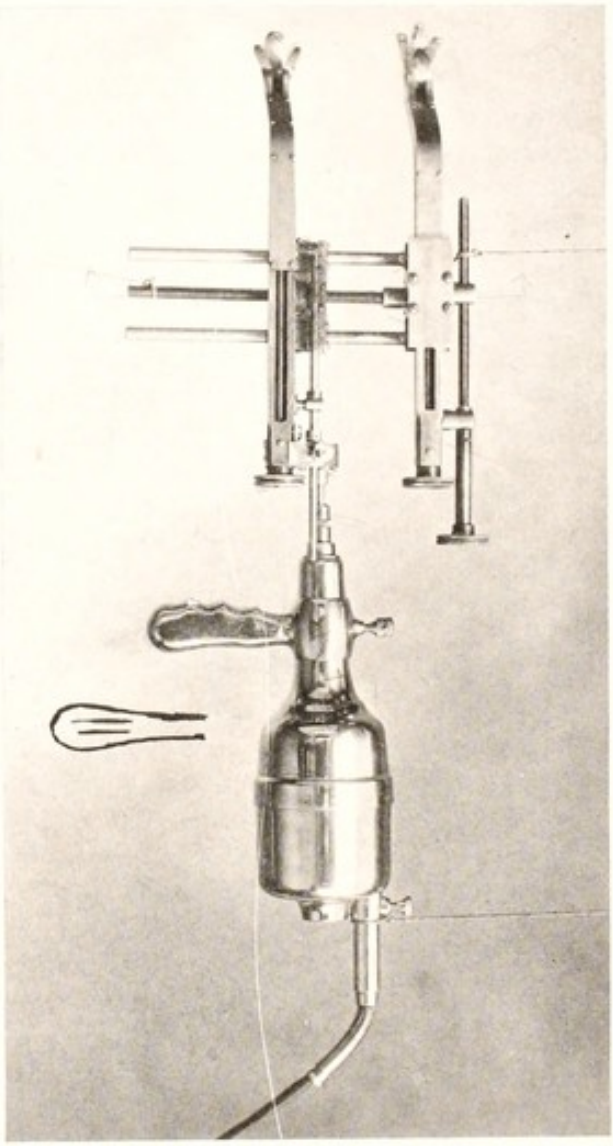


FIG. 84.—Author's electro-operative bone-jack. (For further description see text and Figs. 85 to 87.)

The motor with the cutting instrument removed is devoid of danger, while the same instrument carrying a cutting tool is a constant menace to the surgeon, and his assistants. The foot accidentally touching the switch may start the motor and a vital artery or nerve in the patient, or the fingers of the operator, nurses, or assistants may pay the penalty.

Although not a part of the motor outfit, the author's "*hip-shapers*" should be mentioned in this connection. These hip-shapers, or reamers, consist of two hemispherical, cupshaped instruments mounted in heavy solid

metal handles, one being used for smoothing off the roughened femoral head, the other for reaming out the acetabular cavity. The concave surface of one (for the femoral head) and the convex surface of the other (for the acetabulum) are furnished with radiating ridges or cutters which are put into operation by a rotary to-and-fro movement. These instruments are of great value in preparing the hip for arthroplasty.

The author's *motor bone-clamp* (Fig. 84) for distracting and properly aligning the fragments of a fractured bone, was recently devised by him in response to numerous requests for a bone-clamp to serve as an adjunct to the Albee motor outfit, which could be carried with the rest of the instruments.

The advantages which this motor-driven bone-clamp possesses over those in common use are numerous. (1) Although the instrument can be operated entirely by hand, if so desired, its adaptability to motor power is one of its

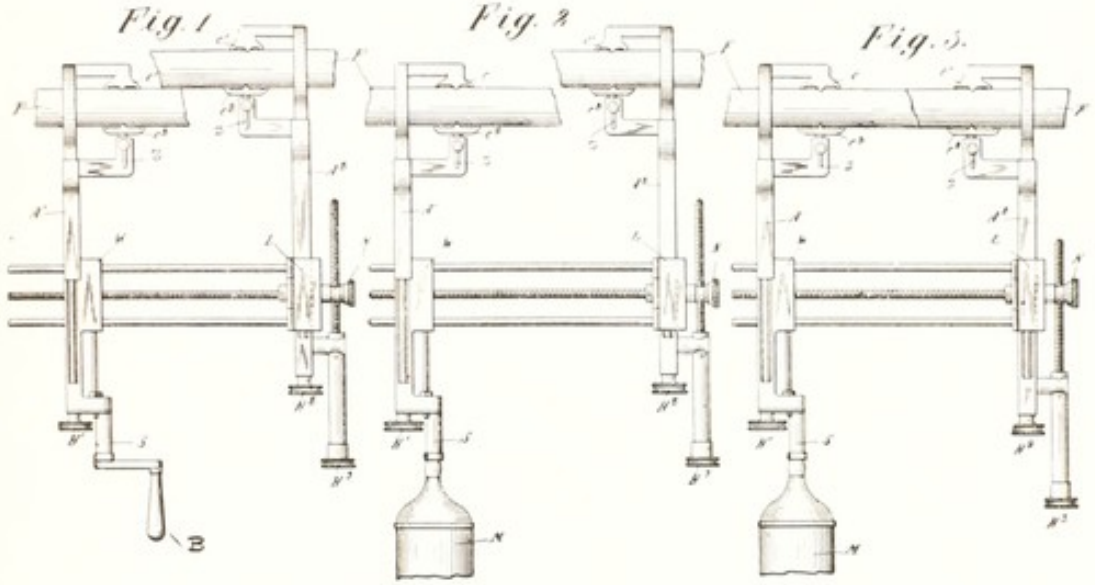


FIG. 85.—Author's bone-jack.

Fig. 1 illustrates jack in position on the bone fragments, which are overriding and laterally displaced.

Fig. 2 illustrates distraction of fragments sufficiently to allow lateral displacement to be corrected.

Fig. 3. Lateral displacement corrected by the screw adjustment at N^3.

This jack has been devised to be used as a supplement to the author's electro-operative bone outfit.

The jack arms A^1, A^2, have the same general contour as the outside of the motor so that one is easily adjusted to the other.

special features, eliminating the tiresome labor and unwarranted length of time required for manual operation. (2) Superficial incision alone is required, the jaws of the clamp being applied directly to the anterior surface of the bone, thus obviating the necessity of deep dissection of the soft parts. (3) The clamp is so devised that free access to the exposed surface of the fragments is afforded for the implantation of an inlay graft or fixation splint of whatever kind the surgeon is using, the gripping claws being so formed and placed that they do not interfere with the motor-twin-saw (Fig. 81). (4) The curve in the long arms of the clamp allows the body of the motor and the overhanging portion of the instrument to be depressed below the level of the operation-field (Fig. 86). (5) The swivel ball joint by which the claws are connected with the apparatus permits adjustment in any direction and to any size or shape of bone. (6) One arm of the instrument is removable and can be applied somewhat in the manner of obstetrical forceps. (7) It

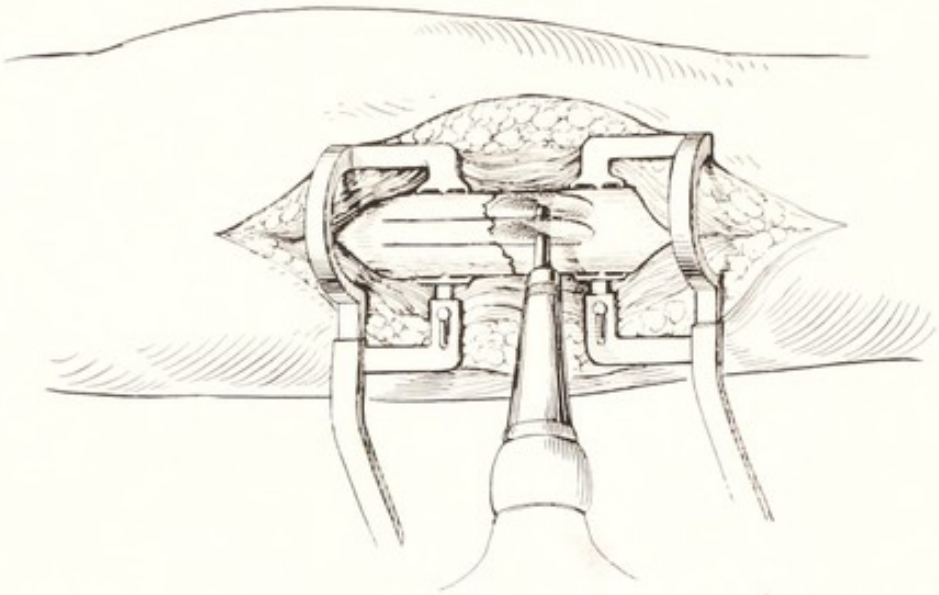
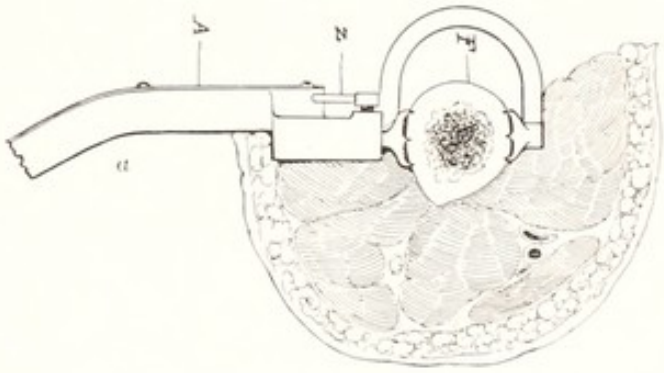
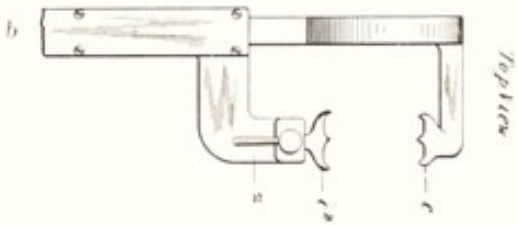


FIG. 86.—Illustrates the author's motor twin-saw at work in shaping an inlay graft and its gutter bed at the same time that the bone fragments are held in place by author's jack. The jack is so devised that it does not interfere with the use of the motor-saw.





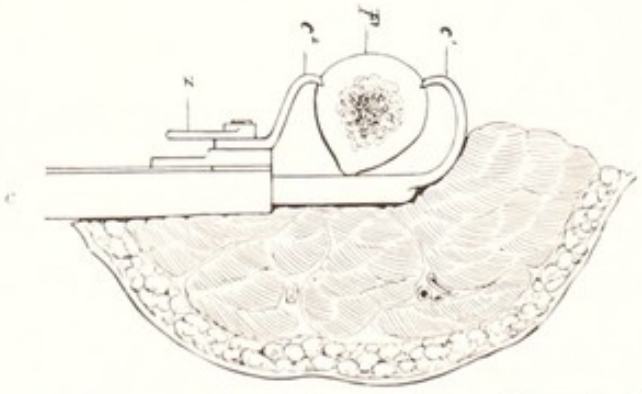


FIG. 87.—*a*, illustrates author's jack gripping the bone. It varies from other jacks or clamps in that it is put on from the incision side of the bone and does not necessitate the extensive separation of the soft parts from the bone to allow the jack or clamp to be put beneath the bone as illustrated in *c*. *b*, illustrates top view of the part of the jack which grasps the bone.

will often produce the desired amount of distraction of fragments when this is unattainable by the indirect means of the traction table—although in difficult cases it should always be used in conjunction with the latter.

Technic of Usage of the Author's Motor Bone-clamp (Figs. 84 and 86).—After the incision has been made and the soft tissues have been superficially separated from the field of operation, the clamp is applied directly to the fragments as follows: The removable arm (A_2) is detached from the instrument (or not, as seems best) and applied to either the proximal or the distal fragment, after which it is inserted in the lock-box (L) and fastened by turning lock-nut (N). By means of the lever-lock (Z), the ball-and-socket claw (C_2) is loosened so that it will adapt itself to the contour of the fragment to be grasped. The fixed arm (A_1) attached to the clamp is then applied to the other fragment. After the rigid claws (C_1) of both arms are in proper position, the swivel ball-joint claws (C_2) are moved against the bones by hand-screws (H and H_2) and locked by moving the lever-locks (Z). The motor (M) is then attached by means of its shaft (S) (Fig. 85).

The motor is then put in operation and when the desired amount of distraction has been effected (Fig. 85) by movement of the arm (A_2) in an "east and west" direction along the lateral (transverse) bars (B), the fragments are moved into alignment in the long diameter of the bone by operating H_3 as in Fig. 87. The ends of the fragments are now allowed to come into apposition by motor power by manipulating the reverse gear (not indicated in the drawing), if necessary, whereupon the fragments are ready for operation. The fragments are now in perfect alignment and apposition, with the clamp holding them firmly; the more superficial surfaces of the fragments are accessible to operation unobstructed by any part of the instrument.

CHAPTER VI

TUBERCULOUS DISEASE OF THE HIP-JOINT

Definition.—Tuberculous disease of the hip-joint (synonyms: hip disease; morbus coxæ) is a chronic destructive process caused by B. tuberculosis which results in various degrees of loss of function and deformity. Under the title "hip disease" there were formerly included a number of pathological processes, but now the term implies tuberculous disease alone.

ETIOLOGY

The modus operandi of the tubercle bacillus has already been considered in the chapter on tuberculosis of bones and joints and need not be reviewed (see Chapter I, page 26 *et seq.*).

Relative Frequency.—As regards tuberculosis, the hip is the most important of all the monarticular joints. As to frequency of involvement, it is second only to the vertebræ. In a series of over 7000 cases of tuberculous disease of the skeleton, Whitman found that over 40 per cent. were Pott's disease, while more than 28 per cent. were hip disease—the remaining 32 per cent. including all the other joints.

Age.—Whitman's data also indicate the preponderance of hip disease in the first decade, 88.1 per cent.; of this 88.1 per cent., 45.6 per cent. were from three to six years of age.

Sex.—Probably on account of their greater activity and therefore more frequent traumatism, boys are more often affected than girls (55: 44).

Side Affected.—The right side appears to be more frequently involved than the left (53 per cent. right, to 47 per cent. left).

ANATOMY OF THE HIP-JOINT

A typical *enarthrodial* (ball-and-socket) *diathrosis.* The rounded femoral head is received into the acetabulum of the pelvis.

The *cartilaginous lining* of the acetabulum is horse-shoe-shaped—broader above and behind and deficient below at the *cotyloid notch* and in the depression at the bottom of the acetabulum which is occupied by a mass of fat, covered by synovial membrane—the so-called *synovial gland.*

The *transverse ligament* bridges over the cotyloid notch, completing the acetabular rim, and converts the notch into a foramen through which articular vessels pass.

The *cotyloid ligament* is the thick fibrocartilage, triangular on section, attached to the rim of the acetabulum, deepening its cavity.

The *capsular ligament* surrounds the joint and is attached to the pelvis near the rim of the acetabulum outside the cotyloid ligament; to the femur, in front, to the intertrochanteric line; behind, to the line of junction of the middle and outer thirds of the neck; above, to the base of the great trochanter. The insertion of the capsular ligament is not in a plane at right angles with the long axis of the femoral neck but is *oblique*, and therefore every fracture of the neck of the femur is at least partially *intracapsular;* there is no such thing as an *extracapsular* variety of fracture of this structure.

Accessory Bands.—These are differentiated portions of the capsule and greatly strengthen the joint. Of these, the *iliofemoral band* (ligament of Bigelow) is the strongest and most important. It is attached above to the ilium, below and behind the anterior inferior spine; inferiorly, it spreads out triangularly to the anterior intertrochanteric line of the femur. Its inner (iliofemoral) and outer (iliotrochanteric) borders are very thick and strong; its intervening portion is thin and weak.

The *pubofemoral* band is the weakest; it extends from an area between the pectineal eminence and the cotyloid notch to the neck of the femur.

The *ischiofemoral* band extends from the ischium just below the acetabulum to the base of the great trochanter, internal to the digital fossa.



FIG. 88.—Tuberculosis of the hip-joint with sequestration.

The *ligamentum teres* (round ligament) attaches the head of the femur to the transverse ligament and the margin of the cotyloid notch.

The *synovial membrane* lines the inner surface of the capsule whence it is reflected on the neck of the femur as far as the articular margin and on the two free surfaces of the cotyloid ligament, thence being continued to the pad of fat at the bottom of the acetabulum and as a tubular covering of the ligamentum teres.

PATHOLOGY AND MORBID ANATOMY

As to the primary infection (osseous or synovial), there is a divergence of opinion, but from a practical standpoint the matter is unimportant. In a well-developed case of tuberculous hip disease, the pathological appearances are as follows:

Fluid in varying amount, and usually semipuruleut or purulent and containing more or less débris, occupies the joint cavity. The *synovial membrane* is thickened, irregular, of gray edematous appearance, and ulcerated in places. The articular *cartilage* is usually either fibrous, wasted and pitted in character, or is undergoing necrosis, dull yellow, and becomes detached in flakes. The *bones* are—as a rule—bare, of worm-eaten appearance, or present definite cavities and sequestra (Fig. 88).

The *contour* of the head and neck may be greatly altered. The head may be completely detached and found loose in the joint cavity, having been separated at its epiphyseal attachment. The neck, by absorption, may be shortened or by alteration of its angle converted into a condition of coxa vara. A "wandering acetabulum" is frequently found, and is the result of



FIG. 89.—Tuberculosis of both hip-joints. Wandering acetabulum. Gant's osteotomy has been performed on left femur for adduction deformity.

pressure by the femoral head on a diseased acetabulum, extending its cavity upward and backward (Fig. 89).

The capsular ligament is soft and relaxed, and the round ligament eroded. Ichor from the joint often traverses the peri-articular tissues, pointing as an ichor pocket in Scarpa's triangle or in the neighborhood of the great trochanter, or perforating the base of the acetabulum and appearing as a pelvic ichor pocket.

Repair by Natural Process.—If left to nature, the tuberculous process undergoes healing by absorption (rarely, by calcification) and connective-tissue encapsulation; or, if secondarily infected, by suppurative separation of diseased bone and evacuation or discharge of sequestra, accompanied by distortion of the joint or deformity of the limb, and is eventually succeeded by ankylosis (Fig. 90), usually of the fibrous type; or dislocation may follow.

SYMPTOMS AND PHYSICAL SIGNS

Symptoms

The disease is insidious in its onset and presents no cardinal symptoms pathognomonic of the affection. In the sense of attracting attention to the condition, pain and limp are the important symptoms, though several other subjective phenomena are encountered.

1. **Stiffness.**—Stiffness of the joint in the morning is an early symptom and is possibly due to diminution in the amount of synovial fluid.

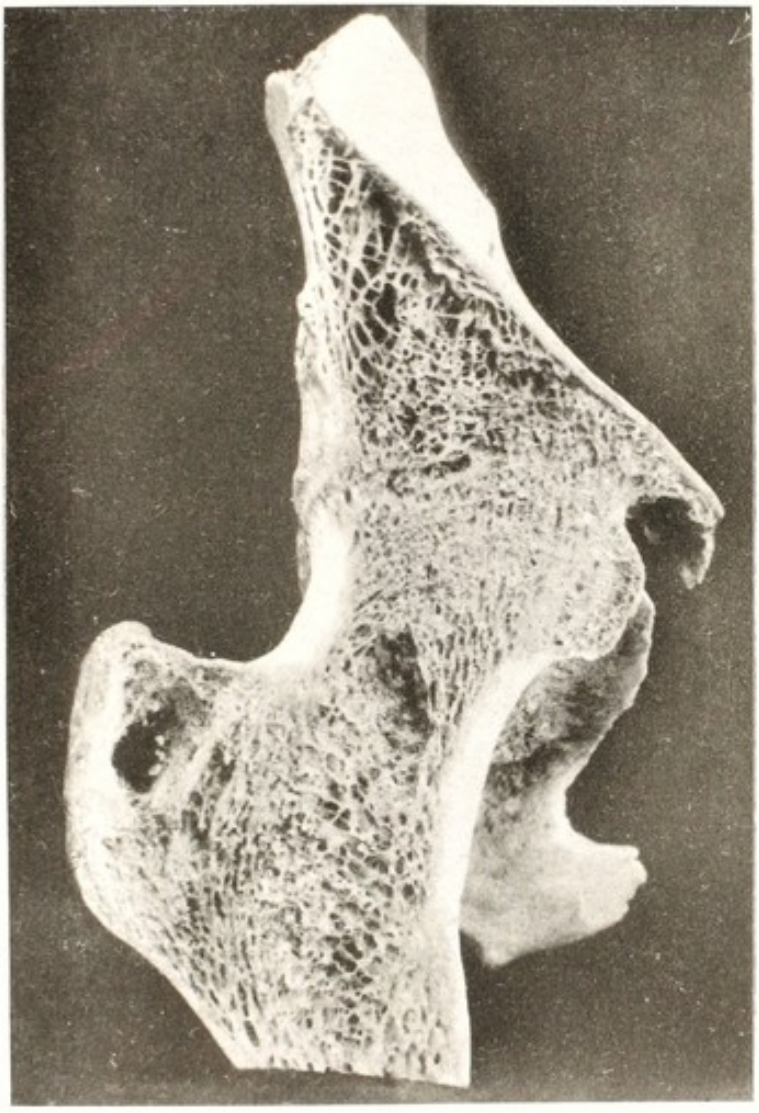


Fig. 90.—Bony ankylosis following tuberculosis of the hip. (Royal College of Surgeons, London. Phelps.)

2. **Lameness.**—Limp is also an early symptom and, in the beginning of the disease, is due to voluntary effort to avoid pain from weight-bearing by the diseased limb. The patient flexes the knee, tilts the pelvis downward, and steps with the foot everted. Lameness in the later stages of the disease, however, is due largely to structural changes within the joint and the consequent alterations in the relative positions of the bones of the limb to the trunk.

3. **Pain.**—This usually follows the nerve distribution, down the front of the thigh or at the inner side of the knee-joint. In more advanced cases, it may be localized in the joint, and is then due to pressure of adjacent bony surfaces or to increased tension on ligaments and muscles.

4. **Protective Attitudes.**—To diminish movement at the hip-joint and consequently to prevent pain, the patient learns to assume various postures—such as supporting the foot of the affected side by the toes of the sound limb and actually producing extension on the affected leg by pressure of the normal limb.

5. **Night Cries.**—These are due to sudden relaxation of muscular immobilization from the effect of sleep and may signify ulceration of the articular cartilages.

6. **Constitutional Disturbances.**—General debility is the rule from the onset. Malaise, irritability, restlessness, loss of appetite, lassitude and decrease in weight are noted. A usual evening temperature increases with ichor formation. If sinus formation and mixed infection ensue, cachexia and amyloid disease may appear.

Physical Signs

The patient should be allowed to walk before removing the clothes, and both gait and attitude studied. The subject should then be stripped and the examination conducted in a systematic and orderly fashion, beginning with observations as to general appearance and then proceeding to palpation of the joint, manipulation of the legs to determine motion, measurements, investigation for ichor formation, and radiography.

General Inspection.—The child may appear well-developed, robust and well-nourished; but is usually under weight and has a prematurely aged, anxious expression of countenance.

Distortions of the Limb.—In addition to the protective attitude of the limb noted under symptoms, other alterations of position are noteworthy, and on a basis of these abnormal positions hip-disease has been divided into three different stages.

First Stage.—Pure flexion, or flexion with slight abduction, may indicate a pure synovial lesion or disease of the bone not as yet in communication with the joint. The distortion is a voluntary effort to minimize the shock and jar upon the diseased limb.

Second Stage.—Flexion, abduction and eversion, and, on attempted correction, lordosis of the lumbar spine and apparent lengthening of the limb—the latter due to downward tilting of the pelvis to bring the abducted leg parallel with its fellow. The cause of this attitude is probably a voluntary attempt to relieve pain.

Third Stage (Fig. 91).—Flexion, adduction and inversion, with apparent or real shortening. This change of position is due to the overpowering of the abductor by the adductor muscles. Apparent shortening is produced by the necessity of uptilting the pelvis to approximate or parallel the adducted limb to its fellow. Real shortening, however, may occur as the result of absorption of the head of the femur, "wandering" of the acetabulum, atrophy of the bone, interference with metabolism and growth, coxa vara or pathological dislocation of the femoral head.

Limp.—Lameness becomes progressively worse. The child tends to drag the leg, and the rhythm of the gait changes—a long step alternating with a short one. The toe is held pointed in and the patient steps upon the

anterior part of the foot. In addition, late in the disease, the hip and knee-joints are flexed and there is lumbar lordosis.

Alteration in Contour of the Region of the Hip.—Wasting of the affected limb, especially in the gluteal region, is probably largely due to disuse. The normal fold in the groin disappears with abduction and external rotation of the leg and increases in depth with adduction and internal rotation. The position of the gluteal fold is lowered; and its depth diminishes with the leg flexed, abducted, and rotated outward; it becomes elevated and diminished in depth on flexion, adduction, and internal rotation. Adduction of the thigh makes the trochanter more prominent; on abduction, it is less. A cold abscess is usually indicated by a fullness around the joint outline. Enlargement of the iliopsoas bursa may be indicated by a bulging of the groin. The inguinal lymph-nodes may be found enlarged.

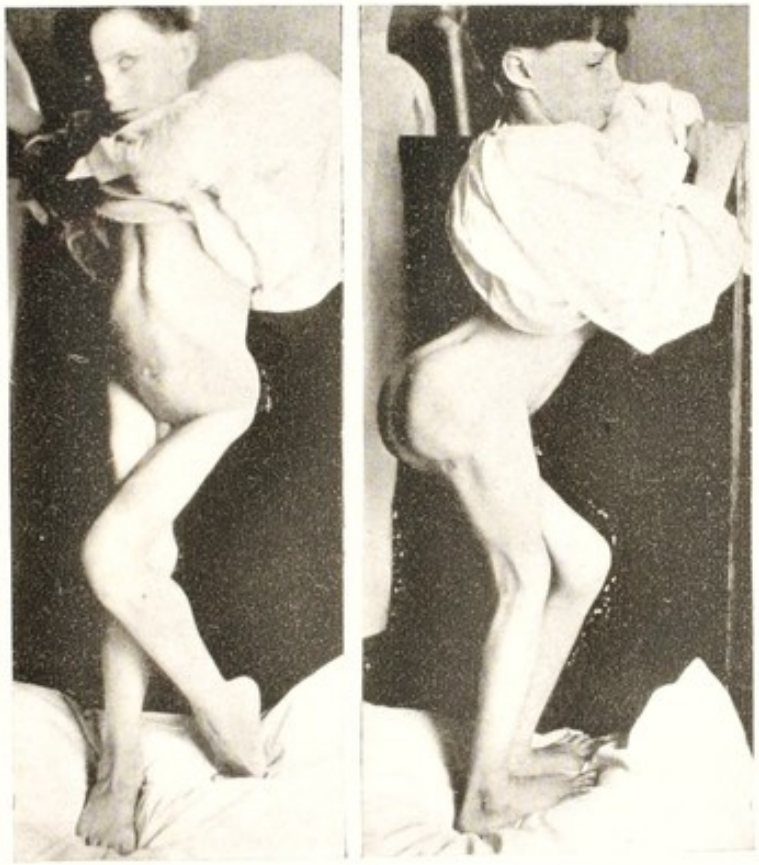


FIG. 91.—Tuberculous arthritis of both hips, exhibiting flexion-adduction and "scissors" deformity, with secondary lordosis from accommodative tilting of the pelvis.

Palpation of the Joint and Neighboring Structures.—Much information may be gained by careful palpation. Firm pressure with the fingers behind the great trochanter will often disclose an effusion into the capsule and will elicit tenderness. The surrounding soft tissue should be examined for inflammatory exudate and abscess. Digital exploration of the rectum is highly important, often revealing an intrapelvic exudate. The trochanters should be compared in size: increase is often an early accompaniment of hip disease. Careful measurements of Bryant's triangle will demonstrate the condition of the femoral head and neck—decrease indicating elevation of the trochanter from disease of these structures or of the acetabulum. The

iliac fossæ should be investigated for the presence of abscess (ichor). The groin is often filled with enlarged lymphatic glands.

Muscular Spasm.—This is a provision of nature for alleviating pain by immobilization of the affected region, and is partly reflex in character, and partly voluntary. All degrees of spasm are encountered, from tonic contraction appreciable only on the extreme of movement to rigidity so great as to suggest ankylosis.

To detect muscular spasm, flex the sound thigh, when any existing lordosis will be at once reduced and persistent flexion of the suspected hip revealed (Thomas' test); also, abduction of the sound limb will be accompanied by adduction of the affected one, and *vice versa*.

Joint Movements.—The normal movements of the hip-joint are flexion, extension, abduction, adduction, rotation, and circumduction. The range



FIG. 92.—Hyperextension at the knee following disease of the hip-joint and its treatment by the traction brace. (Whitman.)

of the first five movements should be carefully gauged, but, in view of the pain usually caused, manipulation of the sound limb should first be performed to gain the patient's confidence.

Flexion, abduction, and adduction are investigated in the dorsal position. The left hand steadies the pelvis (the fingers behind, on sacrum and ilium; the thumb in front, on the anterior-superior iliac spine), while the flexed knee is seized by the other hand and the limb is put through the desired movements.

Rotation and hyperextension are performed with the patient prone. With the open left hand on the sacrum, the fingers can palpate one trochanter, the thumb the other, while rotation is practised by grasping the foot. For hyperextension, fix the pelvis with the left hand, grasp the ankle with the right, and lift the limb. In a normal condition of the joint, hyperextension is possible to about 30 degrees.

Measurements (Figs. 93 and 94).—These include the amounts of real and apparent lengthening, real and apparent shortening; the degree of flexion, abduction, and adduction; and the circumference of the limb.

Real lengthening is extremely rare and of no practical importance. *Apparent lengthening* is due to abduction of the limb and downward tilting of the pelvis. It is the difference between the lines from umbilicus to internal malleolus on the two limbs.

Real shortening is estimated by the comparative measurement from the anterior-superior iliac spine to the internal malleolus of both sides. *Apparent shortening*, due to adduction of the femur and upward tilting of the

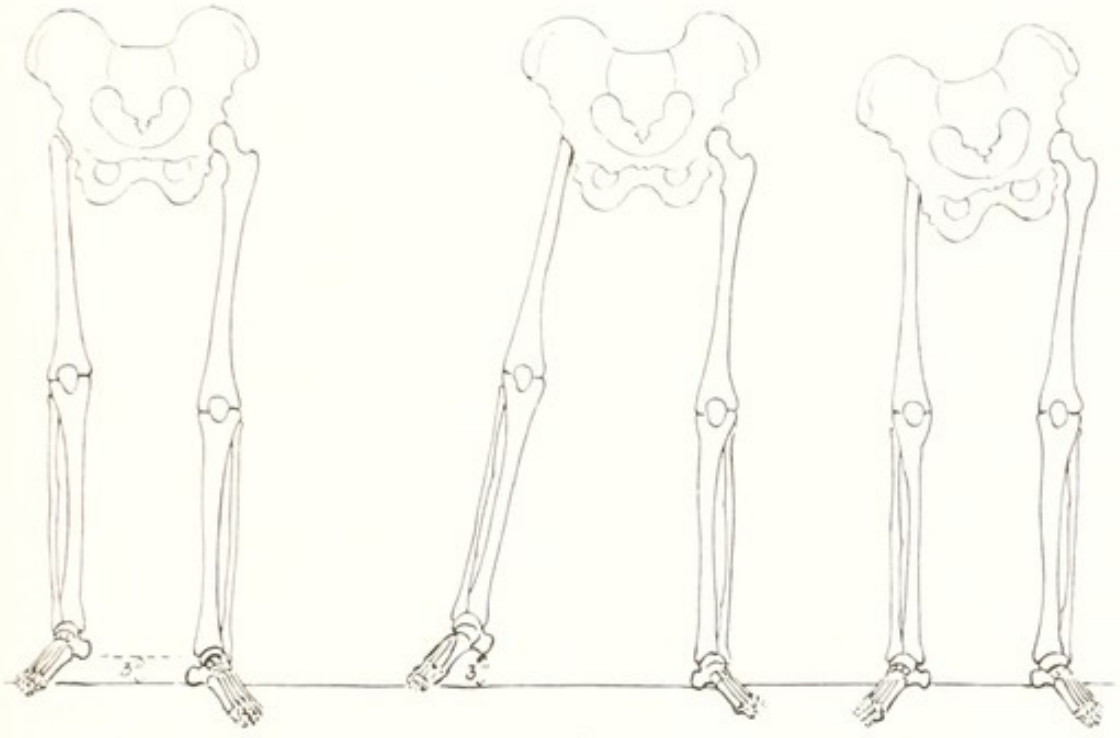


FIG. 93.—Actual shortening. *a*, illustrates destruction with actual bony shortening and ankylosis at the right hip. The limb is at right angles with the pelvis and parallel with the left limb as in walking. The foot is 3 inches from the floor demonstrating that much shortening. The measurements from the anterior superior spines to the malleoli on each side show 3 inches of shortening and about the same amount in the measurements from the umbilicus to the malleoli, *i.e.*, there is no apparent shortening. *b*, illustrates osteotomy at lesser trochanter or author's arthrodesis operation on the hip-joint, and right limb placed in an amount of abduction or obtuse angle with pelvis estimated to be sufficient to make up for the actual bony shortening. *c*, illustrates new relation of limb with pelvis after operation. The pelvis is at an obtuse angle with femur and tilted down sufficient to make up for the actual bony shortening.

pelvis on the affected side, is measured by lines from the umbilicus to the internal malleolus.

Degree of Flexion.—With the patient flat on his back upon a table, raise the extended limb by the toes until lordosis is overcome and the lumbar vertebræ touch the table. Have the leg held in this position by an assistant, and with a tape measure off 24 inches from the table along a line corresponding with the direction of the femur. From this point on the leg, drop a perpendicular line to the table. The number of inches in the latter line can be read as degrees of flexion of the thigh by consulting Kingsley's table.

KINGSLEY'S TABLE FOR COMPUTING DEGREES OF FLEXION OF THE HIP

0.5 inch 1°	6.5 inches 16°	12.5 inches 31°	18.5 inches 50°
1.0 inch 2°	7.0 inches 17°	13.0 inches 33°	19.0 inches 52°
1.5 inches 3°	7.5 inches 19°	13.5 inches 34°	19.5 inches 54°
2.0 inches 4°	8.0 inches 20°	14.0 inches 36°	20.0 inches 56°
2.5 inches 6°	8.5 inches 21°	14.5 inches 37°	20.5 inches 58°
3.0 inches 7°	9.0 inches 22°	15.0 inches 39°	21.0 inches 60°
3.5 inches 9°	9.5 inches 24°	15.5 inches 40°	21.5 inches 63°
4.0 inches 10°	10.0 inches 25°	16.0 inches 42°	22.0 inches 67°
4.5 inches 11°	10.5 inches 27°	16.5 inches 43°	22.5 inches 70°
5.0 inches 12°	11.0 inches 28°	17.0 inches 45°	23.0 inches 75°
5.5 inches 14°	11.5 inches 29°	17.5 inches 47°	23.5 inches 80°
6.0 inches 15°	12.0 inches 30°	18.0 inches 48°	24.0 inches 90°

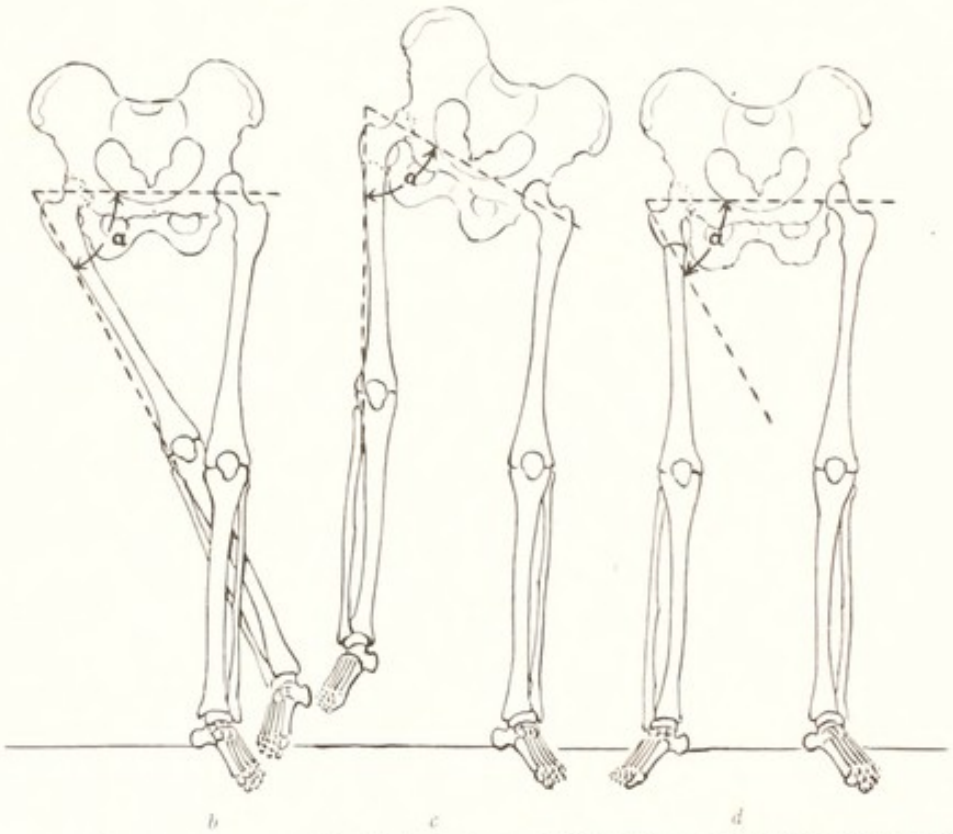


FIG. 94.—Apparent or practical shortening. *b*, illustrates ankylosis of right hip without actual bony shortening with limb in a position of adduction, the limbs crossed and the angle with the pelvis an acute one. There is shortening according to measurements from umbilicus to internal malleoli. There is no shortening in measurements from anterior superior spines to the internal malleoli of each side. *c*, illustrates the limbs parallel as in the act of walking, with the large amount of shortening of the limb as a result of the adduction deformity and the consequent tilting up of the pelvis. The angle between limb and pelvis remains the same as in *b*. *d*, a circular osteotomy has been done at the lesser trochanter, the adduction corrected and the limb placed at a right angle with the pelvis. With the limbs parallel as in walking the pelvis is in a plane horizontal to the floor and it is seen that the apparent shortening has been entirely overcome and both feet are on the floor. That is, the measurements from the umbilicus to the internal malleoli show no shortening. (Mathematical exactness is not considered.)

Estimation of Abduction and Adduction.—To get the degree of these deformities, Lovett has devised an efficient system, viz.:

With the patient in the dorsal position, legs parallel, obtain three sets of measurements for the two legs: (*a*) From anterior-superior spine to internal malleolus; (*b*) from umbilicus to internal malleolus; (*c*) between an-

terior-superior spines. If the apparent shortening exceeds the measured shortening, the affected limb is adducted; if it is less, the position is one of abduction.

To use the accompanying table of Lovett to obtain the degree of deformity, apply two figures, (*a*) the difference in inches between the real and the apparent shortening, and (*b*) the distance between the anterior-superior spines. Apply the former to the extreme left-hand vertical column of figures and follow it to the right to the column containing the figure you have found for measurement between the anterior-superior spines, where the degree of deformity will be found.

LOVETT'S TABLE FOR COMPUTING DEGREE OF DISTORTION OF THE LIMB

Distances between Anterior-superior Spines in Inches

	3	3½	4	4½	5	5½	6	6½	7	7½	8	8½	9	9½	10	11	12	13
¼	5°	4°	4°	3°	3°	2°	2°	2°	2°	2°	2°	2°	2°	1°	1°	1°	1°	1°
½	10	8	7	6	5	5	4	4	4	4	4	4	4	3	3	3	3	2
¾	14	12	11	10	8	8	7	7	6	6	5	5	5	4	4	4	3	3
1	19	17	14	13	11	10	9	9	8	7	7	7	6	6	6	5	5	4
1¼	25	21	18	16	14	13	12	11	10	9	9	8	8	7	7	7	6	6
1½	30	25	22	19	17	15	14	13	12	12	11	10	10	9	9	8	7	7
1¾	36	30	26	23	20	18	17	15	14	13	13	12	11	10	10	9	8	8
2	42	35	30	26	23	21	19	18	16	15	14	14	13	12	12	10	10	9
2¼		40	34	30	26	24	21	20	19	17	16	15	14	14	13	12	11	10
2½			39	34	29	27	24	22	21	19	18	17	16	15	14	13	12	11
2¾				38	32	29	27	25	23	21	20	19	18	17	16	14	13	12
3				42	35	32	29	27	25	23	22	21	19	18	18	16	14	12
3¼					39	36	32	30	27	26	25	22	21	20	19	17	15	14
3½						40	35	33	30	28	26	24	23	22	21	19	17	16
3¾							38	35	32	30	28	26	25	23	22	20	18	17
4							42	38	35	32	30	28	26	25	23	21	19	18

Circumference.—Atrophy of the hip, thigh, and leg is an early feature. The muscles are not soft and flabby, but tense and firm. A tape-measure should be passed around corresponding planes in thigh and leg, and the measurement compared in the two limbs.

Ichor Pocket (Abscess Formation).—Ichor is usually primarily formed within the joint, but it may be extra-articular. In escaping, the route is the weakest portion of the capsule (its posterior-inferior segment). The location of an ichor pocket is no indication of its point of origin. The usual directions and ultimate locations of ichor pocket formations in hip disease are as follows:

Direction		Final localization
1. Outward—under attachment of rectus femoris muscle.	1.	*a*. Anterior border of great trochanter. *b*. Outer side sartorius.
2. Inward	2.	Attachment of adductor muscles, inner side of thigh.
3. Backward—following internal circumflex artery.	3.	*a*. Posterior edge of great trochanter. *b*. Lower border of gluteus maximus.
4. Upward—along sheath of psoas muscle.	4.	*a*. Above Poupart's ligament. *b*. Abdominal cavity.
5. Inward—through floor of acetabulum.	5.	Inner surface acetabulum. Rectal examination.
6. Downward—by gravity.	6.	Remote point (as popliteal space).

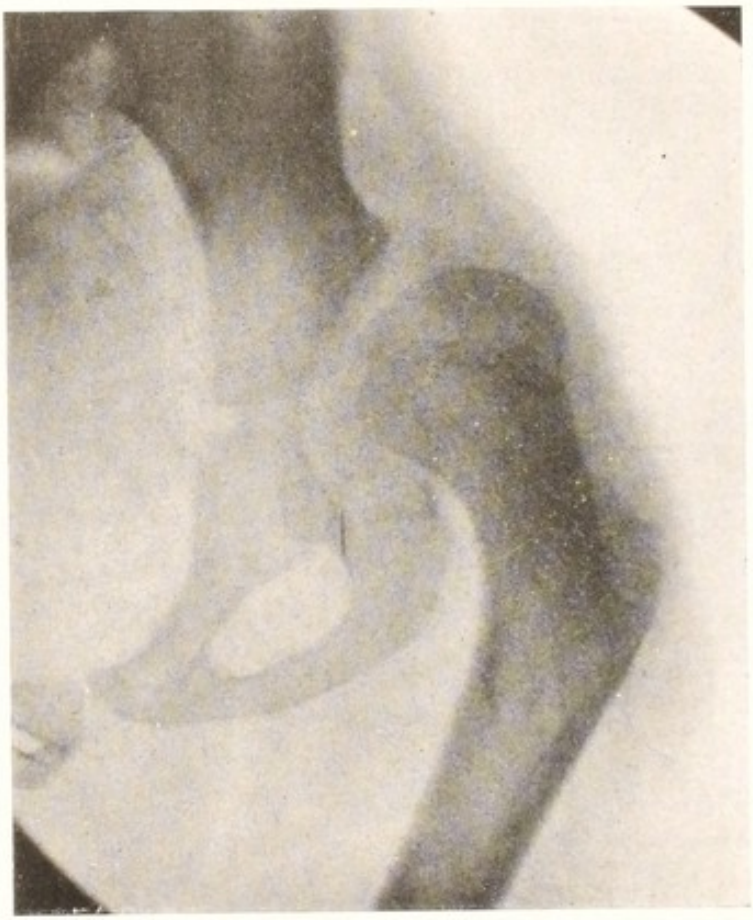


FIG. 95.—Tuberculosis of the hip-joint, with marked adduction deformity. This radiograph well illustrates the great liability of the adducted position leading to dislocation of the femoral head in the case of any lesion of the hip-joint causing destruction of the bony elements of the joint or relaxation of its capsule (—in this case subluxation has already occurred), while it emphasizes the importance of maintaining the abducted position during the progress of the disease.

Röntgenography.—Considerable information may be gained from an *x*-ray plate as to the state of the joint space, synovial membrane, bones, and soft parts. Appearances suggestive of tuberculous disease are as follows:

Joint Cavity.—Increased distance between the femoral head and the acetabulum and displacement of the head from the pelvis often indicate the presence of fluid within the joint. Bony débris may be apparent.

Synovial Membrane.—Thickening of the points of reflection and localized patches.

Bones.—Separation of the epiphysis at the femoral head. Alteration of the angle at the neck and the shaft of the femur. Pathological dislocation of the head of the femur.

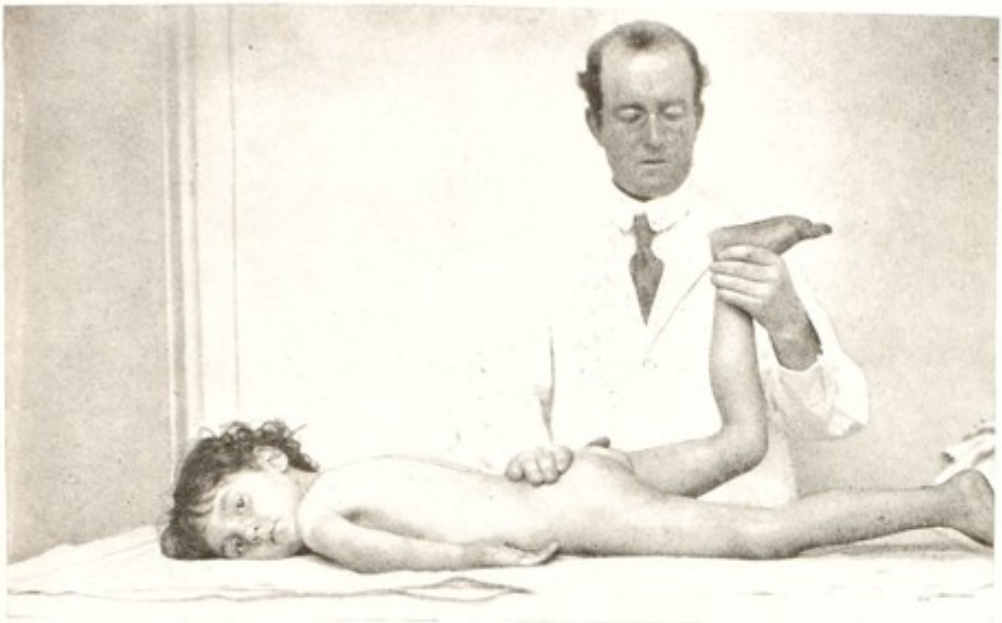


FIG. 96.—Testing hyperextension at the hip; the right side is normal. (Taylor.)

A cloudy, indistinct bony outline. A pitted, worm-eaten appearance at the free edge of the cartilage on the femoral head. An eroded, irregular head with areas of disease in the bone. Irregular acetabular outlines, and occasionally a perforation at the base of the acetabulum.

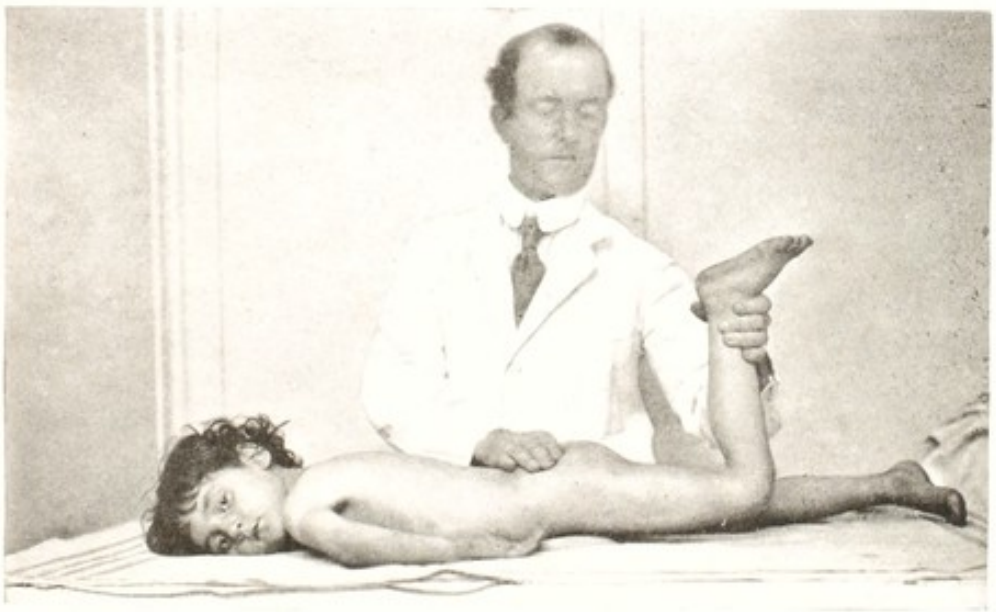


FIG. 97.—Testing hyperextension at the hip; the left side is limited; case of beginning hip tuberculosis. (Posed by Strang.) (Taylor.)

Soft Parts.—An ichor pocket may sometimes be detected by a clear area resistant to the *x*-rays.

The *x*-ray is of the greatest service in all but the very earliest stages of the disease, not only in arriving at the diagnosis but in guiding the surgeon

in the selection of his treatment and its management throughout the whole course of the disease; as long as the bony elements of the joint remain markedly fragile and porous or rarefied, the joint should be protected not

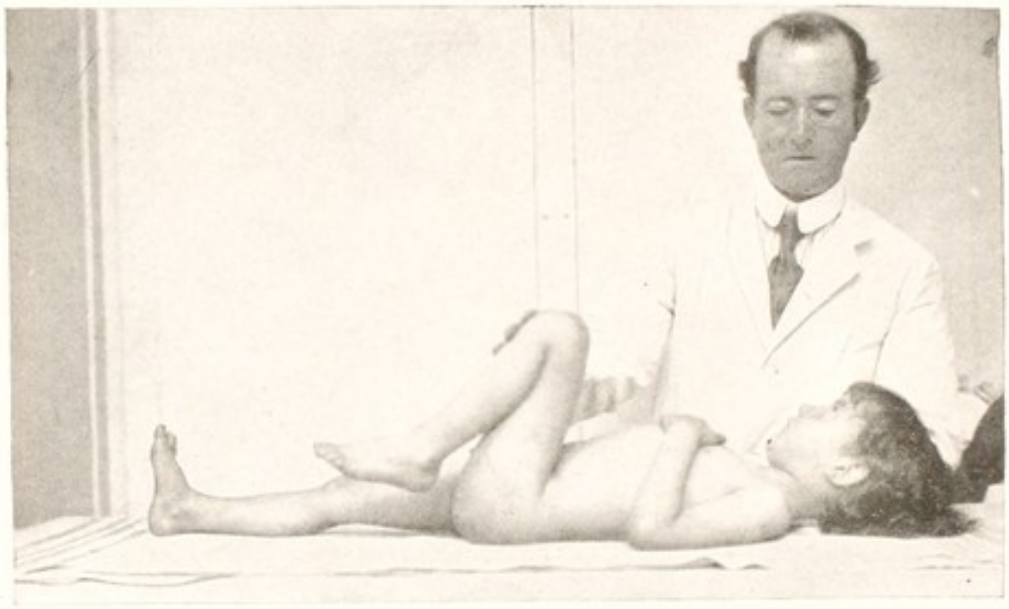


FIG. 98.—Testing flexion of left leg. (Taylor.)

only from the crushing and destructive influences of motion but also of weight-bearing and muscle-pull.

A careful *x*-ray study will aid in determining when the density of the osseous elements of the joint is restored sufficiently to allow weight-bearing; when

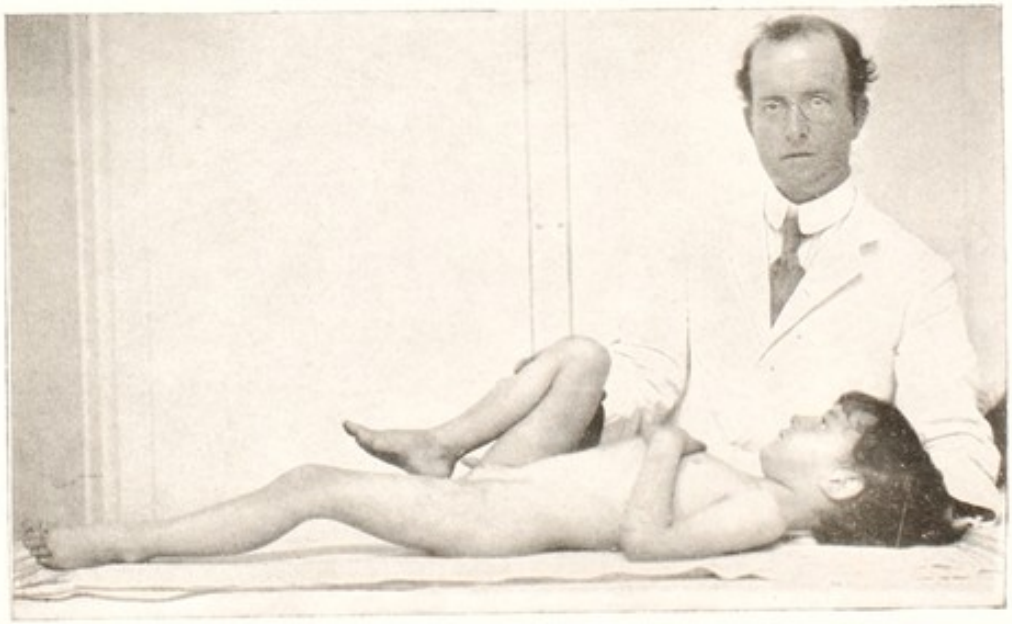


FIG. 99.—Testing extension of left leg. (Posed by Strang.) (Taylor.)

the Phelps brace may be changed to a long or a short spica; the long spica changed to a short one, without crutches; or fixation treatment may be entirely dispensed with (see Chapter on Röntgenography).

DIAGNOSIS

Absolute Diagnosis

The following history and physical signs are practically pathognomonic of tuberculous hip disease:

1. *History.*—*Chronicity* of the affection and its restriction to one joint (monarticular); intermittent but progressive increase of signs and symptoms.

2. *Attitude.*—(*a*) Early in the disease, flexion, abduction and eversion of the limb; (*b*) late in the disease, flexion, adduction and inversion.

3. *Gait.*—Irregularity, a long step alternating with a short one. Flexion at all joints of the affected limb, with flexion of the toes.

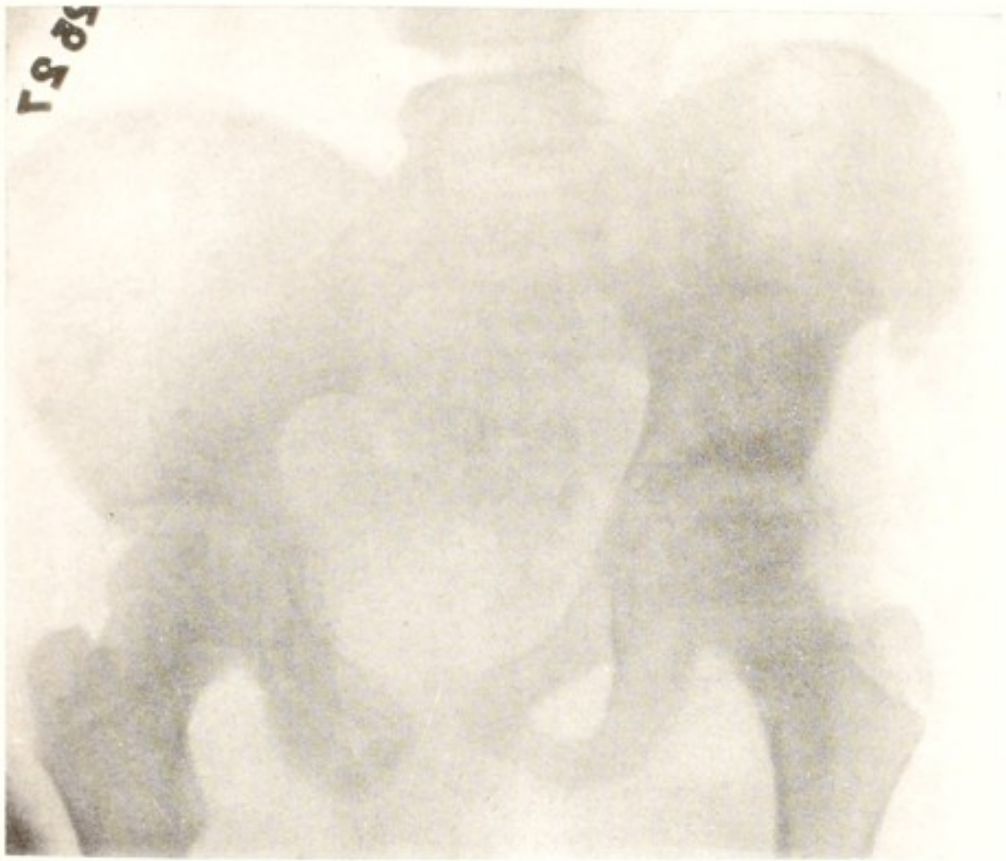


Fig. 100.—Extra-articular tuberculous disease in ilium (left), neither hip-joint being involved.

4. *Joint Outline.*—Wasting of the limb, particularly the buttocks, with alteration in the normal folds in buttocks and groin.

5. *Limitation of Motion and Muscle Spasm* (Figs. 96 to 99).—The most valuable of all physical signs. The most important restriction of motion is that of rotation and hyperextension (patient on face).

6. *Deformity.*—Distortion of the affected limb by abduction, adduction, external, and internal rotation.

7. *X-ray.*—Hazy bony outlines; increased distance between head of femur and pelvis. Thickened synovial membrane. Separation of epiphysis. Coxa vara. Dislocation. Worm-eaten, eroded bone and cartilage. Wandering acetabulum in very destructive cases. Clear space indicating ichor-pocket formation.

Differential Diagnosis.—There are many pathological conditions more or less intimately connected with the hip-joint which may be mistaken for

tuberculous disease. For brevity and clearness, these will be indicated with their points of resemblance and of difference in the following tabulation:

Disease	Points of resemblance	Points of difference
1. Local irritation (vaginitis, etc).	Flexion thigh; pain on movement.	Cause apparent on inspection. No involuntary muscle spasm.
2. Acute adenitis.	Flexion thigh.	No muscle spasm. Inguinal glands obvious. *X*-ray.
3. Local injury (congestion of epiphysis; effusion into joint).	Limp, pain, discomfort.	Temporary. *X*-ray.
4. Anterior poliomyelitis.	Local pain in limb in region of muscles.	Paralysis. The usual diminution or absence of reflexes. *X*-ray.
5. Acute arthritis and epiphysitis. (Pneumonia, diphtheria, typhoid, exanthemata, gonorrhea).	Flexion thigh; pain, limitation movement.	Sudden onset, high fever, severe constitutional disturbance, local heat and swelling. Poly-articular. Gonorrheal urethritis. If of short duration, muscular atrophy not so great.
6. Rheumatism.	In children, occasionally a single large joint.	Sudden. Migratory. Fever. Salicylates relieve.
7. Lumbar Pott's disease.	Limp. Restriction of movement in one leg.	Rigidity in lumbar spine. Only movement limited is extension. Distribution of superficial pain. *X*-ray.
8 Knee-joint disease.	Hip disease often accompanied by pain in the knee.	Local signs.
9. Coxa vara.	Distortion neck of femur. Shortening. Limp.	Movements free except abduction and rotation.
10. Hysterical joint.	Joint sensitiveness. Lameness. Pain.	Usually later life-period. Variable. Inconsistent. *X*-ray.
11. Peri-articular disease (Figs. 100 and 101).	Symptoms resemble those of tuberculous hip.	No muscle rigidity or limitation of rotation. *X*-ray.
12. Peri-nephritis and appendicitis.	Psoas contraction.	History. Limitation of movement restricted to extension. *X*-ray.
13. "Growing pains."	Night cries. Local pain.	Muscle strain. Not progressive. No restriction of motion, etc. *X*-ray.
14. Scurvy.	Pain on motion.	General symptoms. Enlargement shaft of long bone. Knee rather than hip. Artificial feeding. *X*-ray.
15. Arthritis deformans of hip.	Occasionally monarticular.	Adult life. Other evidence of a general disease. Pain only when using limb. *X*-ray.
16. Atrophic polyarthritis.	Childhood. Severe pain. Muscle spasm. Distortion of limb.	Successive involvement of other joints. *X*-ray.
17. Sacro-iliac disease.	Limp. Localized Pain. Attitude.	No muscle spasm at hip. Symptoms and attitude of sciatica. Pain on lateral pressure of pelvis; motion free at hip-joint. *X*-ray.
18. Pelvic disease.	Discomfort. Limp.	Cause explained by appearance of abscess. Muscle spasm, except possibly if iliopsoas abscess. *X*-ray.

Disease	Points of Resemblance	Points of Difference
19. Disease of the bursæ about the joint.	Local swelling and sensitiveness. Limp. Certain limitations of motion.	No muscle spasm. Iliopsoas bursitis; swelling in Scarpa's triangle; gluteal bursitis; local swelling in buttock. *X*-ray?
20. Fracture of the neck of the femur in childhood (traumatic coxa vara).	Limp and discomfort with some muscle spasm.	History of the accident with immediate disability and shortening, and elevation of trochanter. *X*-ray.
21. Epiphyseal fracture.	Limp. Pain. Restricted movement.	Adolescence. Limb adducted, foot rotated outward, $\frac{1}{4}$ to $\frac{1}{3}$ inch shortening. Injury. Use of limb. Motions of abduction and rotation restricted; other motions usually free. *X*-ray.
22. Congenital dislocation of the hip.	Limp.	Limp congenital. No symptoms of disease, no muscle spasm.

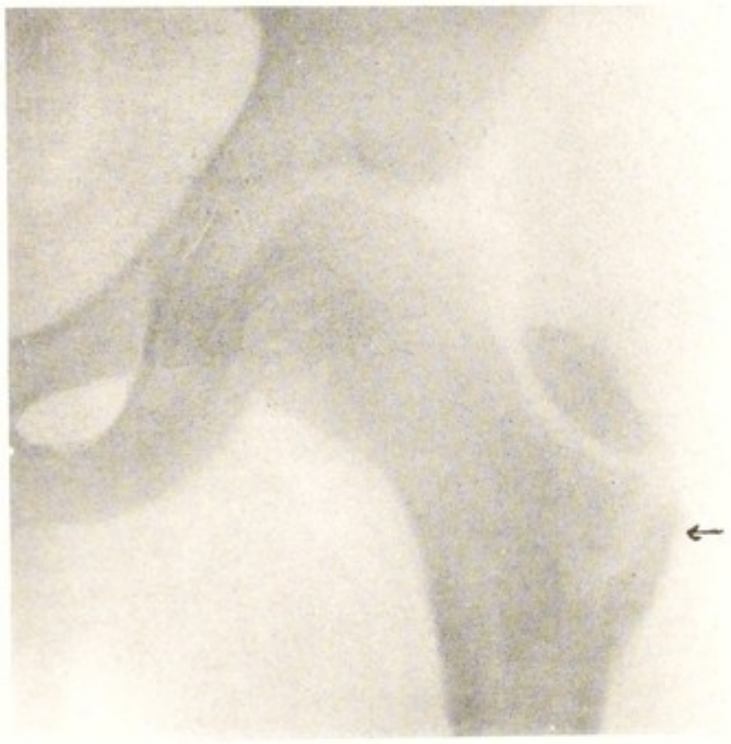


FIG. 101.—Tuberculosis of the great trochanter. A diagnosis of hip disease was made until a skiagraph disclosed the location of the disease. An immediate recovery resulted from the removal of the tubercular focus from the trochanter.

PROGNOSIS

Functional.—In exceptional cases full functional recovery from tuberculous disease may take place. There is, however, usually more or less restriction of motion which in severe cases amounts to complete ankylosis. The functional result depends on a number of factors, viz.:

(*a*) The pathology of the joint when treatment was instituted

(*b*) Nature of the treatment employed.

(*c*) The severity of the tuberculous process.
(*d*) Individual resistance.
(*e*) Length of the treatment. This should occupy a period of no less than two years to effect a cure. It should be continued until the patient can bear full weight on the affected region without pain or muscle spasm, and should be maintained long after all active symptoms have ceased.

Life.—Under good treatment, the mortality is not high. In most instances it is dependent upon abscess formation. In non-suppurative cases the death-rate is less than half that of suppurative cases. In the United States the average mortality is probably 10 to 18 per cent.

The chief immediate causes of death are the following, but it should be borne in mind that about 75 per cent. of these are directly or ndirectly due to secondary infection:

(*a*) Miliary tuberculosis.
(*b*) Tuberculous meningitis.
(*c*) Pulmonary tuberculosis.
(*d*) Amyloid disease.
(*e*) Exhaustion.
(*f*) Intercurrent affections.

TREATMENT

General Treatment

As in all cases of tuberculosis, wherever located, the importance of sunshine, fresh air, hygienic surroundings, nourishing food, etc., cannot be overestimated.

Local Treatment

General Considerations.—Advanced tuberculous disease of the hip is treated in an entirely different manner in children and in adults. From a general standpoint, the therapeutic key-note in the treatment of tuberculosis of the bones and joints with children is conservatism; with adults, operation. With children, however, the striking exception is in tuberculosis of the vertebræ, which should have operative treatment. A tuberculous bone lesion which has been shown by the *x*-ray to be definitely localized, should, however, be excised providing that it is surgically accessible, whether the patient be an adult or a child.

The *x*-ray is the guide *par excellence* to treatment. If the structures in the hip-joint do not show marked rarefaction, and the symptoms are correspondingly mild, the short plaster spica should be employed and atrophy thereby avoided. If, on the other hand, atrophy of the femoral head, in a child (osteoporosis) is already marked and in danger of crushing, the hip should be protected from muscle spasm and weight-bearing by a suitable traction brace (Phelps' preferred), or by a long plaster spica from toe to costal border, with crutches; or, in the severest cases, by the recumbent position in bed with traction in line of deformity, applied by means of pulley and weight, in order to procure the best possible fixation.

In the case of a child with a moderately severe process, a short plaster spica should be employed and the patient allowed to get about on crutches, later being allowed to walk. Supporting treatment should be begun early, forced feeding, rest periods (lying down), heliotherapy, and tuberculin.

In a more advanced case, the patient should be kept in bed with traction and weight applied (the age of the child in pounds, plus one) *in the line of*

the deformity (Fig. 102), until quiescence is established (absence of pain or extreme sensitiveness, night cries, etc.), when a brace (Phelps') or a long plaster spica should be applied and the patient permitted to go about with crutches.

The author agrees with Lorenz that in the severest cases of tuberculous osteitis of the hip the desideratum is bony ankylosis. Lorenz is perfectly consistent in his treatment and applies in these severest cases a short plaster spica extending to the knee, and allows early walking. The rarefied femoral head thus undergoes mechanical crushing, followed by firm ankylosis. The author attains the same results in adults by surgical intervention (arthrodesis), or by two grafts mortised together between the great trochanter and the pelvis, to be described more fully later. In children, however, he believes that in the mild cases the prognosis should be more optimistic, and that the treatment should be planned to abort ankylosis by preventing crushing of the joint surfaces and the fragile osseous elements of the joint by the influences of weight-bearing, muscle spasm, and motion during the acute stage of the disease. Therefore, the wisdom of traction and pulley, with patient in bed, crutches, brace, etc., described herein.

Generally speaking, unless arthrodesis or other permanent method of fixation is employed, one should maintain a conservative attitude toward discarding braces and other apparatus, because of the treacherous nature of osseous tuberculosis.

The local treatment will be considered in the order of its natural sequence, from the management of the most acute symptoms through the stage of recumbency; the ambulatory treatment; convalescent treatment; treatment of deformities and complications; and the operative treatment.

1. THE ACUTE STAGE

When a patient is first seen, with pain, spasm, and flexion of the hip, he should be put to bed on a firm mattress and his discomfort and muscle spasm relieved by traction. This is best done by weight and pulley (Fig. 102). The child's body should be secured by some means; a Bradford frame (Fig. 103) or sand-bags are effective. Apply adhesive strapping to the affected leg (long lateral strips, re-inforced by circular ones), and to their free ends fix a wooden stirrup to which a weight is attached by means of rope and pulley. The amount of weight should equal (in pounds) the age of the child, plus one. More perfect extension can be secured by elevating the foot of the bed. If relief is not rapid, lateral traction may be applied by passing a sling about the upper end of the femur, attaching a weight to its free end, and allowing the latter to hang over the edge of the bed. The pelvis should be fixed by a similar sling and weight acting in the opposite direction. It may be necessary to increase or diminish the weight of extension to secure perfect relief. Remember that traction should be made *in line with the deformity*, whatever it may be, relying on alteration of the line of traction at a later date to overcome the malposition. At the end of some weeks, pain and muscle spasm will have disappeared, allowing removal of extension and fixation of the hip in the recumbent posture.

2. RECUMBENT TREATMENT

For the purpose of fixing and immobilizing the joint, the following methods may be employed:

(*a*) **Long Plaster-of-Paris Spica** (Fig. 104).—Extending from the costal border to the ankle or toes. The limb is put up in slight abduction, with flexion at the hip and slight flexion at the knee.

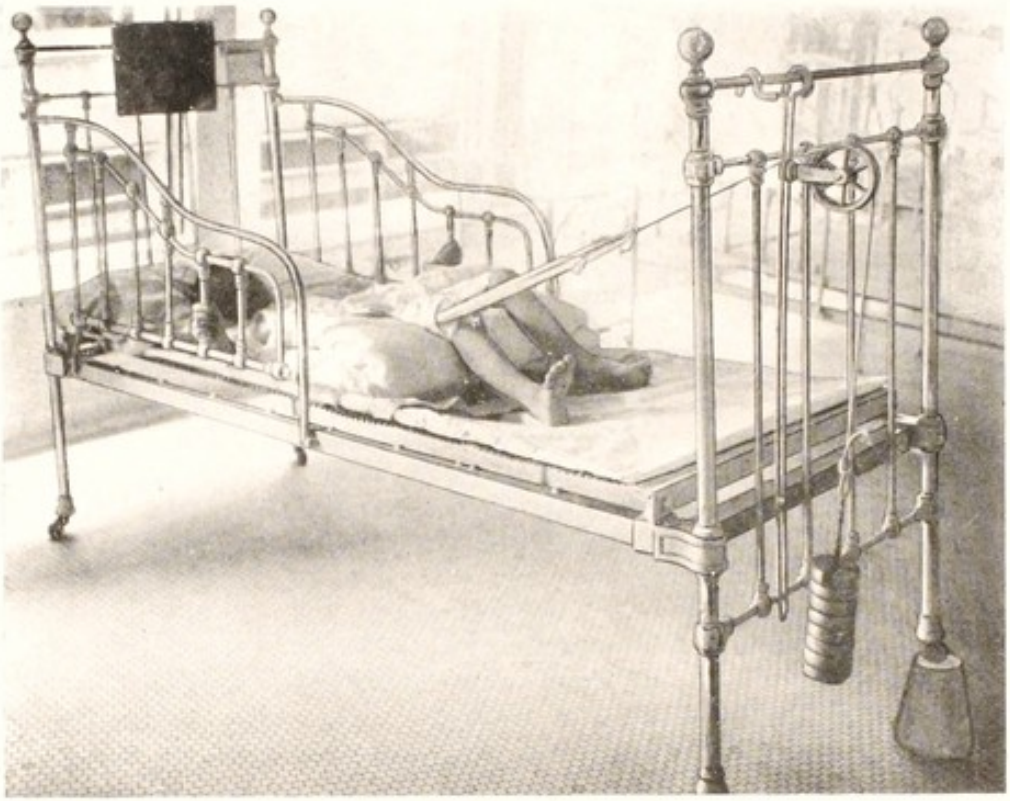


FIG. 102.—Method of applying traction in the line of the flexion deformity in a case of tuberculosis of the hip.



FIG. 103.—Method of fixing the patient to the Bradford frame for traction in hip disease (R. T. Taylor.)

(*b*) **Thomas Hip-splint.**—This consists of a main brace of flat malleable iron, three-quarters of an inch wide and five-sixteenths of an inch thick, extending from the lower angle of the scapula to the middle of the calf.

The lumbar portion is straight, but that portion over the buttocks and thigh is moulded to their respective shapes. To this upright are attached chest, thigh, and leg bands, each bridged over with straps and buckles. The frame is wound with thin boiler felt and covered with leather. A "nurse" (flat iron bar) is attached to and projects from the lower extremity of the upright to prevent attempts at walking.

Complete recumbent fixation is necessary until all pain and muscle spasm are absent and no tendency to deformity exists. To test the result of treatment, have the patient get about in an ambulatory splint for about three days. If the acute symptoms do not return, ambulatory treatment is to be continued; if they do return the recumbent treatment is to be resumed and continued until the joint can be controlled by ambulatory methods.

(*c*) **Traction Hip-splint.**—This apparatus, originally introduced by Davis and modified by Taylor, Sayre, and many others, is constructed on the same general plan as the Thomas hip-splint, but with the important addition of a foot-piece for traction purposes. The upright band extends from the level of the anterior-superior spine to a point 3 inches beyond the sole of the foot. The adjustable foot piece is fitted with a windlass spindle, ratchet wheel, and spring, the projecting end of the spindle being cut square to fit a clock key with which the traction straps may be tightened. The center of the spindle is provided with slots to receive the extension straps. The waist-band of flat steel extends from the center of the outer surface of the thigh above the trochanter to a point just over the opposite anterior-superior spine. This band has an inclination of 20° with the horizon, its posterior end being the higher. It is provided with two perineal bands in front and two behind. The waist band is completed by an adjustable belt. Leg bands encircle the thigh at its middle and the upper third of the calf.

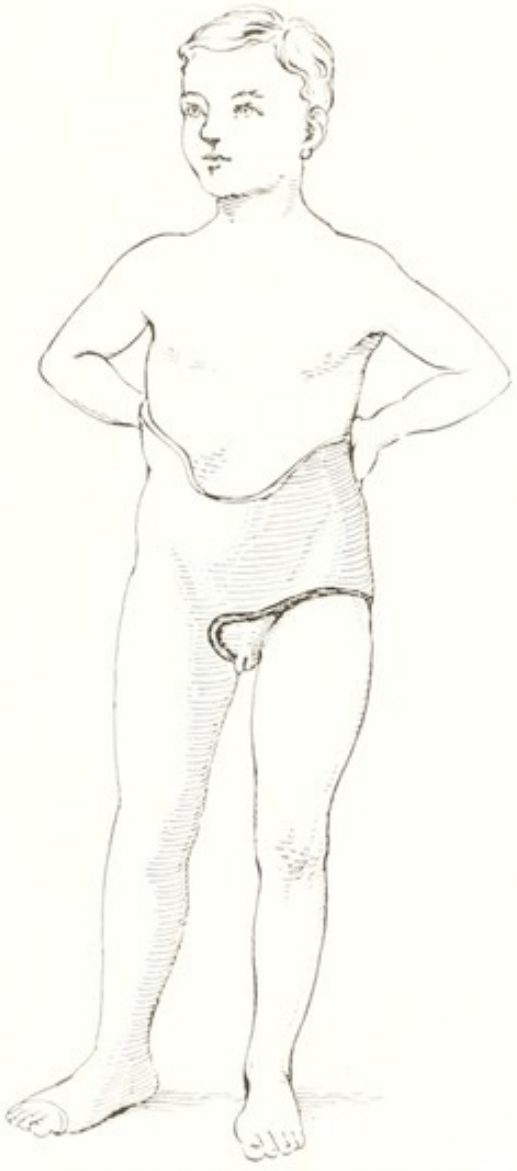


FIG. 104.—The long plaster-of-Paris spica for tuberculosis of the hip or for fixation for other purposes.

3. AMBULATORY TREATMENT

The stage of recumbency with pulley and weight is really a transition from that of the acute symptoms to the ambulatory period. Personally, the author prefers the *Phelps traction splint* with crutches after subsidence of severe pain, muscle spasm, etc., until walking with a short spica or a convalescent brace without crutches is allowed. The change from recumbency to walking should be made gradually, with frequent rest periods.

Three chief methods of securing the hip during the ambulatory period are: (A) The plaster splint and its modifications; (B) The Phelps splint and its modifications; and (C) the Taylor traction splint and its modifications.

(A) **Plaster Bandage and its Modifications.**—(1) *Long Plaster Spica with High Boot and Crutches.*—The limb is encased in a plaster spica from pelvis to toes, a patten is worn on the foot of the sound limb, and the patient allowed to use crutches.

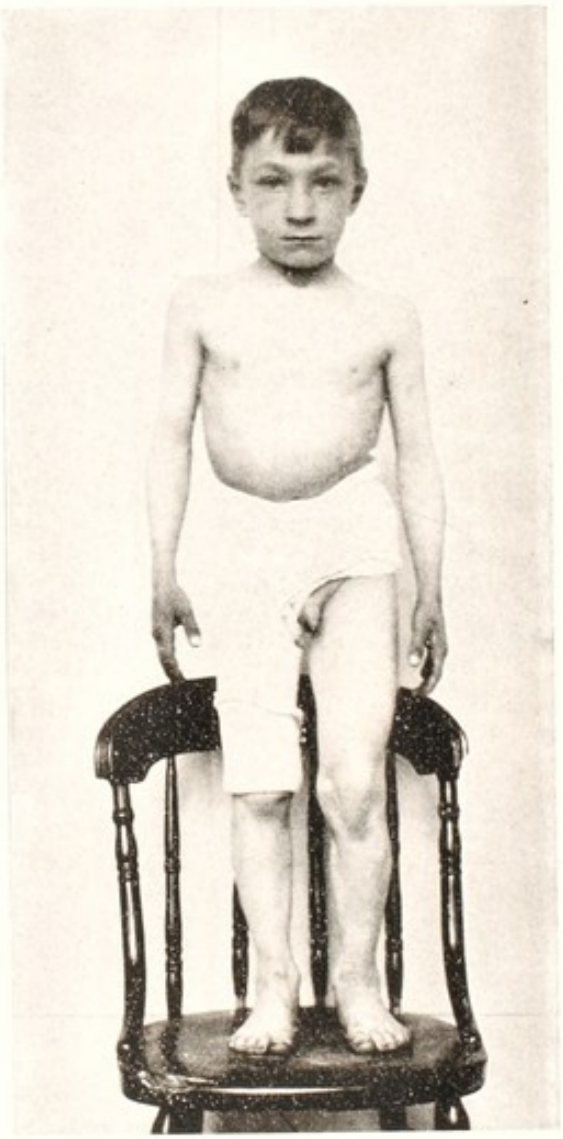


FIG. 105.—Short plaster spica for fixation at the hip; the fixation is better if the spica is prolonged upward nearly to the nipples. (Taylor.)

2. *Short Plaster Spica (Lorenz)* (Fig. 105).—With the limb slightly flexed and abducted, a short plaster spica is applied extending to a point at or just below the knee; the pelvic portion is applied laterally below the iliac crests, anteriorly above the symphysis, and posteriorly above the center of the sacrum. (Note: A high shoe worn on the opposite foot, and the use of crutches are advised by some surgeons, *i.e.*, weight-bearing by the affected limb with consequent crushing of the porous femoral head, may result in bony ankylosis.)

3. *Phelps Traction Hip-splint* (Fig. 106).—This splint affords both vertical and lateral traction. It extends from the axilla or lower thoracic region

to a point beyond the foot, is supplied with an adjustable foot piece and traction straps, and two body bands (thoracic and pelvic) completed by straps and buckles. To the pelvic band and the upright opposite the hip-joint, a Thomas ring is obliquely attached. Semicircular bands clasp the regions of knee and ankle. A special feature is a flat leather pad at the upper third of the thigh, fastened to the upright by cords to produce lateral traction. Vertical extension is secured by traction straps below.

4. *Lorenz Splint with Stilt.*—A steel stirrup projects from the spica about 3 inches beyond the sole of the foot. At the upper end of the spica a semicircle of steel is attached and incorporated in the plaster. The patient walks on the stirrup with his weight transmitted to the pelvic girdle.

5. *Short Spica with Traction Splint.*—Whitman advocated a plaster spica from the middle of the thorax to the knee, and over this a traction brace. The patient wears a high boot on the healthy side.

(B) **The Thomas Splint and its Modifications.**—(1) *Simple Thomas Splint with High Boot and Crutches* (Fig. 107).—An unmodified Thomas splint is worn and a patten used on the healthy side, and the patient allowed to walk with crutches. This is a very common procedure. Opposite-sided chest bands prevent lateral distortions (abduction, adduction).

2. *Combined Thomas and Traction Splint.*—A lateral thoracic bar is attached to the pelvic band of a traction splint, which is extended upward in the axillary line to the midscapular plane. Traction is applied below as in the ordinary traction splint.

(C) **Traction Hip-splint and its Modifications.**—(*a*) *Simple Traction Splint* (Taylor).—This has already been described in its application to recumbent treatment, to which it is best suited, since when used with or without a patten on the opposite foot, the traction straps alternately relax and tighten, allowing a pumping action at the affected joint, for which the splint has been severely criticised by many.

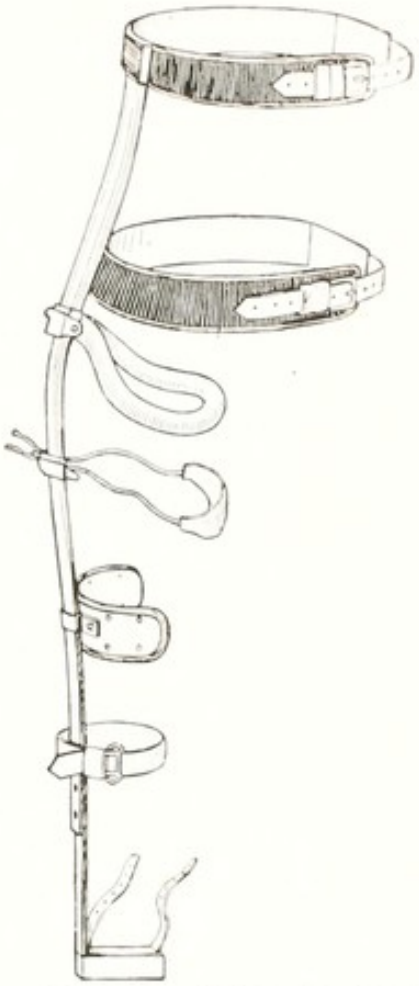


Fig. 106.—Phelps hip brace. This brace affords efficient fixation of the hip, as well as traction and prevention of weight bearing. (Albee, in Johnson, "Operative Therapeusis.")

(*b*) *The Traction Splint* combined with *Short Spica.*

(*c*) The *Combined Traction* and *Thomas Splint.*

(*d*) *Bradford Hip-splint.*—This splint is designed particularly for overcoming muscle spasm and securing abduction. Two lateral steel rods, longer than the limb, are connected below by a flat steel bar with windlass and above by a ring open in front. The special feature of the splint is a steel rod welded to the ring on the side of the healthy limb and so moulded that it passes above the symphysis pubis and under the perineum, the latter portion being made sufficiently long to avoid pressure on the buttock with the patient

seated. Encircling straps hold the splint against the limb. A high sole is worn on the normal side.

(*e*) *Dane Hip-splint.*—The Dane splint consists of a Thomas knee splint with a windlass for extension and with the waist band of a traction splint fastened to the upper end above the ring. There is a perineal band on the healthy side, but none on the diseased side. A supplementary pelvic band is applied low down over the sacrum.



FIG. 107.—The long brace, with Thomas ring and extension upright, similar to Phelps' brace. (Whitman.)



FIG. 108.—Rear view of brace. (Whitman.)

The Selection of an Ambulatory Splint.—The Phelps brace is preferred by the author.

4. CONVALESCENT TREATMENT

The question of allowing the patient to begin to walk gradually with the following aids, may be considered when, after a long period, there are

no active symptoms and no muscle spasm. These points may be ascertained by nightly removal of the apparatus for a month or more, thus allowing voluntary motion at the joint without weight-bearing. If the hip is judged to be in a satisfactory condition for modified weight-bearing, one of the following splints should be tried:

(*a*) **Short Spica to the Knee.**

(*b*) **Convalescent Hip-splint** (Plimpton).—The Plimpton convalescent splint is a Phelps splint minus the upper band, with a light inner bar added. This apparatus exerts a form of traction, but with the heel off the ground, the patient stepping on the toes. The lower end is cut ⅜ inches from the ground and a piece welded to its inner part, extending 2 inches below the sole of the boot



FIG. 109.

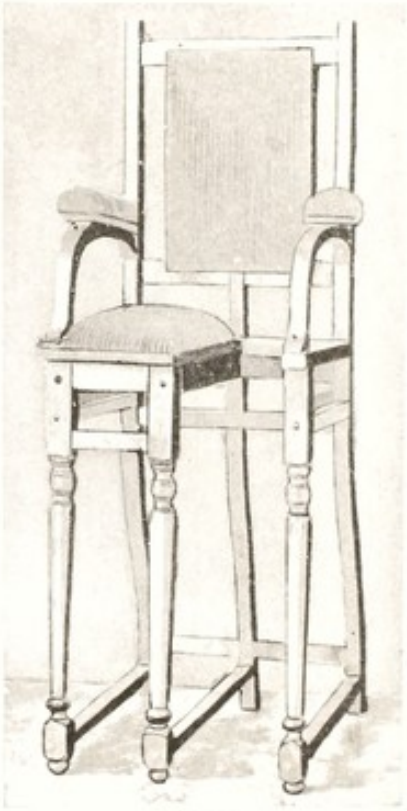


FIG. 110.

FIG. 109.—Modified brace to be worn during convalescence. Same patient as in Fig. 107. The thoracic part has been removed and the lower end of the stem has been made into a caliper, passing through the heel of the shoe. The stem is extended by means of the key until the heel is lifted slightly from the shoe; thus the hip is relieved from shock.

FIG. 110.—A chair to be used with the long hip splint. The patient sits upon the sound side, while the splinted half of the body remains in the extended position, the brace resting on the floor. (Whitman.)

and terminating in a bulbous tip three-quarters of an inch in diameter. The upright extends from the anterior superior spine to a point 1½ inches beyond the bottom of the heel, the foot being held at right angles.

(*c*) **Taylor's Convalescent Splint.**—The lateral brace is jointed at the knee and is slightly longer than the leg. The heel does not touch the bottom of the shoe. The weight is partly removed from the foot and brace by a perineal band.

(*d*) **Convalescent Lateral Brace.**—This consists of a lateral brace, pelvic band, and perineal crutch. The brace is jointed at the knee. Its special feature is the attachment of the lower end to the sole of the boot.

5. THE TREATMENT OF DEFORMITIES

A tuberculous hip may become deformed in several directions, usually in (*a*) flexion, (*b*) adduction (rarely abduction), (*c*) flexion and abduction, (*d*) flexion and adduction. The malpositions of eversion and inversion are usually dependent on abduction and adduction and disappear with removal of their cause.

Early deformity is practically always the result of muscular spasm; while late in the disease process it is due to the contraction of soft parts or to structural changes in the bones, or it is a combination of these two elements.

Correction of these deformities may be obtained in three ways, viz.: gradually, rapidly, or by operative means.

(A) **Gradual Correction.**—This, the most conservative means, may be employed by weight and pulley, by traction splints, plaster bandages, or by the double Thomas splint.

1. *Weight and Pulley.*—When using this method, there are several essential features to be observed to obtain success: first, the anterior superior spines must be on the same level; second, the lumbar vertebral spine should touch the mattress of the bed; third, *traction must at first be maintained in the axis of the limb in its deformed position.* (See Fig. 102.)

The affected limb can be supported by a pillow or by an adjustable wooden triangle. Counterextension is secured by raising the foot of the bed; but, as a rule, this is insufficient for the light bodies of children, with whom two perineal bands, one from each side of the upper corner of the bed-frame, give adequate counterextension. It is also desirable to swathe the body to the bed-frame or to apply shoulder straps to prevent the patient from sitting up. Additional fixation may be secured by a long lateral splint extending beyond the foot and with a cross bar below. The bed clothes should be raised from the feet by a "cradle."

In using the weight and pulley method for correcting deformity, the amount of weight must be increased from day to day. After a few days of traction in the deformed position, the axis of traction should be gradually altered toward normal. This mode of reducing deformity is slow and is useless for correcting true bony ankylosis or structural bony deformity.

2. *Traction Splint* (Taylor).—For stretching plastic and contracted soft tissues, this method is sometimes successful. Its chief advantage is that it permits of locomotion and thus obviates the deleterious effects of recumbency. Its great disadvantage is that with the splint, it is difficult, to secure traction in the desired directions.

3. *Plaster Bandages.*—When plaster is used, it is first applied to the limb in its deformed position and allowed to remain four weeks or more. Occasionally the deformity will have become corrected at the end of this time; if not, a second or third cast is applied, with the limb each time in a more corrected position.

4. *Double Thomas Splint.*—For flexion deformity, the double Thomas splint has often proved beneficial with children. The normal limb is put up in the extended position, and the distorted limb likewise, if the deformity is not too great; in the latter case, the corresponding arm of the splint is bent to accommodate the distortion, but should be subsequently straightened from

time to time to conform to the corrected position. It should be borne in mind that the desirable position in a Thomas splint is with the portions of the upright above and below the pelvis straight and parallel with one another. A preliminary attempt at correction with the weight and pulley may be advantageous.

(B) **Operative Treatment for Correction of Deformity.**—1. **Arthrodesis** (Albee).—The production of surgical ankylosis (arthrodesis) of the adult hip-joint is indicated for the following conditions:

(*a*) Fibrous ankylosis following previous operation, or from other causes (see "Bone-graft Surgery," Albee, p. 264, case ii).

(*b*) Rarefaction (porosis) of the femoral head and neck in the adult, with inevitable or actual crushing of these structures. In other words, the rapid production by scientific and accurate surgical means of the same result that is

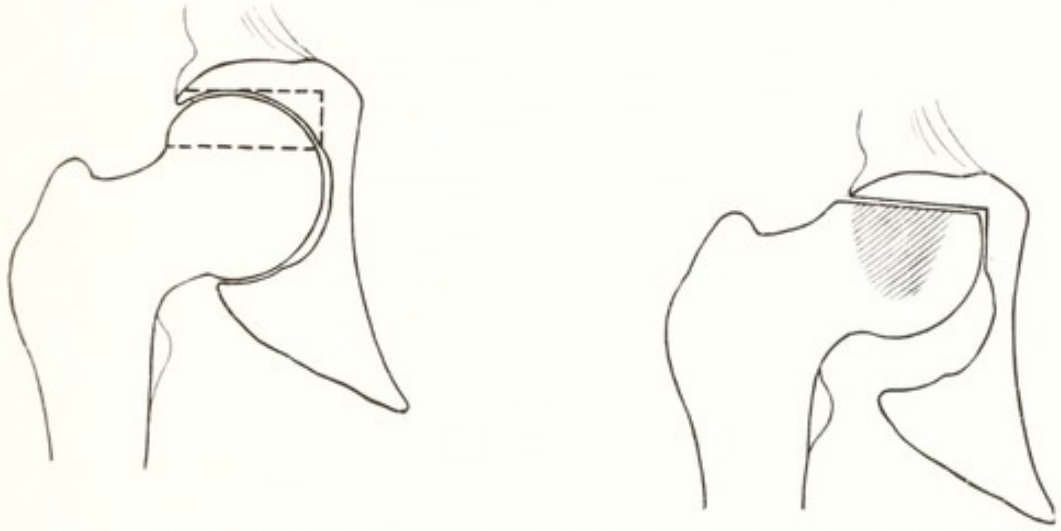


FIG. 111.—The broken lines indicate the amount of bone to be removed. It is removed from the head and the acetabulum in different planes in order to secure the desired abduction of the thigh, when the freshened bone surfaces are brought together.

Apposition of the freshened bone surfaces after the removal of the bone from the head and the acetabulum, and the femur placed in slight abduction. The blackened area indicates where the cartilage is removed when the femur is strongly rotated outward for that purpose.

All the small fragments of bone are not removed with as much care as formerly. They are left in or selected ones replaced on account of their osteogenetic activity.

slowly and clumsily attained in cases with much destruction by allowing the patient to walk with a short spica, according to the advice of Lorenz.

Technic.—The incision is made anteriorly (in thin subjects) from a point just below and outside the anterior-superior spine, downward for 5 inches. The sartorius is retracted outward; the deeper muscles and other structures are separated by blunt dissection, and the iliacus and rectus femoris muscles are retracted inward. A part of any group of osteophytes about the acetabulum is turned upward with the soft tissues adherent to them, since it is considered advisable to preserve as many as feasible on account of their potential bone-producing power. In a thick muscular thigh, where there is much bony outgrowth overhanging the joint, it requires some care to locate the joint accurately.

The capsule now becomes visible and it is incised. With the head of the femur *in situ*, approximately one-third of its upper hemisphere is removed with a long osteotome or chisel, $\frac{5}{8}$ inch in width, in a plane nearly parallel with the long axis of the neck of the femur (Fig. 111). With the same

instrument and a strong curette with a cross-handle, the acetabulum is transformed into a flat-surfaced roof against which the flat surface of the head is finally brought into firm contact by abduction of the thigh, and at their junction many fragmented bone-grafts are placed providing the case is not too acute or there is no secondary infection (Fig. 112). These grafts are selected from the bone fragments already removed or obtained elsewhere, as from the trochanter, etc. If the adductor muscles prevent the required amount of abduction, an open division of these muscles and tendons is made to permit the leg to be brought into the desired position. The acetabular and femoral head surfaces are brought into contact by simply abducting the thigh.

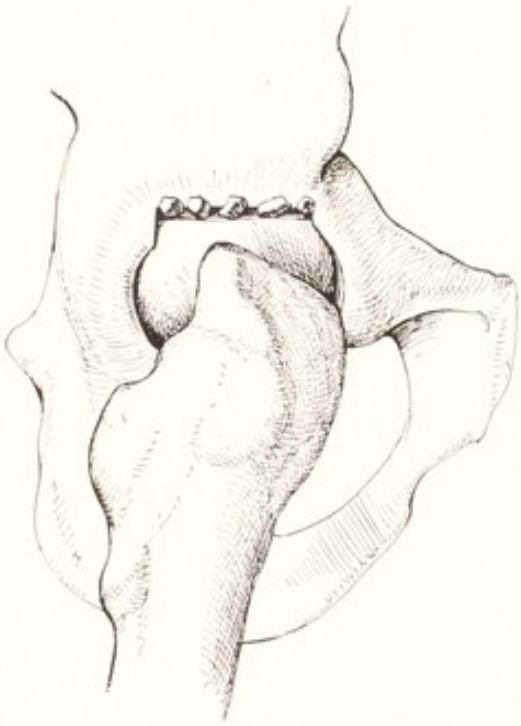


FIG. 112.—Author's arthrodesis of the hip-joint showing the incised flattened superior surface of the head of the femur in apposition with the incised flattened superior surface of the acetabulum, with the parts of osteophytes and small bone-grafts placed along the contacted bone area (lateral view).

Soft tissues are sutured with continuous suture of chromic catgut No. 1; skin, with continuous suture No. 1 plain catgut.

Access to the joint is much facilitated by a position of *adduction* of the limb. For the purpose of orientation, an assistant is constantly kept in readiness to rotate the femur while the operation is in progress. The bone is removed in such a way that the flat pelvic surface is tilted up somewhat mesially in order to produce a locking of the parts and to prevent any possibility of dislocation from weight-bearing.

For the performance of all plastic operations upon the hip-joint, except in very thin subjects, the author prefers the Sprengel or Smith-Peterson subperiosteal approach above all others. The technic is briefly as follows: From a point 3 to 4 inches below the anterior-superior spine, a vertical incision, following the external border of the sartorious muscle, is made upward to the spine of the ilium; thence carried backward, following the iliac crest for two-thirds of its extent. By means of a sharp periosteal elevator the gluteal muscles are reflected with the periosteum of the ilium adherent to them, until the capsule of the hip-joint has been exposed. No other approach to the hip-joint can compare with this one in the extent of exposure of the joint and the facility it offers for all plastic procedures.

In very stout patients with thick thigh muscles, the technic of lateral approach to the hip-joint described by Brackett may be used as follows:

An incision is made from the anterior-superior spine obliquely downward and outward to the middle of the outer side of the trochanter, and then downward 2 inches in the line of the femur. At the point where the oblique portion joins the vertical, just over the trochanter, an incision is made directly backward, 2 to 3 inches in length, down to the fascial portion of the gluteus maximus. After separating the tensor fasciæ femoris and the gluteus medius, the line of separation is extended downward along the line of the original incision, through the fascia lata to the femur, freeing the

attachment of the muscle (vastus externus) from the outer and upper surfaces of the femur. The fascial expansion of the gluteus maximus is then cut through along the line of the posterior part of the original incision, and the outer part of the trochanter is exposed.

This gluteal flap is turned backward and the upper and outer surfaces of the trochanter are fully exposed. The upper portion of the trochanter is then chiselled off by cutting directly backward with a narrow osteotome on a curved line beginning on the outer surface of the trochanter 1½ inches below the tip, and cutting inward for a quarter of an inch, then curving upward to the fossa at the junction of the upper part of the neck and the trochanter. This removes the outer portion and tip of the trochanter, and with it the attachment of the gluteus medius, gluteus minimus, and pyri-

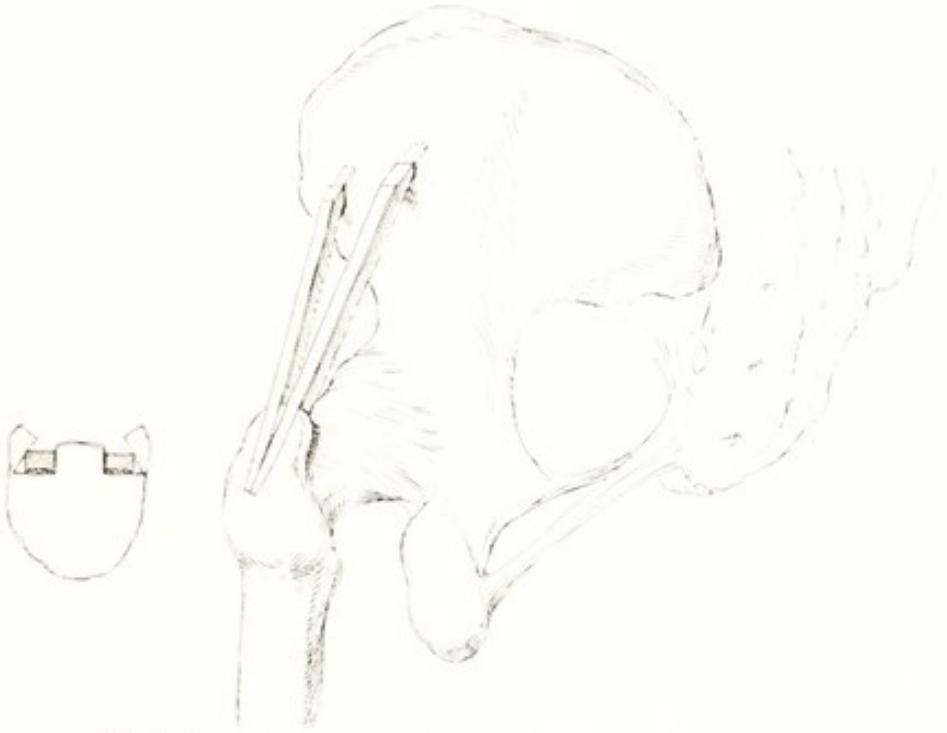


FIG. 113.—Method employed by the author for extra-articular fixation and support of the hip-joint affected by tuberculosis or other destructive lesion. Two tibial bone-grafts are used: one end of each is inlaid in the great trochanter, the other end is made wedge-shaped and driven into mortise made in the wing of the ilium. (See Fig. 114.)

formis muscles. The motor or Gigli saw can be used. Care should be exercised in the removal of this piece not to encroach on the neck, or the bone will be weakened at this angle. The portion of bone removed, with the muscles attached, is deflected backward and upward enough to uncover the upper part of the femoral neck, and the muscular covering of the anterior fibers of the gluteus medius and minimus are easily separated from the region above the acetabular rim. The incision through the trochanter just borders on or opens the outer edge of the capsule on the upper surface of the neck, and the incision of the capsule opens directly into the cavity of the joint. The capsule may be split along its upper surface parallel to the neck and near to its acetabular insertion and cut transversely on each side, thereby exposing the head and rim of the upper half of the acetabulum.

The leg is finally put in a long spica extending from the axilla to the toes, in strong abduction and 10 degrees of flexion. If the convalescence is uneventful, the patient is usually walking in six weeks with the aid of crutches.

A short spica is then substituted for the long one, for a period of seven weeks longer.

In the later cases it has been found that to remove the over-hanging edge of the acetabulum first, renders easier the removal of the upper surface of the head of the femur. If the upper third of the femoral head to be removed is cut into segments by a thin osteotome and by cutting at right angles to the first bone incision, the removal of this portion of the head is facilitated.

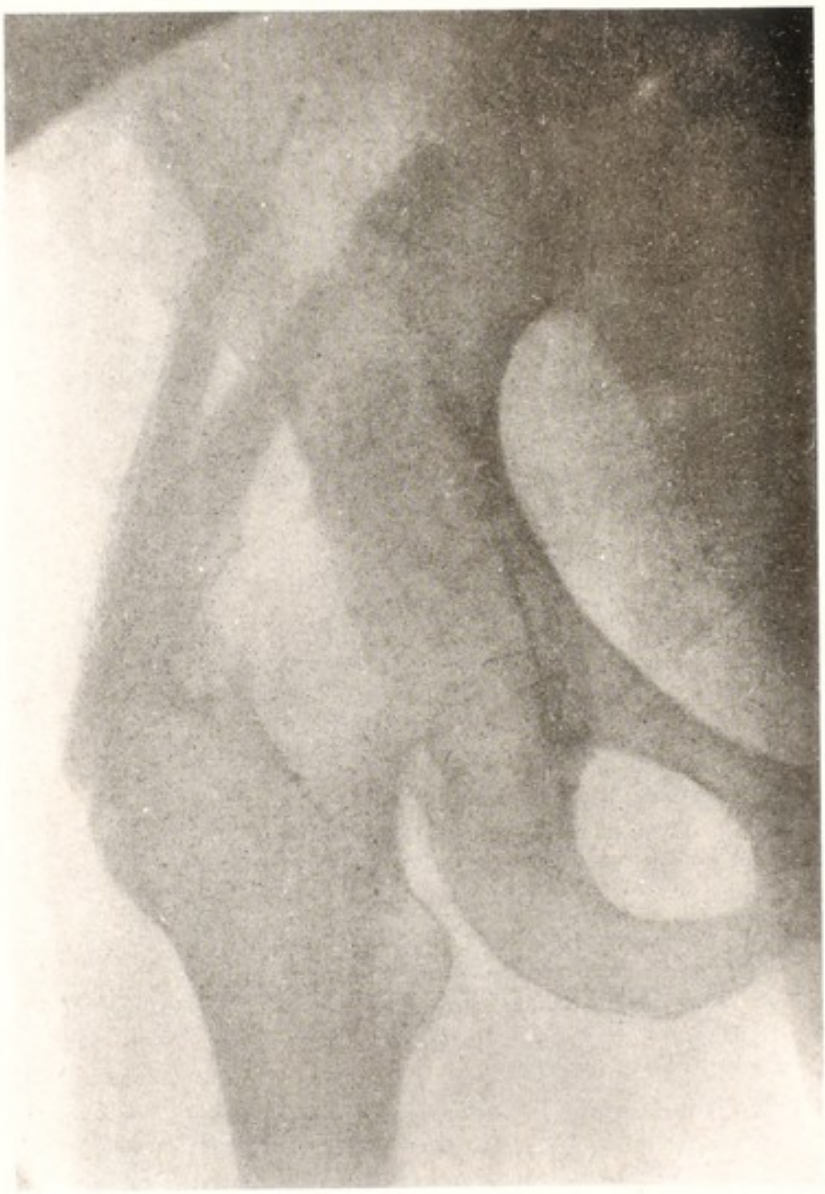


FIG. 114.—Tuberculosis of the hip-joint. Two tibial bone-grafts inserted from the great trochanter to the wing of the ilium for the purpose of extra-articular fixation and support according to the method shown in Fig. 113 for tuberculosis. The marked proliferation of the lower end of the grafts is striking.

After this segment of the head has been removed, all the accessible articular cartilage is sliced from the anterior portion of the head which is brought into view by strongly rotating the femur outward. The cartilage is also removed from the contiguous portion of the acetabulum with a thin osteotome. In operating upon stout persons, one is forced to depend very largely upon the sense of touch in this removal of bone and cartilage.

One precaution should be emphasized, and that is the removal of the over-

hanging osteophytes before incising the femoral head. The reason for this is to avoid being misled and making the capital incision too low, and thus removing a larger segment than is desirable. The removal of one-third of the head furnishes as extensive a fresh bone surface as can be obtained for ankylosis, and at the same time the hip is not loosened nor the limb shortened to any material degree. The tendency in planning the approach, is to regard the hip-joint as being situated lower than it really is.

2. **Subtrochanteric Osteotomy.**—(*a*) *Circular Osteotomy* (Brackett) (Fig. 238).—(For description of technic see Chapter XIV.)

(*b*) *Transverse Linear Subtrochanteric Osteotomy* (Gant) (Fig. 233).—For this operation, either an osteotome or a saw may be used. Through an inci-



FIG. 115.—Radiographic appearance of the hip-joint and femur following Brackett's circular osteotomy (see Figs. 235 and 238, Chapter XIV) which had been performed for the relief of extreme adduction deformity resulting from ankylosis from old tuberculous disease of the hip-joint. The arrow shows the former direction of the femoral shaft (extreme adduction) before osteotomy. (For technic of this operation see Chapter XIV, page 473.)

sion 2 inches below the tip of the great trochanter, the osteotome is introduced with its blade parallel with the long axis of the femur. On reaching the bone, the cutting edge of the chisel is turned to become transverse and the femur is severed as far as the inner wall of compact bone. The osteotome is then withdrawn and the remainder of the bone fractured. The necessary correction of distortion is then made and the limb is put up in a plaster spica in the corrected position. The author employs the circular subtrochanteric osteotomy to the exclusion of all others.

(*c*) *Cuneiform Subtrochanteric Osteotomy.*—A 3-inch vertical incision is made in the outer surface of the affected thigh, with the center about 2 inches below the tip of the great trochanter. A wedge of bone is removed

with an osteotome. The wedge is so planned that its base corresponds to that portion of the shaft opposite the deformity (*i.e.*, in flexion, on the posterior surface; in adduction, on the lateral surface, etc.). The correction is then forcibly made and the limb is put up in plaster in slight abduction and flexion.

3. **Adams' Operation.**—The patient is placed on the side, with the diseased hip uppermost, and a long-bladed knife is thrust inward at a point about one finger-breadth above the tip of the great trochanter and carried as far as and at right angles with the neck of the femur. With the knife *in situ*, an Adams' saw is introduced beside it, and the knife is then withdrawn.

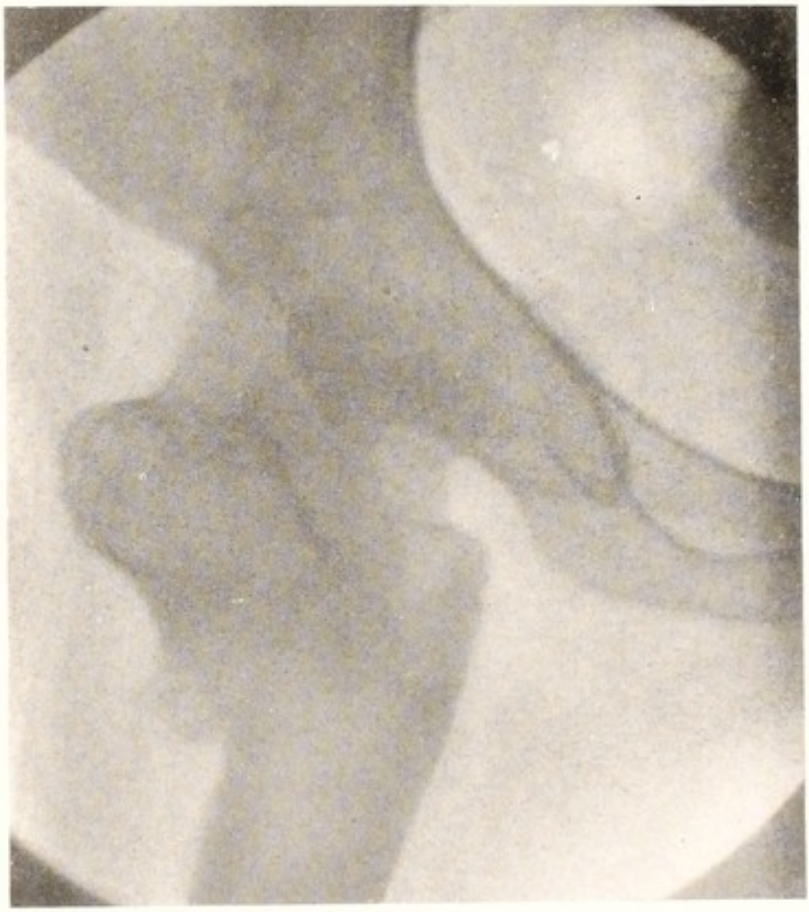


FIG. 116.—Indicates correction of a flexion-adduction deformity of the hip by a Gant's osteotomy and the sliding by internally of the upper end of the lower fragment. This accident is obviated in the author's practice by employing the circular osteotomy of Brackett.

The femoral neck is divided, partially or completely; if partially, the neck is forcibly fractured. On account of the contracture, it may be necessary to divide the tendons of the adductor longus, the sartorius, and possibly the rectus femoris. The limb is immobilized in plaster in slight flexion and abduction.

This operation may also be done by the open method through an incision made vertically above the great trochanter, and the femoral neck severed by an osteotome.

4. **Forced Manual Correction.**—Where the deformity only depends on contracture and shortening of the soft parts, it may occasionally be remedied by the administration of an anesthetic and forcible mechanical stretching of these restricting tissues. Division of shortened flexor or adductor muscles

may be necessary. The manipulation may be completed at one or several sittings, and the limb should be immobilized in plaster in the corrected attitude.

TREATMENT OF COMPLICATIONS

(A) **Abscess (Ichor-pocket) Formation.**—(1) *Conservative Treatment.*—The first consideration is to treat the hip, where the abscess originates, and, *secondly*, to consider the abscess *per se*. If prompt and efficient treatment has been applied to the diseased joint structure, a certain percentage of abscesses will become isolated and undergo resolution without special treatment.

2. *Aspiration and Injection.*—This method of treatment has already been discussed on page 55 in the Chapter on Tuberculosis of Bones and Joints. This treatment is indicated when there has occurred increase in the size of the abscess, extension of the process by tracking, or increase of pain. Aspiration may be employed with or without injection. When fluid is confined within the capsule of the hip-joint, the tension is great and the suffering extreme. A long needle should be selected and, with the patient in the dorsal position with the affected hip adducted and internally rotated, it is introduced at a right angle to the femur at a point just above the tip of the great trochanter, half-way between its anterior and posterior borders. The needle is pushed inward, with the leg strongly adducted, until it touches the femoral neck, when it is directed between the head of the femur and the acetabular rim and the fluid is withdrawn.

3. *Incision of Cold Abscess* (Ichor Pocket).—This is a last resort and should be avoided whenever possible. It is indicated for (*a*) an abscess with contents too inspissated to be removed by aspiration; (*b*) the presence of sequestra in the cavity; (*c*) secondary infection of the abscess.

Rigid asepsis must be observed, as the tendency to pyogenic infection is great. A thicker portion of the abscess wall should always be chosen for the location of the incision, as this affords more tissue and a better chance of permanent healing by primary union. After evacuation, the cavity may or may not be irrigated. The wound must always be closed with great care and in layers by absorbable sutures, inasmuch as drainage is sure to invite infection. A large compress held by a snug spica should be applied after incision as well as aspiration, to prevent re-accumulation of fluid or extravasation of blood.

The author prefers not to irrigate the cavity, and to express the contents with gentleness and without inserting any instrument into the wound, the purpose being to avoid in every possible way any traumatizing of the delicate granulations lining the abscess wall, with the resultant blood extravasation.

(B) **Sinus Formation.**—If the tuberculous discharge is diminishing, the sinus should be let alone. Persistence or increase of the discharge may indicate extension of bone caries or sequestration. This information may be obtained by *x*-ray. For the technic of treatment, the reader is referred to page 57 in the Chapter on Tuberculosis of Bones and Joints. It is needless to emphasize that the mechanical fixation of the joint should be maintained at its best.

OPERATIVE TREATMENT

Much discussion has taken place relative to the proper attitude of the surgeon as to operative interference with a tuberculous process of joints. Between the school of radicals who advocate early surgical intervention and the school of conservative abstinence from all operative interference, a

middle course is desirable, that is, to give conservative measures a thorough trial in every case, supplementing this treatment by surgery when indicated and selected to meet the exigencies of the particular case at hand.

Indications for operation on the joint are briefly as follows:

1. An age beyond adolescence. As a rule, childhood and infancy contra-indicate operation, except as an emergency, or when the disease is well focalized.
2. Abscess formation, with steady advance of the disease.
3. Persistent loss of health.
4. Ungovernable pain.
5. Poor hygienic surroundings.

Procedures.—The operative possibilities consist of arthrodesis, fixation by bone-graft, excision, local cureting, arthroplasty, operative dislocation, and amputation.

Arthrodesis of the hip (Albee) has already been described in detail on page 215 of this chapter.

Fixation by Bone-graft (Albee).—This procedure is indicated in the more acute cases where it is desirable to avoid getting into the focus of active disease.

1. **Author's Bone-graft Fixation of a Tuberculous Hip.**—*Incision.*—With the patient firmly fixed on a traction table, a semicircular incision is made, beginning 1½ inches posterior to the anterior-superior spine, carried forward with a small convexity over the outer surface of the great trochanter, and terminates about 1½ inches below its tip (posteriorly).

Exposure.—The great trochanter and side of the pelvis just posterior to the anterior-superior iliac spine are exposed by separating the fibers of the gluteal muscles.

Graft-bed.—The two points of contact of the inlay (trochanter and lateral wall of ilium) are prepared as follows:

(*a*) The trochanter, by splitting it vertically with the motor saw and turning out each way, by means of the broad osteotome, flaps of bone with the peri-osseous structure as hinges.

(*b*) Two indentations are made about 2 inches apart in the lateral wall of the ilium midway between its crest and the roof of the acetabulum, with the osteotome (½ inch wide). The first indentation is about half an inch posterior to the anterior-superior spine.

The Graft.—A straight graft about 4 to 6 inches in length, as determined by calipers, is removed from the tibia. From one extremity a triangle of bone is removed (Fig. 113) to allow mitering of the two resulting halves produced by splitting the graft longitudinally with the motor saw. The proximal (pelvic) ends are bevelled on the flat with the motor saw.

Fixation of Graft.—(*a*) The bevelled wedge-shaped ends are driven into the indentations in the ilium. (*b*) The mitered ends of the two are implanted in the split trochanter and the flap-doors of the latter are secured by kangaroo tendon. (*c*) Numerous fragmented grafts remaining from the triangle removed for the miter and from bevelling the ends, are placed about the pelvic and trochanteric extremities of the inlay.

Closure.—The muscle is re-united with a continuous suture of No. 1 chromicized catgut, and the skin with a continuous No. 1 plain catgut suture.

Immobilization.—A plaster-of-Paris spica is applied from the toes to the costal border, the limb being placed in slight abduction and flexion.

After-care.—The original long plaster-of-Paris spica is allowed to remain in place with the patient recumbent for ten weeks, when it is removed and an *x*-ray taken; then, if firm union of the graft has occurred and the phys-

ical condition is satisfactory, a short plaster-of-Paris spica is applied and the patient allowed to walk with crutches. This second plaster spica is removed at the end of six weeks.

2. **Excision.**—Complete excision is *almost never indicated*. The one exception to this rule is a virulent septic osteomyelitis, and then the operation is performed only as a life-saving measure. It is contra-indicated in all other instances, for the reason that its result is a failure of bony union and because removal of the femoral head and neck allows upward displacement of the shaft with marked shortening and persistent pain. In short, osseous tissue, which would otherwise aid in producing ankylosis and a stable limb, is removed by the operation. It is far preferable to employ the arthrodesis operation of the author.

When necessary, excision may be performed by four routes: the anterior, external, posterior, and Sprengel or Smith-Peterson sub-periosteal, with numerous modifications. The following are typical of each:

(*a*) *Anterior Excision* (Parker).—With the patient in the dorsal position, make a 3- to 4-inch incision downward from a point half an inch below and external to the anterior-superior spine. The upper part of the incision lies along the external border of the sartorius muscle. Retract the sartorius and the rectus femoris inward, exposing the capsule, which is opened by an incision parallel with the femoral neck. Divide the neck with osteotome or saw, and remove the head. Osseous and other débris is cleaned away from the acetabulum with a curet, and the neck rounded off and forced into the acetabulum by strong abduction of the limb. The capsule is repaired with catgut, the muscles sutured, and the skin incision closed.

Sinuses, if present, should be drained, preferably through a stab wound through the buttock to the back of the joint.

This operation has the advantage of requiring no division of muscles and of facilitating subsequent dressing because of the accessibility of the incision. It gives, however, very poor exposure of the acetabulum.

(*b*) *External Incision* (Langenbeck).—The lateral position is required with the patient on his sound side. A 5-inch incision is made, with its center over the great trochanter. Split and retract the gluteus maximus (above). Pull forward the gluteus medius, exposing the pyriformis which lies behind and gluteus minimus in front. Divide the capsular ligament (which lies between the two latter muscles) over the head and neck of the femur by an incision parallel with the cutaneous wound, and incise the trochanteric periosteum in the same line. Detach and reflect the periosteum from the great trochanter with its muscular attachments. Bare the femoral neck with a periosteal elevator and sever it with saw and chisel. Remove the head, and possibly the acetabular rim. Clear away the synovial membrane with curet and scissors, and scrape the acetabular cavity. The upper end of the femur is rounded and the cavity treated with iodoform and bismuth paste or other preparation, or is let alone. The periosteal flaps are united, and the muscles are sutured with interrupted catgut suture. No drains are inserted unless infection is present.

This operation is best suited for cases requiring removal of the trochanter with the femoral head.

(*c*) *Posterior Excision* (Kocher).—This operation gives the best access to the head and acetabulum.

With the patient in the semilateral position, the lower thigh is extended and the upper (affected) thigh is flexed and adducted.

The incision begins below and behind the posterior-superior spine and

is extended downward to the upper angle of the trochanter and thence straight down parallel with the axis of the femur to a point below the trochanter.

Split the fleshy gluteal portion of the gluteus maximus in its long axis, and divide the aponeurosis to expose the tendon of the vastus externus. The other hip muscles are detached and reflected as follows, in this order: (1) the gluteus medius, from the great trochanter, with a portion of the periosteum of the latter; (2) the gluteus minimus, in like manner; (3) the pyriformis, upward or downward; (4) the obturator internus, inward; (5) the gemelli, downward.

Flex, adduct, and internally rotate the femur. Incise the capsule parallel with the fibers of the pyriformis. Increase the force of inward rotation and divide the ligamentum teres. Sever the neck and remove the head. Clean out osseous débris and sequestra and irrigate the cavity. Round off the severed femoral neck and strongly abduct the limb. The deep wound is closed in layers by interrupted sutures of catgut. After closing the capsule, the gluteus medius is united with the pyriformis and superior gemellus; or the pyriformis and superior gemellus are sutured together. The split in the gluteus maximus is repaired and the skin incision is closed. (For technic of Sprengel or Smith-Peterson Approach see p. 216.)

After-treatment.—The essential postoperative treatment is to secure fixation in the position of the desired abduction. This may be obtained by a modified box-splint, or by a long plaster spica with a window cut over the region of the hip for dressing the wound. Fixation should be continuous for six months, when the patient may get about on crutches, with a patten or cork sole on the shortened limb.

Some surgeons employ extension by weight and pulley until healing takes place, when a double Thomas splint is applied.

After-results of Excision.—Stiles (Brit. Med. Jour., Nov. 16, 1912) reported a series of 59 excisions. In 40 cases traced after the operation, there were 12 deaths (a mortality of 30 per cent.); 2 deaths occurred immediately after operation as a result of tuberculous meningitis, while 9 lived only six months after operation, succumbing to generalized tuberculosis. In 50 per cent. of his series, the result was considered good. The average shortening was $1\frac{3}{4}$ inches. In 8 cases there was recurrence of the disease.

Townsend (Med. News, June 26, 1897) traced 99 cases of excision of the hip and found a mortality of 52.5 per cent. (9 deaths directly due to shock, 28 to exhaustion, 9 to tuberculous meningitis, and 7 to other causes). Over 71 per cent. of those who died lived only six months. Of the living, 55 per cent. were considered cured of their disease.

3. **Local Operations for the Removal of Tuberculous Bone Foci.**—When the *x*-ray shows a circumscribed bone focus without extension to the synovial membrane, it is a justifiable procedure to attempt the elimination of the focus in a patient of any age. This may be done by exposure of the hip by one of the incisions elsewhere described, and the removal of carious bone by the curet.

Huntington (Surg., Gyn. and Obst., ii, 406) advocates tunnelling through the neck and head of the femur, guided by the *x*-ray, and cureting away the dead bone. In such cases ankylosis is not anticipated by Huntington.

4. **Arthroplasty of the Hip.**—To correct an ankylosed deformed position and restore some degree of movement, various tissues have been interpolated between the articular end of the femur and the acetabular cavity.

The greatest caution should be used in undertaking arthroplasty, and then only after many years of quiescence, for there is a very strong tendency

for the tuberculous process to recur, following this operation. (For technic see Chapter XXVIII.)

5. **Operative Dislocation of the Hip.**—Bradford and Lovett noticed that cases of tuberculous osteitis of the hip which had become spontaneously dislocated offered better prospects of cure. They therefore used this as a therapeutic procedure, exposing the head through an incision, curetting away any carious bone, wiping the femoral head with alcohol and dislocating it onto the dorsum ilii, after which the wound was drained and the incision closed. The limb was immobilized in flexion and adduction. After ankylosis became established, they corrected the malposition by osteotomy. (The efficiency of this procedure is doubtful.)

6. **Amputation.**—In very urgent cases, amputation at the hip-joint may become necessary, and when performed bleeding may be minimized by the use of Wyeth's pins. Some of the indications for the operation are:

(*a*) Steady progress of the disease.

(*b*) Numerous sinuses and extensive superficial ulceration.

(*c*) Invasion of the pelvic bones.

(*d*) Great impairment of the general health.

(*e*) Suppuration with beginning waxy (amyloid) degeneration of the viscera.

REFERENCES

HIP-JOINT DISEASE

Macdonald, H. K.: "Tubercular Disease of Hip-joint." Maritime Med. News, Halifax, 1908, xx, 220–228.

Schulz, G. B.: "Hip-joint Disease." Jour. Missouri Med. Ass'n, St. Louis, Mo., 1908–09, v, 227–232.

Feiss, H. D.: "Hip Disease; a General Survey." Cleveland, M. J., 1908, vii, 514–520.

Graham, J.: "Hip Disease." Am. Jour. Surg., New York, 1908, xxii, 1–8.

Berry, W. T.: "Hip Joint Tuberculosis." Jour. Am. Med. Ass'n, 1908, i, 1977–1980.

Houzel: "Coxalgie double et double tuberculose du coude." Bull. et mém. Soc. Anat. de Par., 1908, lxxxiii, 35–41.

Rugh, J. T.: "Course of Flexion in Hip Disease." Am. Jour. Orth. Surg., 1908, v, 471–476.

Perret, C.: "Über die Dauerredultate bei Coxitis tuberculosa an der Hand. von 56 Fällen." Archiv f. klin. Chir., 1908, lxxxv, 561–612.

Horand, R.: "Coxa Vara double, genu valgum d'origine tuberculeuse." Rev. d'orthop., Paris, 1908, 2. S. ix, 505–510.

M'Murphy, N. W.: "Tuberculous Hip Disease." Vermont Med. Month., Burlington, 1909, xv, 238–243.

Anderson, F. C.: "Morbus Coxarius or Hip Joint Disease." South. Med. Jour., Nashville, 1909, ii, 957–962.

Jara Mills Bruce, K.: "Coxitis tuberculosa." Rev. Med. di Chili, 1909, xxxvii 170.

Salve, W. E.: "Tuberculosis of the Hip Joint." Canad. J. M. and S., Toronto, 1909, xxvi, 168–172.

Weeks, S. W.: "Tubercular Arthritis of the Hip Joint." South. M. J., Nashville, 1909, ii, 432–439.

M'Murphy, N. W.: "Tubercular Hip Disease." Tr. N. Hampshire M. Soc., Concord, N. H., 1909, 173–185.

Saarfils: "Über Coxitis." St. Petersb. med. Wochenschr., 1909, xxxiv, 89–91.

Cayre:: "Les Coxalgies douloureuses rebelles." Clinique, Paris, 1909, iv, 86–90.

Kirmisson: "Les Récidives de la coxalgie." Rev. gén. de clin. et de thérap., Paris, 1909, xxiii, 566.

Kirmisson: "Forme fruste ou anormale de la coxalgie." Bull. Acad. de Méd., Paris, 1910, lxiv, 51–55.

Kirmisson: "L'Inversion dans la coxalgie." Rev. internat. de méd. et de chir., Paris, 1910, xxi, 63–65.

Kirmisson: "La Coxalgie avec adduction." Pédiatrie prat., Lille, 1910, viii, 76–80.

Mitt, J. J.: "A Device for Measuring Flexion Deformity in Hip Joint Disease." Jour. Am. Med. Assn., Chicago, 1909, lii, 382.

Larny, L.: "Coxalgie guache chez un enfant de 3 ans, etc." Rev. d'orthop., Paris, 1909, 2e. Sér. x, 367–371.

FIOLLE AND BARBE: "Sur les attitudes vicieuses de la coxalgie." Marseille méd., 1909, xlvi, 712–718.
SEXTON, L.: "Observations on Tubercular Hip Joint Disease." New Orl. M. and S. Jour., 1909–10, lxii, 633–638.
GALLIE, W. E.: "Tuberculosis of the Hip-Joint." Canada, London, Toronto, 1909–10, xliii, 337–341.
STEINHARDT, I. D.: "Tuberculosis of the Hip-Joint." New York M. J., 1910, xci, 803–807.
ARMSTRONG, G. E.: "Tuberculosis of the Hip." Ann. Surg., Philadelphia, 1910, li, 520–523.
WYETH, J. A.: "A Case of Hip-Joint Disease." Med. Rec., New York, 1910, lxxvii, 707.
M'MURPHY, N. W.: "Tuberculous Hip Disease." Med. Progress, Louisville, 1910, xxvi, 27–31.
SEXTON, L.: "Observations on Tubercular Hip-Joint Disease." Virginia M. Semi-Month., Richmond, 1909–10, xiv, 133–135.
ROWLANDS, R. P.: "Tuberculous Disease of the Hip-Joint." Guy's Hosp. Gaz., London, 1910, xxiv, 421–425.
LIEBENTHAL: "Tuberculosis of the Bones and Joints of the Lower Extremity." New York M. Jour., lxxxvi, 1200–1202.
JANKOOSKI, I. I.: "Chronic Hip-Joint Disease Caused by Pyogenic Microbes, and its Complications." Khirurg. Arkh. Vebgaminova, St. Petersburg, 1910, xxvi, 1049–1056.
MENCIERE, L.: "Étude cinématographique du mouvement dans la guérison de la coxalgie et des tumeurs blanches." Pédiatrie prat., Lille, 1910, viii, 371–373.
BROCA, A.: "Tuberculeuse de la rotule hydrarthrose du genu." Rev. prat. d'obst. et de pédiat, Paris, 1910, xxiii, 97–108.
EHRINGHAUS, O.: "Zur Ätiologie der Knochenatrophie bei tuberkulöser Koxitis." Charité-Ann., Berlin, 1910, xxxiv, 755–761.
RAY, H. H.: "The Surgical Affection of the Hip-joint in Infancy and Childhood." Med. Chir., 1911, liv, 249–271.
SMITH, E. H.: "Tuberculosis of the Hip." Pacific M. J., San Francisco, 1911, liv, 412–414.
CAMPBELL, W. C.: "Chronic Affections of Hip." Memphis Med. Month., 1911, xxxi, 287–292.
D'ANTONA, A.: "La Coxite tubercolare." Studien, Napoli, 1911, iv, 95–98.
SCHLEE, H.: "Coxitis tubercolosa." Med. Klin., Berlin, 1913, ix, 339.
GERARD, C. M.: "Des différentes variétés cliniques et anatomiques (radiographie) des affections tuberculeuses de la hanche." Nancy, 1912.
ELMSLIE, R. C.: "Three Cases of an Unusual Form of Disease of the Hip-joint; Calvé's Pseudo-coxalgie." Proc. Roy. Soc. Med., London, 1912–13, Children's Sect., 102–106.

DIAGNOSIS

JACOBS, C. M.: "Symptoms and Differential Diagnosis of Tubercular Hip-joint Disease." Quart. Bull., Northwest. Univ. Med. Sch., Chicago, 1908, x, 80–84.
OSTERHAM, K.: "Diagnosis and Treatment of Coxalgia." Virginia M. Semi-Month., Richmond, 1908, xiii, 78–82.
MARSHALL, V. F.: "Concerning the Diagnosis and Treatment of Hip-joint Disease." Wisconsin M. J., Milwaukee, 1908–09, vii, 399–400.
SALAGHI, M.: "Nuovo Segno per la diagnosi iniziale della coxite." Arch. di ortop., Milano, 1908, xxv, 262–266.
CALVÉ, J.: "Difficultés, du diagnostic de la coxalgie au debut." Presse méd., Paris, 1909, xxii, 122–125.
SHANDS, A. R.: "The Diagnosis and Treatment of the Early Stages of Hip Disease." Virginia M. Semi-Month., 1909–10, xiv, 121–125.
STERN, W. G.: "The Diagnosis of Tuberculous Hip-joint Disease." Cleveland M. J., 1909, viii, 686–696.
SAVARIANA: "Coxalgie fruste simulant la coxa vara des adolescents." Bull. et mém. Soc. de Chir. de Par., 1910, N. S. xxxvi, 891–895.
MAIRE: "Diagnostic et traitement de la coxalgie au debut." Centre méd. et pharm., Gannat, 1909–10, xv, 291–305.
WALDERSTROOM, H.: "Die Herdreaktion auf Tuberkulin bei der Koxitis." Zeitschr. f. Orth. Chir., Stuttgart, 1910, xxvi, 623–642.
FORBES, A. M.: "The Condition of the Lymphatic Glands as a Factor in the Diagnosis of Tuberculosis of the Hip and Lower Spine." Montreal M. J., 1910, xxxix, 518–526.
DUCROQUET, C.: "La diagnostic de la coxalgie." Rev. d'hyg. et de méd. inf., Paris, 1910, ix, 482–491.

JACOBS, C. M.: "Symptoms and Differential Diagnosis of Tuberculous Hip-joint Disease." Iowa M. J., Des Moines, 1910–11, xvii, 555–560.
KIRMISSON, E.: "Sur un point particulier de l'histoire de la coxalgie double." Rev. d'orthop., Paris, 1910, 3e sér. i, 559–562.
MAUCLAIRE: "Symptômes, diagnostic, et traitement de la coxotuberculose." J. de méd. int., Paris, 1910, xiv, 91.
BROCA: "Le diagnostic de la coxalgie au début." Pédiatrie prat., Lille, 1911, ix, 1–6.
SAVARIANA: "Coxalgie au début: diagnostic et traitement." Méd. inf., Paris, 1911, viii, 32–37.
ROCHER, H. L.: "Le Signe de la clef dans la coxalgie au début." Gaz. hebd. des sc. méd. de Bordeaux, 1912, xxxiii, 608.

TREATMENT

LANNELONGUE: "Traitement de la coxo-tuberculose dans la phase de début." Bull. Acad. de Méd., Paris, 1907, 3e sér. lviii, 595–601.
M'ILHENNY, P.: "The Treatment of Coxitis." New Orleans M. and S. J., 1907–08, lx, 535–543.
BRADFORD, E. H., AND SOUTTER, R.: "Traction in the Treatment of Hip Disease." Am. J. M. Sc., Philadelphia and New York, 1908, N. S., cxxxvi, 794–818.
GIBNEY, H.: "Some Observations on the Treatment of Hip Disease." Virginia Med. Semi-Month., Richmond, 1908–09, xiii, 529–531.
CALOTT: "Ce qui doit être le traitement de la coxalgie." Bull. méd. de Québec, 1908–09, x, 481–490.
MARION, G.: "Traitement de la coxalgie." Rev. internat. de méd. et de chir., Paris, 1908, xix, 143–145.
WYNKOOP, E. J.: "The Use of Traction in the Treatment of Hip-joint Disease in Children." Arch. Pediat., New York, 1908, xxv, 198–202.
VILLEMIN: "Traitement de la coxalgie." Bull. méd., Paris, 1908, xxii, 77–83.
ABBOTT, E. G., AND PINGREE, H. A.: "The Ambulatory Treatment of Hip Disease." Med. J. Am. Med. Assn., 1908, i, 427–432.
WILLS, W. Le M.: "Treatment of Hip-joint Disease." Calif. State J. M., San Francisco, 1908, vi, 22–24.
CALOT: "Le Traitement de la coxalgie." Rev. gén. de clin. et de thérap., Paris, 1908, xxii, 161–168.
HOFFA, A.: "Die Behandlung der tuberculösen Koxitis." Monatschr. f. orthop. Chir., Berlin, 1908, viii, 1–3.
RANKIN, H. B.: "Hip Disease: the Responsibilities of the Surgeon and the Indications for Treatment." Quart. Bull. Northwest Univ. Med. Sch., Chicago, 1908–09, x, 51–54.
VILLEMIN: "Traitement de la coxalgie." Ann. de méd. et chir. inf., Paris, 1908, xiii, 86–100.
BARBARIN, P.: "L'Appareil plâtre dans la coxalgie chez l'enfant." Clinique, Paris, 1908, iii, 529–532.
BARBARIN, P.: "Traitement de la coxalgie sans abcés et sans attitude vicieuse." Clinique, Paris, 1908, iii, 513.
GIBNEY, V. P.: "The Influences of Weight-bearing on the Treatment of Tuberculous Hip-joint Disease." Am. Jour. Orth. Surg., 1908–09, vi, 21–34 and 128–132.
BENOIT, C.: "Évolution du traitement de la coxalgie." Pédiatrie prat., Lille, 1908, vi, 229–234.
VIGNARD: "Tuteur à point d'appui ischiatique pour guérie." Lyon méd., 1908, cxi, 464–470.
VIGNARD: "Traitement de la coxalgie avec plombage." Lyon méd., 1910, cxiv, 637.
BIDAUX, R.: "Études sur la traitement de la coxalgie." Rev. internat. de la tuberc., Paris, 1909, xvi, 403–409.
BIDAUX, R.: "Traitement régulier d'un coxalgie prise au début." Rev. internat. de la tuberc., Paris, 1909, xv, 414–425.
WEBER, H.: "Über die Behandlung der Knochenturen tuberculöser Hüftgelenke." Arch. f. orthop., Wiesbaden, 1909, viii, 193–197.
WILCHET, J.: "À propos de la coxalgie et de son traitement local conservateur." Scalpel, Liége, 1909, lx, lxii, 241–253.
VON BONSDORFF, H.: "The Surgical Treatment of Tuberculous Coxitis." Finska Läkr. Sällsk. Handl., Helsingfors, 1909, li, v, 2, 901–921.
DELCHEF, J.: "Technique de la méthode de Lorenz pour la traitement de la coxalgie." Scalpel, Liége, 1909–10, lxii, 635–641.
MAYET, H.: "Comment faut-il traiter la coxalgie?" Rev. mens. de gynéc., d'obstét., et de pédiat., Paris, 1909, iv, 155–161.

SAVARIANA: "Appareils plâtrés dans la coxalgie, etc." Jour. de méd. de Paris, 1909, 2e sér. xxi, 223–225.
SCHWATT: "The Treatment of Abscesses in Hip Disease." Internat. Clin., Philadelphia, 1909, 19, n. ii, 177–189.
WILSON, H. A.: "Treatment of Tuberculous Hip by Weight-bearing and Fixation by the Lorenz Short Spica." South. M. J., Nashville, 1909, ii, 440–444.
BELHAM: "Coxalgie: quelques notes sur son traitement." Ann. de chir. et d'orthop., Paris, 1910, xxiii, 321–326.
BELHAM: "Quelques notes sur le traitement de la coxalgie." Ann. de chir. et d'orthop., Paris, 1910, xxiii, 353–358.
MENCIERE, C.: "Technique du traitement de la coxalgie et des tumeurs blanches pour la conservation du mouvement dans l'articulation." Arch. prov. de chir., Paris, xix, 135–171.
MENCIERE, C.: "Technique du traitement de coxalgie, etc." Pédiatrie prat., Lille, 1910, viii, 366–371.
HENDREX, G.: "Le Traitement de la coxalgie par le méthode conservatrice de Lorenz." Policlinic, Brux., 1910, xix, 65–75.
HENDREX, G.: "Un Cas de coxalgie traité par la méthode ambulatoire." Policlin., Brux., 1910, xix, 201–203.
NEUBER, G.: "Über die Behandlung der tuberculösen Koxitis." Archiv f. klin., Berlin, 1910, xciii, 96–118.
ALAPY, H.: "Die Endergebnisse der konservativen Coxitis und Gonitis-Behandlung." Zeitschr. f. orth. Chir., Stuttgart, 1910, xxvii, 243–278.
DOCHE, J.: "Prognostic et traitement de la coxalgie fistulée." J. de méd. de Bordeaux, 1910, xl, 561–563.
MURPHY, J. B.: "Lesions of the Hip-joint and their Management." Surg. Gyn. and Obst., 1911, xii, 200.
CALVE, J.: "Quelques considérations sur les appareils amovibles en celluloid dans le traitement de la coxalgie et du mal de Pott." Clinique, Paris, 1911, vi, 241–244.
FEISS, H. D.: "Treatment of Hip Disease as Based on its Pathological Mechanics." Ohio M. J., 1911, 165–169.
CONDRAY, P.: "Coxo-tuberculose et son traitement." Rev. de chir., Paris, 1911, xliii, 420–467.
SNIVELY, J. H.: "Extension Apparatus for Hip-joint Disease." Northwest. Med., Seattle, 1912, N. S., iv, 269.
KEPPLER, C. R.: "The Short Spica in the Treatment of Hip-joint Disease." Am. J. Obst., New York, 1912, lxvi, 888–892.
KEPPLER, C. R.: "The Short Spica in the Treatment of Hip-joint Disease." Jour. Med. Soc. New Jersey, Orange, 1912–13 ix, 599–603.
PACKARD, G. B.: "The Mechanical Treatment of Hip Disease." Am. Jour. Orth. Surg., 1912–13, x, 329–332.
BRADFORD, E. H.: "Fixation in the Treatment of Hip Disease." Am. Jour. Orth. Surg., 1912–13, x, 354–362.
TAYLOR, H. L.: "Results in Hip Tuberculosis after Mechanical Treatment without Traction and Hygiene." Am. Jour. Orth. Surg., 1912–13, x, 333–353.
BERRY, W. T.: "Some Thoughts on Resection of the Hip-joint for Tuberculous Disease." Charlotte (N. C.) M. J., 1907, xxxi, 293–299.
BOOTH, H. C.: "Radical Operation for the Cure of Incipient Hip-joint Disease." Buffalo M. J., 1908–09, lxiv, 594.
M'BURNEY, C.: "Amputation at the Hip-joint for Tuberculosis." Med. Rec., New York, 1908, lxxiii, 667.
VIGNARD: "De l'ostéotomie sous-trochantérienne et souscutanée dans le redressement des attitudes vicieuses de la coxalgie guérie." Bull. de Soc. de Chir., Lyon, 1908, xi, 24–27.
VIGNARD: Ditto: Lyon Méd., 1908, cx, 404–497.
VIGNARD: "Deux cas de coxo-tuberculose grave traités par la résection suivie de plombages." Lyon Méd., 1909, cxii, 112–115.
JEANNE AND FORTIN: "La Désarticulation de la hanche dans les vielles coxalgies fistuleuses." Rev. méd. de Normandie, Rouen, 1908, 446–448.
BOWLBY, A. A.: "An Address on 900 Cases of Tuberculous Disease of the Hip, with a Mortality of less than 4 per cent." B. M. J., 1908, i, 1465–1469.
KÖNIG: "Die oparative Entfernung (Resektion) des tuberkulös erkränkten Hüftgelenks." Berl. klin. Wochenschr., 1909, xlvi, 429–431.
DE BEULE, F.: "Hüftgelenks Resektion." Zentralbl. f. Chir., Leipzig, 1909, xxxvi, 1077.
GREENBERG, H. J.: "Resection for Tuberculosis of the Hip-joint." Wisconsin Med. Jour., Milwaukee, 1909–10, viii, 448–463.

VINANT, E.: "Notes sur la coxalgie et la resection de la hanche." Paris. chirurg., 1909, i, 712–722.

HERMAN AND MAFFEI: "La Résection de la hanche dans la coxalgie." J. de chir. et Ann. Soc. belge de Chir., Brux., 1909, ix, 229–237.

CALOT: "Les Injections articulaires dans le traitement de la coxalgie." Rev. méd. et de chir., Paris, 1910, viii, 48–57.

INGRAM, J. W.: "Hip-joint Amputation in Complicated Tuberculous Hip-joint Disease." Med. Sentinel, Oregon, 1910, xvii, 100–102.

BINET, A.: "La Résection dans la coxalgie." Rev. méd. d'est., Nancy xliii, 513.

CONDRAY, P.: "Traitement opératoire et traitement conservateur dans la coxalgie infantile." Gaz. méd. de Paris, 1911, lxxxii, 153

OGILVY, C.: "The Results of Excision of the Hip in Tuberculosis of the Joint." Post-Graduate, New York, 1912, xxvii, 989–998.

CHAPTER VII

TUBERCULOSIS OF THE KNEE-JOINT

Synonyms.—Tumor albus; white swelling.

ETIOLOGY

Tuberculosis of the knee is next in frequency and importance to that of the hip-joint. It is essentially a disease of early life, although it is not so generally confined to children as is hip-disease.

There is often a previous trauma and not infrequently one of the exanthemata. Additional etiological factors are those common to tuberculosis of all joints. The immediate and specific cause of the disease is the localization and development of B. tuberculosis in one or more of the component parts of the joint.

NORMAL ANATOMY

The knee is the largest joint in the body and is of the modified hinge variety (ginglymus). Its component parts are the condylar and trochlear surfaces of the femur, the tuberosities of the tibia and the patella, lined with synovial membrane and banded together by ligaments and muscles.

The fibrous capsule is differentiated into several *external* (superficial) *ligaments*, viz.:

1. *Internal lateral ligament*, extending from the internal condyle of the femur to the inner surface of the head of the tibia.

2. *External lateral ligament*, a rounded cord from the external condyle of the femur to the head of the fibula.

3. *Posterior ligament*, a strong flat band from the back of the inner tuberosity of the tibia to the internal condyle of the femur.

4. *Ligamentum patellæ*, from the lower border of the patella to the tubercle of the tibia. A synovial bursa separates it from the tubercle.

5. *Capsular ligament*, seen only in the intervals between the above. It is thickened behind to form the posterior ligament and is strengthened by expansions of the fascia lata and quadriceps tendon, particularly by the iliotibial band. The capsular ligament really exists in layers with a padding of fat between. It is attached to the femur and tibia not far from their articular margins, and is adherent to the semilunar cartilages.

A set of *internal* (deep) *ligaments* consists of:

6. *Synovial ligaments*, two thin folds extending behind the patella upward on either side (*alar ligaments*) and one stretching backward (*ligamentum mucosum*).

7. *Anterior crucial ligament*, from the inner part of the depression in front of the tibial spine, upward, backward, and outward to the dorsal part of the inner surface of the outer condyle of the femur.

8. *Posterior crucial ligament* from the popliteal notch and behind the spine of the tibia to the front of the outer side of the internal condyle of the femur.

The *semilunar cartilages* are two crescentic plates resting on the circumferential portions of the articular facets of the head of the tibia, covering nearly two-thirds of the surface of the latter. They increase the convexity of the articular surface. They taper at their apices which are attached in front of and behind the tibial spine. The external cartilage is the more movable.

The *transverse ligament* is variable but extends between the outer surface of the anterior portions of the semilunar cartilages.

The *coronal ligament* encircles the tibia between its head and the semilunar cartilages and holds the latter against the tibia.

The *synovial membrane* lines the capsule of the joint and is the largest in the body. Its upper limit is about three fingers' breadth above the upper border of the patella; laterally it covers the anterior third of the outer surface of each condyle, but behind it does not extend upward beyond condyles. It as attached below and in front at the upper border of the tibia. It forms a short cul-de-sac behind the popliteal notch of the tibia. It lines the capsule, the deep aspect of the infrapatellar pad of fat, and both surfaces of the semilunar cartilages. It almost completely invests the crucial ligaments and the tendon of the popliteus. It is reflected above on the metaphyseal part of the femur in front, but behind it does not ascend beyond the epiphysis.

SURGICAL ANATOMY

The thinnest part of the posterior ligament lies below the oblique fibers from the semimembranosus and is the usual route of exit for pus when escaping posteriorly.

The large cul-de-sac of the synovial membrane above the patella and beneath the extensor tendon (which usually reaches 1 inch or more above the inner margin of the trochlear surface of the femur) becomes drawn down when the knee is flexed. Hence this is one reason why this is the proper position in operations on the lower end of the femur.

The bursa between the extensor tendon and the femur (which measures about 1 inch vertically) often communicates with the synovial cavity, which accounts for extension of an infectious bursitis to the latter structure.

The crucial ligaments are entirely outside the synovial cavity.

When the synovial cavity is distended with fluid, the swelling is greatest above and to either side of the patella, causing "floating" of that bone.

An inflamed knee-joint will spontaneously become flexed for the following reasons: (1) Its capacity is increased by flexion, with consequent relief of tension. Its maximum capacity is reached on flexion of 250°; its minimum, on complete flexion.

2. Relaxation of its more powerful ligaments (posterior, posterior crucial, and lateral) occurs in the position of flexion.

3. Reflex muscular action, the more powerful flexors predominating.

PATHOLOGICAL ANATOMY

It is a question still undecided and vigorously debated, whether the disease is primary in the osseous components of the knee-joint or in its synovial membrane. A secondary bone focus of tuberculous disease is more commonly found in the epiphysis of the lower end of the femur than elsewhere.

From a clinical standpoint, two distinct types of tuberculous knee-joint are recognized, viz.:

(*a*) *Chronic tuberculous synovitis*, seen more often in adults than in children.

(*b*) *Tuberculous osteitis*, with pain, muscle spasm, and deformity.

The two types are, however, blended in the same case in many instances, so that all the structures show evidences of tuberculous disease. Incision of a knee-joint generally affected with tuberculosis shows the *synovial membrane* thickened, pink and grey or yellow and semitransparent. It is of soft semigelatinous texture in some places, tough and fibrous in others, and often displays areas of caseation. *Fluid* may be present in varying

amount and consistency. *Adhesions* are usually present, partitioning the joint-cavity into loculi and limiting its mobility. Granulation tissue spreads over the surfaces of the articular cartilage and insinuates itself between the latter and its underlying tissue. *Maceration* of the *cartilage* takes place and if much pressure and friction have been at work the cartilage may be almost entirely destroyed. Following disintegration of its retaining ligaments (particularly the crucial), backward and outward *dislocation* of the *tibia* occurs. *Reactive inflammation* takes place in the *peri-articular* structures and these changes together with those within the joint, produce the firm, resistant, bulbous tumor characteristic of "*white swelling*." Occasionally the predominating feature is a great outpouring of fluid into the joint cavity, causing the designation "*hydrops articuli*" to be applied.

SYMPTOMS AND PHYSICAL SIGNS

The disturbance of function is usually first indicated by stiffness, *local sensitiveness* to touch, with *local swelling* and increased *surface temperature*, all accompanied by *pain* and *lameness* when walking. The pain, at first felt only at intervals, increases in severity and duration; *muscular atrophy* makes the "*white swelling*" more pronounced; the range of *flexion* becomes progressively less, the tibia displaced backward; and eventually *abscesses* and *sinuses* supervene. This is the natural history of the average case; considered more in detail, the symptoms and signs are as follows:

1. **Limping.**—At first, in walking the leg is held slightly flexed, although fully extensible, with, however, slight pain. At a later date, extension becomes inhibited and the limp more pronounced. Lameness is therefore a constant symptom.

2. **Pain.**—The pain is usually moderate, but increases and becomes acute. Its onset is often insidious, the joint may merely become tired more readily. Pain is heightened by sudden movements, jars, weight-bearing. It may be entirely absent, particularly in hydrops which causes a separation of the painful eroded articular cartilages.

3. **Local Heat.**—Increase of local surface temperature is usually apparent from the first, but disappears with the successful application of treatment, and a recrudescence of the disease is indicated by a return of local heat. In the more chronic cases, local heat and redness are entirely absent. The gross appearance of the knee is a cold, white boggy joint, which is clinically known as "white swelling."

4. **Muscular Spasm and Limitation of Motion.**—The former, almost always a feature of this disease, involves chiefly the ham-string muscles, producing a flexion deformity. All the muscles are in a state of spastic contraction. Here, as in practically all similar instances, the flexors (in this case the ham-strings) overcome the extensors, and flexion deformity results.

Muscular spasm is less marked in tubercular knee-joint disease than in hip disease, and in some cases in the early stages it may be so slight that its detection is difficult.

5. **Sensitiveness and Swelling.**—Superficial sensitiveness is often accompanied by a local *tenderness* to deep pressure, particularly at a point over the inner surface of the head of the tibia.

Swelling of the knee is an early sign, indicated by an indistinctness of outline, filling-up of the natural hollows on either side of the suprapatellar ligament and the ligamentum patellæ; and thickening of the lateral surface of the femoral condyles and of the tuberosities of the tibia. Regarding the patella, Tubby has noted an important diagnostic point: the familiar patellar click can be produced in a healthy joint and in the presence of fluid, but when

the synovial membrane is thickened this phenomenon cannot be elicited. Instead of delimiting the distribution of the synovial reflections, as in the early stages, the swelling at a later date becomes fusiform in shape, tapering above and below.

6. **Muscular Atrophy.**—Wasting is present early, embraces both leg and thigh, and is proportionate to the acuteness of the disease process. The wasting accentuates and exaggerates the localized swelling of the knee.

7. **Changes in Appearance of the Joint.**—In addition to the swelling, the affected knee exhibits other changes of appearance. The skin is pale and anemic, of edematous type, and the surface veins are prominent, giving the part a marbled appearance. If, however, pus is present, the skin shows hyperemic foci, and possibly sinuses.

8. **Distortions.**—(*a*) *Primary distortion* consists of flexion of the leg to a greater or less degree, according to the sensitiveness of the component bony parts of the joint, and is due to muscular action. Other deformities of the limb are secondary to this attitude.

(*b*) *Secondary Deformities.*—1. The commonest deformity is *outward rotation of the tibia* on the femur, due to outward traction of the biceps muscle on the head of the fibula. This action is favored by the use of the limb in outward rotation (a position always assumed when disease of the knee-joint is present), and by secondary knock-knee which often accompanies it.

2. *Backward displacement* of the head of the *tibia*, caused by muscular spasm and the marked destructive action of the disease on the contact surfaces of tibia and femur, further aided by the leverage exerted on the joint.

3. *Knock-knee* (genu valgum), due to hypertrophy of the internal condyle with use of the flexed limb in outward rotation, or crushing of the outer femoral condyle or head of tibia.

4. *Genu varum* rarely occurs, but when present is due to destruction of the inner femoral condyle.

9. **Alterations in Length of the Limb.**—Actual lengthening is at first present in some cases, due to the irritant action of the disease upon the epiphyses and consequent increase in their lengths (the lower femoral epiphysis is the one usually involved). There may be an actual increase of an inch or more in length, but this increase usually disappears with the cure of the disease.

On the other hand, if the disease is of a destructive type, shortening (in some cases of 2 or more inches) may be noted.

10. **Abscesses and Sinuses.**—These are common in tuberculosis of the knee and have the same general features as similar processes in other joints.

METHOD AND RESULTS OF EXAMINATION

For future reference, to note the progress of the lesion, and as an aid in accurate diagnosis, a systematic and thorough examination should be made and the accumulated data recorded in the following manner and order.

History.—Details of the present illness and sequence of signs and symptoms.

General Inspection.—(*a*) Enlarged glands; (*b*) evidence of osseous tuberculosis elsewhere; (*c*) general appearance, hair, complexion, skin, attitude, height, weight, limp.

Local Examination.—(*A*) *Inspection.*—(*a*) skin, (*b*) swelling, (*c*) deformity, (*d*) muscular atrophy.

(*B*) *Palpation.*—(*a*) local temperature, (*b*) thickening of neighboring bones, (*c*) enlargement of synovial membrane, (*d*) fluid, (*e*) mobility of patella.

(*C*) *Measurements.*—(*a*) Longitudinal: 1. Anterior-superior spine to

internal malleolus. 2. Top of great trochanter to lower edge of internal condyle (knee flexed). 3. Internal tuberosity of tibia to tip of internal malleolus.

(*D*) Circular: 1. Center of thigh. 2. Center of calf. 3. Knee-joint.

(*E*) Degree of Deformity: 1. Angle of flexion (patient on affected side, trace outline on paper or with gonometer). 2. Range of motion, by manipulation.

(*D*) *X*-ray.

DIAGNOSIS

(A) **Absolute Diagnosis.**—The most important indication of tuberculous disease is the *destructive, monarticular* feature of the lesion. Supple-

B. DIFFERENTIAL DIAGNOSIS

Disease	Points of resemblance	Points of difference
(*a*) Syphilitic synovitis.	Chronicity.	(1) Bilateral effusion. (2) Absence of pain. (3) Small amount of functional disturbance. (4) Other syphilitic stigmata. (5) Response to syphilitic treatment. (6) *X*-ray. Wassermann.
(*b*) Infectious and gonorrheal arthritis.	Pain. Local heat. Muscle spasm and limited motion. Sensitiveness. Swelling.	(1) Sudden onset. (2) Characteristic constitutional and local symptoms of an acute infection. (3) *X*-ray. (4) Aspiration. (5) Bacteriological examination. (6) Complement-fixation test.
(*c*) Trauma.	Limp. Persistent flexion and pain. Traumatic factor. Tenderness. Effusion.	(1) Sudden onset. (2) Rapid disappearance of symptoms under treatment. (3) *X*-ray.
(*d*) Acute Rheumatism.	Monarticular, occasionally. Tenderness. Effusion.	(1) Polyarticular, usually. (2) Fever, local heat, suddenness of swelling, sweating. (3) Cardiac involvement. (4) Therapeutic response. (5) *X*-ray.
(*e*) Hemarthrosis.	Inflammation, local signs (during absorption and organization of clot).	(1) Sudden onset. (2) Personal history of haemophilia; coagulation time. (3) Aspiration. (4) *X*-ray.
(*f*) Arthritis deformans.	Chronicity.	(1) Adult life. (2) Early symptoms during function only. (3) Extreme chronicity. (4) Proliferative bone changes in *x*-ray.
(*g*) Hysterical joint.	Subjective symptoms.	Absence of positive physical signs, including *x*-ray.
(*h*) Charcot's joint.	Effusion. Rapid destruction of joint. Weakness. Deformity.	(1) Pain very slight. (2) Muscular spasm absent. (3) Diagnosis of disease of spinal cord or severe peripheral nerve injury. (4) *X*-ray. (5) Wasserman.
(*i*) Sarcoma of bone.	At or near extremity of femur or tibia.	(1) More localized and irregular swelling of periosteum. (2) More rapid growth. (3) Uninfluenced by local treatment. (4) *X*-ray appearance. (5) Greater destruction.

mentary evidence may be obtained from the family history, occurrence of tuberculosis elsewhere, the history of onset, and by inspection and palpation of the joint. When fluid is present, aspiration and inoculation of a guinea-pig may establish the diagnosis; but it should be remembered that a *negative* result does not prove the *absence* of tuberculosis. The von Pirquet and other tests may give valuable aid. The *x*-ray is an indispensable aid and should be used in every case.

PROGNOSIS

Mortality.—In a series of 300 cases of tuberculosis of the knee-joint, Gibney (Am. Jour. Med. Sci., October, 1893) recorded a mortality of 13 per cent. When death occurs, it is usually due to prolonged suppuration, amyloid disease, or disseminated tuberculosis.

Function.—The outlook for restoration of function is in direct ratio to the early recognition of the disease and the promptness and efficiency of local and general treatment. The following tables from Gibney's statistics show the functional results in his series:

191 of 300 cases had a movable joint.
(74 of 191 cases had mobility of 45° to normal.)
(41 of 191 cases had mobility of 90° and above.)
51 of 300 cases had ankylosis.
(16 of 51 cases had a limb practically straight.)
(35 of 51 cases had flexion of more than 30°.)
125 of 191 cases had a limb that could be nearly straightened.

Deformity.—Aside from the various degrees of ankylosis, the affected limb may be left in one of the following conditions after spontaneous cure or local treatment: Backward displacement of the tibia; genu valgum or genu varum; shortening of varying lengths.

TREATMENT

Treatment is divided into *general* and *local*.

1. **General Treatment.**—This follows the lines already laid down in Chapter I and applies to tuberculous disease of all bones and joints. Fresh air, sunshine, and forced feeding are invaluable in the general treatment of the disease. Tuberculin and its congeners should be given a fair trial, and the free use of cod-liver oil, iron, etc., should be prescribed in every case.

2. **Local Treatment.**—The case of the affected joint itself may be considered in two main divisions, viz., *conservative* (mechanical) treatment, chiefly applicable to children, and *operative* treatment, chiefly applicable to adults, together with certain accessory therapeutic methods commonly used to supplement these two main lines of local treatment.

In children, the *conservative* treatment of this joint as well as of a tuberculous hip, should be followed, as a rule, to the last, and except in the case of localized lesions operation should be sedulously avoided whenever possible. This is especially important on account of the large amount of shortening which invariably occurs from interference with epiphyseal growth when an excision is performed in childhood. The functional results of conservative treatment are seen at their best in the case of children to whom, moreover, immobilization is not so pronounced a hardship as in adults.

For the sake of emphasis, it may be repeated that the key-note of the treatment of tuberculous knee-joint is, for children, conservatism (except in the case of a strictly localized or extra-articular lesion); for adults, operation except in the mildest cases.

Conservative Treatment.—As in all instances of tuberculous disease of the bones and joints, a tuberculous knee demands, first of all, *absolute rest* until the acute symptoms have completely subsided (fixation or recumbent treatment), after which the patient may be allowed to walk with the affected joint immobilized (ambulatory treatment).

In the author's practice, every case of tuberculosis of the knee-joint in which the conservative method of treatment is to be followed is managed after the following plan, each stage of treatment being administered in the order given.

1. *Recumbency* with *traction* (*i.e.*, fixation or recumbent treatment) until the acute symptoms have entirely subsided.

2. *Gradual Reduction of the Amount of Traction.*—Intelligent, constant observation is necessary to note whether the acute symptoms do or do not recur.

3. The patient is allowed out of bed after a period of observation has proved the absence of all acute symptoms, and a splint is worn to immobilize the limb and remove weight-bearing from the affected joint.

4. Weight-bearing is allowed under strict observation, but immobilization of the limb is continued. If any recurrence of acute symptoms is noted, the patient must at once be relieved of weight-bearing until subsidence of the symptoms.

5. A removable splint is worn. With the patient in bed without his splint, voluntary motion, gradually increased, may be permitted.

To recapitulate: In all cases except the very mildest, the initial treatment is recumbency in bed with the most efficient immobilization with adequate traction (which varies from 5 to 15 pounds in the case of a child). A useful guide is to slowly decrease the amount of traction until the symptoms subside. A choice may be made from the methods of recumbent treatment about to be described. One should be conservative in abandoning recumbency as it is the most effective means of distraction and immobilization; ambulatory methods are far less certain in this respect.

These various stages of the conservative treatment will now be considered in greater detail.

(A) *Fixation* (Recumbent) *Treatment.*—This method has to be applied to every case as soon as a diagnosis has been made. Fixation in the recumbent position with the desired amount of traction may be secured by: (1) weight-extension, (2) Thomas knee-brace, (3) Thomas knee-brace applied over a plaster-of-Paris splint, or (4) by a long plaster-of-Paris spica.

1. *Weight and Pulley.*—With the patient in bed, direct extension is secured by a weight attached to the leg by adhesive strapping or mole-skin stickers applied and bandaged as far as the knee. *It is essential that traction be applied in the line of the deformity*, whatever that may be. If the usual flexion deformity exists, proper traction is secured by an angular splint or double inclined plane, which should be diminished as fast as the deformity is overcome and the leg is brought to the extended position. Countertraction can be made by means of a perineal band (when the limb is straight) or by raising the foot of the bed; or (when flexion deformity exists) by a band applied to the thigh above the knee and connected with weight-extension. The combination of traction and the extended position of the leg is the most certain means of preventing subluxation of the tibia on the femur.

2. *Thomas Knee-brace* (Figs. 117 to 120).—Although this brace was primarily designed for ambulatory treatment, it can be very effectively used in recumbent treatment.

The brace consists of two lateral uprights connected by a cross-bar which acts as a stilt below, and an obliquely placed padded ring above into which the thigh is fitted at the groin, thus supporting the superimposed body-weight. This padded ring is oval, flattened to fit the groin in front, expanded behind (to fit the buttock), and wider on its inner than its outer side. The ring has a double inclination, laterally (due to the longer outer upright), and posteriorly (to fit the tuberosity of the ischium), its angles being 135° and 145° respectively. Between the uprights are leather bands to support the thigh and leg posteriorly. Straps are attached to the foot-piece for traction.

Moleskin or adhesive strapping for extension is applied as far as the knee, and after the brace is in place the knee is bandaged to it. Two shoulder-

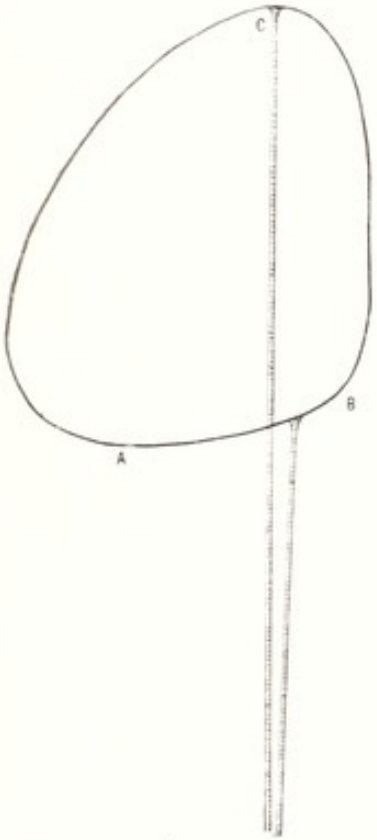


FIG. 117.

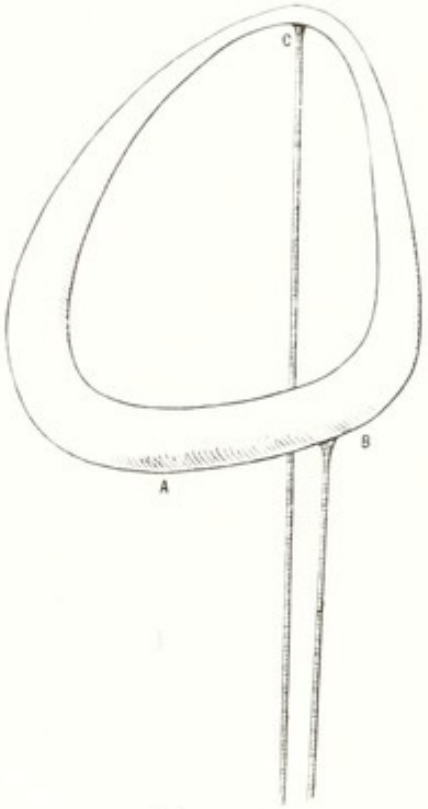


FIG. 118.

FIG. 117.—The Thomas knee splint, showing the inner bar *B* placed farther to the front than the outer bar *C*; *A* is the lowest part of the ring; upon this rests the tuberosity of the ischium. (Whitman.)

FIG. 118.—The ring of the Thomas knee splint after padding. (Ridlon.)

straps (one in front and one behind) worn over the opposite shoulder, steady the brace and prevent its slipping down off the limb.

3. *Plaster Bandage and Thomas Knee-brace.*—If greater immobilization of the joint is desirable, it may be secured by an appropriate plaster-of-Paris bandage and the Thomas knee-brace worn over this together with traction straps. This combination can be used with the patient continuously in bed, as well as in the course of ambulatory treatment.

4. *Long Plaster-of-Paris Spica.*—In certain cases a long plaster-of-Paris spica seems to afford better immobilization than any other method, and it can be used as a means of recumbent treatment with or without the use of traction applied by means of long moleskin "stickers" attached to the leg below the knee with their ends brought out through the plaster above

the ankle-joint. A "spreader" fastened to the free ends of the "stickers" affords means of attaching the weights.

After the acute symptoms have entirely subsided and the deformity has been reduced by one of the methods enumerated above, gradual reduction of the amount of traction may be allowed. It is necessary, however, that the surgeon exercise intelligent, constant observation to note whether or not the acute symptoms recur under this reduction of traction. *Clinical indications* for the cessation of recumbency and the beginning of ambulatory treatment are improvement in the general condition and absence of night cries, irritability, muscle spasm, and joint sensitiveness.



FIG. 119.—The Thomas knee brace. (Whitman.)

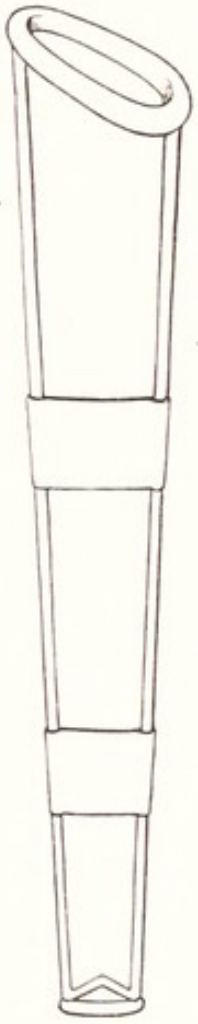


FIG. 120.—Thomas knee brace. It is used to immobilize and relieve weight-bearing of knee or ankle. (Albee, in Johnson "Operative Therapeusis.")

(*B*) *Ambulatory Treatment.*—The patient is allowed to go about with one of the following appliances:

1. *Plaster-of-Paris Bandage.*—This provides excellent protection as well as fixation of the joint, and its application is simple and rapid. The bandage is applied from toes to groin or, if greater fixation is desired, as a long spica; but a short plaster bandage from mid-thigh to mid-calf is not only a useless encumbrance but may defeat the very purpose for which it was applied, and hence should never be used. The advantages of evenly padding the limb

and of manually moulding the plaster, during its plastic state, about the bony prominences so as to afford more perfect immobilization, cannot be too strongly emphasized. Further details in plaster-of-Paris technic should be observed in this connection and may be found more fully discussed in the chapter devoted to that subject. With the plaster bandage properly applied the patient may be allowed to get about on crutches. If flexion happens to be present, it can be corrected in stages by applying the plaster at intervals of a few weeks, increasing the extension slightly at each successive application.

2. *Thomas Knee-brace* (described above).—The Thomas knee-brace may be used for walking by raising the boot of the healthy limb or by the use of a patten (Fig. 119). This brace, as compared with the caliper splint of Thomas, is a much safer means of providing adequate traction and preventing weight-bearing. The caliper splint, unless kept constantly adjusted to keep pace with the child's continuous growth at all times, is likely to be ineffective. The essential feature of the caliper splint is that the upright bars are attached to the boot in such a way as to pull it away from the foot and prevent the heel from bearing the body-weight. But the limit of "play" between the foot and the boot is very small, and unless constant supervision is practised (a difficult task for the layman) or if the child should grow rapidly, the foot and the boot eventually come in contact.

3. *Caliper Convalescent Splint* (Thomas).—The advantages of this splint are that in walking on a stilt-ring, the patient walks on the sole of the boot; furthermore it is a very simple brace to make. This is accomplished by cutting off the lower ends of the two lateral bars and turning them in at right angles to be fitted into a steel tube which is passed through the heel of the boot. The bars are still left longer than the limb so that the patient's heel is separated nearly an inch from the inside of the boot when walking, thus avoiding impact of the heel with the ground. To avoid friction and possible ulceration of the heel, a triangular piece is cut out of the back of the boot and a loose piece of leather is sewed over it for the heel to play upon. Retaining straps or bandages should confine the mid-thigh and lower leg regions to the brace. The upper of the shoe serves as an anklet in producing a certain amount of traction.

Accessory Treatment.—As adjuvants of local treatment, various remedial agents are to a greater or less extent employed.

1. *The actual cautery*, sparingly used in the event of exquisite local tenderness, is often very effective by producing counter-irritation.

2. *The x-ray* has given variable results in the hands of different authorities. Details of its use as a therapeutic agent in tuberculosis of the bones and joints will be found in the chapter on Tuberculosis of the Bones and Joints.

3. *Ichthyol ointment*, in a strength of about 40 per cent., sometimes relieves pain and local congestion.

4. *Bier's hyperemic treatment*, is applied for one-half hour to one hour daily, the time being gradually extended until the treatment is more or less continuous during the day.

5. *Calot's injection* of naphthol-camphor and creosote-iodin solutions, already considered in the Chapter on Tuberculosis of the Bones and Joints, may have a favorable influence on the lesion.

6. *Lannelongue's sclerogenic injections*, to induce the formation of scar tissue to circumscribe the lesion. The method is as follows: A 10-per cent. solution of chloride of zinc is prepared, and with a fine hypodermic needle from 8 to 10 minims are injected at various points around the diseased area. The injections are made into healthy tissue immediately adjoining the disease.

7. *Tuberculin.*—(For technic of usage, see Chapter on Tuberculosis of the Bones and Joints, pages 59 and 60.)

OPERATIVE TREATMENT

Before proceeding to a detailed account of operative procedures it will be well to review a considerable part of what has already been said, in order the better to comprehend the indications for operation and the general plan of operation.

The knee-joint, unlike the hip-joint, is situated superficially and is not deeply covered by musculature. Early recognition of disease is possible, and because of the size and character of the joint architecture, together with the long leverage control made possible by its position at the ends of long bones, the control of joint motion is more easily maintained.

Tuberculous Osteitis in Childhood.—Tuberculous osteitis of the knee is not so frequently met with in childhood as is tuberculous infection of the spine or hip. Compared with other lesions of the knee-joint, it is the most common. Primary tuberculous involvement of the joint synovia in children is rare. The joint invasion is from a primary bone focus in either the upper end of the tibia or the lower end of the femur which gradually extends and involves the joint structures. Occasionally the patella is found to be the seat of the infection.

The characteristic symptoms of tuberculous osteitis manifest themselves at a very early stage in the disease and readily suggest themselves to the experienced clinician. Occasionally other causes of the local symptoms are present which must be borne in mind, as acute infections and gonorrheal arthritis, acute articular rheumatism, hemophilia, syphilis, sarcoma, Charcot's disease, arthritis deformans, and hysterical joint, from which the tuberculous infection should be differentiated by the special means of examination at hand, in order to eliminate error. The röntgenogram should always be employed, and both the well knee and the involved one should be taken for comparison in the two planes, lateral and anteroposterior.

As in other joints infected with tuberculosis in childhood, the essential treatment is conservative (when a distinct focus cannot be localized and removed), and a well-ordered régime of life, plenty of fresh air and sunlight, and a full diet, varied and of an easily assimilated character, are important factors in the treatment.

Local treatment consists of uninterrupted immobilization of the joint as the prime factor in arresting the activity of the disease and the prevention or correction of deformity. *The drainage of a tuberculous abscess should be avoided*, as it is impossible to guard against mixed infection after drainage has been established. If, however, a tuberculous abscess has become secondarily infected, it should be opened and drained in keeping with the rules of ordinary surgical technic. (For further details, see Chapter I.)

Infection will occur although dressings may be made ever so carefully, especially as the sinus is apt to persist for a long time and repeated dressings are necessary. This rule does not apply to the aseptic incision of an uninfected cold abscess with immediate closure of the abscess incision by carefully placed subcutaneous skin sutures after the contents have been evacuated. Excision of the joint should be abstained from in all cases where the patient is under sixteen to eighteen years of age, on account of the damage to the epiphyseal cartilage and the extreme shortening of the limb resulting therefrom.

Tuberculous Osteitis in the Adult. Operative procedure has proved advantageous in properly selected adult cases, though in childhood it has been very bad practice. In the adult, there exists a full development of bone and joint structure and therefore excessive shortening from interference with the epiphysis is avoided. In long-standing cases, angular deformity resisting correction by the usual conservative measures is readily remedied, and firm bony union between femur and tibia is the result. Formerly, excision of the knee was undertaken with the primary object of the removal of all the tuberculous tissues, and the production of ankylosis was considered of secondary importance. This led to excessive removal of bone, with shortening; to the lessening of the diameters of the opposed ends of the femur and tibia on account of the bone incisions being made above the expansions of the femoral condyles and below the tibial head; to prevention of the approximation of the incised bone end surfaces, resulting often in non-union; to the constant liability of not removing all tuberculous tissues; and to laxity of peri-articular structures (particularly the long flexor and extensor muscles) by decrease in the long axis of the limb, thus diminishing firm contact of the cut bones and a stimulus to bony union.

In a large percentage of adult cases subjected to the above treatment the results are not ultimately satisfactory and not a few come later to an amputation of the limb, either as a life-saving measure or in order to allow the application of a serviceable artificial limb, on account of the failure of bony union or the occurrence of excessive deformity.

The essential factor in the arrest of a tuberculous process is the production of a bony ankylosis. This point has been emphasized by Ely in his writings, and has been followed by such satisfactory results that in the author's opinion it cannot be too strongly advised. As the chief consideration rests upon the production of bony ankylosis in these adult tuberculous knees, it is the author's purpose to outline those methods of his technic which experience has proved to be most certain and reliable.

First, to emphasize more forcibly the accuracy, ease, and certainty of these methods, some statistics of methods and results as applied by other authors will be reviewed for contrast, as, for example, 28 consecutive excisions of the knee in the period from 1907 to 1913 in the orthopedic service of the Massachusetts General Hospital performed by different orthopedic surgeons, reported by Osgood, and this report is herewith abstracted:

Following at least a month's fixation in plaster so as to render the disease somewhat quiescent, the cases receive a two- to four-day preparation of the knee. On the table, benzine-iodin preparation is given and an Esmarch or other tourniquet is applied. The usual U-shaped incision is made from above one femoral condyle to the other, crossing the patellar tendon about an inch above its insertion. The proximal cut end of the patellar tendon is seized and turned back with all the structures overlying the joint included, dissected up, and the knee is gently flexed as the dissection proceeds. Much of the exposed tuberculous tissue is removed and the articular ends of the femur and tibia are developed. Only sufficient bone is sawed off the articulating ends of the femur and patella to reach beyond the disease, and the patella is either removed or its under surface is sawed off. Only evident masses of diseased soft parts are removed. Bone and soft-tissue surfaces are swabbed with tincture of iodin. The tourniquet is removed and bleeding is controlled.

For the past four years, the custom in the orthopedic service, in the absence of a sinus or a mixed infection, has been to fix the bone ends by malleable iron plates or aluminium wire clamps screwed in place by steel wood-screws with the thread cut to the head. A test of the fixation is demonstrated by

lifting the leg by the foot. The patellar ligament is reunited, as well as the deep structures overlying the joint, followed by the skin-flap suture, and the limb is placed in a plaster splint which is changed in four weeks when, if favorable, the patient is discharged in a plaster splint, with crutches. The immediate postoperative freedom from pain, together with the earlier firm union, by these methods was noted.

End Results of the Plating Fixation Above Described.—Comparison is made in the reported 28 cases between the results obtained when metal plating was used and when simple excision was performed. Of the 14 simple excisions, including 2 cases wired by silver wire, 4 came to re-excision, and 2 of these and 1 other were subsequently amputated to save life. Four had sinuses before the operation, and 9 after. Pain persisted for several months after operation in 5 cases. Eventual union occurred in 6. The time of union was two months or less in 2; three or more months in 11; and there is no record of eventual union in 5. In both cases in which wire was used it had to be removed subsequently.

Comparing the cases where metal clamps or plates (8 clamps and 6 plates) were used: None required a re-excision. One case was amputated later, because of secondary infection. Two had sinuses before operation; 5 had sinuses after operation. All healed except 1. Pain persisted several months after the operation only in the amputated case, and to a slight degree in 1 other case for four months after the operation. Eventual union occurred in 13 cases. Time of apparent firm union was one month or less in 6 cases; two months or less in 4; and three months or more in 3. In 5 cases the metal clamps or plates gave subsequent trouble and were removed.

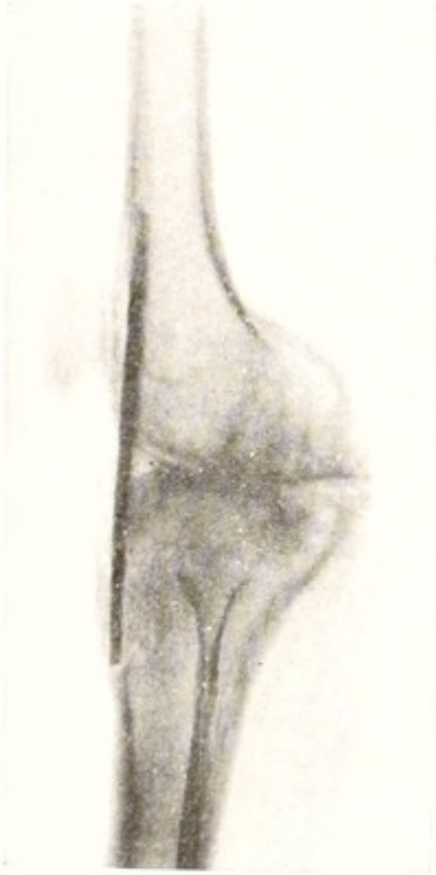
From the foregoing report, it is obvious that the actual fixing together of denuded bone ends has a decided advantage, not only in the relief of pain but in hastening bony union; but it is also apparent here, as has been the universal experience of other users of foreign material in securing bone fixation, that the removal of the metal at a subsequent operation was necessitated in a large percentage of cases on account of the trouble it was causing.

From the author's experience, it is reasonable to believe that had autogenous bone-grafts been used for fixation purposes, delayed union and a subsequent operation (for the removal of the metal clamp) with the accompanying disturbance and inconvenience could have been avoided. For amplification of this point the reader is referred to the chapters on the treatment of fractures and the fundamental principles involved in the use of the bone-graft.

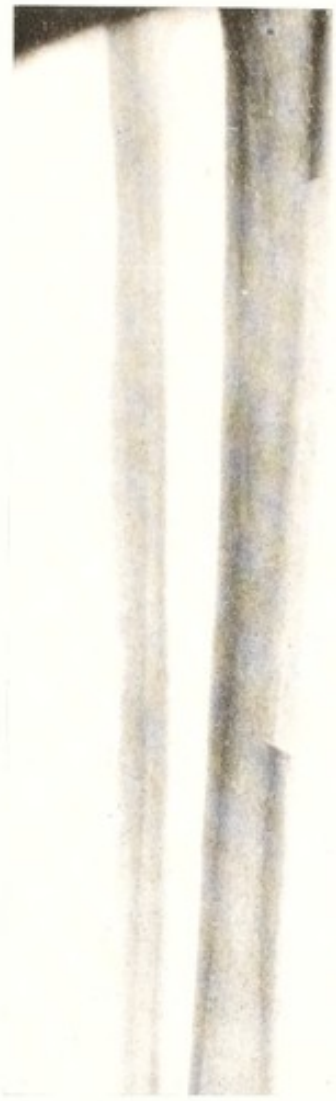
As compared with the foregoing report of 28 cases done by various men in the Massachusetts General Hospital in the five years mentioned, the author outlines his technic of application of the inlay bone-graft in his fixation operation for tuberculous knee-joint disease in late adolescence and in the adult. During the past four years 24 cases have been operated upon, the youngest patient being eighteen years of age; and in every instance bony union was obtained in eight weeks' time, as shown clinically and by the röntgenogram (Figs. 121 and 122). In all but one case the graft has united, and in no instance has it come out or had to be removed. These cases, as well as various other applications of the bone-graft in tuberculous joints where they span through tuberculous areas, have conclusively proved the resistance of the bone-graft to tuberculous infection, as well as to attenuated pyogenic infections described elsewhere in this book. In view of these facts and the excellent mechanical fixation afforded by the inlays, as well as the stimulation to osteogenesis on the part of the host bone and the osteo-



a



b



c

FIG. 121.—*a.* and *b.* show sliding tibial inlay inserted for tuberculosis of the knee-joint. *c.* indicates cavity in tibia three weeks after the removal of graft.

genetic force which the bone-graft exhibits, its striking advantage over metal for the purpose of not only securing bony union but of securing it early is apparent. No pain from failure of fixation was experienced after operation by the inlay-graft method, and with the aid of crutches the patients were up and walking in their plaster splints in six weeks' time. Where formerly a long plaster-of-Paris spica was relied upon for the fixation and relief from pain, following the ordinary excisions, it is found that a simple plaster splint extending from the toes to the groin is sufficient in most cases.



FIG. 122.—Cured tuberculous knee. Rontgenogram taken six months after arthrodesis and the insertion at arrow points of inlay graft formed from the patella. There was apparently firm union in six weeks.

In all cases where there is the slightest doubt as to the advisability of operation, *x*-ray examination should invariably be made. If the bone lesion is well localized and accessible, it should be removed by operation without delay. But in no instance in children, where the process is at all generalized or involves a considerable portion of the joint, should operative interference be practised except as a last resort.

It is again emphasized that the prime object of an operation upon a generalized and extensive adult tuberculous knee is not to remove the tuberculous tissue but to secure bony union, although the adequate removal of tuberculous tissue should not be neglected.

1. **Erasion with Bone Transplantation.**—(*a*) *Albee's Tibial Bone-graft.*—This procedure is designed for the treatment of acute and chronic adult tuberculosis, where there is fibrous or incomplete bony union.

The order of procedure for procuring and placing a bone-graft (as given in the chapter on the subject of bone-grafting) is here reversed, the graft being removed *prior to* the preparation of its bed in the recipient host bone, on account of the danger of soiling the tibial field if the tuberculous knee-joint is first entered. A tourniquet is applied to the upper part of the thigh while the limb is elevated. The field of operation, which is prepared by the iodin method, should extend from the ankle-joint to well above the knee-joint.

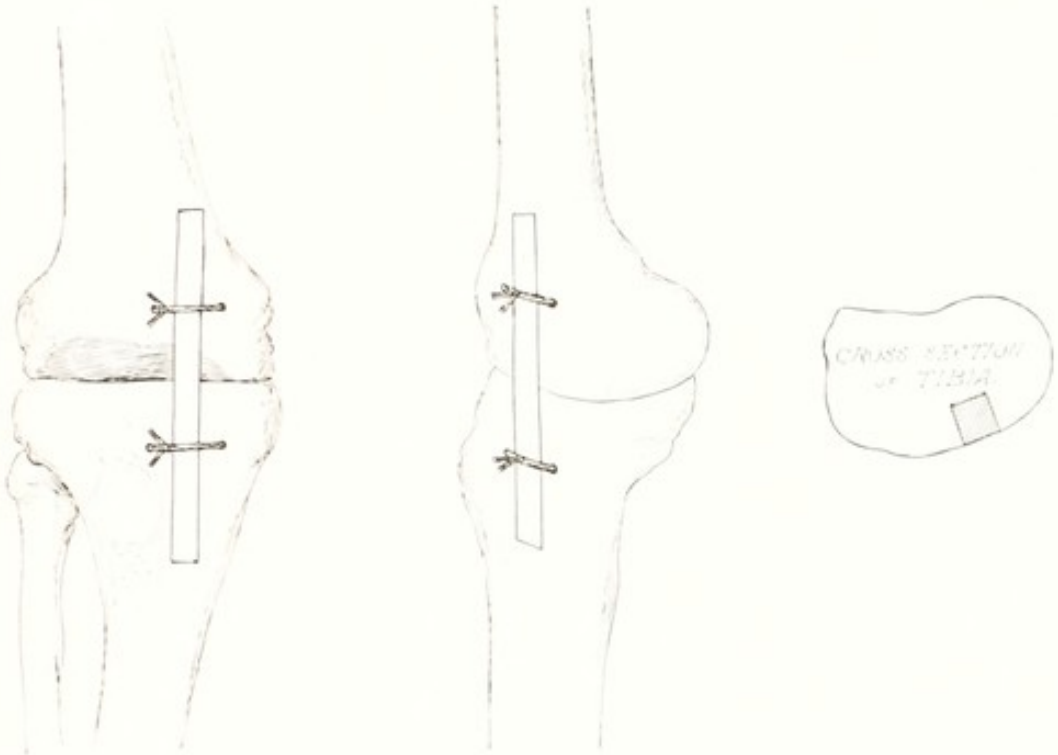


FIG. 123.—Tibia inlay graft and the kangaroo fixation ligatures in an erasion operation for a tuberculous adult knee. This diagram also indicates the small amount of bone which should be removed, by saw-cut, from tibia and femur.

1. The *graft* is removed from the tibia in the prescribed manner. In this particular instance its width is determined not by the condition of its recipient bed but by the width of the medullary canal of the bone from which it is obtained. The object is to get a graft as wide as possible, from the antero-internal surface of the tibia, in length, it should measure 4 to 5 inches. It is placed in salt solution until wanted. The wound in the tibia is then sutured and dressed.

2. The *incision* of the knee-joint is U-shaped and reaches from one femoral condyle to the other, with its convexity downward, crossing the patellar ligament about 1 inch above its insertion.

3. *Exposure* of the *joint* is obtained by dividing the patellar ligament and dissecting up and turning back the deep structures overlying the joint. The crucial ligaments, if present, are divided as well as the lateral ligaments of the joint, and the upper end of the tibia is drawn forward and the leg is flexed.

4. *Removal* of *articulating surfaces* of tibia and femur and the posterior surface of the patella is accomplished by cutting transversely with a narrow bladed bone saw (Fig. 125). The tibial head is made into a cylindrical sur-

face concave from before backward; the femoral condyle, into a cylindrical surface convex from before backward, to fit the concavity of the upper cut end of the tibia. These surfaces are then apposed.

5. The *graft bed* is prepared with the author's circular twin-motor-saws, adjusted twice the thickness of the saw-blade nearer together than when removing the graft, by cutting across the central point of the opposed tibia and femur, half of the bed being formed from the former and half from the latter. Its size should correspond to the tibial graft. The strips of bone between the saw-cuts are severed distal to the joint with a small motor-saw (author's cross-cut saw) and removed with a narrow chisel.

6. *Placing and Securing the Graft* (Fig. 123).—With the small motor-drill, holes are drilled in the femoral condyles and head of the tibia on either side

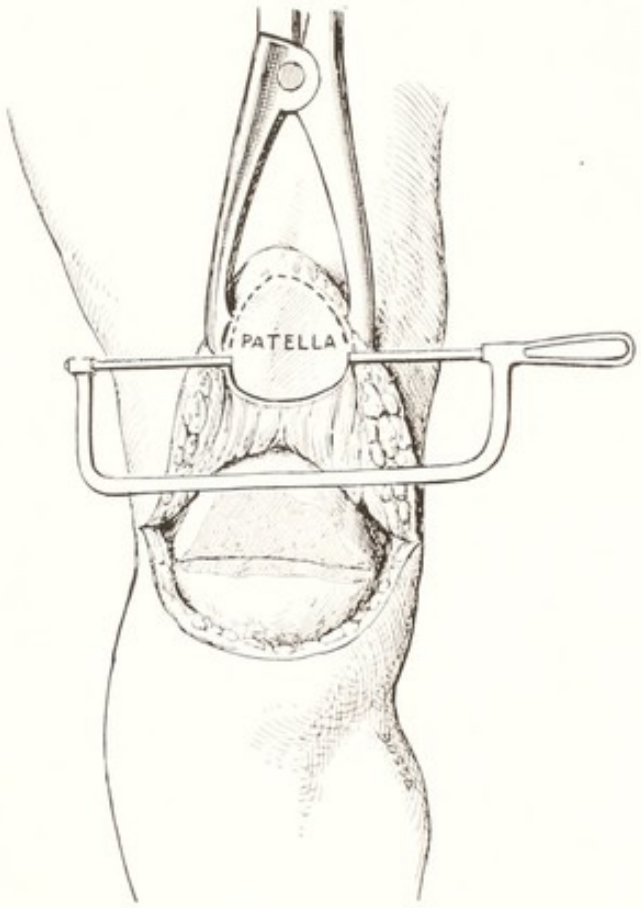


FIG. 124.—Illustrates method of removing posterior infected or cartilaginous surface of patella before enucleation and forming into inlay grafts. (See Fig. 125.)

of the gutter and strong kangaroo-tendon sutures are passed ready to be tied over both ends of the graft. The graft is placed in its bed after the holes are drilled, the sutures placed and pulled up from the bottom of the gutter in large loops to admit of its passage. The sutures are then drawn taut and tied.

7. *Closure* of the *incision* is made in the manner described elsewhere, the patellar ligament having been re-united with chromic catgut.

8. *External fixation* of the part is secured by a long plaster-of-Paris bandage extending from toes to groin. The tourniquet is then removed.

The importance of leaving on the tourniquet until after the application of a large compression dressing and the fixation plaster-of-Paris splint up to the location of the tourniquet, cannot be emphasized too strongly. This applies not only to every knee operation but to every extremity operation where this

measure of temporary hemostasis is employed. A well-moulded plaster-of-Paris splint should be applied to the region of the operation and distally for vascular support, whether or not it is needed for immobilization purposes. The principal reasons for this are: First, the establishment of support to the vascular system before postoperative relaxation from the after-effects of the tourniquet can occur, which might lead to extravasation into the regions of the wound; second, the uncontrollable bone ooze, which is so likely to accumulate and form a hematoma while the dressings and fixation splint are being applied, if the tourniquet is removed before the wound closure, especially since every motion of the limb produces friction and is likely to

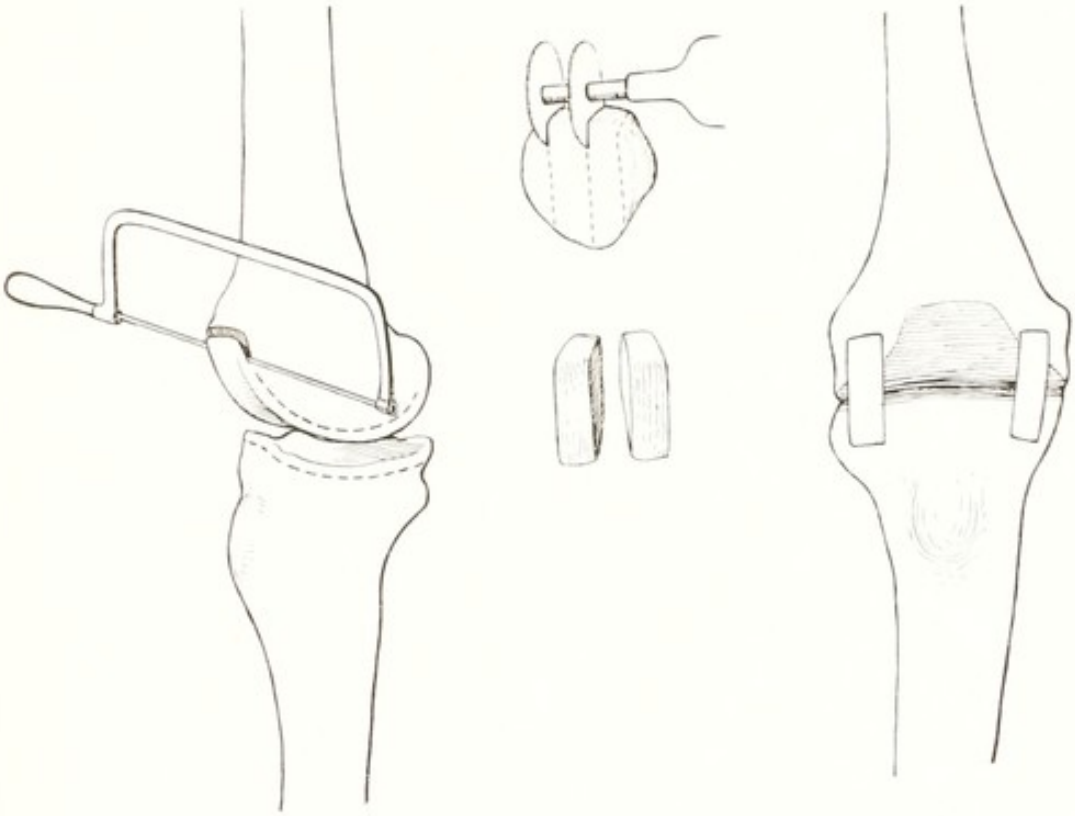


FIG. 125.—*A* shows the line of removal of the articulating surface of femur and tibia by the narrow bow-saw in producing the arthrodesis of the knee-joint. *B*, the splitting of the patella into segments by the twin motor saw, to produce two bone-grafts to be placed in gutters. *C* sawed from the two condyles of the femur into the head of the tibia by the twin motor saw adjusted at the same distance apart as when cutting the two inlay grafts from the patella. The author has found that the tibial graft 4 to 5 inches long affords a much better fixation and influences a more rapid and certain union between the tibia and femur, than the short and unsatisfactory patella graft, therefore he has been influenced to use the tibial graft.

rub away whatsoever clot may have formed for purposes of hemostasis. The total resultant hematoma is sure to be less if the tourniquet is left on than if it were removed and the bleeding vessels (which are possible to be ligatured) tied before closure of the wound.

Remarks.—Fragmented grafts obtained in preparing the graft bed can be used at the periphery of the contact surfaces of tibia and fibula if the tuberculous process is subacute or chronic and there is no secondary infection present. These hasten bone-growth and the process of fixation.

It is to be noted that only sufficient bone is removed from the articulating surfaces of the tibial tuberosities and femoral condyles to furnish closely

approximated raw bone surfaces; and only apparent and easily accessible tuberculous infected soft tissues are cut away, together with whatever synovia can be easily reached with curved scissors. No undue effort is made to remove all tuberculous bone, so that very little additional shortening results from the operation. Bone sinuses are cleaned out with a curet. If the patella is found to be tuberculous, the diseased part is removed or, if too extensively involved, it is enucleated and discarded.

The plaster splint is left on for five to seven weeks, at the end of which time it is changed and the patient is allowed to go home on crutches. The second plaster splint can usually be discarded in from two to three months, or as determined by *x*-ray examination.

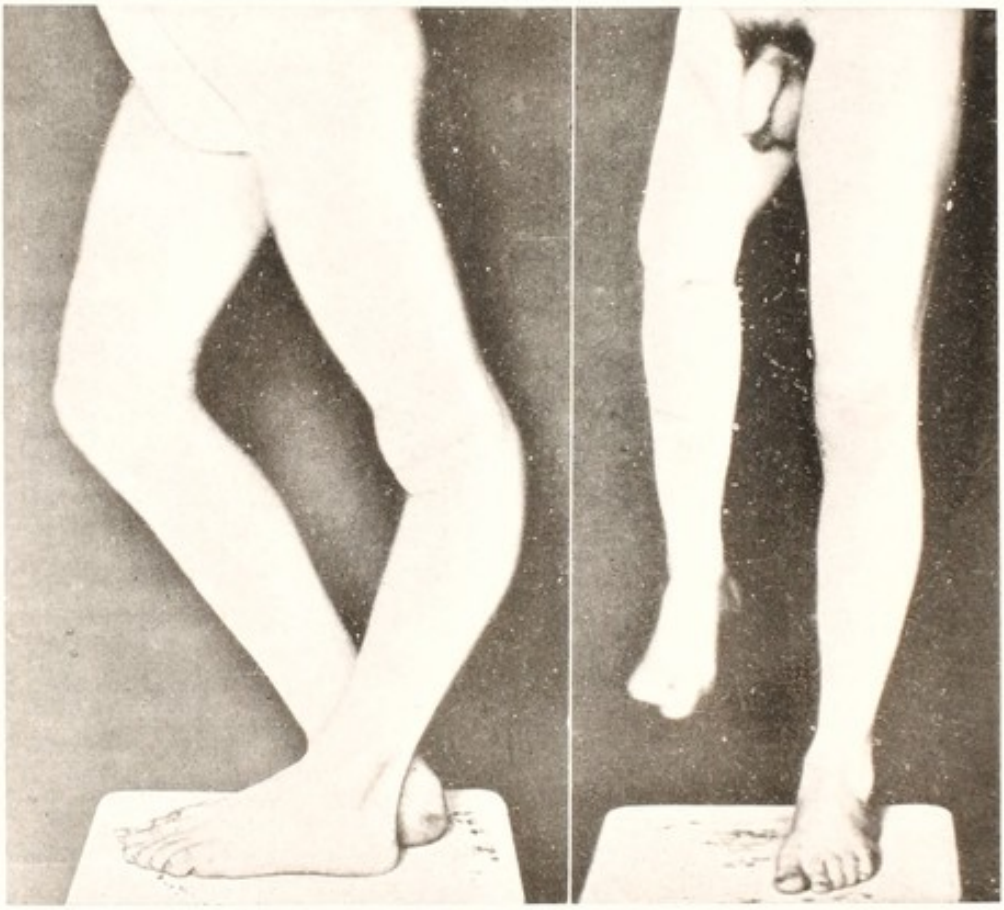


FIG. 126. FIG. 127.

FIGS. 126 and 127.—Results after early excision of the knee. The patient at the right has 10 inches shortening. (Taylor.)

There is no doubt that the accurate mortising together of the femur and tibia by the graft hastens firm ankylosis and renders it more certain; also that the postoperative relief from pain experienced by these patients following the inlay fixation offers a great advantage over the former simple excision of the knee.

(*b*) *Albee's Patellar Bone-graft* (Fig. 125).—If desirable or necessary, the patella may be utilized for bone-grafts in the erasion of the knee-joint, but the author has abandoned its use because of the shortness of the grafts, and instead uses bone-grafts obtained from the tibia. (For description see author's "Bone-graft Surgery," W. B. Saunders Co., 1915.)

(*c*) *Patella Bone-graft* (Hibbs).—Hibbs has used the patella as a bone-graft in operating to produce bony ankylosis of a tuberculous knee. The

patella is placed anteriorly between the head of the tibia and femur in a sulcus made in the apposed surfaces of these bones. One of the objects of this operation of Hibbs is to take up the slack of the lateral ligaments at the same time that the joint is stiffened by impingement upon the patella.

Hibbs' technic (Hibbs, R. A., "An Operation for Stiffening the Knee-joint," Annals of Surg., 1911, liii, 406–7) for stiffening the knee-joint is as follows:

The knee-joint is exposed by a transverse incision just below the patella. After denuding the patella of periosteum and cartilage, it is mortised horizontally into a space prepared for it by removal of the cartilage just anterior to the center of the tibia and femur. Care is taken to avoid injury to the crucial ligaments and the epiphyses of tibia and femur. The periosteum is carefully preserved during its removal from the patella, brought down over the freshened area, and stitched to the periosteum around the edges of the tibia and femur. The patient is allowed to walk in plaster at the end of four to six weeks, and all support is removed at the end of the fifth to the seventh month.

The author believes that if any graft is used at all, it should be used in such a way as to act not only as a fixation agent but as an osteogenetic bridge or splint, extending into and contacted with the *healthy* osseous tissue of femur and tibia at some distance from the point of erasion, and not implanted as an island of healthy osseous tissue in a tuberculous area; therefore the author uses his inlay tibial graft of a length not less than 4 inches.

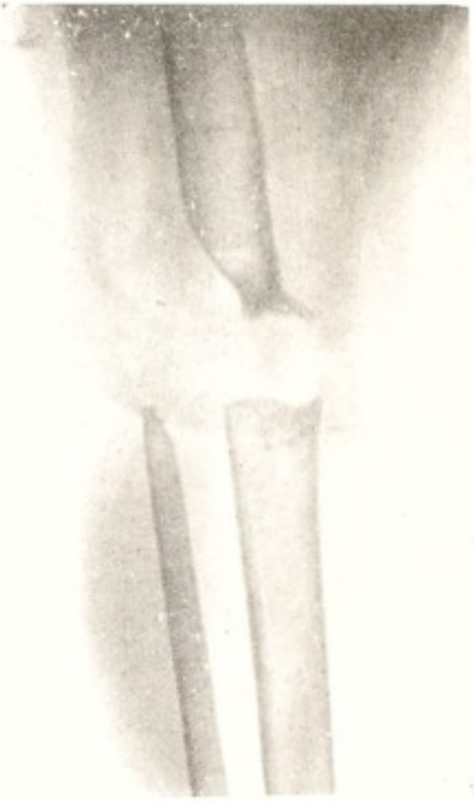


FIG. 128.—Roentgenogram of a flail knee following a complete excision of the joint. The liberal removal of bone has resulted in non-union and a limb perfectly useless. This condition could have readily been avoided by simply producing an arthrodesis after a more conservative removal of bone and the implantation of inlay grafts. Sinuses still persist and the result is a failure.

2. **Excision.**—Inasmuch as the author believes that total excision of the knee-joint (including the condyle of the femur and the head of the tibia) is unjustifiable on account of the great shortening of the limb entailed, space will not be allotted to a further consideration of the subject (Figs. 127 and 128).

3. **Removal of a Peri-articular Bone Focus.**—Although early invasion of the neighboring joint is the rule, it occasionally happens that an isolated bone focus can be detected by the *x*-ray before such an event has occurred. It should then be approached by an extra-articular route and thoroughly removed by the gouge and curet in order to prevent infection of the joint. An *x*-ray (preferably stereoscopic) should always precede the operation, to accurately localize the process. If this procedure is successful, joint function will be preserved; if not, the joint may come later to erasion and fixation by bone-graft.

4. **Amputation.**—This is the last resort, indicated (*a*) when local attempts at eradication of the disease and arthrodesis have failed; (*b*) when the joint and

neighboring structures are riddled with sinuses and there is much abscess formation; (*c*) when a diffuse osteomyelitis is extending from the joint to

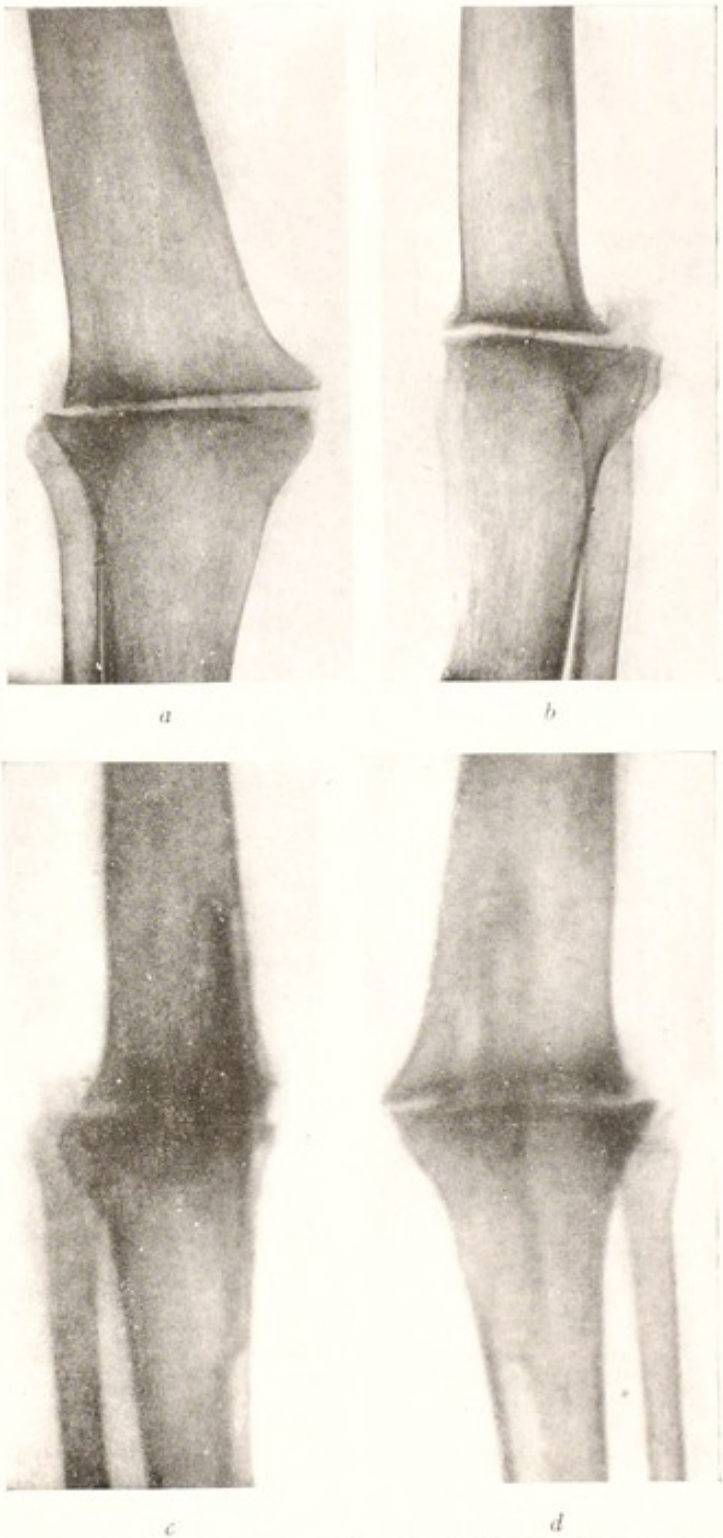


FIG. 129.—*a*, *b*, non-union of one year's duration following the usual excision operation for a tuberculous knee. The leg was shortened 2½ inches by removal of the femoral condyles and portion of head of tibia. Thus causes the diameter of femur end to be small as shown in (*b*). *c*, *d*, are *x*-rays three months after the insertion of a sliding inlay graft from tibia showing firm union and complete relief of all symptoms.

adjoining bones; (*d*) when there is rapid failure of health; and (*e*) in early childhood with extensive involvement of the epiphyseal cartilages and with

the prospect of an early cure only at the cost of great shortening and a useless limb. The point of election for amputation is the mid-thigh, but with extensive osteomyelitis a wide berth should be given the infected region.

5. **Ankylosis of Patella to Femur.**—Tuberculous disease located in the patella has in some instances caused its fixation to the femoral condyles without involvement of the rest of the joint. The resulting immobility may be relieved by separation of the patella from the femur and interposing a flap of the muscle, or fascia and fat between their apposed surfaces. This procedure, however, should not be attempted until years after subsidence of all local symptoms. Exposure is obtained by a longitudinal incision on the inner side of the patella, and the vastus internus is utilized in fashioning the fascial-fat flap. (See Chapter XXVIII.)

Correction of Deformities

Deformity at the knee-joint as the result of tuberculous disease is of three varieties: (*a*) flexion deformity; (*b*) external rotation; and (*c*) backward displacement of the tibia on the femur.

Flexion deformity at an early period is due to reflex action of the hamstring muscles. At a later stage it is caused by true structural shortening and contraction.

External rotation is the result of exaggerated action of the biceps femoris.

Backward displacement of the tibia is the result of infection, softening and stretching of the ligaments, especially the crucial, combined with the weight of the limb and contraction of the posterior (flexor) muscles; also as the result of attempts to extend the leg in the face of flexion contracture.

For the relief of these deformities, various mechanical and operative procedures have been devised. An attempt at reduction of the deformity should be made by mechanical means before operative measures are employed, unless the latter are strongly indicated.

Of mechanical procedures, the plaster bandage, weight and pulley, forcible correction by reverse leverage, the Billroth splint, the Thomas knee-splint and the genuclast are those most in use. Operative interference may be practised by cuneiform osteotomy with or without the author's inlay bone-graft and by linear osteotomy (in children) for bony ankylosis with deformity, or by Osgood's technic where there is motion combined with flexion deformity.

Mechanical Correction

1. **Plaster Bandage.**—In mild grades of deformity, chiefly muscular, this method sometimes affords relief. The bandage should extend from groin to toes, and manual extension of the leg should be obtained during its application; or an anesthetic may be administered to overcome muscle spasm. In the latter event, a deformity of some standing may be reduced by traction and slight leverage, and held corrected by plaster. The head of the tibia should be supported and drawn forward by the hand as the deformity is gently reduced.

2. **Traction by Weight and Pulley.**—This is especially applicable to cases caused by muscular contraction. During the use of the weight and pulley, the leg must be supported so that no direct leverage is exerted at the seat of disease.

3. **Forcible Correction by Reverse Leverage** (Whitman).—In the American Journal of Medical Sciences for May, 1903, Whitman described a method that has given much satisfaction in the more resistant cases, especially if accompanied by subluxation.

The patient is placed in the prone position with the feet projecting over the end of the table. "The body of the patient is then elevated by means of pillows to conform to the deformity, that is, the thigh of the affected limb is raised sufficiently to allow the tibia to lie evenly upon its anterior border on the table. The operator with one hand holds the head of the tibia against the table and with the other massages the contracted tissue of the popliteal region, gradually exerting more downward pressure on the thigh but never to the extent of lifting the tibia from the table; thus further luxation is impossible. As the contraction gives way, the pillows are removed." The limb is placed in a plaster-of-Paris bandage for three to four weeks.

If correction is not possible by this method, open tenotomies are made of the contracted hamstring tendons. Care should be taken to avoid injuring the external popliteal nerve. If correction is still impossible of accomplishment by this method, open operation will be necessary. (For technic, see page 254.)

4. **The Billroth Splint.**—In obstinate cases the Billroth splint may be employed. After thoroughly padding the bony prominences, particularly the outer surface of the femoral condyle and the popliteal region of the tibia, a plaster-of-Paris bandage is applied from groin to toes and re-inforced in the popliteal portion. In the plaster, on either side of the knee, are incorporated Billroth splints. These are expanded tin splints to which curved and slotted steel bars are attached. After hardening, the bandage is divided above the knee by a circular cut into two parts; the bolts in the slotted splints, which have been connected, are so adjusted as to form a hinged splint whose center of movement is slightly in front of the knee-joint. Slight extension of the leg produces such action of the lateral hinges as will gradually force the tibia from the femur. This action causes gaping of the popliteal portion of the circular incision which is maintained by inserting a cork wedge. Larger wedges are introduced from day to day until the deformity is gradually corrected, and the limb straight, when a new plaster bandage is applied and worn for several weeks.

5. **Thomas Knee-splint.**—The Thomas knee-brace may be applied to meet two indications, viz.: (*a*) A flexion deformity due to simple muscle spasm is relieved by its traction. (*b*) In the event of true contraction and shortening later in the disease, the knee can be gradually forced toward the splint by an elastic or flannel bandage which can be tightened as it becomes lax in the process of correction.

6. **Genuclast.**—This instrument is particularly applicable to cases of backward subluxation of the tibia. A very satisfactory type is the genuclast of Bradford and Goldthwaite. The instrument consists of lateral steel bars attached to a handle, catapult fashion. The bars are applied to the sides of the leg. A plate attached transversely to the upper ends of the bars and furnished with an adjustable screw, exerts pressure posteriorly over the head of the tibia and prevents its subluxation. Strong linen bands connect the extreme tips of the upright bars and pass over the knee and similar bands encircle the lower third of the tibia; by this means, counter-extension is obtained. Considerable leverage can be obtained with this instrument, and care should be observed in its use.

OPERATIVE CORRECTION

When firm bony ankylosis with the usual flexion deformity exists, the only hope of straightening the leg lies in cutting the bone at the junction of the femur and tibia (osteotomy), with or without the removal of a wedge

of bone. Occasionally some motion exists with flexion deformity, and by Osgood's technic (see page 254) the latter may be corrected and movement still preserved. This operation is indicated in those cases which cannot be straightened except by removal of bone.

1. **Cuneiform Resection or Osteotomy of the Knee.**—(*a*) *With Inlay Bone-graft* (Albee's method).—(Especially applicable to cases of marked flexion where the contour of the joint has been markedly changed by destruction of joint surfaces and by the process of repair and where there is persistence of a small amount of motion which cannot be utilized as in Osgood's procedure). The fundamental reason for the use of the bone-graft in this connection is the great number of non-unions resulting from the continued inhibitory action of the tubercle bacillus on bone-growth. The advantages of the inlay graft in an erasion operation on the knee are very similar to those which demand its use in pseudarthroses following fractures. Here, however, the advantages of using the graft are even greater (as compared with foreign-body fixation agents) in that the viability of the cellular content of the graft is evidently not affected by the possibly existing tuberculous infection.

A U-shaped incision, with its base upward and its lower limit at the tibial tubercle, is made and a saw or osteotome is used to remove a wedge of bone from the fused tibial-femoral junction. The cuts in each bone should be made at nearly right angles with the long axes of the bones, and the apex of the wedge should not completely sever the bones (if the joint is completely ankylosed) but should stop within at least $\frac{1}{4}$ inch of their posterior surfaces; this avoids wounding the popliteal artery and neighboring structures and prevents the formation of a projecting angle of bone at that point after correction. The remaining bridge of bone is broken by forcible flexion of the leg after the wedge has been removed.

After the usual preparation of the patient's leg, a tibial graft is obtained and a gutter prepared for its reception at the site of osteotomy, in the manner described for grafting and erasion of the knee with bone transplantation (this chapter); the only difference being the order of the procedure; in this instance first the gutter is prepared and then the graft obtained, whereas in erasion the order was reversed. After insertion of the graft and closure and dressing of the wound, a plaster bandage is applied from toes to groin, and kept on for six weeks, followed by a second one to be worn two or three weeks. The cast is removed as soon as there is firm union, which is usually in eight weeks, and the patient is allowed to walk. It is best to allow the patient to bear weight on the limb while walking with crutches for two or three weeks before removing the cast, for the purpose of hastening the union.

(*b*) *Without Bone-graft.*—The same technic is observed as above described, except that no retaining bone-graft is employed. The practice of fixing the opposed raw-bone surfaces with nails, metal plates, or other foreign bodies is not advised.

2. **Linear Osteotomy.**—This procedure is particularly applicable to children, and may be performed near the joint or at some distance above.

(*a*) *Supracondylar Osteotomy.*—In this operation near the joint, a longitudinal incision is made with its center about one finger's breadth above the upper limit of the external condyle on either the inner or outer side of the rectus tendon, and a broad osteotome is inserted and the femur severed. If necessary, tenotomy of the hamstring tendons may be performed. The above subcutaneous osteotomy is of special service in cases of ankylosis with deformity where a large amount of scar tissue exists about the location of the knee-joint. This procedure avoids extensive severing of skin and sub-

cutaneous tissues and therefore lessens the danger of gangrene of the foot and lower leg from interference with circulation.

(*b*) *Diaphyseal Osteotomy.*—J. W. Perkins recommends that in the case of children osteotomy be done in the diaphysis well above the joint, for two reasons: first, to avoid the epiphyseal line; second, to prevent injury to or stretching of the popliteal vessels and nerves. The great objection to the operation is the necessity of removing a rhomboid of bone, causing considerable shortening.

The osteotomies just described apply to cases of bony ankylosis with deformity and entire loss of function. If any useful motion exists in the joint, it may be preserved and the deformity overcome by Osgood's technic, by a cuneiform osteotomy, or by the osteotomies just described.

3. **Osgood's Osteotomy for Flexion Deformity with Motion.**—"A 2-inch linear incision is made on the outer side of the leg, posterior to the edge

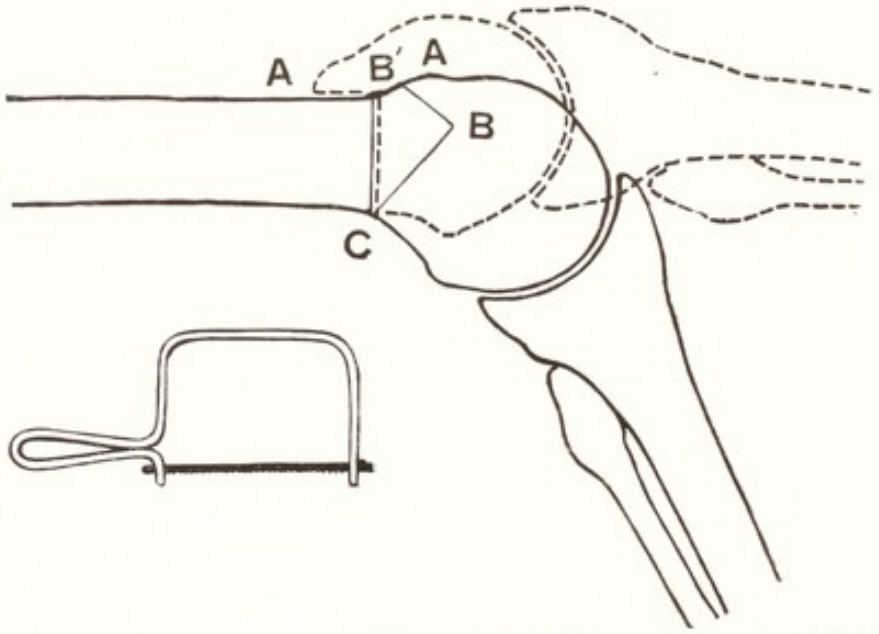


FIG. 130.—Drawing of mechanic's coping saw and diagram of osteotomy for straightening knee, so as to preserve free motion when it exists. Saw is entered at *A*, by freeing its end temporarily from bow. Saw incision to *B* and thence to *C*. At *C* saw is removed from bow and left for orientation.

Another saw is entered at *B'* and bone incision to *C* is made. Quadrilateral piece *A*, *B*, *C*, *B'*, is pushed out laterally. Leg straightened bringing *A'* to *A* and *B* to *B'*. (After Osgood.)

of the upper cul-de-sac of the knee-joint and extending upward from about the level of the upper border of the patella. This incision is carried down to the bone, and with a blunt dissector a space is cleared over its upper surface. A second incision is then made at the same level on the inner side of the femur, and a similar space is cleared beneath the cul-de-sac over the upper surface of the femur joining the space made through the outer incision.

"The flexible blade of an ordinary coping or jig-saw (Fig. 130) is now pushed through, teeth down, in the path made by the blunt dissector and inserted in the arms of the bow; the blade passes over the top of the bone beneath the upper cul-de-sac. The first cut is made forward and slightly toward the posterior surface of the bone, toward the lower end of the femur for about three-quarters of an inch to 1 inch and then inclined sharply downward, *i.e.*, toward the posterior surface of the femur backward, that is, toward the upper end of the table.

"When the posterior cortex has been partially sawed through, the arms of the bow are removed and the detached saw is left in as a marker for orientation. A second saw-blade, teeth downward, is now passed through the path above the bone and made to engage it above the entrance of the first saw, depending upon the size of the wedge required.

"A cut is now made in a straight line down to the position of the first saw, and both saws are removed. Thus a quadrilateral surface of bone is freed, which is pushed out through one of the incisions.

"Extension is then made, and either a green-stick or a complete fracture of the posterior cortical shell is made, while the lower end of the upper fragment is forced against the upper end of the lower fragment, which projecting upper lip made by the first saw-cuts keeps it from displacing backward and apparently anchors it quite firmly.

"After closure of the wounds, a plaster-of-Paris dressing is applied, and in our cases union has apparently been firm in from four to six weeks."

4. **Arthroplasty.**—The author believes that *ankylosis from an old tuberculous osteitis is a contra-indication to arthroplasty*, even after a lapse of years. This general rule may be broken in very rare instances. The operation should never be attempted in cases in which the joint is injured by pyogenic infection until after the lapse of a period of at least one year after the last symptom. Great conservatism and caution should be exercised, and this procedure should never be undertaken unless it is certain that no vestige of infection remains.

It is necessary that all vestiges of the original tuberculous process be entirely eliminated for a period of many years before this operation is attempted. Although the knee is the most difficult joint of all in which to secure perfect restoration of function, Murphy has had good results from his method (See Chapter XXVIII).

Treatment of Abscesses and Sinuses

These should be treated along the lines laid down for tuberculosis of the hip and other joints, and should never be drained. Abscesses in the region of the knee are, however, superficial and easily recognized and treated. Sinuses in this region are short and direct, and not tortuous and dissecting as in the case of the hip.

REFERENCES

PATHOLOGY

Barbarin: "De l'allongement atrophique des os du membre inférieur dans la tumeur blanche du genou chez l'enfant." Rev. d'orthop., Paris, 1908, 2e sér. ix, 182–184.

Defais, A.: "Contribution à l'étude des synoviales tuberculeuses à graines riziformes de l'articulation du genou." Rev. internat. de la tuberc., Paris, 1909, xv, 426–432.

SYMPTOMS AND PHYSICAL SIGNS

Swan, R. L.: "A Clinical Lecture in a Reference to Some Tubercular Diseases of the Knee-joint and to the Treatment of Synovial Cavities." Med. Press and Circ., London, 1907, N. S. lxxxiv, 542.

Barbarin, P.: "Les attitudes vicieuses dans les tumeurs blanches du genou chez l'enfant." Clinique, Paris, 1907, ii, 773–777.

Barbarin, P.: "Les Durations consécutives à la tumeur blanche du genou chez l'enfant:, leur mechanisme, leur traitement." Paris chirurg., 1909, i, 533–539.

Broca, A.: "À propos de 3 cas de tuberculose de genou." Pédiatrie prat., Lille, 1910, viii, 301–306.

Drem, D.: "Tuberculous Synovitis of Knee-Joint, etc." Proc. Roy. Soc. Med. London, 1907–08, i, Clin. Sect. 10.

JOHNSON, R.: "Enlarged Knee-joint, Probably Tuberculous." Clin. Jour., London, 1908–09, xxxiii, 63.
LANZ, O.: "Gonarthritis tuberculosa." Nederl. Tijdschr. v. Benusk, Amsterdam, 1908, ii, 698.
VAN KAATHOVEN, J. J. A.: "A Case of Tuberculous Arthritis of the Knee, Apparently much Aggravated by Biers Congestion." Therap. Gaz., Detroit, 1908, xxxii, 170–172.
SWYNGHEDAUW: "Tumeur blanche du genou." Écho méd. du nord., Lille, 1908, xii, 252.
CABANÈS, E.: "Tuberculose et ankylose vicieuse du genou." Bull. méd. de l'Algérie, Algeria, 1908, xix, 284.
DUVERGEY, J.: "La Tuberculose du genou circonscrite au cul-de-sac quadricipital." Gaz. hebd. des sc. méd. de Bordeaux, 1908, xxix, 397–400.
RIVES: "Tumeur blanche du genou." Montpel. méd. xxviii, 38–41.
PECKHAM, F. E., AND HAMMOND, R.: "Ankylosis of the Knee Following Tuberculosis." Boston M. and S. J., 1909, clx, 447.
STERNHARDT, I. D.: "Tuberculosis of the Knee-joint." New York M. Jour., 1909, xc, 305–308.
DUPUY DE FRENELLA: "Les Déviations dans les tumeurs blanches du genou chez l'enfant." Paris chirurg., 1909, i, 723–725.
JUDET: "Les Dévaitions dans les tumeurs blanches du genou chez l'enfant." Paris chirurg., 1909, i, 651–656.
WALTIKER: "Tumeur blanche du genou." Bull. et mém. Soc. de Chir. de Par., 1909, N. S. xxxv, 1154–1156.
BROCA, A.: "Les Attitudes vicieuses dans la tumeur blanche du genou." Pédiatrie prat., Lille, 1910, viii, 323–326.
ADDISON, O. L.: "Old Healed Tuberculous Disease of Knee-joint: Increase in Length of Limb." Proc. Roy. Soc. Med., London, 1910–11, iv, Sec. Stud. Dis. Clin., 39.
FIDON: "Tuberculose du genou, etc." Bull. Soc. Méd. Chir. de la Drôme, Valence, 1910, xi, 56–59.
SHERILE, J. G.: "Observations on the Surgery of the Knee-joint." Surg., Gyn. and Obstet., Chicago, 1910, x, 205–207.
MATTHEWS, F. S.: "Tuberculous Synovial Gonitis." Ann. Surg., Philadelphia, 1910, li, 946.
DU CROQUET, C., AND BEAU, U.: "Les Déviations du genou dans la tumeur blanche." Arch. de méd. d'enf., Paris, 1911, xiv, 241–249.

DIAGNOSIS

GURÈRIN, A. "Diagnostic d'évolution tuberculose de l'hémarthrose du genou." Rev. gén. de clin. et de thérap., Paris, 1909, xxiii, 201.

TREATMENT

HAMMOND, W. N.: "The Modern Surgical Treatment of Knee-joint Diseases." Hahneman Month., Philadelphia, 1909, xliv, 749–753.
IMPALLOMENI, G.: "Le Traitement de l'ostéoarthrite tuberculeuse du genou chez l'enfant doit être résulument conservateur." Rev. d'orthop., Paris, 1909, sér. x, 501–536.
DE VREESE, C.: "Nouveau Traitement de l'hydræthrose du genou." Ann. Soc. d'Anvers, 1910, lxxii, 131–137.
ZELDOVICH, Y. B.: "Treatment of Tuberculosis of Knee-joint." Russk. Nach. St. Petersburg, 1911, x, 842, 876–911.
CHARRUR, A.: "Résultats éloignés du traitement du genou par les injections profondes de chloride de zinc." Gaz. hebd. des. sc. méd. de Bordeaux, 1911, xxxii, 75.
BIDOU, A.: "Du traitement actuel de la tumeur blanche du genou." Lyons, 1912.
BALDWIN: "Tuberculous Disease of the Knee-joint." West London M. J., London, 1913 xviii, 39.
GALLOCUN: "Ostéoarthritis tuberculeuse du genou." Normandie Méd., Rouen, 1913, xxix, 10–15.

OPERATIVE TREATMENT OF KNEE-JOINT DISEASE

DAVIS, H.: "Secondary Excision of the Knee-joint." St. Barth. Hosp. Reps., 1908, London, 1909, xliv, 143–151.
FERGUSON, A. H.: "Excision of the Knee-joint." Surg. Gyn. and Obst., 1908, vi, 68–71.
BERGER: "Les Indications opératoires dans la tumeur blanche suppurée du genou." Rev. gén. de chir. et de thérap., Paris, 1908, xxii, 38.

LENHART, H.: "Beiträg. zur Resektion des tuberkulösen Kniegelenks." Beitr. z. klin Chir., Tübingen, 1900, lxi, 455–477.
CLARKE, J. J.: "Excision of the Knee-joint." Polyclin., London, 1909, xiii, 40.
CRESPOLTI: "La Resezione del ginocchio per osteomyelite tubercolare." Gaz. internaz. di med., Napoli, 1900, xii, 62.
EDMUNDS, A.: "Arthrectomy of the Knee-joint." Med. Press and Circ., London, 1909, N. S. lxxxvii, 581.
LEHR, H.: "Die Resektiondeformität des Kniegelenks; ein Beitrag. zur Frage der operativen oder konservativen Behandlung der Kniegelenkstuberkulose in Kindesalter." Zeitschr. f. Orth. Clin., 1909, xxiii, 529–550.
GIBNEY, V. P.: "The Part Arthrectomy Plays in the Treatment of Tuberculous Joints, more Particularly the Knee-joint." Am. Jour. Orth. Surg., 1909–10, vii, 22–30.
OLLIVIER: "Résection sans drainage pour un arthrite tuberculeuse du genou." Lyon chirurg., 1910, iv, 68–74.
MOREAU, J.: "Résection totale du genou pour tumeur blanche." Clinique, Brux., 1912, xxvi, 679–695.

CHAPTER VIII

TUBERCULOUS DISEASE OF THE ANKLE, TARSUS, LONG BONES OF THE HAND AND FOOT, SHOULDER, ELBOW, WRIST, SKULL BONES, INFERIOR MAXILLA, SUPERIOR MAXILLA, MALAR BONES, AND RIBS

I. TUBERCULOUS DISEASE OF THE ANKLE-JOINT

ETIOLOGY

Frequency.—Tuberculosis of the ankle occurs in about 0.7 per cent. of tuberculous disease of joints of the lower extremity and in about 15.5 per cent. of tuberculous joints of all varieties. It thus takes third place among tuberculous joint affections, occuring next to the knee in sequence.

It occurs more frequently in children than in adults.

NORMAL ANATOMY (FROM GERRISH)

The ankle is a hinge-joint, in which the articular surfaces of the lower end and internal malleolus of the tibia and of the external malleolus of the fibula form a mortise, into which the upper and lateral facets of the astragalus fit as a tenon. The transverse ligament helps to complete the tibiofibular socket behind. The *capsule*, strengthened and protected by the strong tendons passing over it, is divided for description into the following ligaments:

(*a*) The **internal** or **lateral** or **deltoid ligament,** strong, flat and triangular, radiates from the lower and ventral borders of the internal malleolus downward and backward to the rough inner surface of the astragalus, downward to the sustentaculum tali of the os calcis, and downward and forward to the navicular and the margin of the inferior calcaneo-scaphoid ligament. A so-called *deep portion* descends from the notch on the lower border of the malleolus to the depression on the inner surface of the astragalus.

(*b*) The **external lateral ligament** presents three separate diverging bands: 1. The *anterior fasciculus*, short and ribbon-like, passes from the ventral border of the external malleolus obliquely forward and upward to the astragalus, in front of its external lateral facet. 2. The *middle fasciculus*, strong and round, descends slightly backward from the tip and the fore part of the outer surface of the external malleolus to the middle of the outer surface of the os calcis. 3. The *posterior fasciculus* is the strongest and passes from the hind border and the fossa on the inner side of the external malleolus almost horizontally inward to the outer surface of the astragalus, behind the facet, and to its external tubercle.

(*c*) The **anterior ligament** is a thin loose membrane between the lateral ligaments in front. It is attached above to the ventral margin of the lower end of the tibia, above a slight transverse groove, and below to the rough upper aspect of the head of the astragalus. A mass of fat beneath it rests in the groove of the neck of the astragalus.

(*d*) The **posterior ligament,** very thin and weak, consists of scattered oblique fibers between the dorsal margins of the articular surfaces of the

tibia and the astragalus. The flexor longus hallucis tendon serves largely as a posterior ligament.

The *synovial membrane* is very loose on the anterior and posterior ligaments, forming folds between the tibia and the astragalus. It forms a short *cul-de-sac* between the tibia and fibula, in addition to lining the ligaments of the ankle.

The *movements* of the ankle are flexion and extension through a range of less than 90 degrees.

Pathology

The gross and microscopic appearances of the joint are the same as in articular tuberculosis elsewhere. The primary focus occurs with about equal frequency in synovial membrane and osseous structures. The astragalus is the commonest osseous focus, probably on account of its great vascularity. Extension from the astragalus is forward through the anterior ligament, when the disease appears as an extra-articular ichor pocket (abscess) on the dorsum of the foot; or posteriorly into the ankle-joint.

Symptoms and Signs

1. *Limp* is the earliest sign.

2. *Pain* soon follows and is felt anteriorly and laterally. It can be accentuated by strong plantar flexion which stretches the anterior ligament and brings tension upon the astragalus. It is also intensified by direct pressure on the os calcis.

3. *Position.*—Abnormal position occurs in chronological order, viz.: (*a*) *Dorsal flexion* (relaxation of the anterior ligament to relieve the astragalus of pressure); (*b*) *plantar flexion*, and (*c*) equinovalgus (relieves the os calcis of the body-weight).

4. *Gait.*—The patient "walks stiff" and upon the toes.

5. *Swelling* is an early sign, is uniform and appears in the anterior aspect of the ankle. It later appears about the malleoli if the synovial membrane becomes further involved. If confined to the front it usually indicates disease of the astragalus.

6. *Palpation.*—Increase of local temperature may be noted. The synovial sac feels boggy, and free fluid may be detected. It is sometimes possible to appreciate thickening of the bones.

7. *Limitation of Movement.*—Both flexion and extension are limited.

8. *Muscle spasm* is present.

9. *Peri-articular ichor pockets* may appear in the region of the external or internal malleolus.

10. *Sinuses.*—These may be numerous and often lead directly into the joint.

11. *X-ray Appearances.*—Rarefaction is characteristic. It may be so extreme that the bones look like empty shells with finely penciled outlines.

Diagnosis

Actual Diagnosis.—This should offer no difficulty, in the presence of the following phenomena:

1. Chronicity.
2. Monarticular affection.
3. Childhood.
4. Swelling anteriorly and laterally, spindle-shaped—muscular wasting.
5. Lameness.
6. Sequence of dorsi-flexion, plantar flexion and equinovalgus.
7. Pain and tenderness with muscular rigidity.
8. Slight afternoon temperature.

DIFFERENTIAL DIAGNOSIS

Disease	Points of resemblance	Points of difference
1. Chronic traumatic synovitis.	Swelling. Sinuses. Pain. Lameness.	Elastic, boggy swelling absent. Much less pain. No local tenderness. *X*-ray.
2. Tuberculosis of the tarsus.	Chronicity. Monarticular. Childhood. Swelling. Pain. Lameness.	Inversion and eversion limited.
3. Rheumatism, rheumatoid arthritis, etc.	Swelling, lameness, tenderness.	Polyarticular. Less pain. No muscle spasm. Responds to specific treatment.
4. Infectious arthritis.	Swelling, lameness, limited motion, pain, tenderness, etc.	History of acute onset, with fever, etc.
5. Sprain and other injuries.	Monarticular. Swelling. Lameness. Pain. Tenderness.	History of acute trauma. Absence of local signs of serious disease.
6. Rigid flatfoot.	Chronicity. Lameness.	Symptoms localized at meditarsal joint. Pain only on use.

Prognosis

Functional recovery is to be expected if treatment has been prompt and efficient. Coincident involvement of the tarsal bones makes the outcome more dubious. Flatfoot sometimes forms a troublesome sequel of the disease.

Treatment

General Treatment.—Proper attention should be paid to the question of fresh air, sustaining diet, the free use of codliver oil and as much exercise on crutches as can comfortably be obtained.

Local Treatment.—This consists of conservative and operative measures. To be effective, local treatment of tuberculous disease of the ankle-joint or tarsus should be based upon an intelligent conception of the pathology of the lesion, and should follow this general plan:

I. If the lesion is sharply localized (whether of tibia, astragalus, os calcis, etc.):

Eradication of focus by { (*a*) Cureting. (*b*) Excision of affected bone.

II. The general disease of the affected part should be treated in the following manner, and in the order given:

1. Immobilization:

(*a*) Plaster-of-Paris.
(*b*) Extension.
(*c*) Splint.
(*d*) Bone-graft (Albee).

} With recumbency; or, if the case is ambulant with a device to remove weight-bearing.

2. Radical excision (Kocher or Ochsner methods).
3. Amputation (in very advanced cases).

III. If the process has healed with deformity:

1. If bony deformity, restoration by bone-graft.
2. If due to contractures, appropriate tendon-lengthening.

Treatment of the general disease of the affected part as above outlined is as follows:

1. **Immobilization.**—(*a*) *Plaster-of-Paris.*—Fixation is most easily and effectively secured by a plaster-of-Paris case, which is particularly applicable

to this region, being moulded to the bony prominences and extending to the tubercle of the tibia. The foot should be put up at right angles and if sinuses are present windows should be cut for their proper treatment. If the symptoms are not acute, the patient may be allowed to walk with crutches (bearing no weight on the diseased foot) with an elevated sole on the boot of the healthy foot.

(*b*) *Extension.*—On account of the peculiar conformation of the ankle-joint, extension is very difficult of application. Where demanded by severe persistent pain and muscle spasm, it may be secured by a series of short adhesive straps applied over the anterior and posterior aspects of the joint, converging on each side laterally to a point a few inches below the malleoli, where a stirrup is attached and traction thus obtained by weight and pulley. This should be supplemented by a plaster-of-Paris splint with the adhesive strips brought out through its end. The patient should, of course, be kept in bed during this treatment.

(*c*) *Jones' Crab Splint.*—This consists of a piece of sheet iron moulded to fit the calf of the leg; riveted to it is an upright extending along the posterior aspect of the heel and the sole of the foot, as far as the toes; at the latter point and at the heel, bands are attached to encircle the foot. The splint is retained by a bandage about the calf of the leg and the foot.



FIG. 131.—Bone-graft arthrodesis of the joints between the os calcis, astragalus and tibia and of especial value in tuberculosis.



FIG. 132.—A method of arthrodesis and support of the cuneiform, cuboid, scaphoid, and astragalus bones by tibial bone-graft. Especially applicable in tuberculosis.

Adjuncts to conservative treatment are Bier's hyperemia (which may be extremely beneficial in the case of tuberculous disease in this locality) and tuberculin treatment.

(*d*) *Fixation of Tuberculous Osteitis of the Ankle by Bone-graft* (Albee).—For the treatment of tuberculous ankle-joint and tarsal disease, the author has applied the bone-graft as an internal fixation splint, supporting and immobilizing the diseased parts to a degree impossible of attainment by external splints, and thereby hastening the arrest of the tuberculous process.

In the instance of an adult, when the question of amputation was strongly

considered to relieve the patient of an extensive tuberculous infection of the tarsus, three bone-grafts were inserted, one from the internal malleolus to the os calcis; a second from the internal malleolus to the internal cuneiform bone; and a third, from the external malleolus to the cuboid bone.

Technic.—The leg and foot were prepared for operation, and a tourniquet tightly applied above the knee. A U-shaped skin flap was turned up, exposing the internal malleolus. A bed was prepared for the fixation of joined ends of the grafts coming from the internal cuneiform bone and the os calcis. As these two grafts were to be joined at an obtuse angle at the malleolus in the manner of an inverted "V" the bed was prepared by turning one osteoperiosteal flap down and two upward, with motor-saw or a sharp osteotome. Short skin incisions were made over the inner surface of the posterior portion of the os calcis and internal cuneiform bone, and beds were prepared in like manner for the ends of the grafts by turning up



FIG. 133.—Rontgenogram of an acute tubercular ankle in a young man twenty years of age. The symptoms were not relieved by a carefully fitted plaster-of-Paris dressing and month of recumbency in bed. Pain was entirely relieved by the insertion of bone-grafts from the external and internal malleoli to the posterior end of the os calcis, the cuboid bone and the internal cuneiform.

osteoperiosteal flaps. Subcutaneous tunnels were made with a broad ligament clamp, joining these incisions with the one over the internal malleolus.

The same procedure was carried out in forming a bed for a graft reaching from the external malleolus forward to the cuboid bone. The lengths of these grafts were determined with calipers. The antero-internal surface of the tibia of the same leg was then exposed, and with the twin-motor-saw, the required grafts, each $\frac{3}{8}$ inch wide and the full thickness of the cortex, were removed from the central portion of this tibial surface. The ends of the two grafts which were to be joined at the internal malleolus were mortised. This was very quickly done with the motor-saw. These two grafts were pushed through the subcutaneous tunnels already prepared for them, the mortised ends joined, and they were covered in by the osteoperiosteal flaps which were drawn over them with interrupted sutures of medium kangaroo tendon.

The other ends of these grafts, as well as the graft implanted on the outside of the foot, were secured in place in a similar manner. The skin wounds

were closed by continuous catgut sutures, and a plaster-of-Paris dressing applied with the foot at a right angle.

Figure 134 is a röntgenogram of this patient's foot, taken more than two years after operation, showing the grafts present much increased in strength and securely grown in. At the time of operation, in preparing the bed for the graft of the external side of the foot, tuberculous tissue was accidentally opened into and, although the graft spanned through this area of infected tissue, it healed in promptly. This is one of many instances where the author has placed grafts through tuberculous areas without interference with the

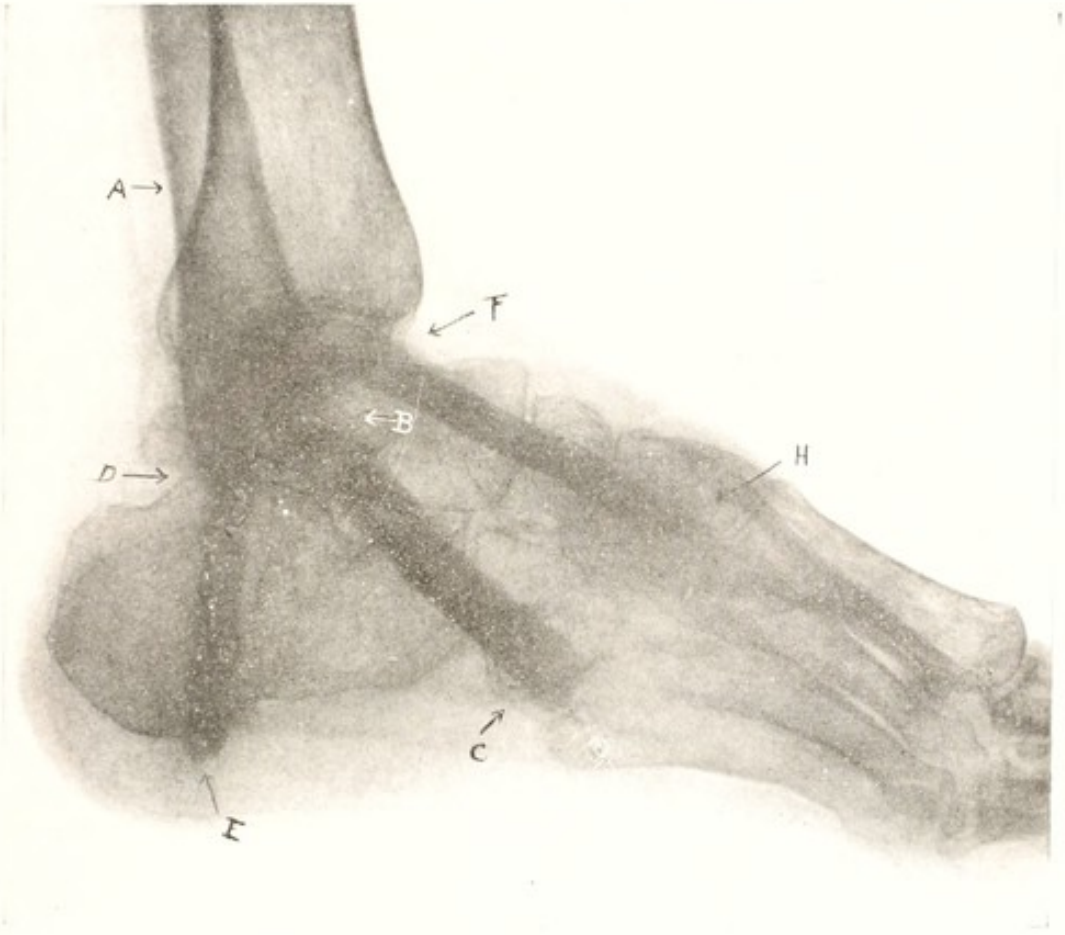


FIG. 134.—Röntgenogram of same case as Fig. 133 taken two years and four months after the insertion of the bone-grafts. The symptoms remain entirely relieved and the disease apparently cured. The hypertrophy and increase in density of the graft are very striking, especially at *B* and *D*. The fibula in which they are inserted is even hypertrophied from increased stress at *A*.

union of the graft to its bed. The result in this case was especially gratifying because the tarsal osteitis was advanced and very acute at the time of operation, and a well-moulded plaster cast with recumbency in bed had failed to relieve the pain. With the implantation of the bone-grafts, pain immediately subsided and the disease was completely arrested. One year later walking and weight-bearing produced no pain or other evidence of active disease and this relief of symptoms has persisted to the present time, over three years after the operation, in spite of the fact that the patient recently developed a tuberculous infection of the kidney and a relapse of the lung condition from which he suffered prior to the operation. Of 6 such cases, the results have been excellent in 5.

2. **Excision Operations.**—Excision of the ankle-joint for the cure of tuberculous osteitis is far inferior to the method of fixation by bone-graft. It removes the joint structures, disturbs the mechanical relations of ankle and tarsus, produces shortening and is mutilating. It is indicated only in

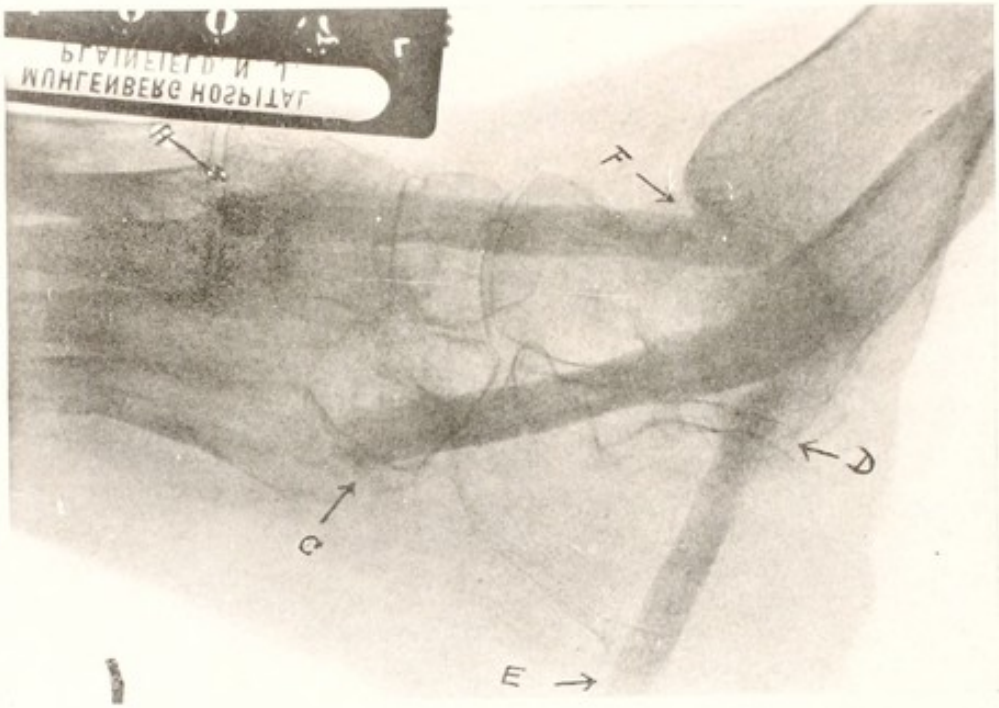


FIG. 135.—Röntgenogram taken two months after the insertion of the grafts. *AF* is graft from internal malleolus to internal cuneiform. *CD* is graft from external malleolus to the cuboid. *DE* is graft from external malleolus to the os calcis.



FIG. 136.—Showing excellent weight-bearing function and outline of graft extending from internal malleolus to internal cuneiform bone.

the event of profound cachexia, amyloidosis or extreme secondary infection.

The procedures usually followed are the methods of Kocher, König and Ochsner.

(*a*) *Kocher's Operation.*—Dislocation of the foot inward, with consequent free exposure of the ankle-joint is the distinguishing feature of this operation.

A J-shaped incision is used, following the terminal 2 inches of the posterior border of the fibula, passing beneath the tip of the external malleolus and ending on the dorsum of the foot at the end of the peroneus tertius tendon.

The external saphenous vein and nerve are retracted. The peroneus longus and brevis are divided just in front of the external malleolus and their tendons separately secured with retaining sutures and identifying artery clamps.

The periosteum is elevated from the external malleolus. The anterior ligament is divided across the front of the joint as far as the anterior edge of the internal malleolus, and the external lateral ligament severed at the tip of the external malleolus. The tibial attachment of the anterior ligament and the underlying periosteum are elevated upward. The tendon sheaths and periosteum are separated from the posterior surface of the fibula.

The foot is now dislocated inward until the sole faces upward. If freer exposure is desired the posterior and transverse ligaments may be detached from the back of the tibia; the entire articular surface is thus exposed.

The diseased bony structures having been removed, the separated ligaments are re-united, the severed tendons sutured, their sheaths closed and the skin wound repaired.

(*b*) *Ochsner's Operation.*—Ochsner's technic (Ochsner, Clinical Surgery, p. 727) makes even freer exposure than the above method.

An incision is made across the front of the ankle-joint from malleolus to malleolus. After division and retention by identifying sutures and clamps of the extensor tendons, the joint is entered by a transverse incision and freely exposed by dislocating the foot downward and backward until the sole approximates the calf of the leg. After eradication of the tuberculous foci, the foot is replaced, tendons and sheaths re-united and the wound closed.

The tendency to flat-foot following these excision operations may be to a certain extent counteracted by an appropriate metal plate.

3. **Amputation.**—In rare instances extensive disease of the ankle and tarsus especially when complicated by secondary infection, sinus formation, etc., may demand amputation. Care should be taken to remove the affected part well above the tuberculous area, to avoid inoculation of the stump.

Corrective Treatment (If the Process has Healed with Deformity).—(1) *Restoration of Destroyed Osseous Tissue by Bone-graft* (Albee).—A bone-graft may be implanted into the healthy bones on each side of the focus of disease, thus spanning it. The diseased tissues may or may not be removed, according to judgment. Or the diseased focus may be removed and a bone-graft modelled to take its place and fill in the deficiency at the same time that it is inlaid into contiguous bone on each side, thus preventing malformation of the foot resulting from loss of support by the removal of the infected bone.

2. *Correction of Equinus Deformity.*—In long-standing cases, equinus, often in the valgus position, is common. An anesthetic should be administered, the deformity corrected by manual force, aided by Thomas' wrench if necessary, and the restoration of position maintained by plaster-of-Paris bandages. Tenotomy of the tendo Achillis may be necessary.

II. TUBERCULOUS DISEASE OF THE TARSUS

ETIOLOGY

The astragalus is the most commonly affected, the os calcis next. Of the joints, the mid-tarsal is the most frequently involved. The joints are

infected as a rule by extension from the tarsal bones. A tuberculous endarteritis of the nutrient vessel is often encountered.

Anatomy

Seven bones make up the tarsus, viz.: astragalus, os calcis, scaphoid, three cuneiforms and the cuboid. The cuneiforms articulate with the three inner metatarsals, the cuboid with the two outer metatarsals. Six separate synovial membranes exist between the individual bones. Two distinct



Fig. 137.—Localized tubercular focus in scaphoid bone. Excision of the focus led to an immediate recovery.

synovial sacs separate the astragalus and os calcis. The anterior tarsa joint, between the scaphoid, cuboid, cuneiforms and the bases of the second and third metatarsals, is the largest and most important tarsal joint.

Pathology

The essential pathological changes in the tarsal bones and joints are similar to those in other localities.

Symptoms and Signs

1. *Pain* is an early symptom, but is less marked than in ankle-joint tuberculosis because of the relative immobility of the tarsal bones.

2. *Limp* and the *equinovalgus* position are present as in disease of the ankle-joint.

3. *Swelling.*—The distinguishing feature of the swelling is its occurrence on a plane below the ankle. It is confined to the dorsum of the foot early in the disease.

4. *Motion.*—Limitation or abolition of all movements of the joint involved is the rule.

Diagnosis

The essential feature is to differentiate the disease from tuberculosis of the ankle-joint. This can be conclusively demonstrated by röntgenography, location of pain, swelling and limitation of motion.

Treatment

The *general* and *conservative* treatment of tuberculosis of the tarsus is the same as that of the ankle.

Operative Treatment.—1. Fixation of the tarsus by bone-graft (Albee). 2. Restoration of destroyed osseous tissue by bone-graft (Albee). Both these operations have been described in the treatment of tuberculosis of the ankle. Other operative procedures on the tarsus are as follows:

3. *Anterior Tarsectomy.*—Two lateral incisions are made, the one on the median border of the foot extending from the posterior third of the first metatarsal backward to the head of the astragalus; the lateral incision begins at the posterior third of the fifth metatarsal and extends to the upper surface of the os calcis in front of the external malleolus. To gain access to the involved bones it is necessary to divide the attachments of the tibialis anticus and posticus, peroneus tertius, longus and brevis, ligate the dorsalis pedis artery and remove the base of the fifth metatarsal. The affected structures are removed with a chisel or saw. The operation produces considerable anteroposterior shortening.

4. *Resection of Os Calcis.*—A horseshoe-shaped incision is made beginning laterally at the base of the fifth metatarsal, encircling the heel and ending on the median surface below the internal malleolus. The resulting flap is reflected downward and as much of the os calcis as is desirable can be removed with the gouge. Restoration may in cases not secondarily infected, be made by means of bone-graft. In the latter instance portions of the os calcis should be saved if possible, into which the graft should be inserted.

5. *Resection of the Astragalus.*—The astragalus is exposed by a Kocher incision, beginning several inches above the ankle, following the fibula and ending at the base of the fifth metatarsal. The bone may be partially or wholly resected, and in the latter instance it may be restored by a bone-graft which is contacted with or inserted into the remaining astragalar fragments.

6. *Posterior Tarsectomy.*—Kocher has advocated this operation for tuberculous disease of the os calcis and astragalus. A long curved incision is used, beginning a few inches above the ankle-joint at the lateral border of the tendo Achillis and extending downward and forward behind the external malleolus, ending at the base of the fifth metatarsal. The peroneal tendons are retracted forward. The operation includes the total or partial extirpation of os calcis and astragalus and is unduly mutilating, resulting in great deformity. Since the advent of the bone-graft it is rarely indicated and only then in cases secondarily infected.

III. TUBERCULOUS DISEASE OF THE METACARPAL AND METATARSAL BONES, AND PHALANGES

Etiology

Tuberculous disease of the long bones of the hand and foot occurs almost always in infants in the first five years of life, although it is occasionally encountered in adults.

The predisposing etiological factor is possibly the relatively great size of the nutrient artery of these bones and the abundance of red bone-marrow in childhood.



Fig. 138.—Tuberculous phalangitis; three months' duration; cure after curettage by Albee. (Taylor.)

The affection is usually multiple and symmetrical and is frequently associated with tuberculosis of the skin, lymph-glands and other bones.

Pathology

The characteristic fusiform enlargement of the bone has given rise to the term "*spina ventosa*" to designate this condition.

The primary pathological change is an obliterating endarteritis which

results in substitution of fibro-myxomatous tissue for the normal red bone marrow. The lamellæ become rarefied and absorbed. The constricted arterial lumen causes ready lodgment of a tuberculous embolus, and an infiltrating tuberculous lesion is produced. The fusiform enlargement is due to the deposit of new subperiosteal bone.

The affection is more frequent in the hands than the feet, but the metacarpal bones and the phalanges are involved equally. In the foot, the metatarsal bone of the great toe is the member most often attacked.

Symptoms and Signs

1. *Uniform thickening* of the bone with
2. *Dull, aching pain* are the first signs of the disease.
3. The *skin* becomes thin, dusky and shiny.
4. *Fistulous openings* are common.
5. *Eruption* in the case of the phalanges occurs on their lateral surfaces; in the metacarpals and metatarsals, on the dorsum of the hand or the foot.
6. *Sequestra* are common, largely from secondary infection from fistulæ. Spontaneous cure frequently takes place, but with adhesion between the scar and the bone, and usually with shortening of the long axis with lateral deviation or rotation deformity.

Diagnosis

Spina ventosa must be distinguished from the two following conditions:

1. **Syphilitic Dactylitis.**—Röntgenography with other evidences of congenital syphilis, the Wassermann reaction and the result of antisyphilitic treatment should be sufficient for differentiation.

2. **Enchondroma.**—In tumor formation, the compact bone exists as a shell covering the tumor, without loss of osseous substance.

Prognosis

Life prognosis is good, unless dissemination of the disease has occurred.

The local prognosis depends upon the treatment, shortening and deformity being the rule in untreated cases. When resection with restoration by bone-graft is practised in favorable cases the functional and cosmetic results are excellent.

Treatment

Treatment is conservative and operative.

(A) **Conservative Treatment.**—1. *Hand.*—*Splints* of wood or aluminum with adhesive straps to immobilize the affected member are efficacious, or a *plaster-of-Paris* bandage may be applied from elbow to finger-tips.

2. *Foot.*—The most satisfactory immobilizing agent is the plaster-of-Paris bandage which should extend from the toes to the middle of the leg. No weight-bearing should be permitted, but the patient may go about with a Thomas knee splint.

Immobilization in the case of hands or feet is necessary for twelve months.

(B) **Operative Treatment.**—The most satisfactory treatment is resection of the affected bone with restoration of the destroyed part by a bone-graft especially in the adult. When the disease (from secondary infection) is too far advanced to permit of this, amputation is advisable.

1. *Resection with Restoration by Bone-graft.*—(*a*) *Metatarsals and Metacarpals.*—A straight incision is made in the dorsum of the hand or foot

in line with the diseased bone. The extensor tendons are retracted. The periosteum is incised and elevated, together with the attached interossei muscles. The affected bone is divided with the small single motor-saw, osteotome or bone cutter beyond either end of the diseased area, but an attempt should be made to save the head of the bone and not to encroach on the epiphyseal cartilage or enter the joint.

In the case of the first metacarpal bone, the incision is made along the radial side of the extensor brevis pollicis and the periosteum incised between the origin of the abductor brevis pollicis and the abductor indicis.

(*b*) *Phalanges.*—Lateral incisions are employed between the extensor tendon and the digital vessels and nerves. The periosteum is elevated and the bone resected, an attempt being made here, as with the metacarpals and metatarsals, to save the head of the bone and the epiphyseal cartilage and to avoid the joint, when inserting the graft.

In the case of the first phalanx of the great toe, a single lateral incision is used, to the inner side of the extensor tendon.

The bone defect is replaced by a graft taken from the crest of the tibia of the same patient. If phalangeal or metacarpal stumps are not too short the graft is mortised or inlaid into them. Strong traction should be applied to the distal end of the finger or toe while the graft is being inserted tightly into place. A snugly fitting plaster splint should be applied to the finger and hand, or toe and foot and allowed to remain in place for eight to twelve weeks. The resistance of cortical bone-graft to tuberculous infections and to attenuated infections of other varieties has been repeatedly proved by the author. As a rule, the functional and cosmetic results are excellent. The motion in the joints of children gradually returns by use.

2. *Amputation.*—Amputation of one or more fingers is rarely necessary if resection and restoration by bone-graft is employed. In the case of the toes, it may be indicated, but in disease of the great toe, every effort should be made to preserve the member by resection and bone-grafting.

IV. TUBERCULOUS DISEASE OF THE SHOULDER-JOINT

Tuberculosis of the shoulder-joint is not common and is rarely seen in children.

Anatomical Data

Although the articulation between the rounded humeral head and the shallow glenoid cavity is a simple joint, its three prolongations corresponding with the tendons of the long head of the biceps (bursa m. biceps hum.), the subscapularis (bursa m. subscapularis) and the infraspinatus (bursa m. infraspinatus), give these diverticula an importance in connection with tuberculous disease of the shoulder in that they determine the course of infection and the direction of abscess formation.

Pathology

Tuberculous disease of the shoulder-joint is classified pathologically as (1) *caries sicca* and (2) *caries carnosa*.

1. **Caries sicca** (Volkmann).—This condition is almost entirely confined to the shoulder-joint, and is characterized by the formation of peculiarly dry and fibrous granulation tissue. Fibromyxomatous tissue replaces the head of the humerus. The lamellæ are rarefied. The joint ligaments contract, force the head of the humerus against the glenoid cavity and cause its atrophy which results eventually in its disappearance.

2. **Caries carnosa** (König).—The presence of vascular, proliferating granulation tissue characterizes this form. The interlamellar spaces are filled with flesh-like granulation tissue, which is microscopically highly vascular and abounds in tubercles.

Symptoms and Physical Signs

Insidiousness of onset is the striking feature of tuberculosis of the shoulder. This is to be accounted for by the fact that being a non-weight-bearing joint, there is no exaggeration of symptoms, and because of the movability of the scapula on the thorax, the shoulder-girdle can be moved *en masse*, while the joint itself remains immobile.

1. **Pain** is an early symptom. It is felt particularly at night when lying on the affected shoulder, and is experienced in front of the joint and at the insertion of the deltoid. It is dull and aching in character. Referred pain may be felt in the elbow and forearm.

2. **Tenderness.**—Pressure on the outer side of the coracoid, on the greater tuberosity of the humerus and at the posterior margin of the deltoid elicits tenderness.

3. **Rigidity.**—Abduction and rotation are particularly limited, illustrated by difficulty in placing the hand behind the head or the back.

4. **Wasting.**—Atrophy of the deltoid brings into prominence the bony outlines of the joint.

5. **Abnormal Positions.**—Early in the disease, slight abduction is evident. Later, when fluid is present, abduction, flexion and internal rotation are assumed, and the tip of the shoulder is depressed. At a still later period, the arm is held across the chest in extreme adduction. Increase of surface temperature and enlargement of the bones entering into the formation of the joint may be observed.

6. **Abscess Formation.**—An ichor pocket may follow the subscapularis or infraspinatus tendons and point in the axilla, or the long head of the biceps and appear in front of the joint; or perforating the capsule above and below the subscapularis, beneath the deltoid, point in front of or behind its insertion.

Special Clinical Features of Caries Sicca

Two phenomena characterize this lesion, viz.: absence of swelling and abscess formation. Muscular wasting of the deltoid is often so extreme that the head of the humerus seems to be absent from the glenoid fossa. The shoulder has the appearance of a subcoracoid dislocation. The arm is held close to the chest, and there is great pain on any attempted movement. Eventually complete fibrous ankylosis in a position of adduction, with real shortening in the long axis of the arm results.

Diagnosis

Actual Diagnosis.—This is based on the insidious onset, pain, tenderness, rigidity and atrophy.

Differential Diagnosis.—Tuberculous disease must be differentiated from *subdeltoid bursitis and dislocation* of the shoulder.

(*a*) *Subdeltoid Bursitis.*—In this condition abduction and inward rotation (arm behind back) are the most painful. (Anteroposterior motion is usually free and without pain.) In tuberculosis, all movements cause equal distress. The muscular atrophy is far more extreme in tuberculosis than in subdeltoid bursitis.

(*b*) *Dislocation.*—With a history of trauma, the differentiation may be difficult, but an *x*-ray examination will establish the diagnosis.

Prognosis

Partial or complete ankylosis is inevitable. The best position is moderate abduction and flexion. As for expectation of life, the outlook is worse than in other joints, possibly on account of the proximity of the lung, and the relatively higher percentage of cases with pulmonary involvement. The death rate is higher than in joints of the lower extremity.

Treatment

(A) **Conservative Treatment.**—The disease here as elsewhere, is treated by rest, which may be secured in various ways, viz.:

1. *Sling* and *plaster-of-Paris* circular splint. The wrist is fixed to the neck by a sling, with the elbow at a right angle. The thorax, axillary space and shoulder are well padded with cotton wadding. With the arm to the side, the thorax, shoulder and arm are included in a carefully moulded plaster-of-Paris dressing.

2. *Plaster-of-Paris Bandage.*—Another method of fixation, consists of the application of a plaster-of-Paris cast to include the chest, diseased shoulder, arm and hand. The arm is held flexed at a right angle and away from the chest wall, to enable the patient's clothing to be put on. As a lining to the cast, stockinet or a jersey shirt is used, and padded by the use of Shaker flannel bandages over bony prominences. The dressing, when well-fitted, furnishes a most efficient fixation and comfortable method of treatment.

(B) **Operative Treatment.**—The indications for operative interference are the constant danger of infection of the lung and to eradicate the lesion and secure complete ankylosis of the joint which relieves all pain.

The operation of choice is erasion followed by fixation of the joint by bone-graft. Excision of the joint is an undesirable procedure in that the resulting deformity is great.

Arthrodesis with Bone-graft Peg (Albee).—After the usual iodin preparation of the field of operation, the incision is made from a point on the clavicle above the coracoid process, obliquely downward and outward along the anterior border of the deltoid. The deltoid is retracted outward, the pectoralis major with the cephalic vein inward. Divide the anterior border of the deltoid just below its attachment to the clavicle to assist in retraction. In the interval, there appear, from above downward, the pectoralis minor, coracobrachialis with the short head of the biceps, the anterior surface of the neck of the humerus and the tendon of the pectoralis major. By pressing the finger on the humerus at the outer edge of the coracobrachialis and biceps, the bicipital groove of the humerus is felt, containing the long head of the biceps in its sheath; the sheath is slit and the biceps tendon retracted inward. This partially opens the capsule of the shoulder-joint; the opening is further enlarged and the head of the humerus dislocated out of the wound which may be easily done by strong external rotation of the humerus.

All cartilage is removed from the head of the humerus and the approximating surface of the acromion by a small hand-saw, the single motor-saw or osteotome and from the glenoid cavity by a bone-gouge or motor burr. With an assistant holding the scapula in good position, the head of the humerus is approximated to the glenoid cavity and acromion process and

the arm slightly externally rotated and anteriorly elevated (90°). The joint is fixed in this position in the following manner:

A hole is made with the motor drill vertically downward through the acromion and through two-thirds of the diameter of the humeral head. A bone-graft dowel-peg previously fashioned by the author's dowel-shaper from an autogenous tibial bone-graft is driven through the acromion and head of the humerus. The periosteum is closed over the drill hole, sheaths, muscles and tendons re-sutured, the skin wound closed, and a plaster-of-Paris bandage applied to hold the arm in the desired position where it should be kept for at least two months.

V. TUBERCULOUS DISEASE OF THE ELBOW-JOINT

Tuberculosis of the elbow-joint occurs fourth in order of frequency, outranking tuberculous disease of the shoulder and of the wrist. It is commonest in the first ten years of life.

Anatomy of the Joint

The bones entering into the formation of the elbow-joint are the lower end of the humerus and the upper ends of the ulna and radius. The lower epiphysis of the humerus—its articular surface and its two centers of ossification, the outer (capitellar) and inner (trochlear)—is included in the joint. The capitellar center begins to ossify at two years; the trochlear not until eleven years of age. The upper epiphysis of the ulna remains cartilaginous until the tenth year; that of the radius until the sixth year. The synovial membrane is reflected upward for some distance on the humerus, but not to any great extent upon the ulna, and is prolonged about the head of the radius as the "recessus sacciformis."

Pathology

Authorities differ as to whether the primary focus is osteal or synovial and also as to the most common location of this original focus. It is probable that in the majority of cases the primary focus is osteal and most frequently found in the lower epiphysis of the humerus.

Symptoms and Physical Signs

The chief clinical manifestations of the disease are pain, tenderness, swelling, stiffness, deformity and muscular atrophy.

1. **Pain.**—This is an early symptom, is confined to the joint and is increased on movement. At a later stage, neuritis of the ulnar nerve may give rise to numbness and tingling along the inner aspect of the forearm.

2. **Tenderness.**—Sensitiveness to pressure is first noticeable in the sulci at either side of the olecranon. The surface temperature is elevated.

3. **Swelling.**—A doughy, elastic sensation to touch with increase in size of the joint, made more prominent by the advent of effusion, is early detected. Later the swelling is more general, and spindle-shaped. Thickening of one or more of the bones may be detected.

4. **Stiffness.**—Stiffness is early due to muscle spasm and is at first limited to the extremes of flexion and extension. At a later stage the joint becomes fixed midway between flexion and extension, with the forearm midway between pronation and supination.

5. **Deformity.**—The characteristic deformity is a fusiform swelling with the elbow at right angles and the forearm midway between pronation and supination.

6. **Muscular Atrophy.**—Wasting of the upper arm is more marked than the forearm; in the latter, muscular activity is possible and muscular tone is preserved.

7. **Röntgenography.**—An *x*-ray picture should complete the examination and is not only of diagnostic and prognostic importance, but serves as a guide to treatment.

Differential Diagnosis

There are only two conditions which one may confuse with tuberculous disease of the elbow-joint.

1. **Syphilitic Osteitis.**—This affects the metaphysis, as a rule. It is, however, usually a multiple lesion, and other luetic stigmata can be demonstrated, or a positive Wassermann reaction obtained.

2. **Stiffness Following Trauma.**—Persistent limitation of motion may be encountered as the result of long-continued fixation, but the traumatic history will establish the diagnosis.

Prognosis

If treatment is undertaken early, the functional outlook is good. Even after excision, a considerable percentage of cases recover satisfactory motion.

Treatment

Treatment is divided into *conservative* methods whose principle, as in tuberculous joints generally, is fixation; and *operative* procedures, consisting of various methods of excision.

A. **Conservative Treatment.**—Fixation of the elbow should be made with the arm in the most efficient position should ankylosis ensue. The ideal position is flexion to 90° with the forearm midway between pronation and supination.

1. *Plaster-of-Paris Bandage.*—Plaster-of-Paris is the best material and method for fixing the elbow. If sufficient flexion cannot be obtained at the first sitting, the plaster bandage may be applied in two segments, one for the arm, the other for the forearm, and an interval left at the elbow to which a removable plaster bridge may be applied. When the desired degree of flexion has been obtained, the interval can be bridged with fresh plaster bandage incorporated into the two segments already in position, or the first plaster bandage may be entirely removed and re-applied with the arm in increased flexion.

Fixation by the sling or plaster-bandage methods, should be employed for at least eighteen months, when manipulation and massage may be begun, if the tuberculous process has subsided.

2. *Halter Sling* (Jones and Ridlon).—A wide bandage is used, one or two turns taken about the wrist, and the ends knotted about the neck. The neck-piece may be threaded through a piece of rubber tubing to prevent chafing. The arm is carried close to the body with the clothes put on over it.

3. *Bier's Hyperemia.*—If passive hyperemia is to be employed as an adjunct to other treatment, the elastic compression should be applied to the upper arm.

B. **Operative Treatment.**—This consists of *excision* of the elbow by one of two methods viz.: the posterior excision of Langenbeck or the lateral excision of Kocher.

1. *Posterior Excision* (Langenbeck).—A posterior vertical median incision is used, from a point 2 inches above, to a point 2 inches below the joint, and extending down to the bone throughout, and passing through the triceps, opening the posterior part of the joint and exposing the olecranon and the subcutaneous surface of the ulna. The periosteum is incised in a line with the primary incision and elevated with the triceps and anconeus from the inner and outer surfaces of the ulna. The pronators and flexors, with the internal lateral ligament, are elevated with the periosteum from the antero-lateral aspect of the internal condyle. The lower end of the origin of the triceps is separated from the posterior surface of the humerus. Avoid the ulnar nerve in the groove between the olecranon and the internal condyle.

The outer half of the joint is now exposed. The ligaments covering the posterior part of the head of the radius are incised, and the supinator brevis elevated with the periosteum from the neck of the radius and retracted outward. The origin of the anconeus is detached from the outer part of the humerus. The origins of the extensors and the external lateral ligament are divided. The elbow is sharply flexed, exposing the interior of the joint. Force the lower end of the humerus out of the wound, by strong flexion, and separate the anterior ligament and brachialis anticus from its ventral surface. Sever the humerus at the epicondylar region or well above the disease focus. Divide the neck of the radius well below the head. Separate the attachments of the anterior ligament and brachialis anticus from the coronoid process of the ulna, and remove the articular surface of the ulna and as much osseous tissue as is diseased. After removal of the bony structures, cut away every vestige of synovial membrane. Re-suture all detached muscles with their periosteum—triceps, anconeus and supinator brevis. Fix elbow by plaster bandage from ends of fingers to axilla, supplemented by sling and circular plaster-of-Paris bandage about thorax.

2. *Lateral Excision* (Kocher).—The incision is made from a point 2 inches above the joint, carried down back of the external supracondylar ridge, over the head of the radius, along the outer border of the anconeus, between it and the extensor carpi-ulnaris to the ridge of the ulna 2 inches below the tip of the olecranon. Separate the supinator longus and the extensor carpi radialis longus from the triceps to expose the humerus. Expose the ulna by separating the extensor carpi ulnaris and the anconeus. Retract inward the triceps, anconeus and ulnar nerve. The remainder of the operation is performed as in Langenbeck's technic given above.

After-treatment.—The arm is immobilized in a plaster-of-Paris dressing in the same manner as after Langenbeck's operation. The arm is kept at the side of the chest in extension and moderate supination for two or three weeks. The cast is then removed and the arm immobilized for twenty-four hour periods, alternately in flexion and extension. At the end of four to five weeks of this treatment, the plaster dressings are abandoned, the patient allowed to carry the arm in a sling, and gradually to exercise it, supplemented by massage and manipulation.

VI. TUBERCULOUS DISEASE OF THE WRIST-JOINT

Tuberculosis of the wrist is *uncommon* (about 2 per cent. of affections of all joints). It is exceedingly rare in children.

Anatomy

The striking anatomical features of this joint are the *multiplicity* of the *carpal bones* and the *intricacy* of the *synovial sacs*.

Carpal Bones.—These are arranged in two nearly parallel rows of four bones to each row. Designated from radial to ulnar side, they are,

Upper Row.—Scaphoid, semilunar, cuneiform and pisiform.

Lower Row.—Trapezium, trapezoid, os magnum and unciform.

Synovial Sacs.—These are numerous and complex, viz.:

1. Between the lower ends of ulna and radius is the recessus sacciformis inferior.

2. Between the articular surfaces of radius above and the scaphoid and semilunar and cuneiform below, there is an extensive synovial sac.

3. Between the pisiform and cuneiform is a small sac.

4. The transverse carpal joint extends between the two rows of carpal bones and sends prolongations between the individual bones.

5. Between the trapezium and the first metacarpal is a single sac.

6. Between the trapezoid, os magnum and cuneiform above and the four inner metacarpals below is a complex synovial membrane.

Pathology

Tuberculosis of the wrist is usually of osseous origin. The commonest sites for the primary focus are the lower end of the radius and the os magnum. In view of the intricacy of the synovial arrangement detailed above, it will be appreciated how rapidly they may become invaded. Because of the multiplicity and small size of the individual carpal bones, dissemination is virulent.

The disease extends to the sheaths of the flexor tendons which undergo fibromyxomatous degeneration with the secretion of a viscous fluid containing seed-like masses which represent inspissated secretion from the tendon sheaths. Abscesses and sinuses are common.

Symptoms and Physical Signs

1. **Pain** is a prominent feature. At first localized to the focus of disease, it gradually assumes the character of "tightness" in the joint. It is increased on pressure and movement, particularly on approximating the lower ends of ulna and radius.

2. **Swelling** is readily detected, at first on each side of the joint, later encircling the wrist. The tendon sheaths stand out prominently, particularly the palmar ganglion. The characteristic of the swelling is its fusiform outline. Disease limited to the carpal bones is usually accompanied by no swelling.

3. **Deformity.**—The usual position is partial flexion, but the hand occasionally lies in the plane of the forearm.

4. **Limitation of Motion.**—All movements are restricted. Spasm of the long muscles passing over the joint is often present.

5. **Muscular Atrophy.**—The forearm is particularly affected. The hand usually remains well-nourished.

6. **Abcesses.**—When present, they occur on the dorsum of the wrist and hand.

Diagnosis

The diagnosis is not difficult. Confirmatory evidence is offered by röntgenography, tuberculin tests, etc.

Prognosis

In children, good functional result may be expected from prompt treatment. In adults, pulmonary involvement often occurs. Early fixation by bone-graft after conservative means have failed, offers the best outlook in adults.

Treatment

A. **Conservative Treatment.**—*Fixation by Plaster-of-Paris.*—The ideal position for immobilization is with the hand in moderate dorsiflexion, which gives the flexor muscles the most efficient leverage in case ankylosis occurs. The bandage should extend from the finger-tips to the elbow, and must be kept in position until the disease is apparently cured—this entails immobilization for at least eighteen months. The cast is removed gradually, beginning with exposure of the fingers, then of the metacarpophalangeal joints, then the entire thumb, and finally total removal. Massage and judicious manipulation should be begun early.

B. **Operative Treatment.**—1. *Fixation by Bone-graft* (Albee).—The most complete fixation is afforded by a bone-graft inlaid in the radius and os magnum or the radius and base of the third metacarpal bone.

After a dorsal incision has been made as in the excision operation described below, and the carpus exposed, the periosteum is incised and elevated over the distal extremity of the radius and os magnum or third metacarpal bone. With the twin motor-saw a gutter is prepared, measurements of which are taken with the flexible probe and calipers and a bone-graft removed from the tibia and inserted in the prepared bed. The graft is held in place by kangaroo tendon about the metacarpal bone and by the same material through drill holes in the radius or os magnum, if the latter has been used instead of the metacarpal bone. After suturing periosteum and skin, the wound is dressed and the forearm, from finger-tips to elbow, immobilized in plaster-of-Paris bandages for at least three months.

2. *Excision* (Ollier).—Two incisions are used in the Ollier operation; one from a point at the middle of the dorsal surface of the second metacarpal upward and inward following the radial side of the extensor indicis as far as the interstyloid level, when the incision changes its direction to run parallel with the long axis of the forearm for $1\frac{1}{2}$ inches above the interstyloid line; the other incision is made on the ulnar side of the dorsum of the wrist, from a point $1\frac{1}{4}$ inches above the tip of the styloid process to $\frac{3}{4}$ inch below the base of the fifth metacarpal, along the inner side of the extensor carpi ulnaris and extending down to the bone.

In the outer incision the tendon and sheath of the extensor indicis lie exposed and are retracted inward. The insertion of the extensor carpi radialis brevior is exposed, the periosteum to its inner side is incised and separated outward with the insertion of the muscle. The periosteal incision is prolonged upward, dividing the capsule of the joint and the posterior annular ligament between the extensor indicis and the extensor pollicis longus.

The posterior surface of the carpus now lies exposed through the two incisions. With care, the tendinous insertions can be preserved.

First, remove the semilunar through the outer incision. Next, the cuneiform. Third, remove with rongeur forceps the hook of the unciform, then its body. The pisiform is usually retained, with the trapezium, unless diseased. The lower ends of the radius and ulna, if involved, are removed with a small single motor-saw. If possible preserve the carpal ends of the

metacarpal bones. All diseased soft parts should be removed, and the annular ligament re-sutured. The wound may or may not be drained, according to judgment.

After-treatment.—A complete plaster-of-Paris bandage, or a plaster-of-Paris anterior splint may be used. The hand is immobilized in moderate dorsiflexion. Massage and electricity should be early employed to prevent fibrous union of tendons. The immobilization should be maintained until consolidation of the wrist is well advanced—six months or longer.

VII. TUBERCULOUS DISEASE OF THE SKULL BONES

The skull bones are occasionally affected with tuberculosis in children, secondarily to tuberculous disease elsewhere.

Pathology

The frontal bone presents the commonest site of infection. The lesion is of hematogenous origin and constitutes a tuberculous osteomyelitis of the diploë. An ichor pocket frequently forms beneath the pericranium overlying the lesion; if it remains thus localized, it is delimited by the cranial sutures, but if the pericranium is perforated, the abscess becomes superficial, secondary infection readily occurs and sinus formation results. The process rarely extends inward to the meninges. Sequestrum formation is common.

Symptoms and Physical Signs

There are very few symptoms and signs of the disease.

Pain, at first local, usually subsides on the appearance of an ichor pocket and follows the consequent reduction of tension.

Swelling is due to a subpericranial ichor pocket.

Prognosis

Tuberculous disease of the skull bones usually indicates a wide dissemination of the infection. The outlook, therefore is unfavorable. If treatment is long delayed or neglected the meninges may be inoculated or a brain abscess develop.

Treatment

Conservative measures have no place in the treatment of this condition. Operative removal of the focus of disease with the insertion of a bone-graft to repair the defect in the skull, is the procedure of choice. The bone-graft should not be used in the presence of secondary infection.

A semicircular incision is made down to the bone and the flap of soft tissue and pericranium dissected up. The diseased focus is removed with a gouge, rongeur or curette or preferably with the author's rotary laminatome. If the dura is thickened and adherent to the brain cortex it should be dissected away, providing cortical symptoms have appeared.

All the dimensions of the bone defect are then carefully taken with calipers or compasses and are transferred to the upper portion of the anterior internal surface of the tibia selected as the source of the graft material. The exact size and contour of the graft are outlined in the periosteum with the point of the scalpel, from the caliper measurements. The graft is removed with the author's small saw, the cuts being bevelled the same as those at the edge

of the skull opening, so that the transplant will rest firmly on the skull and cannot be driven down upon the brain beneath. The graft is held in place by three or four ligatures of medium kangaroo tendon placed in corresponding drill holes in the edges of the graft and skull opening. If the convexity of the skull demands it, the graft is sawed nearly through on the endosteal (or what is to be the concave surface) at intervals of $\frac{1}{8}$ inch so that the graft can be bent to conform to the contour of the skull. The upper end of the tibia is selected rather than the lower portion because its cortex is thinner and its surface flatter and broader. A graft covered on both sides with periosteum may be obtained by the same technic from the scapula. A rib or portion of the ilium has been utilized for the purpose. The scalp is closed in the usual way.

VIII. TUBERCULOUS DISEASE OF THE LOWER JAW

Tuberculosis of the inferior maxilla is more common than would be supposed. It occurs usually in the period of the second dentition and frequently affects children of phthisical parents.

Pathology

The disease is hematogenous in origin. The body of the jaw, is the usual site of the lesion which occurs in relation to the blood-vessels entering the roots of the teeth. Tuberculous granulation tissue is developed about the root and the tooth becomes loosened. The disease then invades the cancellous bone in the interior of the jaw. The periosteum is thickened by a deposit of new subperiosteal bone. An ichor pocket frequently forms in the ramus of the jaw.

Symptoms and Physical Signs

1. **Pain** follows the distribution of the inferior dental nerve.
2. **Loose teeth** are characteristic. A striking feature is the absence of bleeding following their extraction.
3. **Swelling** is marked and is due to new subperiosteal bone deposited on both surfaces of the jaw.
4. **Abscess.**—An ichor pocket may point outward toward the skin or inward and perforate the mucosa of the mouth. In the latter event, there is danger of inoculation of the larynx, bronchi or mesenteric lymph nodes.
5. **Adenitis.**—The submaxillary and submental lymph glands are usually enlarged.

Diagnosis

This may be so difficult as to require an anesthetic for a thorough examination of the jaw. Signs of tuberculosis elsewhere, a positive von Pirquet tuberculin test, röntgenogram, etc., will offer assistance.

The condition may be confused with the following:

1. **Dentigerous Cyst.**—Cystic disease occurs between the ages of twenty and forty, is of very slow growth, causes gradual expansion of the maxilla and is not accompanied by superficial abscess formation. The *x*-ray again is of value.
2. **Simple Periostitis.**—The acute or subacute onset is characteristic of this condition.

Prognosis

Early and complete removal of the diseased bone affords a good prognosis. Sinuses discharging into the mouth are prone to infect the larynx, bronchi and mesenteric nodes and give a graver aspect to the situation.

Treatment

There is no satisfactory conservative treatment to be offered with the exception of extraction of any loose, carious teeth.

Operative treatment consists of a preliminary cleansing of the buccal cavity and the removal of carious teeth and diseased bone is usually sufficient. Resection of the diseased portion of the jaw and restoration by bone-graft may be necessary in very virulent and advanced cases.

Subperiosteal Resection with Restoration of the Defect by Inlay Bone-graft (Albee).—*Resection.*—The incision extends along the ramus, follows it downward along its posterior border, turns at the angle and runs parallel with and a little below the lower margin of the body of the jaw and in length varies in accordance with the extent of the disease. The upper part of the incision is superficial and avoids injury to the facial nerve; the lower part of the incision extends to the bone. Ligate and sever the facial artery if necessary. Incise the periosteum along the line of the skin incision and elevate it, with the masseter muscle. From the inner surface of the jaw, elevate the periosteum and the internal pterygoid in like manner. Remove with the motor-saw, burr or chisel the affected segment of the jaw.

Restoration of the Defect by Bone-graft.—The inlay tibial graft offers a highly satisfactory agent for spanning the gap produced and holding the remaining fragments in alignment. The graft and the gutter are produced by the twin-motor-saw blades adjusted at the same distance apart, producing an accurate fit of the graft which is held in position by kangaroo-tendon sutures passed through drill-holes in the jaw fragments.

The support and fixation of the fragments may be sufficient, but it is safer to wire the teeth of the lower jaw, if any are available after resection, to corresponding ones of the upper jaw. The teeth adjoining the site of disease should never be selected for wiring as they are likely to become loosened. The dental plate offers an excellent means of postoperative fixation.

The periosteum is sutured with a continuous No. 1, chromicized catgut and the skin with No. 1 plain catgut.

The postoperative dressing consists of a leather chin-piece or a four-tail bandage.

Especial directions should be given that the patient take liquid diet and keep the mouth as clean as possible with mouth washes, but the wound must be sealed off from the oral cavity, and if this cannot be accomplished at the time of resection the bone-graft insertion must be deferred until later.

IX. TUBERCULOUS DISEASE OF THE UPPER JAW AND MALAR BONE

A tuberculous lesion of these structures originates in the vicinity of the suture between the malar bone and the superior maxilla. Ichor pockets readily form and point in the face, zygomatic fossa or floor of the orbit, and because of the tenuous skin, sinus formation is common. Sequestration is frequently encountered.

Abscess and sinus formation are practically the only clinical features.

Conservative treatment is unavailing. An incision should be made obliquely downward and outward from a point just below the infra-orbital margin, over the malar bone. The diseased bone is readily accessible and is removed by the bone-gouge, motor-saw or burr. The defect is repaired by a bone-graft inlay as described in the treatment of tuberculous disease of the skull if there is no secondary infection and the wound can be sealed off from the oral cavity.

X. TUBERCULOUS DISEASE OF THE RIBS

The lesion may be a primary tuberculous osteomyelitis or as recently shown by Robinson of the Mayos' Clinic, cases always hitherto diagnosticated as primary tuberculosis of the rib may be secondary infections from a focus in a pleural recess.

The clinical history is indefinite. Pain on respiration is present. Early abscess formation is characteristic. The ichor pocket may overlie the lesion or follow the track of nerves, blood-vessels, or tissue planes, viz.: an abscess from the posterior extremity of a rib may follow the intercostal vessels to the midaxillary region or the border of the sternum; a costochondral ichor pocket may gravitate downward, enter the sheath of the rectus and infiltrate the entire anterior abdominal wall. Occasionally the ichor pocket is lodged between the pleura and chest wall.

Early excision of the diseased rib should be performed. A broad curved incision is employed, with its convexity downward and not lying directly over the lesion. Reflection of the flap exposes the rib which is resected, subperiosteally (a sharp periosteal elevator being used with force in separating the periosteum) with the single motor-saw, well beyond the tuberculous focus. The affected side of the chest is immobilized by wide strips of adhesive plaster for a period of about five weeks.

REFERENCES

ANKLE-JOINT AND TARSUS

EWALD, P.: "Plattfuss und Fusswurzeltuberkulose." Münch. med. Wochschr., 1907, liv, 2326–2329.

BROCA: "Tuberculose d'un ancien pied plat." Presse méd., Paris, 1907, xv, 760.

WALTHER: "Ostéoarthrite tuberculose du tarse antérieur." Bull. et. mém. Soc. de Chir. de Paris, 1907, xxxiii, 1188.

VASSALIN, C. N.: "Conservative Treatment of Tuberculous Tibiotarsal Arthritis." Spitalul Bucuresci, 1907, xxvii, 476–492.

STICH, R.: "Über die Erfolge der operativen Behandlung der Fussgelenkstuberkulose." Dtsche. med. Wochenschr. 1908, xxxiv, 1227–1241.

EDMUNDS, A.: "Tuberculous Disease of the Os Calcis." Med. Press and Circo., London, 1908, N. S. lxxxv, 401.

MEYER, W.: "Tuberculosis of the Tibio-tarsal Joint." Ann. Surg., 1908, xlvii, 810.

LEPHRO, P.: "Lésions tuberculeuses du cou-de-pied et astragalectomie." J. de Soc. méd. de Lille, 1908, i, 10–12–15.

REYNIER: "Ostéite tuberculeuse du cubitus guérie par les bains et les applications d'eaux chlorurées sodiques." Bull. et mém. Soc. de Chir. de Paris, 1908, N. S. xxxiv, 606.

TIXIER: "Ostéoarthrice tuberculeuse du cou-de-pied." Lyon méd., 1908, cx, 1308–1402.

MASSABRIAN AND GUEIT: "Tuberculeuse du tarse antérieur." Montpel. méd., 1908, xxvi, 494–496.

FRANK, F.: "Die Resektion bei Fussgelenkstuberkulose nach Bardenheuer." Deutsche Zeitschr. f. Chir., 1909, xcix, 480–523.

CHAPUT: "Tumeur blanche du pied guérie par la méthode de Bier." Bull. et mém. de Soc. de Chir. de Paris, 1909, N. S. xxxv, 377.

MEYER, W.: "The Result of Bier's Treatment in Tuberculosis of the Tarsus." Ann. Surg., 1909, i, 639.

MURPEN, T. K.: "Radical Treatment of Tuberculous Disease of the Tarsus and Ankle-joint." B. M. J., London, 1910, ii, 1145–57.
SEVER, J. W.: "Tuberculosis of the Ankle-joint and Tarsus." Jour. Am. Med. Ass'n, Chicago, 1910, lv, 2128–2133.
EDMUNDS, A.: "Tuberculosis of the Foot." Med. Press and Circ., London, 1910, N. S. lxxxix, 471.
HENRI BOURGEOIS: "Contribution à étude de la tarsectomie antérieure par incision transverse dans les cas de tuberculose du tarse antérieur." Lyons, 1911, 43 pp.

METATARSAL AND METACARPAL BONES AND PHALANGES

BUDDE: "Zur Frage der ausgedehnten Resektionen am Tarsus und Metatarsus." Deutsche Zeitschr. f. Chir., Leipzig, 1907, xc, 573–608.
STEINMAN: "Spina Ventosa." Corr.-Bl. f. Schweiz. Ärzte, Basle, 1907, xxxviii, 23.
HEINECKE, F. K.: "Beiträge zur Behandlung der Spina ventosa mittels freier Autoplastik." Berlin, 1908, G. Shade.
LOZANO, P.: "Ostéo-artritis tuberculosa en los ninon." Rev. Ibero am. de cien., Madrid, 1908, xx, 94–96.
ROEPKER, O.: "Handgelenkstuberculose, Trauma durch Heben eines Puffers." Zeitschr. f. Bahn-u. Bahnkassenärtze, 1908, iii, 249–251.
PELS, LEUDSEN: "Über die Behandlung der Spina ventosa mit tels freier Autoplastik, Zugleich ein Beiträg. zum Knochentransformationsgesetze." Charité-Annal., Berlin, xxxii, 345–359.
KUZMAN, Y. U.: "Tuberculosis of the Metacarpal and Phalangeal Bones, their Peculiarities and Treatment." Khirurgia, Moskow, xxviii, 795–821.
BAILLEUL, LOUIS: "Des ostéites tuberculeuses des petits os longs de la main et du pied, (Spina ventosa) et des déformités, etc." Paris, 1911, G. Steinhut, 296 pp., 8vo.
MARIE: "Lésions osseuses des petits os de la main et du pied." Gaz. hebd. des sc. méd. de Bordeaux, 1913, xxxiv, 283.
GREEN, R. M: "Tuberculous Osteomyelitis of the Digits." Boston M. and S. Jour., 1913, clxx, 797–801.

SHOULDER-JOINT

KELLOCK, T. H.: "Excision of Joints, a New Method of Operating at the Shoulder." Tr. Clin. Soc., London, 1907, xl, 94–97.
MORRIS, R. T.: "Tuberculosis of the Scapula." Post-Graduate, 1908, xxiii, 324.
SCUDDER, C. L., AND BARNEY, D. J.: "Excision of the Shoulder-joint." Pub. Mass. Gen. Hosp., Boston, 1909, ii, 446–464; Am. Surg., Philadelphia, 1909, xlix, 696–706.
GILLETTE, H. J.: "A Simple Dressing for the Treatment of Tuberculous Disease of the Shoulder-joint." Am. Jour. Orth. Surg., 1909–1910, vii, 31–34.
DUCHAMP: "Arthrite tuberculeuse de l'épaule à marche rapide." Loire méd., St. Étienne, 1909, xxviii, 134.
SCUDDER: "Excision of the Shoulder-joint." Boston M. and S. Jour., 1909, clx, 549.
SEVER, J. W.: "Tuberculosis of the Shoulder in Children." Boston M. and S. Jour., 1910, clxii, 383–386.
ZHACHENKO, H. S.: "Dry caries of the Shoulder-joint." Sibirsk. Vrach Gaz., Irkutsk 1910, iii, 485–497.
PERAIRE: "Tumeur blanche de l'épaule." Paris chirurg., 1910, ii, 155.

ELBOW-JOINT

LOSSEN, W.: "Beiträge zur extrakapsularen radikal Resektion der tuberculosen Ellenbogengelenke." Deutsche Zeitschr. f. Chir., 1905, xcii, 120–155.
DAWBARN, R. H. M.: "Excision of the Elbow." Internat. Jour. Surg., New York, 1908, xxi, 348.
COTTAM, C. G.: "The Early Restoration of Function after Excision of the Tuberculous Elbow-joint." Am. Jour. Surg., New York, 1908, xxii, 108.
SCHONEIDLER, V.: "Über Ellenbogenresektion mit Erhaltung der Beweglichkeit." Berlin klin. Wochenschr., 1908, xlv, 1521.
HARTWELL, J. A.: "Resection of Tuberculous Elbow." Am. Surg., Philadelphia, 1908, xlviii, 454.
HANCOCK, I. H.: "Resection of the Elbow-joint." Internat. J. Surg., New York, 1909, xxii, 73.
ISELIN, H.: "Gabelgelenk am Ellenbogen nach teilweiser in Kindesalter." Deutsche Zeitschr. f. Chir., xcviii, 571.

CUMSTON, C. G.: "Resection of the Elbow in Children." New York M. J., 1910, xcii, 297–301.
REMER, H.: "Über die funktionellen Resultate der Resektion Ellenbogengelenkes mit Interposition eines Muskellappens nach Helferich." Deutsche Zeitschr. f. Chir., Leipzig, 1910, civ, 209–240.
SEVER, J. W.: "Tuberculosis of the Elbow." Boston M. and S. Jour., 1910, clxii, 666–669.
ROSS, G.: "Tuberculous Arthritis of the Elbow." Tr. Phila. Acad. Surg., Philadelphia, 1012, xiv, 01.
HECKMANN, J.: "Tuberculosis of the Elbow Treated by Bismuth Paste Injections." Post-Graduate, New York, 1013, xxviii, 252–254.

WRIST-JOINT

KUNNER: "La tumeur blanche du poignet." Rev. méd. de la Suisse Rom., Genève, 1908, xxviii, 153
VILLARD: "Résection du poignet et plombage." Lyon chir., 1908–9, i, 306.
REVERDEN, J. L.: "L'Arthrite tuberculose du poignet droit." Rev. méd. de la Suisse Rom., Genève, 1908, xxviii, 248.
GERARD, L. M.: "La tuberculose du poignet chez l'enfant." Rev. Internat. de la tuberc., Paris, 1909, xvi, 21–38.
BOSQUETTE.: "Tumeur blanche du poignet." Dauphiné méd., Grenoble, 1909, xxxiii, 128–130.

SKULL BONES

PAGÈS.: "Ostéite tuberculeuse du crâne." Lyon méd., 1908, cxi, 51–53.
TOURNEAUX, J. P., AND DUCUING, P., "Un cas d'ostéite tuberculeuse du crâne." Toulouse méd., 1910, 2e sér. xii, 187.
SEILHAN, FRANÇOISE: "Contribution à l'étude de la tuberculose de la voût du crâne." Toulouse, 1911, 70 pp.

RIBS

ROWLANDS, R. P.: "The Treatment of Caries of the Ribs." Guy's Hosp. Rep., London, 1907, lx, 245–247.
BARBARIN, P.: "Un cas de tuberculose costale traité par le radium." Paris, chirurg., 1911, iii, 433–435.
GROSS: "Spina ventosa costale." Prov. méd., Paris, 1912, xxiii, 515.

SPECIAL REGIONS

PATELLA

GOLDING, BIRD: "Tubercle of the Patella." Guy's Hosp. Gaz., London, 1907, xxi, 465–468.
MURPHY, J. B.: "Tuberculosis of the Patella." Surg. Gyn. and Obst., 1908, vi, 263–273.
KIRMISSON: "La Tuberculose primitive de la rotule." Paris, 1908.

PUBES

MOIGNET, ÉMILE: "Contribution à l'étude de l'ossitis tuberc. du pubis." Paris, 1911, Jour. etc. Circ., 48 pp.

ISCHIUM

ZELLMEYER: "Études cliniques de la tuberculose de l'ischion." Rev. internat. de la tuberc., Paris, 1909, xv, 101–104.

MASTOID

MACKENZIE, D.: "Tuberculous Disease of the Petrous or Mastoid Process." Clin. J., London, 1910–11, xxxvii, 190.

MALAR BONE

LIPRAT, J. H. G.: "Tuberculose de l'os malaire." Paris, 1908.

Palate

Dittrieb: "Tubercolosis mucosæ palati duri." J. Cutan. Dis. Incl. Syphilis, New York, 1910, xxviii, 300.

Sternum

Jacques, R.: "De la tuberculose du sternum." Rev. internat. de la tuberc., Paris, 1910, xviii, 408–414.

Batut, L.: "Affections des os; tuberculose du sternum." Bull. Soc. Méd. Chir. de la Drôme, Valence, 1911, xii, 186.

Moreston: "Tumeur blanche sterno-claviculaire traitée par les injections de parmol." Bull. et mém. Soc. de Chir. de Paris, 1912, N. S. xxxviii, 1462–1464.

CHAPTER IX

FOCAL INFECTIONS

The great importance of focal infection as an etiological factor in joint disease has been repeatedly emphasized in the past few years by the brilliant work and eloquent writings of Rosenow, Murphy and Frank Billings of Chicago, Hastings of New York, Poynton and Paine, Theobald Smith, Rosenau and Anderson, Victor C. Vaughan, and many others. A series of lectures by Dr. Frank Billings, delivered at Stanford University Medical School and published in book form in 1916 (Ref. "Focal Infection," Frank Billings, Sc. D., M. D., D. Appleton & Co., N. Y., 1916) contains a wealth of information and an exhaustive bibliography, and to it we are indebted for much of the material in the following remarks on this subject. Although the subject of focal infection belongs, strictly speaking, to the realm of bacteriology, those of us who think in terms of a delicate balance between the complicated immunizing machinery of the body, on the one hand, and the vast horde of infectious agents, on the other, will appreciate the tremendous importance which is attached to the subject and this will justify the considerable amount of space which is here devoted to it.

A focus of infection is any circumscribed area of tissue which is inoculated with pathogenic bacteria. Infectious foci may be (*a*) primary—when they are usually found in tissues communicating with a mucous or cutaneous surface, or (*b*) secondary—in adjacent or distant structures as the result of direct extension or of hematogenous or lymphogenous dissemination.

LOCATION OF PRINCIPAL PRIMARY FOCI

1. *Teeth and Jaws.*—Pyorrhea dentalis and alveolar abscess.
2. *Faucial, lingual,* and *nasopharyngeal tonsils.*
3. *Mastoid cells.*
4. *Maxillary* and other *accessory sinuses.*
5. *Submucous* and *subcutaneous abscesses,* including paronychia of the toes and fingers.
6. *Gastro-intestinal Tract.*—(*a*) Cholecystitis, (*b*) appendicitis, (*c*) intestinal ulcers, (*d*) *intestinal stasis* from any cause with its consequent putrefaction process and attendant toxemia, if not bacteriemia.
7. *Respiratory System.*—(*a*) Bronchitis, (*b*) bronchiectasis, (*c*) empyema, (*d*) abscess of the lung.
8. *Genito-urinary Tract.*—(*a*) Vesiculitis seminalis, (*b*) prostatitis, (*c*) cystitis, (*d*) pyelitis, (*e*) metritis, (*f*) salpingitis, (*g*) vulvovaginal abscess, (*h*) urethritis, (*i*) copentis.
9. *Lymphatic System.*—Infectious lymphadenitis, secondary to the primary focus and from which infection may be propagated long after elimination of the primary focus.

ETIOLOGY OF FOCAL INFECTIONS

1. **Pyorrhea Dentalis and Alveolar Abscess** (Riggs' Disease).—Of *prime* importance to orthopedic surgeons, in the light of recent investigations,

is the subject of Riggs' disease. It is astonishingly prevalent in all classes of adults, though less common in the young. The fundamental lesion is infection of the peridental membrane, the periosteum of the root and neck of the tooth. The crown may remain intact. Infection first appears as a maceration and infection of the edges of the gum, whose vitality may be lowered by ill-health, malnutrition, etc. As a result of bacterial invasion, the gums become retracted and expose the peridental membrane. If the latter is destroyed, the soft parts become ulcerated and an acute or chronic alveolar abscess is the result.

Of the rich bacterial flora in the mouth in Riggs' disease, two organisms are of paramount importance, viz.: *Endameba buccalis* and *Streptococcus viridans*. C. C. Bass and F. M. Johns (ref. Jour. A. M. A., 1915, lxiv, 553) believe the former to be the chief etiological factor in the development of pyorrhea alveolaris, while F. W. Hastings (ref. Jour. Experim. Med., 1914, xx, 71), as the result of exhaustive studies, believes that "Streptococcus viridans is the probable causative agent of the disease in many cases of arthritis deformans." Probably more than 40 per cent. of cases of arthritis deformans should be considered as chronic infective deforming arthritis, according to Hastings. Mechanical conditions further enhance the danger of dissemination of infection: the abscess at the root of the tooth is contained in a rigid shell (alveolar process) in which the tooth acts like a piston, being forced against the shell at each movement of mastication, compressing the abscess and literally squeezing the infectious material into the adjacent tissues by hydraulic pressure.

2. **Tonsillitis and Infected Adenoids.**—As a source of infection, not only is the enlarged and susceptible tonsil a menace but the stumps remaining after tonsillotomy may contain infected crypts concealed by the postoperative scar. Adenoids may also harbor an extensive bacterial flora, which may include the streptococcus viridans and endameba buccalis.

3. **Mastoiditis suppurativa,** with the presence of virulent strains of streptococcus and pneumococcus, is a source of danger.

4. **Maxillary** and **other accessory sinuses,** particularly those harboring chronic undetected foci, should not be overlooked in the search for a focal infection.

5. **Cervical Lymphadenitis.**—Enlarged cervical lymph nodes, secondary to infections of the head, are exceedingly common. One investigator found these glands infected with streptococcus in 90 per cent. of the specimens examined. Glandular fever in children causes wide dissemination through the lymph system, while in adults it is a slower and less extensive invasion of the deeper cervical nodes. Infection of the lymphatic glands may remain long after extirpation of the primary focus.

6. **Chronic bronchitis** and **bronchiectasis** are probably etiological factors in pathological conditions of the bones and joints, from the slow distribution of toxins.

7. **Empyema.**—A residual focus persisting after the evacuation of the pleural abscess should be considered.

8. **Gastro-intestinal Tract.**—(*a*) *Intestinal stasis*, from whatever cause, chronic constipation, incomplete obstruction from congenital or acquired anatomical abnormalities, induces putrefaction and results in a toxemia which frequently finds expression in various degrees of damage to the bones and joints. Furthermore, infectious material from the intestine also invades the intestinal lymphatic tissues or the lymph-nodes of the mesentery.

(*b*) *Appendicitis.*—The usual cause of this disease is a member of the streptococcus group, coming from a focus in the mouth or throat. Chronic

appendicitis may infect the mesenteric lymph nodes and thence, through the lymphatic vessels and blood-stream, the liver and its adnexa.

(*c*) *Cholecystitis*, produced by a focus in the head and resulting in acute or chronic inflammation with subsequent formation of gall-stones, may be a source of dissemination of infectious matter.

(*d*) *Rectum.*—Ulcers, infected hemorrhoids, and localized abscesses are very common and are potent factors.

9. **Urogenital Tract.** (*a*) *Endometritis* as a site of focal infection is important only after infection from normal gestation or as the result of abortion.

(*b*) *Salpingitis* is usually a gonococcal infection with obliteration of the tube.

(*c*) *Gonorrheal vaginitis* usually remains a local process. Only in rare instances does infection of the joints and other tissues occur from uterine, vaginal, or tubal foci.

(*d*) *Vesiculitis Seminalis.*—Credit for the original demonstration that arthritis can be dependent upon systemic absorption from infected seminal vesicles, belongs to Dr. Eugene Fuller of New York. Fuller discovered (ref. "The Cure through Genito-urinary Surgery of Arthritis Deformans and Allied Varieties of Chronic Rheumatism," Trans. Amer. Ass'n G.-U. Surg., 1913, viii, 121–134) that cultures from cases of chronic vesiculitis did *not* yield the gonococcus but uniformly the streptococcus. He further states that on account of the close proximity of the seminal vesicles to the rectum, infection takes place by direct transmission through the intervening tissues. In certain old chronic cases, marked vesiculitis and characteristic joint disturbances co-exist without any history of gonorrhea. Fuller has performed seminal vesiculotomy for the relief of "rheumatism" in 69 of a total of 346 cases. Of the 69, between 20 and 25 cases represented extremely chronic or most advanced joint affections; all the more acute cases were relieved, the cure of the joint complications being rapid. Fuller's operation, by draining the septic focus, puts an end to the systemic toxemia. Fuller states that a thorough incision throughout the entire length of the vesicle, and most efficient drainage, are necessary, as also are the removal of pyogenic granulation tissue from the lining of the vesicles and freeing the vesicles from surrounding adhesions.

(*e*) *Prostate.*—The gonococcus, streptococcus, staphylococcus, bacillus tuberculosis, colon bacillus, and others may be found in the prostate, which is an important source of secondary involvement of the bladder, ureters, and kidneys, and inferentially of more distant parts.

(*f*) *Cystitis.*—Pyogenic bacteria, B. tuberculosis, B. pyocyaneus, B. typhosus, and other organisms have been found in the bladder. The colon bacillus is a normal inhabitant of the genito-urinary tract but may become virulent when stasis occurs in the bladder. Local extension from the bladder and through the lymphatic apparatus to the base of the bladder and walls of the ureters, the pelvis and parenchyma of the kidneys, and the perirenal tissues has been noted by S. Sugimura (ref. Virchow Archiv, ccvi, 20) and by C. Franke (ref. Ergebniss d. Chirurg. u. Orthopöd., 1913, vii, 671). The usual method of infection of the kidney and its pelvis is through the blood-stream with pyogenic bacteria, and the typhoid, colon, tubercle, and other bacilli. In fatc, many infectious diseases are accompanied by a local expression of the infection, the urine often yielding cultures of the specific micro-organism operating in the system (ref. Dick, G. F. and G. R., Jour. A. M. A., 1915, lxv, 6).

10. **Subcutaneous Abscesses, Suppurative Paronychia, Furuncles, Carbuncles.**—Systemic infection or bacteriemia is liable to follow these focal processes, particularly in debilitated individuals, notably diabetics.

NATURAL AND ACQUIRED IMMUNITY

The mere fact that the majority of individuals who harbor foci of infection escape systemic or remote secondary local infection is, to the author's mind, no cause for disbelief in the etiological relationship between chronic infectious arthritis, for example, and extensive Riggs' disease. Such freedom from systemic infection in certain individuals is dependent upon the principle of immunity, both natural and acquired, and it is only in persons whose immunizing machinery is permanently or temporarily defective that clinical manifestations are found.

This freedom from systemic or local evidence of infection may also be due to extreme diminution of virulency and pathogenicity of the bacteria which may, in some instances, exist as harmless parasites anywhere in the body. But natural and acquired immunity are not absolute. Such factors as physical wear and tear, prolonged mental strain, starvation, exposure, immersion, alcoholic debility, etc., not only undermine the natural resistance but very probably, in many instances at least, enhance the virulence of latent pathogenic bacteria, particularly those of the nose and throat, endowing them with specific pathogenicity and tissue affinity. The exhaustion and debility from the foregoing causes have an important etiological bearing on the occurrence of chronic infectious arthritis and myositis, while many minor ailments, such as subjective distress referred to particular tissues, muscles, and joints, are very likely due to mild infection from a focus in the mouth or throat, particularly in those whose vital resistance is lowered from some cause. This supposition has abundant support in the elimination of clinical manifestations in many instances upon eradication of these foci of infection.

DIAGNOSIS OF THE FOCUS OF INFECTION

When one is confronted with a case of chronic infectious arthritis (particularly the proliferative and degenerative types of arthritis deformans), or of any other bone or joint disease which our present-day knowledge associates with a primary infectious focus, it is incumbent upon the surgeon to locate the site of the focus. Such a problem can be most rapidly and conclusively solved by the modern metropolitan hospital, which serves as a clearing house with its army of specialists. In the case of chronic infectious arthritis, the most likely location of the focus of infection is in the head and usually in the form of an alveolar abscess or acute or chronic tonsillitis and sinusitis; in the case of gonorrheal arthritis, the urogenital system. If such a focus is not easily detected, the most painstaking and thorough search should be instituted into possible fields of extension, even into uninfected organs and tissues in some instances. To aid in this search, it is essential to obtain a careful history of past and present ailments, to enlist the cooperation of specialists in all branches of medicine, to make free use of the *x*-ray in the matter of a suspected alveolar abscess, and, most important of all, to obtain infectious material by scraping the tartar and exudate from the exposed neck of the tooth, and even by puncturing the alveolar process with a hypodermic needle, and to submit such infectious material to a thorough microscopical and cultural examination; the Endameba buccalis and bacteria, including Streptococcus viridans, are the usual flora of an alveolar abscess.

It is particularly important to examine for their bacterial content all the *excretions*, sputum, urine, vaginal and urethral discharges, and the exudate "milked" from the seminal vesicles and prostate. Other body tissues which

may have a strong causal relationship to foci of infection include the synovial fluids, enlarged lymph-nodes (in the neighborhood of infected structures), infected muscle, fibrous nodes on tendons and aponeurosis, and the blood, not only that in general circulation but that in the exudate of a focus. Material from these sources should be subjected to microscopical examination, immediate cultivation, and immediate inoculation into experimental animals. Billings (*loc. cit.*) emphasizes the fundamental doctrine of Koch in his statement that "the discovery of the similarity of the pathogenic organisms in cultural characteristics, in the focus of infection and in the infected tissues, and the production of a similar infectious process in the inoculated animal from the tissues of which the infectious bacteria are afterward recovered, constitute reasonable proof of the etiologic relation of the focus of infection to the existing systemic infection."

CHANNELS OF DISSEMINATION OF THE INFECTIOUS AGENT AND ITS TOXINS

Hematogenous.—The blood is the usual means of dissemination from a primary focus in the production of systemic infection and intoxication. The infectious agents are analogous to emboli. Wherever they lodge, the production of a pathological lesion and its resulting clinical manifestations is dependent upon the type and virulence of the bacteria concerned and the character of the tissue and function of the organ involved.

Lymphogenous.—By way of the lymphatic vessels and lymph-nodes the infection may pass from a primary focus to other tissues. Lymphogenous may occur synchronously with hematogenous dissemination. Common examples of this method of infection are the secondary infection of the lymph-vessels and nodes of the neck, and occasionally also of the mediastinum, following primary infection of the tonsils, nasopharynx, accessory sinuses, and mastoid. Again, tertiary infection of lymphogenous character is noted from the secondary focus.

Systemic Intoxication.—This occurs in two ways: (*a*) from *exotoxic* bacteria (*e.g.*, B. diphtheriæ and B. tetani) and (*b*) by *endotoxins*. In the latter instance, the toxins may be produced "by biochemical reactions excited by the micro-organisms and the tissues and cellular exudate of the focus; also that autolysis of the dead micro-organisms of the focus sets free the endotoxin." It is logical to assume that degenerative and metabolic changes in the joint may be caused in some such way by toxic material elaborated in a focus of infection.

Transmutability of Bacteria.—The transmutability of bacteria (which has been apparently confirmed by Rosenow for members of the streptococcus group of organisms) and the fact that "the property of transmutation is reversible" are of great importance in the study of joint affections. Of particular significance to us are the transmutability of the diplococcus rheumaticus in virulency and specific pathogenicity and the relationship of this organism to arthritis.

Rosenow's observations in this connection are so significant and present such a rich field for thought and research that it appears worth while to incorporate in this work some of his deductions which have been quoted by Billings (*loc. cit.*).

". . . . . streptococci from the various diseases often have a most striking affinity or tropism for the organs or tissues from which they are isolated . . . . . 24 strains from rheumatic fever produced arthritis in 66 per cent . . . . . in contrast to an average of arthritis in 27 per cent.

of the animals injected with strains from sources other than rheumatic fever. . . . . In many instances . . . . . no other focal lesions could be found except those in the organ in question.

"That the streptococci are the underlying cause of the disease from the lesions of which they were isolated is indicated further by the fact that they have elective affinity for the corresponding structures in animals. . . . . the cells of the tissues for which a given strain shows elective affinity take the bacteria out of the circulation as if by a magnet adsorption. A careful study revealed no constant relation between localization and clumping or size of the bacteria.

"There is some evidence to show that certain bacteria of very low virulence (commonly found in chronic foci of infection) tend actually to make the soil more favorable. But it must be considered that difference in the host may afford the peculiar type of reaction, or that the individual harbors a particular form of focus of infection which is favorable for bacteria to acquire elective properties.

"Since different bacteria may acquire simultaneously affinity for the same tissue, diseases which resemble each other more or less closely, such as the different forms of arthritis, may be due to bacteria of different species, each having elective affinity for the different structures involved."

The results of Rosenow's "numerous animal experiments (833) with streptococci (220) from a wide range of sources," showed that "joint lesions occurred more often (27 per cent.) than lesions in any other organ, corresponding to the frequent occurrence of spontaneous arthritis in man and animals." He observed also that the relatively non-virulent strains of streptococci isolated from chronic lesions exhibit a more highly developed "tendency to localize electively within a limited range, "monotropism," than do the more virulent strains from acute lesions. . . . . the bacteria which have grown in a given tissue acquire a greater affinity for this tissue . . . . . hence the secondary focus . . . . . would appear to be less important as a distributor of bacteria than the primary focus; if, however, the secondary focus happens to be in a joint, of which there are many, it may play an important rôle in causing extension to uninvolved joints and in preventing recovery."

ACUTE INFECTIONS OF THE BONES AND JOINTS RELATED TO FOCAL INFECTION

1. **Acute Articular Infection.**—The infectious nature of acute rheumatic fever has now been established beyond question. The specific microorganism was demonstrated in 1900 by Poynton and Paine (ref. Lancet, London, 1900, ii, 861) to be the Diplococcus rheumaticus (syn. M. rheumaticus; Streptococcus rheumaticus) isolated from the blood, joint exudates, throat, endocardial nodes, joint capsules, tonsil, alveolar abscess, etc. Its specificity as the etiological organism in acute articular rheumatism has been proved repeatedly by animal inoculation with reproduction of the disease. It is possible that the intestinal tract and mesenteric lymph-nodes may be a secondary or even a primary focus of rheumatic fever. Many of the well-known clinical features of the disease—its prevalence in temperate zones, among persons in unhygienic surroundings, its predilection for the young, particularly males, and the influence of exposure in precipitating an attack, features hitherto difficult to understand, are clarified and rendered intelligible by recent scientific investigations. For instance, the excess of lymphoid tissue in the pharynx of the young invites focal infection.

It has also been experimentally demonstrated that lowering of temperature enhances the virulence of specific micro-organisms and at the same time reduces the vital resistance of the individual. Sudden lowering of the body temperature by exposure, then, enhances the virulence of micro-organisms latent in an infectious focus and converts a relatively benign into a formidably virulent source of infection. The important rôle played by these latent smouldering foci has been emphasized in the case of acute articular rheumatism, by removal of the tonsils. The apparent persistence or recurrence of attacks of acute articular rheumatism after tonsillectomy, is due to the existence of the Diplococcus rheumaticus in the lymph-nodes of the neck.

2. **Gonococcal Arthritis.**—A systemic infection, gonococcemia, may in some instances result from a gonococcal focus in the prostate, seminal vesicles, joints, and tendon sheaths, thrombosis of veins contiguous to a localized gonococcal infection or infection of the venous sinuses of the uterus. The most frequent local expression of gonococcemia is, however, gonococcal arthritis, which may be a mild and monarticular infection, or polyarticular and suppurating. The knee is the joint most commonly affected by the monarticular form of lesion, and in males with 10 times greater frequency than in females. It usually complicates an acute attack of gonorrhea, but it may be a very late sequel of a residual focus in the genito-urinary tract from sudden increase of virulence of latent gonococci.

The gross lesions of gonococcal arthritis are synovitis and peri-arthritis, with bursitis and tenovaginitis. The synovial effusion is usually serofibrinous and occasionally may be purulent. Purulent synovitis and tenovaginitis are, however, more frequent. Periarthritis of the wrist, with suppuration extending along the sheaths of the tendons of the hands, is a common event. Periostitis of the os calcis, with spur formation and exquisite tenderness of the heel is a striking lesion due to the gonococcus.

With careful technic, the gonococcus may be obtained from infected tissues and exudate of the joints, tendon sheaths, and bursæ. In old lesions, the gonococcus is mixed with streptococci and staphylococci. Great damage is invariably done to the joint and much disability ensues; but operation in the purulent cases, if done early, may save the joints and tendon sheaths, with more or less preservation of function. In cases without suppuration, the protracted course excites obliterative changes in the blood-vessels, with resulting disturbances of nutrition, retrogressive metabolic changes in the joints and tendons, and consequent deformity and impairment of function.

Gonococcal arthritis is frequently confounded with acute articular rheumatism, although it more frequently involves the tendon sheaths and is occasionally attended by suppuration. Moreover, it may involve joints rarely attacked by rheumatism, viz., the intervertebral, temporomaxillary, sternoclavicular, and sacro-iliac joints. Both affections may be polyarticular. In gonococcal arthritis, pain in the affected joint is often out of all proportion to the extent of the local infection, and the febrile disturbance, which in articular rheumatism is usually great, is often insignificant. The salicylates and other antirheumatic drugs which are so efficacious in acute rheumatism are of no avail in gonococcal arthritis. Eradication of the infectious gonococcal focus is frequently followed by rapid relief of the joint symptoms.

3. **Acute Osteomyelitis.**—Although traumatism, with more or less severe laceration of the soft tissue overlying the affected bone, affords the most frequent means of direct entry of micro-organisms into the bone-marrow, it often happens that the injury is very insignificant, unaccompanied

by a break in the skin, and acts as the means of establishing a locus minoris resistentiæ. In the latter case, bacteria (usually tubercle bacilli, streptococci, or staphylococci) which happen to be lying dormant in the head or lymph-nodes, become activated through some cause or other and gravitate to the local area of decreased resistance in the bone.

CHRONIC JOINT DISEASE RELATED TO FOCAL INFECTION

The streptococcus, gonococcus, tubercle bacillus, typhoid bacillus, and the Spirocheta pallida are the most common infectious agents encountered in chronic arthritis. Other organisms occurring in the infected tissues of chronic arthritis and myositis probably represent a mixed infection or are present purely as parasites.

The *streptococcus* and the *gonococcus* produce a chronic arthritis whose morbid anatomy and gross lesions (and hence deformities) are practically identical. The infection is hematogenous, has its origin in a focal infection, and is accompanied by endothelial proliferation or embolism in the smaller arteries. The invading organisms are of relatively low degree of virulence in each instance, and hence the resulting tissue reactions are less violent than in the case of more active bacteria, partake of the nature of fibrinoplastic exudate, and there is an attempt to wall off the area of infection. This variability in the virulence of the organisms concerned in chronic arthritis may at the same time produce a serofibrinous exudate in the joints and tendon sheaths and small hemorrhages in the subserous tissues and muscles. The low virulence of the infectious agent, the embolic method of infection of the tissues, and the resulting tissue reaction have as their practical result a local anemia from endarteritis of a more or less obliterating type. The consequent malnutrition from decreased blood supply, and deficient oxygenation of tissue is extreme and is followed by either proliferative or degenerative change in all the joint structures, tendons, and muscles, as described by Nichols and Richardson (see page 322 on Arthritis Deformans).

From the viewpoint afforded by our present-day knowledge of the infectious nature of these chronic joint conditions, that through the medium of the blood-stream an embolus composed of infectious organisms reaches the periarticular tissues or deeper tissues of the joint (the end arteries of the subcapsular tissue), or through the nutrient artery involves the epiphyseal marrow, these proliferative and degenerative joint changes of Nichols and Richardson assume a clarity which was perhaps not afforded them in 1909, when the rôle of chronic infection was not so fully appreciated. Their clear and concise description of the pathological changes in these joints is all the more remarkable for that very reason.

The varying degrees of virulence of the offending micro-organisms, the general vital resistance, and the local joint resistance will determine the grade and type of change in the tissue of the external joint structures, in the subcapsular regions, and in the epiphyseal marrow. Hence, in younger normal individuals suffering with a virulent bacterial invasion, a proliferative lesion may be expected; while in individuals with joint tissue vitally impaired by reason of age, trauma, or other causes, the reaction is less severe and a degenerative lesion is in order.

Repetition of hematogenous infection, by repeated doses of infectious material from the focus, aggravate the degree of joint damage by continued destruction of blood-vessels, recurrent traumatization of the pathological tissue and continuous deprivation of oxygen supply.

The final result of this burden of repeated infection of a joint is retrograde metabolism, but whether due entirely to malnutrition or in part to irritants of bacterial or biochemic origin within the tissue, in no way impairs the validity of the principles outlined. To quote Billings (*loc. cit.*, *p.* 110): " . . . . the proper understanding of chronic infectious arthritis involves an understanding of the following principles:

" (1) The infection of the joints, muscles, and other involved tissues with pathogenic organisms which usually are members of the streptococcic group, and the gonococcus, which are of relatively low virulence; (2) a hematogenous infection with embolism, with resulting injury of the blood-vessels and small hemorrhages into the infected tissues; (3) lessened blood supply and oxygenation and consequent relative starvation of the infected tissues and, dependent upon the malnutrition, favorable conditions for the continued life and multiplication of the infectious organisms; and finally (4) retrograde metabolism due to the malnutrition."

Chronic myositis may complicate a chronic arthritis of streptococcal origin or may occur independently in single muscles or groups of muscles. It is less commonly associated with chronic gonococcal arthritis in which tenovaginitis is the more frequent extra-articular involvement.

The variety of anatomical types of lesion (periarthritis, synovitis, osteoarthritis, panarthritis), any or all of which may co-exist in the same individual, is influenced by the degree of bacteriemia, the grade of virulence of the microorganisms, the amount of tissue resistance, and the hematogenous mode of infection. Although the primary infection may occasionally be so severe as to resemble mild or acute rheumatic fever, the onset is usually insidious with, however, exacerbations of hyperpyrexia. Tenderness of the infected tissues is always present, and is increased by anything which disturbs the general or local circulation, such as exposure, fatigue, or general nervous irritability. Intermittent re-infection of the joints and muscles, with attendant exacerbation of symptoms is not unusual and is due to variable activity of the focus of infection. Pain is usually slight except on movement. Although chronic gonococcal arthritis is more frequently encountered in the intervertebral, sacro-iliac, sternoclavicular, and temporomaxillary joints than is chronic streptococcal arthritis, yet the chronic involvement of the above-named joints is not prima facie evidence of chronic gonococcal infection. Chronic infectious myositis, with or without arthritis, is accompanied by shortening of the muscle bundles (the result of the embolic infection, together with hemorrhage and connective-tissue proliferation), with tenderness and pain on contraction. The infectious agent displays a predilection for certain muscles, viz., the masseter, biceps humeri, hamstrings, anterior tibial, and erector spinæ, although occasionally all the skeletal muscles are involved.

General debility, with anemia, emaciation, and nervous irritability, is the result not alone of the chronic infections, but is also enhanced by ill-advised restrictions of diet and by drugging, purging, irrational use of vaccines, etc., all of which accelerate the retrogressive metabolic changes which may eventually convert the peri-articular connective-tissue structures (aponeurosis, tendons, etc.) into true bone.

Chronic tubercular arthritis is invariably associated with a tuberculous focus or generalized tuberculous process, and usually exists as epiphyseal osteomyelitis with secondary involvement of the joint. Tuberculous tenovaginitis is also usually a secondary infection from the peri-articular tissues.

Infections of the vertebræ by the typhoid bacillus, gonococcus, and streptococcus result in identical gross lesions.

Nerve involvement, usually a perineuritis, is frequently a secondary

infection from a chronic infectious joint with secondary infectious myositis. The branches of the brachial plexus and of the sciatic trunks are the ones most often implicated. One of the most frequent causes of neuritis is a focal infection of the teeth, tonsils, or the accessory sinuses of the head, while the gonococcus is sometimes responsible for neuritis or perineuritis.

TREATMENT OF FOCAL INFECTION

Prevention

The vast importance of the subject of focal infection from the standpoint of the orthopedic surgeon demands that some consideration be given to the question of *prevention*, before proceeding to discuss the treatment of the acute and chronic affections of the bones and joints resulting therefrom.

Personal cleanliness, especially of the skin, mouth and throat, and particularly the careful cleaning of the teeth and gums *several times* (not once) a day, will go far toward preventing dental caries and general disease arising from that source.

Adenoids and **tonsils,** if unusually large, not only offer excellent culture media but also, by obstructing proper ventilation and drainage, invite local infection of the mucous tracts of the head. Children are particularly prone to infections of the mouth, throat, nose, accessory sinuses, middle ear, and mastoid; therefore prevention of streptococcic infection of these structures would lessen the morbidity from both acute and chronic joint affections in children.

Pyorrhea dentalis and **alveolar abscess** are exceedingly important as definite etiological factors in chronic joint disturbances. The streptococcus group and also other bacteria are the pathogenic agents from these foci which cause systemic infection, while the Endameba buccalis probably acts as an aggravator of the local process and may serve as the medium of transmission of the disease to others by personal contact or through fomites. The subtle character of chronic dental and alveolar abscesses, which renders them undiscoverable to both patient and dentist till a gross visible lesion is produced, constitutes their dangerous aspect. Hence the importance of the routine *x*-ray examination of the jaws, the only means of making an accurate diagnosis. *Emetin* is useful in the elimination of the endameba from the mouth, but the result is temporary only and does not eradicate the bacteria at the focus nor restore the peridental membrane (dental periosteum), absence of which results in death of the affected tooth whose presence thereafter as a foreign body offers a constant breeding ground for bacteria. The surest method of attacking the Endameba buccalis by emetin is to administer the latter hypodermically in ten-day periods, with gradually increasing intervals, as practised in its employment against amebic dysentery. If eradication of the dental or alveolar abscess is impossible by other means, operative interference is indicated in those who suffer from joint affections of obscure etiology. Apicoëctomy, with curettage and disinfection of the old abscess cavity is the procedure of choice in the case of infected incisor and bicuspid teeth, while extraction is necessary in the case of molar teeth, whose tortuous roots are not accessible to apicoëctomy. In the performance of these dental operations for the eradication of focal infection the end justifies the means, as abundantly attested by clinical evidence of recovery from chronic joint affections following such procedures.

In **persistent lymphadenitis,** if irremediable by constitutional treatment, it is advisable to dissect out the enlarged glands to prevent dissemination of the bacteria, particularly the tubercle bacillus.

Infection of the Gastro-intestinal Tract.—Infected food (*e.g.*, milk) and the swallowing of purulent secretions of the nose, throat, or bronchi, are the usual sources of contamination. If not destroyed by the gastric or intestinal juices, the bacteria get into the mucous membrane of the bowel or the efferent lymph-nodes, remain quiescent there until activated to virulency from some cause, and produce some local or systemic infection. Chronic constipation, with or without anatomical anomalies of the intestinal tract, lowers the resistance of the tissues of the intestine. Morbid anatomical conditions favor the increase of general virulence or the elective affinity of these organisms. Prevention of infection of the digestive tract may be accomplished in two ways, viz.: (*a*) by eradication of the sources of the muco-pus swallowed in the course of nose and throat affections; this coincidently eliminates foci of infection of the head; and (*b*) by avoiding contaminated foods.

Intestinal stasis from chronic constipation or abnormal anatomical conditions, demands adequate medicinal treatment. Extirpation of the colon as advocated by certain radical enthusiasts, is rarely justifiable; but a chronic appendicitis or a chronic cholecystitis warrants thorough surgical intervention on account of the possibility of their etiological relationship to acute and chronic joint conditions.

Rectum.—Disease of the rectum associated with the colon bacillus and the streptococcus presents particularly dangerous foci for lymphogenous and hematogenous invasions of the system and should be treated surgically if ineradicable by other therapeutic means.

Acute and chronic infectious processes of the female genitalia, especially infections of the uterus and its adnexa in the puerperium, become surgical problems after they have failed to yield to suitable medical regimen.

Infectious foci of the male urogenital apparatus are a very common source of local disease, by extension, and probably also of systemic invasions. Prompt recourse should be had to surgery, if such foci do not rapidly disappear by medical therapeutics.

Infected wounds of the skin and mucous membranes, boils, suppurative paronychia, are all prolific sources of bacterial dissemination and should be radically treated.

TREATMENT OF ACUTE AND CHRONIC AFFECTIONS OF THE BONES AND JOINTS RESULTING FROM FOCAL INFECTION

The removal of the etiological focus of infection is, of course, the desideratum in every instance. This, however, is occasionally impossible on account of inaccessibility of the focus or because the grave condition of the patient will not permit of it. For instance, in acute rheumatic fever with endo-, peri-, or pancarditis, the precarious condition of the patient contraindicates tonsillectomy for the removal of the commonest etiological focus; hence such a procedure must be postponed until late in convalescence.

But in the chronic infectious types of arthritis, *early* removal of the infectious focus is the rule. However, accidents occasionally occur even in these chronic cases, as instanced by Billings (*loc. cit.*, p. 135) in the case of a girl of eighteen suffering with a disabling chronic polyarthritis and myositis due apparently to multiple chronic alveolar abscesses, who had many teeth extracted and the abscesses cureted, whereupon there ensued streptococcus bacteriemia with acute hemorrhagic myositis, pleuritis, pericarditis, and myocarditis, with submucous and subcutaneous hemorrhages and death. A similar accident is reported by the same author in a case of mild arthritis and

myositis in which the tonsils were removed; the operation was followed by acute general myositis, with great subsequent deformity due to shortening of the muscles.

Two pertinent deductions can be made from the events chronicled above, viz.: (1) proof of the *focal origin* of serious systemic and joint affections; and (2) the *discretion* which it is necessary to exercise in operative technic in order to guard against the dissemination of bacteria from an infectious focus.

In acute joint conditions (*e.g.*, acute articular rheumatism), the *Streptococcus rheumaticus may reside in more than one focus at the same time* (in the tonsils, alveolar abscess, and maxillary sinusitis synchronously), so that extirpation of one focus alone, tonsillectomy, for instance, does not always prevent recurrence of the affection. Hence the need for systematic eradication of every accessible focus of infection of the head in persons addicted to repeated attacks of acute articular rheumatism. Billings (*loc. cit.*, p. 137) believes that *salicylic acid* has a *specific bactericidal effect* on the Streptococcus rheumaticus if given in sufficiently large sterilizing doses in the first few days of an attack.

Acute Gonococcal Arthritis.—Early removal of the focus in the genito-urinary tract is usually followed by marked improvement in the affected joint, even in the event of gonococcemia, provided there is no endocardial involvement. Purulent exudates, however, require surgical treatment.

Osteomyelitis.—The removal of the pyogenic bacterial focus in the tonsils, jaws, cranial sinuses, or elsewhere, may have no appreciable effect on the localized bone lesion, and hence Billings suggests (*loc. cit.*, p. 141) that the etiological focus be removed coincidentally with surgical treatment of the osseous lesion.

Chronic Types of Infectious Arthritis

The basis of the successful treatment of these chronic infectious arthritides lies in a general knowledge of the patient's physical assets and liabilities and an accurate localization of existing foci of infection. Destruction of bone and cartilage, bony ankylosis, profound sclerotic changes, and muscular atrophy cannot, of course, be repaired; while malnutrition of the tissues from obliterating and destructive vascular changes favors the transformation of connective tissue, tendons, aponeuroses, ligaments, and cartilage into bone, a feature characteristic of chronic infectious non-purulent arthritis of whatever type, irrespective of the specific micro-organism concerned in the lesion.

Therefore institutional care is necessary to assure strict supervision of the patient with a chronic form of arthritis of obscure etiology. Residence in a hospital should be insisted upon for the eradication of all foci of infection, to build up the general health and nutrition of the body, and to restore the circulation of the affected part to normal. Such treatment will go a long way toward checking the retrograde metabolism, at the same time favoring resolution of the local pathological exudate.

At the time of the preliminary examination of the patient, one may require the services of specialists in the examination of the nasopharynx, ears, accessory sinuses, pelvic viscera, and blood, also *x*-ray films of the jaws and plates of the joints, in the search for the etiological focus of infection and to assay the extent of articular involvement. Microscopical examination and culture of the blood, of accessible exudates in the joints, and of foci in the head, pelvis, urogenital apparatus, etc., or qualitative, quantitative, and

bacteriological examinations of the urine and feces, may give a clue to the cause operating in a given case. Animal inoculation with cultures obtained from these sources may reproduce the disease in question. Under local anesthesia it is sometimes advisable to remove portions of infected muscle, joint capsule, fibrous nodes and lymph-nodes in the neighborhood of the infected tissues for the purpose of histological and bacteriological examination.

The diagnosis having been established, treatment resolves itself into two departments, viz.: (1) eradication of all primary and secondary foci of infection; and (2) strengthening all the natural defences of the body.

1. **Eradication of All Foci of Infection.**—The completeness of this should be assured by repeated examination. Crypts of tonsillar tissue may be left after tonsillectomy, or an infected sinus may be incompletely treated. Extraction of a tooth may be necessary to cure an alveolar abscess which had been apparently cured by palliative measures. Residual gonococci in the prostate or seminal vesicles may cause recrudescence of an apparently eradicated process.

2. **Strengthening the Natural Body Defences.**—Upbuilding of the native body defences includes careful therapy in the following respects: (*a*) rest, both of body and mind; (*b*) strengthening food; (*c*) tonics; (*d*) cheerful surroundings, and plenty of good air and sunshine; (*e*) hydrotherapy; (*f*) active and passive exercise; (*g*) Bier's hyperemia; and (*h*) the rational administration of appropriate bacterial antigens and vaccines to stimulate the patient's immunizing machinery to generate specific antibodies.

(*a*) *Rest, Sunshine, and Fresh Air.*—The rest enjoined should be adapted to meet the idiosyncrasies of the individual. If recumbency in bed becomes irksome, substitute it for or alternate it with rest in a wheel-chair in the company of cheerful nurses and companions. Absolute rest should be enforced in all febrile cases until the temperature becomes normal, and in every case until all discomfort in the affected joint has disappeared; because it is an established fact that *activity of infected tissues lowers their natural resistance* and aggravates the existing infection. To insure rest of the affected joints, temporary immobilization by bandages, splints or plaster casts, often hastens resolution of the lesion.

Abundant sunlight and fresh air are of the greatest importance. During inclement weather a solarium should be used for this purpose, while on pleasant days the patient should be kept in the open air during the greater part of the day, but protected from draughts.

(*b*) *Nutrition.*—A generous mixed diet, including an abundance of fats, oils, green vegetables and fruits is demanded on account of the notoriously poor general nutrition of patients suffering with chronic infectious arthritis; while a full complement of proteid food, both animal and vegetable, is necessary to overcome the protein defect in the wasted tissues of the joint. Water, milk, buttermilk, cream, and fruit juices should be taken in generous quantities.

(*c*) *Tonics.*—Hematinic and other tonics, as well as laxatives, and in certain cases analgesics (such as the salicylic acid compounds), should be given in accordance with the needs of the individual case. The extract of thymus gland is occasionally of benefit. But there are no specific drugs known to affect the joint lesions. Narcotics should be studiously avoided.

(*d*) *Environment.*—On account of the mental depression so common in this class of patients, a cheerful environment is of paramount importance, and the patient's companions, nurses and others, should be imbued with this optimistic spirit.

(*e*) *Physiotherapy.*—To overcome the local malnutrition so provocative of local retrograde metabolism, improvement of the general and local circulation of blood is imperative. To secure this, various measures may be adopted, viz.: *hydrotherapy*, *active* and *passive exercises*, local applications of *superheated dry air*, and Bier's method of inducing *hyperemia*.

(*f*) *Hydrotherapy.*—Alternating hot or cold showers or sprays may be given once a day for a few minutes. The greater the force of water, the more stimulating its effect on the circulation. The hot-cold spray repeated several times in a few minutes is particularly efficacious. If these showers or sprays are not practicable of application, salt glows and alcohol rubs are a poor substitute.

(*g*) *Passive exercise* should be administered by a nurse, or preferably by a professional masseur. Manipulation is at first practised by hand, but as the case progresses the Zander apparatus can be used as an adjunct.

Active Exercise.—Calisthenics are of especial value when properly supervised and modified to meet the individual requirements of the particular case at hand. Walking, riding, driving, swimming, and gymnastic work may be indulged in when the condition of the affected joints will permit. All exercises, both active and passive, should, whenever possible, be under the strictest supervision by a skilled mechanotherapist.

(*h*) *Bier's Hyperemia.*—Localized hyperemia by one of the methods advocated by Bier has a distinct value in selected cases.

(*i*) *Serum and Vaccine Therapy.—Serum Therapy.*—The production and use of antisera in the treatment of chronic arthritis due to focal infection present so many problems and obstacles as to render them valueless, in the author's experience. The impossibility of obtaining efficient antisera is probably due to several factors, viz., variant strains of bacteria which are morphologically indifferentiable; individual variations in pathogenicity and virulence. In order to obtain satisfactory therapeutic results, it seems to be absolutely essential that the bacteria employed possess "type" specificity in order that an efficient antiserum may be produced.

Vaccine Therapy.—The therapeutic use of vaccines dates from 1902, when Sir Almroth Wright evolved the use of autogenous vaccines in chronic infectious disease. He believed that the immunizing machinery of the body, exhausted by prolonged infection, could be stimulated to produce specific antibodies by the inoculation of attenuated cultures of the same organism concerned in the chronic disease at hand. Theoretically, this contention is entirely rational, and in certain cases is practicable. The higher development of our knowledge concerning the pathogenic bacteria commonly encountered in chronic infectious joint disease, however, has shown that unless the dead bacteria employed in the autogenous vaccine are of the same specific type in virulence and tropism as those which are causing the infection of the individual, they are not only clinically ineffectual but, by adding their increment to the burden of toxemia already borne by the individual, may be a positive detriment. Again, it is often extremely difficult, in chronic diseases of the bones and joints, to state definitely the bacteria which are the true etiological factors in a given case.

In patients under the strict régime of the hospital, the author has been able in certain instances to isolate the suspected bacteria from the blood, lymph-nodes, fibrous nodes, joint exudates, joint tissues, muscles, skin, and from the infected marrow in osteomyelitis. In the latter case, however, the danger of encountering secondary invaders usually obscures the identity of the etiological micro-organism except in the case of a hidden sequestrum which has not been exposed to the outer air by sinus formation prior to

operation. Accurately to ascertain the tissue tropism of the bacteria concerned, it is usually necessary to inoculate laboratory animals and from their tissues again to isolate the bacteria from which autogenous vaccines may then be prepared and used with some hope of therapeutic effect, particularly if the vaccines are sensitized with antiserum. In the case of colon bacillus cystitis as the etiological factor in chronic arthritis, the author has found that an autogenous vaccine prepared from cultures of the feces is equally efficacious with one made from organisms isolated directly from the bladder itself.

It must be borne in mind that an arthritis begun by one organism may be continued by a secondary invader engrafted on the primary process, and if autogenous vaccines are to be of any service in such cases they must be prepared from these secondary and final invaders. A striking case in point occurred in the author's experience. A case of pneumococcus infection of the pleura with empyema was associated with endocarditis and multiple arthritis. The empyema was drained, but the sinus persisted with a seropurulent discharge. Autogenous sera and autogenous vaccines of pneumococcus were administered but had no appreciable effect upon the arthritis condition, even after prolonged use. The author was called in consultation at this period and suggested using an autogenous vaccine prepared from the sinus leading into the empyemic cavity, believing that a superimposed secondary infection was causing the endocarditis and polyarthritis. Swabs from the depth of the sinus yielded a pure culture of the Streptococcus aureus, from which an autogenous vaccine was prepared. Its administration was followed by recovery in an incredibly brief time.

In chronic infectious arthritis, the dosage of autogenous vaccine varies from ten million (10,000,000) to two billion (2,000,000,000) and is administered every five to seven days or, when indicated, at shorter intervals, in rare instances as often as once a day. A mistake frequently made by clinicians is to abandon other therapeutic measures after beginning the use of vaccines. On the contrary, it should be constantly remembered that bacterial vaccination is but one of the many means of stimulating the patient's body defences and should be accompanied in every instance by the other therapeutic methods which have been outlined above.

(*j*) *Non-specific Protein Antigens.*—The intravenous injection of typhoid, of colon, and of other non-specific protein antigens administered in chronic infectious arthritis has given astonishingly beneficial effects in a few instances. Jobling and Stetson (Jour. A. M. A., 1915, lxv, 515) believe that these ferments are bactericidal and that at the same time toxic substances are rendered non-toxic. The violent reaction following the intravenous injection of these foreign proteins may possibly be followed by a condition of refraction (anti-anaphylaxis), with failure of the organism to react to the invading bacteria. The use of these foreign protein antigens is still in the experimental stage.

REFERENCES

Bass, C. C., and Johns, F. M.: "Pyorrhea Dentalis and Alveolaris." The Jour. A. M. A. 1915, lxiv, 553.

Barrett, M. F.: Preliminary Report, Dental Cosmos, 1914, lvi, 948.

Smith, Allen J., Middleton, W. S., and Barrett, M. F.: "Tonsils as a Habitat of Oral Endamebas." The Jour. A. M. A., 1914, lxiii, 1746.

Sugimura, S.: "Ueber die Beteilung der Ureteren an den akuten Blasen entzündungen nebst Bemerkungen über ihre Fortleitung durch die Lymphbahnen der Ureteren." Virchow Arch., ccvi, 20.

Franke, Carl: "Die Koliinfection des Harnapparats und deren Therapie." Ergebniss d. Chirurg. u. Orthopäd., 1913, vii, 671.

DICK, GEO. F., AND DICK, GLADYS R.: "The Bacteriology of the Urine in Non-suppurative Nephritis." The Jour. A. M. A., 1915, lxv, 6.
KOLLE, W., AND WASSERMANN, A.: "Latency of Infectious Bacteria." Handbuch der Path. Mikroorganismen, 1903, i, 147.
ROSENOW, E. C.: "Immunological and Experimental Studies on Pneumococcus and Streptococcus Endocarditis." (Chronic Septic Endocarditis.) Jour. Inf. Dis., 1909, vi, 245.
ROSENOW, E. C.: "A Study of Pneumococci from Cases of Infectious Endocarditis." Jour. Inf. Dis., 1910, vii, 411.
ROSENOW, E. C.: "Immunological Studies in Chronic Pneumococcus Endocarditis." Jour. Inf. Dis., 1910, vii, 429.
ROSENOW, E. C.: "Transmutation Within the Streptococcus-Pneumococcus Group." Jour. Inf. Dis., 1914, xiv, 1.
ROSENOW, E. C.: "The Etiology of Acute Rheumatism, Articular and Muscular." Jour. Inf. Dis., 1914, xiv, 61.
ROSENOW, E. C.: "The Bacteriology of Appendicitis and Its Production by Intravenous Injection of Streptococci and Colon Bacilli." Jour. Inf. Dis., 1915, xvi, 240.
ROSENOW, E. C.: "The Etiology and Experimental Production of Erythema Nodosum." Jour. Inf. Dis., 1915, xvi, 367.
ROSENOW, E. C., and SANFORD, A. H.: "The Bacteriology of Ulcer of the Stomach and Duodenum in Man." Jour. Inf. Dis., 1915, xvii, 219.
ROSENOW, E. C.: "The Newer Bacteriology of Various Infections as Determined by Special Methods." The Jour. A. M. A., 1914, lxiii, 903.
ROSENOW, E. C.: "Bacteriology of Cholecystitis and Its Production by Injection of Streptococci." The Jour. A. M. A., 1914, lxiii, 1835.
ROSENOW, E. C., AND OFTERDAL, SVERRI: "The Etiology and Experimental Production of Herpes Zoster." The Jour. A. M. A., 1915, lxiv, 1968.
ROSENOW, E. C.: "Iritis and Other Ocular Lesions on Intravenous Injection of Streptococci." Jour. Inf. Dis., 1915, xvii, 403.
BILLINGS, FRANK: "Chronic Focal Infections and Their Etiologic Relations to Arthritis and Nephritis." Arch. Int. Med., 1912, ix, 484.
BILLINGS, FRANK: "Chronic Focal Infections as a Causative Factor in Chronic Arthritis." The Jour. A. M. A., 1913, lxi, 819.
BILLINGS, FRANK: "Chronic Infectious Endocarditis." The Arch. Int. Med., 1909, iv, 400.
BILLINGS, FRANK: "Clinical Aspect and Medical Management of Arthritis Deformans." Ill. Med. Jour., 1914, xxv, 11.
BILLINGS, FRANK: "Focal Infection Its Broader Application in the Etiology of General Disease." The Jour. A. M. A., 1914, lxiii, 899.
BILLINGS, FRANK: "Systemic Disease of Focal Origin." Forchheimer's Therapeusis, 1914, v, 169.
SCHOTTMÜLLER, H.: "Die Artuntersuchendung der für Menschen Pathogenen Streptokokken durch Blutagar." Münch. Med. Wchnschr., 1903, l, 809.
SCHOTTMÜLLER, H.: "Zür Aetiologie der Pneumonie Cruposa." Münch. Med. Wchnschr., 1905, lii, 30.
SCHOTTMÜLLER, H.: "Endocarditis Lenta." Münch. Klin. Wchnschr., 1910, 880 (quoted by Libman).
COLE, RUFUS, AND DOCHEZ, A. R.: "Report of Studies in Pneumonia." Trans. Ass'n Am. Phys., 1913, xxviii, 606.
HAESSLI, HANS: "Der Verhalten der Streptokokken Gegenüber Plasma und Serum und ihre Umzüchtung." Mitth. a. d. Hamb. Staats Kramkenamst, 1910, xl, 10.
FORSSNER, G.: "Renale Lokalisation nach intravenösen Injektionen mit einer dem Nierengewebe experimental angepassten Streptokokken cultur." Nord. Med. Arkiv., 1902, xxxv, 1–56.
POYNTON, F. J., AND PAINE, A.: "The Etiology of Rheumatic Fever." The Lancet, 1900, ii, 861.
POYNTON, F. J., AND PAINE, A.: "A Further Contribution to the Study of Rheumatism; the Experimental Production of Appendicitis by the Intravenous Inoculation of the Diplococcus." The Lancet, 1911, ii.
POYNTON, F. J., AND PAINE, A.: "Observations Upon the Arthritis Produced in Rabbits by the Intravenous Inoculation of a Diplococcus Isolated from Cases of Rheumatism." Trans. Path. Soc., London, 1904.
POYNTON, F. J., AND PAINE, A.: "Observations Upon Certain Forms of Arthritis." Br. Med. Jour., 1902, ii, 1414.
POYNTON, F. J., AND PAINE, A.: "The Pathogenesis of Rheumatic Fever." Trans. Path. Soc., London, 1901.
POYNTON, F. J., AND PAINE, A.: "The Relation of Malignant to Rheumatic Endocarditis." The Lancet, 1902, i, 1036.

POYNTON, F. J., AND PAINE, A.: "Remarks on the Infectious Nature of Rheumatic Fever, Illustrated by the Study of a Fatal Case." Br. Med. Jour., 1904, i.
POYNTON, F. J., AND PAINE, A.: "Some Further Investigations and Observations Upon the Pathology of Rheumatic Fever." The Lancet, 1910, i, 1524.
BEATTIE, JAMES: "Acute Rheumatism." Edinb. Med. Jour., 1914.
WALKER, E. O. A., AND RYFFEL, J. H.: "The Pathology of Acute Rheumatism and Allied Disorders." Br. Med. Jour., 1903, ii, 659.
OSLER, WM.: "Chronic Infectious Endocarditis." Quar. Jour. Med., 1909, ii, 219.
OSLER, WM.: "On the Visceral Complication of Erythema Exudativum Multiforme." Am. Jour. Med. Sci., 1895, cx, 629.
HORDER, THOMAS J.: "Infective Endocarditis." Quar. Jour. Med., 1909, ii, 289.
LIBMAN, E., AND CELLER, H. L.: "The Etiology of Subacute Infective Endocarditis." Jour. Am. Med. Sci., 1910, cxl, 516.
LIBMAN, E.: "A Study of the Lesions of Subacute Bacterial Endocarditis with Peculiar Reference to Healing or Healed Lesions, with Clinical Notes." Jour. Am. Med. Sci., 1912, cxliv, 313.
HERRICK, JAMES B.: "The Healing of Ulcerative Endocarditis." Med. News, 1902, xxxi, 10.
LENHARTZ, H.: "Ueber die Septische Endocarditis." Münch. Med. Wchschr., 1901, xlviii, 28.
BAEHR, GEO.: "Glomerular Lesions of Subacute Bacterial Endocarditis." Jour. Am. Med. Sci., 1912, cxliv, 327.
LOHLEIN, M.: "Ueber Hämorrhagische Nieren Affektionen bei Chronischer Ulcerösen Endokarditis." Med. Klin., 1910, vi, 10.
KRETZ, RICHARD: "Angina und Septische Infektion." Zeitschr. f. Heilkund., 1907 xxviii, 296.
CANNON, DR.: "Ueber die Frage der hämatogenen Infektion bei Appendicitis und Cholecystitis." Deutsch. Zeitschr. f. Chir., 1908, xcv, 21.
GIBON, A., AND NAMBA, K.: "Zur Frage über die Genese der Appendicitis." Beiträg. z. Path. Anat. u.z. Algem. Path., 1912, lii, 130.
ADRAIN, C.: "Die Appendicitis als Folge einer Allgemeinerkrankung." Klinisches und Experimentelles. Mitteil, a.d. Grenzgeb. d. Med. u. Chir., 1901, vii, 407.
HEYDE, M.: "Bakteriologische und Experimentelle Untersuchungen zur Aetologie der Wurmfortsätzentzüngen (mit besondere Berücksichtigung der Anaëroben Bakterien)." Beitr. z. Klin. Chir., 1911, lxxvi, i.
ASCHOFF, L.: "Pathogenese und Ätiologie der Appendicitis." Ergebnisse d. Inner Med. u. Kinderheilkund, 1912, ix, 1.
VINCENT, H.: "Sur la thyroidism dans la rheumatisme aigu, et sur l'origine rheumatismale de certain cas du goitre exophthalmique." Compt.-rend. Soc. de Biol., 1907, lxiii, 389.
VINCENT, H.: "Rapports de la maladie Basedow avec la rheumatisme aigu." Bull. de la Soc. Med. de Paris, 1907, xxiv, 1286; Semaine Med., 1907, Mar. 20, 143. Ibid., 1907, Nov. 21, 575; Ibid., 108, Jan. 1, 47; ibid., 1908, Oct. 28, 527.
OPIE, E. L.: "The Etiology of Acute Hemorrhagic Pancreatitis." J. H. H. Bull, 1901, 182.
DAVIS, D. J.: "Bacteriological and Experimental Observations on Focal Infection." Arch. Int. Med., 1912, 505.
JACKSON, LELIA: "Experimental Rheumatic Myocarditis." Jour. Inf. Dis., 1912, xi, 240.
LE COUNT, E. R., AND JACKSON, LELIA: "The Renal Changes in Rabbits Inoculated with Streptococci." Jour. Inf. Dis., 1914, 389.
IRONS, ERNEST E.: "Bacteriology and Immunity. Studies in Gonococcal Immunity." Trans. XVIIth Internat. Med. Cong., 1913, 87.
IRONS, ERNEST E., AND NICOLL, H. K.: "Complement Fixation in the Diagnosis of Gonococcal Infections." Jour. Inf. Dis., 1915, xvi, 303.
PEARCE, RICHARD M.: "The Scientific Basis of Vaccine Therapy." The Jour. A. M. A., 1913, lxi, 2115.
SMITH, THEOBALD: "An Attempt to Interpret Present-Day Uses of Vaccine." The Jour. A. M. A., 1913, lx, 1591.
SMITH, THEOBALD: "Theobald Smith and Phenomena." (Anaphylaxis.) Referred to by many experimental workers. See Jour. A. M. A., 1906, 1910, and Lewis, P. A., Jour. Exper. Med., 1908, x, 1.
BABCOCK, ROBT. H.: "Chronic Cholecystitis as a Cause of Myocardial Incompetence." Jour. A. M. A., 1909, lii, 1904.
NICHOLS, EDWARD H., AND RICHARDSON, FRANK L.: "Arthritis Deformans." Jour. Med. Research, 1909; N. S., xvi, 149.
WEIL, RICHARD: "Anaphylaxis and Its Relation to Problems of Human Disease." Cinn. Lancet Clinic, 1913, Nov. 19.
WEIL, RICHARD: "Studies in Anaphylaxis. Desensitization; Its Theoretical and Practical gnificance." The Jour. of Med. Research, 1913, N. S. xxiv, 233.

WEIL, RICHARD: "Studies in Anaphylaxis." The Jour. Med. Research., 1914, N. S. xxv, 299.
VON PIRQUET, C. E.: "Allergy." Arch. Int. Med., 1911, vii, 259.
ROSENAU, M. L., AND ANDERSON, JOHN F.: "Hypersusceptibility." Jour. A. M. A., 1906, xlvii, 1007.
ROSENAU, M. L., AND ANDERSON, JOHN F.: "A Study of the Cause of Sudden Death, following the Injection of Horse Serum." Hygienic Laboratory Bull., 1906, No. 29.
ROSENAU, M. L., AND ANDERSON, JOHN F.: "Studies on Hypersusceptibility and Immunity." Hygienic Laboratory Bull., 1907, No. 36.
ROSENAU, M. L., AND ANDERSON, JOHN F.: "Further Studies Upon the Phenomenon of Anaphylaxis." Hygienic Laboratory Bull., 1909, No. 50.
VAUGHAN, V. C.: "Protein Split Products in Relation to Immunity and Disease." Lea and Febiger, Philadelphia, 1913.
AUER, J., AND LEWIS, PAUL L.: "Acute Anaphylactic Death in Guinea Pigs." Jour. A. M. A., 1909, liii, 458 and Jour. Exper. Med., 1910, xii, 151.
PARK, W. H.: "A Critical Study of the Results of Serum Therapy in the Diseases of Man." The Harvey Lectures, 1905–06, 101, Lippincott.
JOBLING, JAMES W., AND PETERSON: "Bacterio-Therapy in Typhoid Fever." Jour. A. M. A., 1915, lxv, 515.
GAY, FREDERICK P., AND CHICKERING, HENRY T.: "Treatment of Typhoid Fever by Intravenous Injections of Polyvalent Sensitized Typhoid Vaccine Sediment." The Arch. of Int. Med., 1906, xvii, 303.
HASTINGS, T. W.: "Complement Fixation Tests in Chronic Infective Deforming Arthritis and Arthritis Deformans." Jour. Exper. Med., 1914, xx, 52.
HASTINGS, T. W.: "Concerning a Polyvalent Antigen for the Complement Fixation Test for Streptococcus Viridans Infection." Jour. Exper. Med., 1914, xx, 72.
PHILLIPS, LLEWELLYN: "Emetine in Amebiasis." Jour. Trop. Med. and Hygiene, 1914, Aug. 15.
MELTZER, S. J.: "Bronchial Asthma as a Phenomenon of Anaphylaxis." Jour. A. M. A., 1910, lv, 1021.
JOBLING, J. W., PETERSON, W. F., AND EGGSTEIN, A. A.: "The Mechanism of Anaphylactic Shock. Studies on Ferment Action." Jour. Exper. Med., 1914, xx, 401, and 1915, xxii, 401.
KLOTZ, OSKAR: "Experimental Bacterial Interstitial Nephritis." Trans. Ass'n American Physicians, 1914, xxix, 49.
OPHULS, W.: "Subacute and Chronic Nephritis as Found in One Thousand Unselected Autopsies." Arch. Int. Med., 1912, ix, 156.
SIPPY, B. W.: "Gastric and Duodenal Ulcer, Medical Care by an Efficient Removal of Gastric Juice Corrosion." Jour. A. M. A., 1915, lxiv, 1623.
THAYER, W. S.: "On Gonorrheal Septicemia and Endocarditis." Amer. Jour. Sci., Nov., 1905, N. S. cxxxi, 751.

CHAPTER X

INFECTIOUS DISEASES OF THE BONES AND JOINTS

The number of non-tuberculous diseases of the bones and joints is quite large. For purposes of description, we have made an arbitrary division of these affections into: (I) Those constitutional disorders whose chief clinical manifestations are the general and localized distortions which they produce, and (II) those diseases of the bones and joints in which the etiological factor is presumed to be, or has been proved to be, a parasite, either vegetable (bacteria) or animal.

The first division comprises (See Chapter XIX):

1. Rickets.
2. Infantile scurvy.
3. Osteomalacia.
4. Osteogenesis imperfecta.
5. Fragilitas ossium.
6. Acromegaly.
7. Osteitis deformans (Paget's disease).
8. Leontiasis ossea.
9. Chondrodystrophia fetalis.
10. Hypertrophic pulmonary osteo-arthropathy.
11. Hemophilic joints.

The infectious processes which invade the bones and joints are as follows:

12. Acute infectious osteomyelitis (See Chapter XVI).
13. Staphylococcal and streptococcal arthritis.
14. Acute arthritis of infancy.
15. Gonorrheal arthritis and osteitis.
16. Pneumococcal arthritis.
17. Typhoid arthritis and osteitis.
18. Arthritis complicating the exanthemata.
19. Dysenteric and other intestinal arthritides.
20. Arthritis complicating the following diseases:

    (*a*) Influenza.
    (*b*) Diphtheria.
    (*c*) Erysipelas.
    (*d*) Glanders.
    (*e*) Cerebrospinal meningitis.
    (*f*) Small-pox.
    (*g*) Tonsillitis.
    (*h*) Typhus.
    (*i*) Malaria.

21. Arthritis deformans (See Chapter XI)—Still's disease.
22. Syphilitic synovitis, arthritis, and osteitis.

In this chapter we shall consider the *infectious processes* invading the bones and joints (excluding those which are not of particular interest to the orthopedic surgeon), viz.:

- (*a*) Gonorrheal arthritis and osteitis.
- (*b*) Syphilitic disease of the bones and joints:
  - I. Acquired syphilis
    1. Localized periostitis.
    2. Osteitis and osteomyelitis.
    3. Serous synovitis.
    4. Gummatous synovitis.
    5. Chondro-arthritis.
    6. Syphilitic spondylitis.
  - II. Hereditary syphilis
    1. Cranium.
    2. Face.
    3. Long bones and other osseous lesions.
    4. Joints.
  - III. Special syphilitic types
    1. Syphilitic epiphysitis.
    2. Syphilitic dactylitis.
    3. Syphilitic curvature of tibiæ.
- (*c*) Staphylococcal and streptococcal arthritis.
- (*d*) Acute arthritis of infancy.
- (*e*) Pneumococcal arthritis.
- (*f*) Typhoid affections of the bones and joints.
- (*g*) Actinomycosis.
- (*h*) Hydatid cysts of bone.
- (*i*) Madura foot.

GONORRHEAL ARTHRITIS AND OSTEITIS

Etiology.—The process is part of a systemic, hematogenous infection with the gonococcus, whose origin is usually the urethra or its adnexa. It complicates from 2 to 10 per cent. of cases of gonorrheal urethritis. It affects women as well as men, and is not uncommon in children.

Of the joints, the knee is most often affected. The diaphysis of the long bones (humerus and femur) and the os calcis (spurs on its plantar surface) are sometimes the seat of infection.

Pathology.—The following pathological conditions are encountered:

1. *Hydrops Articuli.*—This is often monarticular, commonly involving the knee. The onset is frequently sudden, the joint becoming quickly distended with fluid which disappears slowly. The temperature is only moderately elevated (99° to 102°).

2. *Serofibrinous Synovitis.*—This form which is frequently polyarticular, is characterized by very little fluid, a plastic inflammation, with exudate within the joint, and considerable peri-articular inflammation.

3. *Empyema Articuli.*—Here there is a definite collection of pus within the joint, accompanied by profuse inflammatory exudate and a varying degree of destruction of the joint structures.

4. *Phlegmonous Inflammation.*—In this type, the characteristic feature is diffuse infiltration of all the joint structures, with dense adhesions which eventually produce ankylosis.

5. *Peri-articular Suppuration.*—Stetten (Archiv. of Diagnosis, N. Y., Jan. 1914) has called attention to the occurrence of peri-articular suppuration of pure gonococcic origin, simulating an ordinary pyogenic tenosynovitis or cellulitis and following an arthritis of the neighboring joint, which in itself may be non-suppurative.

Clinical Features.—The non-suppurative cases are usually subacute and accompanied by a peculiar edematous boggy swelling, discomfort, weakness, and stiffness on use of the joint. More severe cases are characterized by local heat and muscle spasm.

In suppurative cases the skin is red, glazed, and hot, the joint exquisitely tender to pressure and to jarring, swollen, and its motion is limited. There are also signs of systemic disturbance, fever, etc.

Diagnosis.—*Actual* diagnosis is based on the monarticular localization and the obstinate, painful swelling, with a history or the presence of a

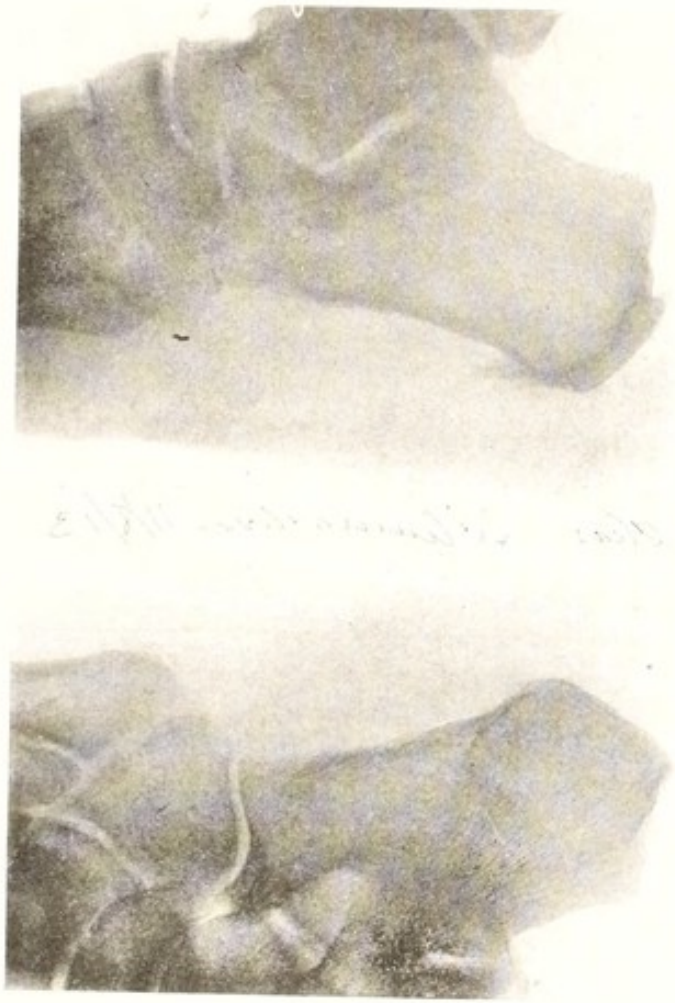


FIG. 139.—Gonococcal arthritis associated with spurs on the os calcis. Note also the bone proliferation in the insertion of tendo achilles (upper figure). Lower figure is an inverted normal os calcis.

urethral discharge. *Differential* diagnosis: Gonorrheal arthritis must be distinguished from traumatic, tuberculous, and syphilitic synovitis. The distinguishing point of differentiation is the primary focus in the genitalia.

Prognosis.—In mild cases, with efficient treatment, the outlook for functional recovery is good. In the suppurative and serofibrinous inflammations, ankylosis usually occurs.

Treatment.—The eradication of the focus of infection, urethra, bladder, seminal vesicles, is essential.

Rest in bed, support of the joint, and local applications of heat or cold are necessary. An ice-bag is often very efficacious. The joint should be immobilized as soon as the most acute symptoms have subsided. This is best done

with plaster-of-Paris. The duration of immobilization varies with the pathological state of the joint, but should not be too protracted in any case. The plaster should be removed and re-applied as the swelling recedes. At a later period, partial immobilization with a removable splint and passive exercises, gradually increased, are in order. If suppuration occurs, the joint must be incised and drained. Vaccines are of debatable value.

If contractures and ankyloses have occurred, an anesthetic may be required to break up the adhesions, after which heat and massage should be applied. For flatfoot following a gonorrheal joint, a properly fitted arch support should be used.

SYPHILITIC DISEASE OF THE BONES AND JOINTS

I. Acquired Syphilis

The lesions are manifested chiefly during the tertiary period, and consist of localized periostitis, osteomyelitis and osteitis, as the chief bone disturbances; and serous synovitis, gummatous synovitis, and chondro-arthritis as the leading affections of the joints.

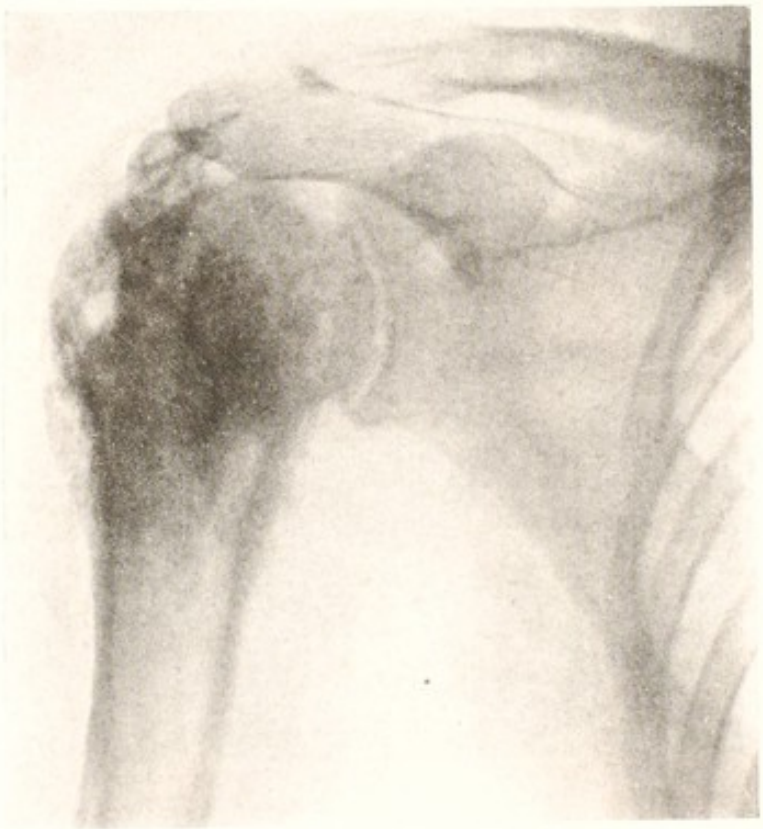


Fig. 140.—Syphilitic involvement of the head of the humerus as shown by periostitis extending down shaft, areas of marked density and punched-out appearance at upper inner aspect of articular surface of the humeral head. The Wassermann test was positive and case entirely cleared up under anti-syphilitic treatment. This case was previously diagnosed tuberculosis, sarcoma, and ostitis fibrosa.

1. **Localized Periostitis.**—This lesion affects chiefly the tibiæ. It occurs as a circumscribed swelling over which the skin is not adherent. There is considerable tenderness present and subjective pain, worse at night. The lesion may break down and give place to an ulcer at whose base superficial necrosis of the underlying bone may be present. Besides the tibia, the skull, sternum, and other of the long bones are sometimes affected.

2. **Osteitis and Osteomyelitis** (Fig. 140).—Gummatous osteitis may be local or diffuse. When localized, fracture often results. Generalized inflammation produces sclerosis of the bone, rendering it thicker and heavier. The spongy bones are subject to syphilitic osteomyelitis. The commonest sites are the head and face, particularly the nose. The vault of the skull may be the seat of suppuration, necrosis, and perforation.

3. **Serous Synovitis.**—Pain, redness, and swelling are the leading features. The condition may become chronic.

4. **Gummatous Synovitis.**—This condition resembles tuberculous synovitis, but is less prone to suppuration and is free from pain and limitation of motion.

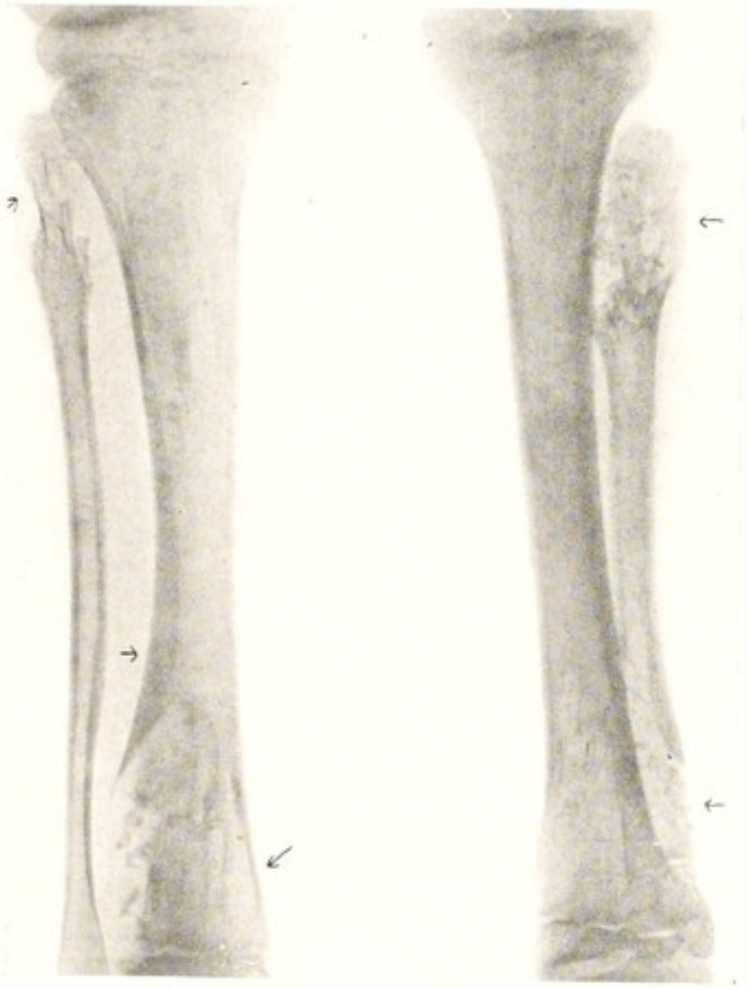


FIG. 141.—Congenital syphilis with unusual bone manifestation. The arrows indicate new growths of the form of osteochondromata and irregular thickening of the cortex in both tibiæ and fibulæ.

5. **Chondro-arthritis** (Fig. 141).—Gummata in the articular ends of the bones are the underlying lesions.

6. **Syphilitic Spondylitis.**—The principal syphilitic lesions of the vertebræ are localized periostitis, gummata, nodes, and caries from softening of the gumma or extension of a syphilitic pharyngeal ulcer.

The upper cervical vertebræ are most often affected. The clinical manifestations are pain (worse at night), dyspnea, dysphagia (from pressure), and rigidity of that portion of the spine. Large sequestra are common. Suppuration and angular deformity are rare.

A differential diagnosis must be made from tuberculosis of the spine.

In the latter condition, abscess is more common, there is less new bone formed, and the deformity is greater. The age of the patient, other signs of syphilis, a positive Wassermann reaction, and response to salvarsan are aids in diagnosis.

The treatment, aside from the specific salvarsan, is that of Pott's disease (see also Chapter XII, Part II).

II. Hereditary Syphilis

The cranium, face, and long bones of the extremities are the principal locations of the lesions.

1. **Cranium.**—(*a*) Local signs consist of premature ossification or delayed union of the fontanelles. The frontal bone is more convex and prominent than usual, or the protuberances are unduly exaggerated, or the bone may be keel-shaped. The parietal bosses are frequently enlarged.

(*b*) The entire cranium may be larger than normal (macrocephalic) or smaller (microcephalic).

2. **Face.**—The nose is chiefly affected and undergoes destruction, accompanied by purulent discharge. The resulting type of nose may be depressed at the bridge, or the tips of the nasal bones may be destroyed, giving the nose a "tip-tilted" appearance.

3. **Long Bones.**—The tibia is most often the seat of disease. Clinically, chronic pain, worse at night, paroxysmal crises, characterize the lesions. Pathologically there are chronic osteitis, hypertrophy, and gummata.

Other osseous lesions: (*a*) Exostoses, seen principally in the upper end of the tibia, also in the extremities of ulna and radius, and in the malleoli.

(*b*) Cicatrices adherent to bone.

(*c*) Local deformities, chiefly the "saber-shin" of the tibiæ.

4. **Joints.**—Syphilitic epiphysitis is accompanied by a serous effusion into the joint. Other joint lesions are pyarthrosis and chondro-arthritis.

Special Clinical Types

(*a*) **Syphilitic Epiphysitis.**—This lesion is confined to infants under twelve months. Osteochondritis is the underlying process. There is an enlargement resembling rickets, usually of the lower end of the femur, but also seen in the upper end of the humerus. Shortening of the limb occurs. The epiphysis may become separated from the shafts as a sequestrum and suppuration occur, the joint being co-incidently involved.

(*b*) **Syphilitic Dactylitis.**—Children are the usual victims. It is less common than the "spina ventosa" of tuberculosis and more often affects the metacarpal and metatarsal bones than the phalanges; the reverse is true of tuberculosis.

(*c*) **Syphilitic Curvature of the Tibiæ** (Fig. 142).—Bowing of the tibiæ is due to diffuse osteoperiostitis, an overgrowth of the cortex on the convex side, which, in the tibia is almost certain to affect the crest primarily, because of the repeated traumata to which that portion of the bone is subjected. This results in the saber-shaped shins with bow always anteriorly; this is in striking contrast, from the radiographic standpoint, to a bowed bone undergoing functional hypertrophy, where the thickening of the cortex is on the concave side. In syphilis, the hypertrophy affects the convex side, is purposeless, pathological, and the bone bends as the result of longitudinal overgrowth of one side of its long diameter; in the hypertrophy resulting from weight-bearing, overgrowth affects the concave surface (the point of greatest

stress in an end-thrust through the arc of a circle), is purposeful, and follows mechanical overweighting and is, moreover, a physiological hypertrophy. The condition is frequently symmetrical.



FIG. 142.—Syphilitic osteomyelitis with anterior bowing of tibia. "Saber-shaped tibia."

The following table from Tubby (*loc. cit.*, vol. ii. p. 393) will aid in distinguishing it from a similar bowing of the tibiæ seen in rickets:

	Rachitic curves	Syphilitic curves
Age.	Generally under 3.	Occurs up to 15.
History.	Signs of rickets present.	Syphilis in parents, and signs of hereditary syphilis in child.
Direction of curvature.	Antero-external, or antero-internal.	Generally purely anterior. (*Tibia en lame de sabre*).
Position of curve.	Generally in upper or lower third.	Middle of shaft.
Crest of tibia.	Sharp.	Smooth and rounded.
Surfaces of tibia.	Flat or concave.	Convex.

TREATMENT

Antisyphilitic remedies are indicated in all these osseous and articular lesions, salvarsan when available; otherwise mercury and iodides. An acutely inflamed joint demands immobilization during the antisyphilitic treatment.

Rhinoplasty by Bone-graft.—Defects of the nose were formerly restored by a reflection of periosteal and bony flaps from the forehead or cheeks.

This had the great disadvantage of leading to extensive scars and possible necrosis. The use of inorganic material, as formerly employed, such as gold, silver wire, and the injection of paraffin should be discarded inasmuch as they occasion necrosis and necessitate subsequent removal. Animal bone, whose use was suggested by Sir Watson Cheyne, should not be employed on account of its unreliability. Finney (Surg. Gyn. and Obst., June, 1907) has successfully used a finger to reconstruct the nose destroyed by congenital lues, and prior to Finney's successful work, attempts to use the finger for this purpose by similar technic had been made by Hardie (1875), Sabine (1879), Bloxam (1895), Tums (1897), and Vredena (1902). A great step in advance was made by Carter, who successfully employed a bone-graft obtained from the rib.

The author has obtained excellent results in postsyphilitic destruction of the nose, and in deformities of the nose from other causes, by placing a bone-graft through an incision in the tip of the nose. This incision is most satisfactory because of the ability to obtain precise apposition of its edges on account of the cartilaginous framework present, and also because of the fact that a slight scar at this point is scarcely noticeable. The bed for the graft is prepared by thrusting a small scalpel longitudinally through the subcutaneous tissue of the nose, halfway between the skin of the bridge and the mucous membrane beneath it until the glabella of the frontal bone is reached. The periosteum of this bone is incised in the median line, and with a small curet, under the guidance of external palpation, the periosteum is peeled sideways and the bone beneath scarified for a fresh contact with the upper end of the graft.

The skin is approximated with one horsehair suture. This incision leaves a scar so situated that, as has been said, it is negligible. Hemorrhage about the graft is prevented by prolonged digital pressure. The graft is held in place without fixation sutures by the cohesive character of the dense tissues in which it lies embedded.

STAPHYLOCOCCAL AND STREPTOCOCCAL ARTHRITIS (Figs. 143, 144 and 145)

The origin of these joint lesions is found in penetrating wounds, invasion by a neighboring focus of disease, and involvement in a septicemic process when the vitality of the joint has been previously lowered from some cause, such as blows, exposure, etc. The lesions vary from a mild synovitis to complete disorganization of the joint, which may be converted into a pus sac with extensive peri-articular infiltration.

Clinical Features.—These vary from a faint hyperemic surface with a minimal amount of effusion, to a joint whose surface is dusky, purplish red, greatly swollen, and with all functions suspended. The constitutional symptoms vary with the type and severity of the lesion. In the purulent form, chills, fever, great prostration, and occasionally evidences of pyemia are noted; the joint movement is lost, it is held rigid, and the slightest movement causes excruciating pain. The climax is reached by complete disorganization of the joint with abnormal mobility, which is accompanied by appreciable grating of the denuded ends of the bones. Synchronously there is evidence of more profound intoxication.

Prognosis.—The outlook depends on the nature and virulence of the infectious agent, and the degree of involvement. In synovitis with effusion, the prognosis is good with adequate treatment. When suppuration occurs, permanent ankylosis is the rule; occasionally death results.

Treatment.—Immobilization, local and general anodynes, and weight-extension should be used in the acute stage. In simple effusion, Bier's

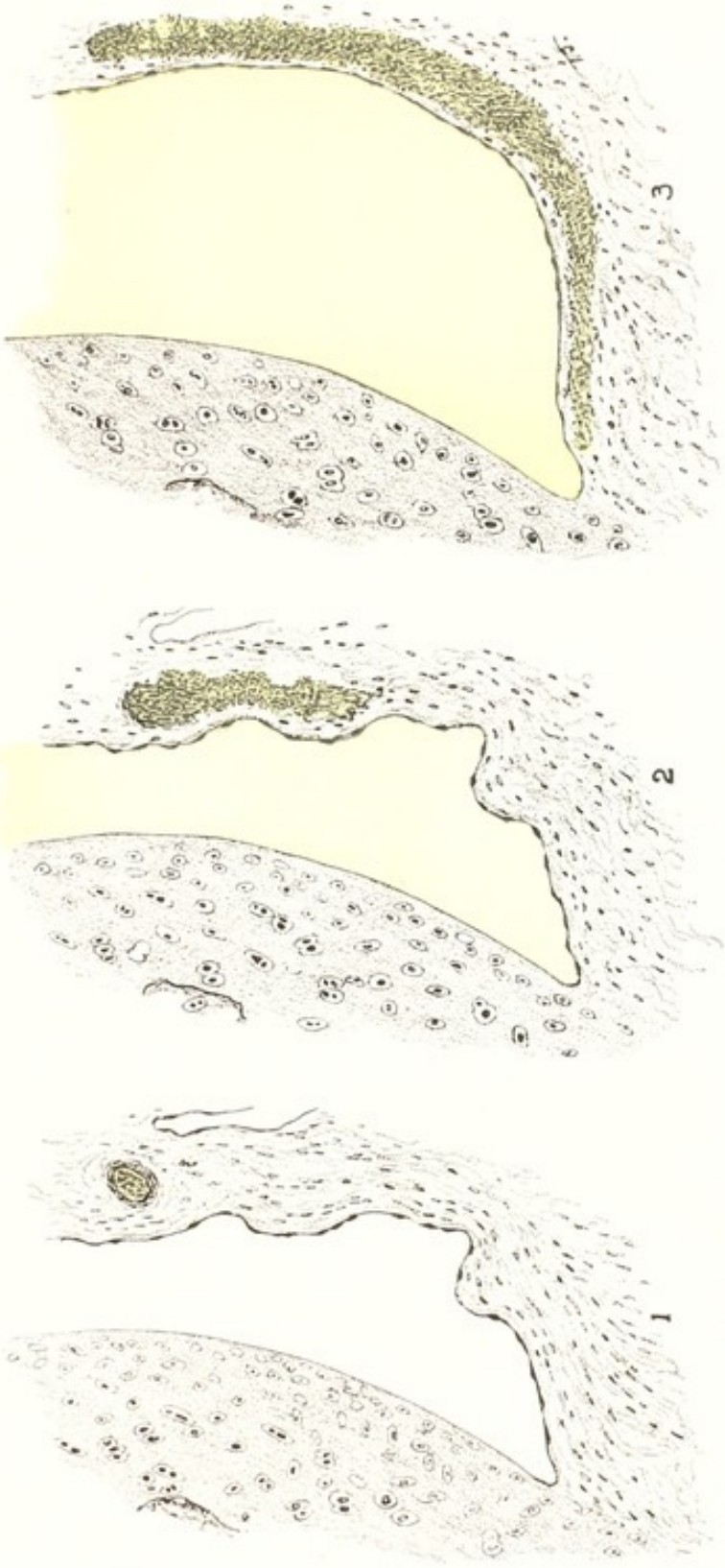


FIG. 143.—The histogenesis of a metastatic knee-joint infection. 1. A nidus of infection lodged in the subsynovial vascular layer of the capsule; 2, the focus spreading beneath the synovial membrane—early outpouring of fluid into the joint from irritation of synovia; 3, the march of the subsynovial infection; further distention of the joint with fluid. (Murphy.)

hyperemia often gives relief from pain. If much fluid is present, aspiration is advisable.

In septic arthritis of the less severe type, immobilization of the joint, with repeated aspiration, may be sufficient. A wide incision, with exposure

of the joint surfaces, should be avoided if possible, because of the inevitable destruction of the joint surfaces and consequent interference with their future function which are sure to follow. In the virulent purulent form, the joint should be incised laterally and dependently, drained, and irrigated with large quantities of weak solution of bichlorid of mercury (1 : 1000 solution),

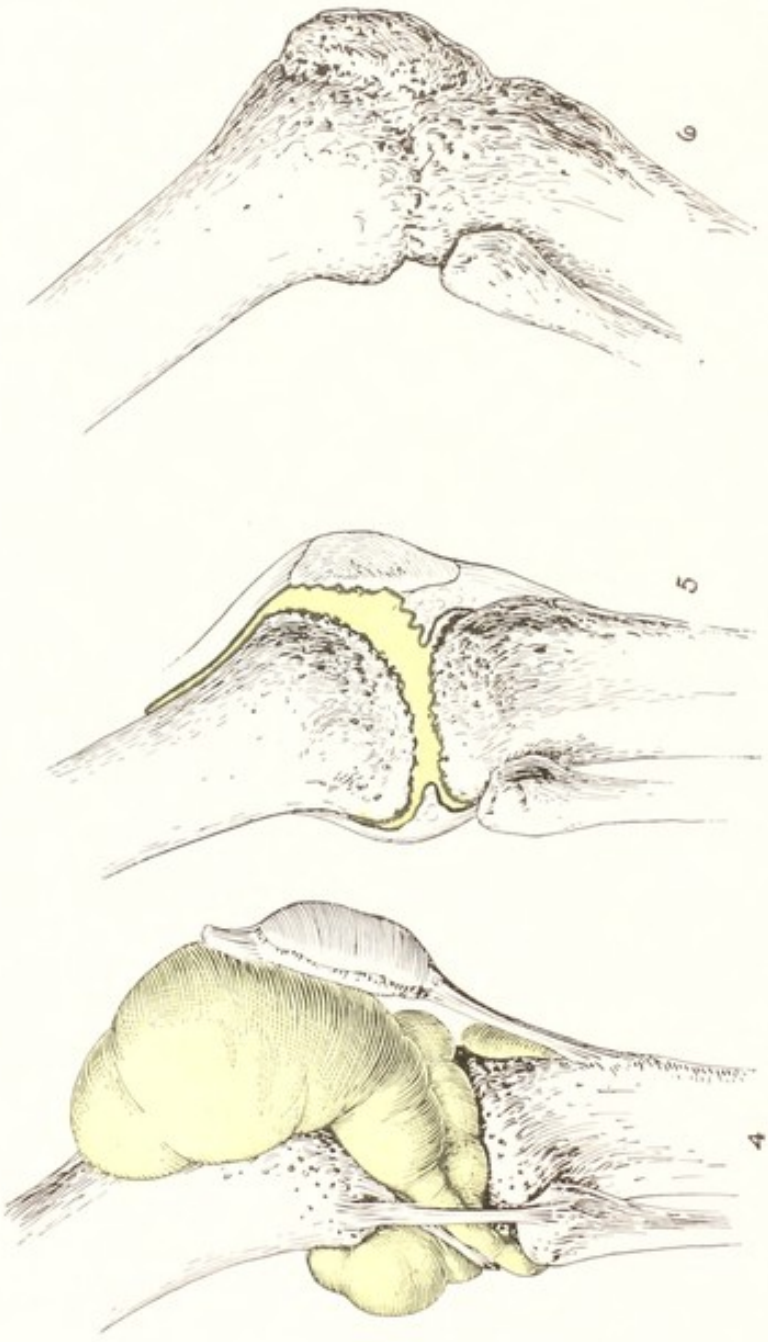


FIG. 145.—5. Erosion of articular cartilages and roughening of bone-glands; 6, the knee-joint as a tombstone to neglect: bony ankylosis in the vicious position of flexion. (Murphy.)

FIG. 144.—Distention of the capsule and associated bursæ with fluid, "floating" of the patella. (Murphy.)

or with hot normal saline solution. An autogenous vaccine should be prepared from the pus, and administered in the usual manner. If life is endangered, amputation may have to be performed.

Massage, baking, and manipulation of the joint should be begun early but used judiciously, as soon as the acute stage is passed. Murphy recommended the injection of formalin and glycerin in the less severe cases.

ACUTE ARTHRITIS OF INFANCY (Fig. 146)

Infants under one year occasionally suffer with a septic epiphysitis which by perforation of the articular cartilages, produces a purulent arthritis. The infectious agent is usually the staphylococcus or streptococcus. The lesions may be polyarticular, and the joints are usually disorganized. Early immobilization should be enforced, incisions made, and autogenous vaccines administered.



FIG. 146.—Old infectious arthritis of infancy involving the hip-joint with marked destruction of the femoral head and neck.

PNEUMOCOCCAL ARTHRITIS

Infection of a joint with the Diplococcus pneumoniæ may occur as a primary or a secondary lesion. Primary pneumococcal arthritis occasionally occurs without the presence of any other demonstrable lesion. Infection in such a case is determined by septicemia, the election of the joints being founded upon preceding trauma, etc. The source of the diplococci is the nasopharyngeal mucosa. Secondary pneumococcal arthritis is seen during the course or as a sequel of lobar or bronchial pneumonia. This is much the commonest form.

The lesion varies from mild inflammation to a serous type, or to purulent arthritis. The knee is the usual site, the shoulder coming next in frequency. The diagnosis is made from the co-existence of lobar or bronchopneumonia, and may be confirmed by aspiration of the joint and bacteriological examination. The prognosis is grave. Disorganization often results, with permanent ankylosis. Death is commonly observed.

Treatment consists of immobilization, pulley traction, incision, and drainage, and the administration of autogenous pneumococcus vaccine.

TYPHOID AFFECTIONS OF THE BONES AND JOINTS

I. Typhoid Joint Affections

1. **Rheumatic Typhoid Arthritis.**—This affection is usually polyarticular, often accompanied by multiple ankyloses, and frequently preceded by a rheumatic history.

2. **Septic Typhoid Arthritis.**—Suppurative inflammation of the joints depends upon a mixed infection of typhoid bacilli and pyogenic bacteria. The source of infection is usually found in sacral bed sores, boils, intestinal and external ulcers. Any joint may be invaded. The clinical course is like that of all septic inflammations of joints, and is frequently fatal, because of the added element of typhoid toxemia. Vigorous stimulation is necessary.

3. **Typhoid Arthritis Proper.**—(*a*) *Polyarticular Form.*—This is the most frequent form. The lower extremities are the commonest situations. This lesion does not increase the danger of death. Ankylosis is infrequent. The symptoms are the same as in the monarticular form.

(*b*) *Monarticular Form.*—The larger joints (particularly the hip, but also the elbow, shoulder, ankle, and knee) are mainly affected. The pain is slight, but often prolonged. Swelling is appreciable, except in the hip and shoulder, which are hidden by the soft parts. Its origin is spontaneous, but in rare cases it may arise by extension from a periostitis or necrosis. Suppuration is exceptional. The joint gradually resumes its functional activity.

Keen (Surgical Complications and Sequels of Typhoid Fever, Philadelphia, 1898) states that "more than half of all the cases of typhoid arthritis are followed by spontaneous dislocation, nearly all of which are of the hip joint."

(*c*) *Post-typhoidal Dislocation of the Hip.*—This is analogous to the dislocations of locomotor ataxia, the exanthemata, hemiplegia, sciatica, and "rheumatism."

The bacilli probably invade the joint, and either die or become attenuated, but excite an effusion which slowly stretches the capsule (a well known cause of dislocations) and other ligaments, possibly also causing swelling of the gland at the bottom of the acetabular cavity. The distension affects the posterior and weaker portion of the capsule, allowing the slightest force (a fall or even muscular exertion), especially adduction, to produce dislocation of the head upon the dorsum ilii.

The majority of the cases are in adolescents under twenty. The dislocation is usually single. The presence of the dislocation may be undetected on account of ignorance of its possible occurrence, the apathetic state of the patient, absence of pain, or because the great intensity of the latter precludes examination. It is observed oftenest during convalescence.

Treatment.—Reduction is usually easy on account of relaxation of ligaments when the dislocation is discovered early; if undetected until late, reduction is difficult and sometimes impossible, necessitating osteotomy. Recurrence is possible, and should be anticipated by the use of a binder or plaster-of-Paris spica.

Prophylaxis is important. The hip-joint should be kept under observation and examined, especially in children, for signs of pain or effusion. Abnormal positions of the legs in bed, adduction and internal rotation, favor spontaneous dislocation, and when any disturbance in the hip-joint is detected the legs should be maintained in abduction and external rotation by sand-bags, splints, and adhesive plaster; or mild extension by weight and pulley. If fluid threatens dislocation, it is advisable to aspirate the joint.

II. Typhoid Bone Affections

Osseous lesions are the most frequent complications of typhoid fever, with the exception of involvement of the larynx.

Etiology and Pathology.—Malnutrition is a predisposing and injury an exciting cause of necrosis. Thrombosis and embolism are rare causes.

B. typhosus is the direct etiological factor of all the osseous lesions. It has *virulent pyogenic powers*, which are strikingly shown in the bone affections of typhoid fever. In many cases the typhoid bacillus can be isolated in *pure culture* from the lesions, in some instances from cases with an open sinus which has been patent for months or years, when every opportunity was offered for the invasion of the ordinary pyogenic cocci. The typhoid bacillus not only shows remarkable viability in general, but an especially marked viability in bone lesions.

Favorite seats of the bacillus are the spleen, bone marrow, and gall-bladder. In the bones particularly, the organisms occur in the largest numbers and live the longest.

Bone abscess, necrosis, periostitis, and osteomyelitis may occur at very long periods after the original disease; in one case, after a period of seven years the typhoid bacillus was recovered in pure culture from a bone lesion. Probably in very many cases the focus of infection is dormant, undoubtedly encapsulated, long after convalescence; hence the need to support the general health and guard against even slight traumatism, to avoid activation of such foci and their possible dissemination. A case in point has been quoted of a blow on the forearm six weeks after convalescence, which was followed by an abscess of the ulna. Instances are recorded of the appearance of a bone lesion, its subsidence, and subsequent recrudescence.

The predilection of the typhoid bacillus for the bones is also evidenced by the favorable nidus which they offer for its growth; this is indicated by the frequent multiplicity of the osseous lesions. For instance, in one case there was involvement of the left tibia, left scapula, left femur, right humerus, and right tibia. It is to be noted that multiple bone lesions in typhoid are not synchronous, but occur successively, often with wide intervals between the individual involvements.

A curious phenomenon is the rapid growth in stature of adolescents following an attack of typhoid fever. This may be explained by the irritant action of typhoid bacilli upon osteogenetic tissue.

The bone lesions are occasionally localized at the site of an old fracture. Recent injury also tends to cause localization of the bacilli; the same influence is exerted by severe muscular activity following convalescence.

Varieties of Bone Lesion.—The two chief lesions are:

1. Osteoperiostitis (and chondritis).
2. Osteomyelitis.

and from either there may result

3. Caries.
4. Necrosis.
5. Bone abscess, etc.

Periostitis is the most frequent lesion and is seen chiefly in the ribs. Necrosis is most common in the tibia; in the ribs, it is not encountered, but occasionally affects the costal cartilages. Periostitis, osteomyelitis, and chondritis are the usual lesions of the ribs and costal cartilages. Central necrosis, *i.e.*, necrosis of the bony lamellæ lining the wall of the medullary cavity, is frequently encountered in the tibia.

"Shirt-stud abscess" ("bouton de chemise" or "dumb-bell abscess"),

is a peculiar lesion; a localized abscess forms beneath the periosteum of the tibia, and directly beneath it another abscess forms under the external layer of the bone cortex or in the medullary cavity, the two abscesses being connected by a sinus through the wall of the cortical bone.

Sex.—Males largely predominate in susceptibility to typhoid bone lesions.

Age.—About three-fourths of the cases are thirty years of age and under, leaving a not inconsiderable percentage of cases in later adult life.

There is only one locality in which osseous disease is confined almost uniformly to later life, viz.: the ribs and costal cartilages. No case has been recorded, so far as known, before the twentieth year.

In contradistinction to tuberculous bone lesions of a particular part, typhoid periostitis and osteomyelitis do not affect the general health, they are almost purely local in their effects. It is a question whether this may not be due to an acquired immunity resulting from the disease.

Localization of the Lesions.—Typhoid bone disease with extraordinary frequency affects the lower extremities—in the proportion of 112 to 104 instances of lesions of bones in all other parts of the skeleton, according to Keen's figures. This is possibly due to the fact that the legs are situated at the most distant part of the peripheral circulation, where nutrition is least active and consequently most easily disturbed and impaired.

The more superficial bones (head, sternum, clavicle, ulna, tibia, ribs, hands, and feet) are affected nearly 4 times as frequently as bones deeply situated.

These deductions are apparent by a glance at the following table of localizations, taken from Keen's "Surgical Complications and Sequels of Typhoid Fever."

Skull	1	
Mastoid	3	
Frontal	1	
Parietal	2	
Superior maxilla	5	
Inferior maxilla	2	
Head total		14
Sternum	3	
Ribs	40	
Vertebræ	6	
Trunk total		49
Clavicle	5	
Scapula	2	
Humerus	11	
Forearms	2	
Radius	2	
Ulna	15	
Hands	4	
Upper extremity total		41
Pelvis	8	
Femur	22	
Tibia	91	
Fibula	3	
Foot	8	
Lower extremity total		132
Total number of bones attacked		236

DATE OF ONSET OF BONE LESIONS (KEEN)

First two weeks	16
Third to sixth week	66
Months to years after the fever	104
	186

The bone lesions are therefore really a sequel and not a complication. The reasons for the late onset are:

(*a*) Muscular strain incident to standing and walking during convalescence, and the return to manual labor.

(*b*) Blows and slight traumatisms incidental to the postconvalescent period.

(*c*) Slow changes in the bones begin at that time.

(*d*) The bacilli, migrating from other parts, seek the favorable environment of the bones and lie dormant there, anticipating a lowering of the vital resistance and the establishment of a locus minoris resistentiæ.

Symptoms.—The fever, anorexia, dry tongue, and constipation of typhoid may be absent, the local symptoms predominating, but there may be a temporary exacerbation of the former symptom-complex.

The leading clinical signs are pain, tenderness, and swelling, the latter out of proportion to the size of the lesion; resolution often begins, otherwise redness and fluctuation usher in the formation of an abscess.

In other cases, long after subsidence of the local disease, the pain and swelling re-appear and proceed to abscess formation. There may be several such recrudescences, finally resulting in suppuration or permanent healing.

Treatment.—*Operation* is indicated *at once*, even before fluctuation appears. Incision should be followed by excision of the abscess walls, as the bacilli reside therein. If eradication of the diseased tissue is not thorough, a few organisms may remain *in situ* to light up a fresh lesion. This is particularly true of the ribs and sternum. A typhoid rib must be *resected* beyond the limits of the disease, not merely gouged out, and the same treatment accorded the sternum. Even if the pleural cavity is entered, no harm is done, provided careful aseptic technic has been observed.

The "collar-button abscess" requires especially thorough surgical treatment, in order to eradicate the internal as well as the superficial part of the abscess.

Incomplete operations mean persistent sinus formation. The tendency to chronicity, persistent sinus formation, and recurrence are among the most characteristic features of typhoid bone lesions.

Prognosis.—The outlook is uniformly good. The death rate is low and not attributable to a pure typhoid lesion in any single instance, but usually to mixed infection.

ACTINOMYCOSIS

The *ray fungus* occasionally invades the bones from a primary focus in the respiratory or gastro-intestinal tract.

The disease is usually encountered in the upper and lower jaws. The ribs, sternum, and spine have also been known to have been attacked.

The clinical signs are enlargement of the affected bone, with sinus formation and a persistent discharge which contains the "sulphur granules."

In the jaw, the condition may be mistaken for sarcoma or gumma; in the spine, for Pott's disease.

The outlook is serious. Treatment consists of large, progressively increased doses of potassium iodid, which may check the disease process.

HYDATID CYSTS OF BONE

These are very rare. The ends of the long bones, vertebral bodies, and pelvis are occasionally invaded by the embryos of tenia echinococcus. The cysts differ from those of the liver in being multiple and scattered

throughout the medulla. Rarefaction and fracture, necrosis, and occasionally suppurative arthritis are the lesions.

Clinically, chronic pain in the bone, egg-shell crackling, and uneven enlargement are the features. In the spine, angular deformity and paralysis, (see Chapter XXVII on Neoplasms of Bone).

Treatment consists of early incision and eradication of the cysts. If suppuration has occurred with fracture, amputation is indicated.

MADURA FOOT

Synonym.—*Mycetoma.*—The affection is produced by inoculation of the foot by a specific fungus, and is encountered in the habitually bare-footed males of India and other tropical countries.

Clinically, an indurated patch forms, containing black or yellowish nodules in which is found the fungus. Suppuration, sinus formation, and necrosis of bone follow. The disease remains localized and chronic. The only treatment is amputation.

REFERENCES

GONORRHEAL ARTHRITIS

MARSHALL, C. F.: Med. Am., 1900, p. 290.
BEUNICKE: "Die gonorrhoeische Gelenkentzündung." Berlin, 1899.
LUCAS, CLEMENT: Trans. Roy. Med. and Chir. Soc., 1899.
PATON, E. PERCY: "Infectious Diseases of Joints." Clin. Jour., May 24 and 31, 1905.
VAQUEZ AND LANDRY: "Young's Orthopedic Surgery," p. 531.
KIMBALL: New York Med. Rec., Nov. 14, 1903.

SYPHILITIC DISEASE OF BONES AND JOINTS

POWER, D'ARCY: Ency. Med., vol. xii, p. 24.
HILTON: "Rest and Pain," 3d ed'n.
LEYDEN: "Über einen Fall von syphilitischer Wirbelerkrankung." Berl. klin. Wochenschr., 1889, No. 22.
OLLIVIER: Traite de la moelle epinière et de ses maladies, vol. i, p. 350.
WADE: Med. Chir. Trans., vol. xxxiii.
OGLE: Med. Chir. Trans., 1872.
FISCHER: Syphilitische Nekrose des Atlas.
HEILUNG: Deutsche Zeitschr. f. klin., Bd. 22.
BECK: Trans. Ulster Med. Soc., 1876.
TISSIER: Nélaton's Pathologie chirurgicale, 2d part.
LEVOT: Thèse de Paris, 1881.
DUNLOP: Brit. Med. Jour., 1893, vol. ii, p. 1380.
COLLES: "Pract. Observ. on the Venereal Dis." Joachimsthal's Handbuch, part ii, p. 1251.
CARPENTER, G. A.: "Hereditary Syphilis and Cranio-tabes." Brit. Jour. Chil. Dis., vol. v, No. 2, p. 36.
JOACHIMSTHAL: Handbk. der orth. Chir., part i, p. 103.
MOSES: Beiträg. z. Wesen der Kongenitalen Syphilitischen "Tibia en lame de sabre." Diss., Königsberg, 1904.
ZITTMANN: Ency. Med., vol. xii, p. 22.

PNEUMOCOCCAL ARTHRITIS

BEZANANCON AND GRIFFON: Sociéte de Biologie, July, 1899.
CAVE, E. J.: Lancet, Jan. 12, 1901, p. 82.
ALLEN, D. P.: Annals of Surgery, October, 1901.
DUDGEON, L. S., AND BRANSON, W. P. S.: Lancet, Aug. 1, 1903, p. 316.
FORNACA, LUIGI: Giornale dell'Academiz de Med. di Tornio, March, 1906.
HERRICK, J. B.: Amer. Jour. of Med. Sci., July, 1902.
HERZOG, HANS: Jahrb. f. Kinderheilk., April, 1906.

Léroux, Léon: "Les Arthrites à pneumocoques." Paris, 1905.
Pasteur, W.: Lancet, May 27, 1905, vol. i, p. 1409.
Pasteur and Courtauld: Lancet, June 23, 1906, vol. i, p. 1747.
Raw, Nathan: B. M. J., December, 1901.
Secretan, W. B., and Wrangham, W.: B. M. J., April, 1906.
Paton, Percy: Clin. Jour., May 24 and 31, 1905.
Lesas, Dennis G.: Zeitschr. f. orth. Chir., Bd. xxiv, Hefte 1 and 2.
Strickler: N. Y. Med. Jour., July 17, 1909.

TYPHOID AFFECTIONS OF THE BONES AND JOINTS

Gibney: Trans. Amer. Orth. Ass'n, 1889.
Gibney: University Med. Mag., 1891, vol. iv, No. 2.
Gibney: New York Med. Jour., April 20, 1907.
Fussell: N. Y. Med. Jour., Dec. 17, 1889.
Eskeridge: Kansas City Med. Index, January, 1893.
Quincke: "Typhusbacillen in Knochenmark." Berl. klin. Wochenschr., 1894, No. 15.
Quincke: "Über Spondylitis typhosa." Mitteilungen a. d. Grenzgebieten d. Med. u. Chir., Bd. 4, ii. 1899.
Quincke: "Über Spondylitis infectiosa." Ibid., Bd. 2 v, 1903.
Osler: Johns Hopkins Hospital Rep., 1894 and 1895.
Study: Medical Record, July 28, 1894.
Klein: "Ostitis typhosa." Inaug. Diss., Kiel, 1896.
Newcomet: International Med. Mag., 1896.
Könitzer: Münch. med. Wochenschr., 1899, No. 35.
Painter: Annals Gyn. and Ped., December, 1899.
Tinker: Phila. Med. Jour., March 3, 1900.
Lovett and Withington: Boston M. and S. Jour., March 29, 1900.
Neisser: Deutsche Ärzte-Zeit., December, 1900.
Zenker: "Über Spondylitis typhosa." Diss., Leipzig, 1900.
Bonardi: La clin. med. ital., April, 1901.
Crittenden: N. Y. Med. News, 1901, vol. 79, No. 1.
Taylor: Phila. Med. Jour., Dec. 28, 1901.
Kühn: Münch med. Wochenschr., 1901, No. 23.
Cutler: Boston M. and S. Jour., June 26, 1902.
Freiberg: Amer. Med., Oct. 11, 1902.
Ely: Med. Record, Dec. 20, 1902.
Moorehouse: Boston M. and S. Jour., July 17, 1902.
Pallard: Revue méd. de la Suisse romande, 1902, No. 8.
Schanz: Arch. f. klin. Chir., Bd. 61, Heft 4, 1902.
Weigel: Trans. Amer. Orth. Ass'n, 1902.
Winokwow: Abstr. Centralbl. f. Grenzgebiete d. Med. u. Chir., 1902.
Arapow: "Über Spondylitis typhosa." Russ. Arch. f. Chir., 1903.
Cannon: Medical Herald, October, 1903.
Fichtner: Deutsche militärärztl Zeitschr., 1903, 2.
Herz: Zeitschr. f. orthopäd. Chir., 1903, Bd. 8, Heft 5.
M'Crae: Johns Hopkins Bulletin, March–April, 1903.
M'Crae: Amer. Jour. Med. Sc., December, 1906, vol. ii, p. 878.
Weir: Amer. Surg. and Gyn., April, 1903.
Fraenkel: "Über Erkankungen des roten Knochenmarks, besonders der Wirbel, bei Abdominaltyphus." Mitteil. a. d. Grenzebieten d. Med. u. Chir., Bd. ii, Heft 1.
Duncan: Amer. Med., Sept. 10, 1904.
Germain: Gazetta d. osp. ed. clin., 5 Gingno, 1904.
Goldthwait: Boston M. and S. Jour., April 7, 1904.
Guyot: Gazette hebd. d. sc. méd., Jan. 7, 1906.
Herrick: Trans. Ass'n Amer. Phys. vol. xxi, 1906.
Vickery: Trans. Ass'n Amer. Phys., vol. xxl, 1906.
Love: Glasgow Med. Journ., December, 1906.
Wilson: Med. Chronicle, August, 1906.
Silver: Amer. Orthop. Surg., October, 1907.
Myers: Amer. Jour. Orthop. Surg., October, 1907.
Rock, Carling, and King: Lancet, April 23, 1910, p. 1136.
Lord: Boston M. and S. Jour., 1902 vol. i, p. 689.
Floss: Centralb. f. d. Grenzgebiete d. Med. u. Chir., 1905, S. No. 17, *et seq.*
Halpenny: Surg., Gyn. and Obst., December, 1909, p. 649. Also Trans. XVI, Cong. Int. de Méd. Compte Rendu, Sect. VII. "Orthopédic." 2d Fascic, Bud-Pesth, 1910, with bibliography.

CHAPTER XI

CHRONIC INFECTIOUS ARTHRITIS

The trend of modern thought on the etiology of chronic inflammation of the joints is strongly in the direction of an infectious origin, as indicated in the text on focal infections elsewhere in this book. The author is so impressed with the infectious character of these chronic arthritides that at the risk of adverse criticism he classifies them under the caption, "Chronic Infectious Arthritis." Despite the fact that cultures from the joint tissues in these cases have hitherto been uniformly sterile, it appears safe and reasonable to assume, nevertheless, that a focus of infection is present somewhere in the body and that its baneful influence is expressed by the endotoxins or exotoxins of bacteria either living, dead, attenuated, or of such a character that they defy detection by our present-day methods. Inasmuch as the end result of these chronic processes is distortion of the joint, the generic term "arthritis deformans" will be retained for purposes of description.

ARTHRITIS DEFORMANS

It is believed that clinical manifestations of disease and clinical study of cases form an unsound basis on which to establish a scientific classification of disease, and yet such is the basis on which the classification of the deforming arthritides has been established by all who have written on the subject. In view of the great confusion which has hitherto existed regarding the pathological processes involved (mainly on account of variable clinical manifestations) in these deforming arthritides, their obscure etiology, and the varying relations between pathological processes and symptoms, the researches of Nichols and Richardson (ref. "Arthritis Deformans" by Edw. H. Nichols and Frank L. Richardson, Jour. of Med. Research, N. S. xvi, 1909) are of paramount importance. Their work, based on a pathological and clinical study of 65 cases of chronic non-tuberculous deforming arthritis, with complete autopsies on 26 of the series, marks a distinct advance in our knowledge, affords the basis for a more scientific classification, and may fairly be considered the most recent as well as the most authoritative work upon the subject. The observations of Nichols and Richardson will therefore be drawn upon largely in our consideration of the subject.

Pathological Types

Two very definite pathological groups have been differentiated by Nichols and Richardson, viz.:

1. Primary proliferative changes in the joints, chiefly in the synovial membrane and perichondrium.

2. Degeneration of the joint cartilage.

These types are marked by distinct gross and histological differences. But Nichols and Richardson have repeatedly emphasized the fact that the two pathological types "do not correspond to two definite pathological factors, *i.e.*, to two definite and distinct diseases." Hence they seem to imply

that the two types of lesion may co-exist in the same patient. In a personal communication, Nichols states that "it is perfectly possible, though quite unusual, to find proliferative and degenerative arthritis co-existing . . . . . the cases are in my experience quite uncommon, but they do occur." Proliferation or its opposite, degeneration, may occur, "hence the same end result may be produced in these joints by a variety of irritants or agents, and a given agent or irritant may produce a variety of gross appearances."

The original lesions occur in the synovial membrane or cartilages, and arise from a variety of causes, viz.: trauma, acute suppurative infections, gonorrhea, syphilis, faulty metabolism, and possibly many other processes may excite proliferation of the synovial membrane; while senility, trauma, dislocations, neoplasms of bone, gout, diseases of the central nervous system, have been known to induce degeneration of cartilage. The process once started tends to continue, or its primary cause may continue to act indefinitely. "A given cause in either of the two pathological types may produce a considerable variety of different appearances, while at the same time a number of different causes may lead to the same end result in either type," in a manner analogous to the production of arteriosclerosis. It not only is sometimes impossible from a pathological examination to tell what particular etiological factor was operative in a particular case, but it has also been noted that a given cause may produce any one of a variety of gross appearances in a given joint."

I. Proliferative Arthritis

Synonyms.—Atrophic type of arthritis deformans; rheumatoid arthritis (Goldthwaite, Painter and Osgood); arthritis deformans.

The primary change in this type is *proliferation of the synovial membrane and the perichondrium*, occasionally accompanied by *proliferation of the connective tissue and endosteum of the epiphyseal marrow* immediately below the joint cartilage. The principal change is in the synovial membrane, the perichondrial changes varying in extent in different cases. The results of these changes in the synovial membrane and perichondrium are as follows:

(*a*) A *pannus*-like layer of granulation tissue extending over the joint cartilages, with consequent destruction and absorption of the latter wherever the two are in contact.

(*b*) *New formation* of *cartilage* or *bone* resulting from *perichondrial proliferation*.

(These two processes may go on simultaneously.)

(*c*) Analogous changes outside the joint cavity, consisting of *proliferation of the connective tissue of the marrow* spaces of the epiphysis just below the zone of provisional calcification, with coincident formation of very vascular granulation tissue.

(*d*) This granulation tissue of the marrow, by extension upward through the zone of provisional calcification, may destroy and cause the *disappearance of the overlying articular cartilage*.

(*e*) Synchronously with its destruction from below, the articular cartilage may be eroded by the *destructive action* of the *synovial pannus* on its surface.

(*f*) Other changes in the epiphyseal marrow consist of proliferation of the endosteum of the epiphysis, resulting in the formation of new bone or cartilage along the epiphyseal margin of the articular surface.

Etiology.—Nichols and Richardson believe, as a result of their observations, that this series of changes is not a manifestation of a single disease of the joints, *i.e.*, they are not produced by a single etiological factor. They

have noted this series of changes in one or in many, in large or in small joints of the same patient, and under various conditions, viz.:

The lesions may be the end result of suppurating affections, may follow gonococcus infection, may occur in the course of "Still's disease," may come on suddenly in single joints without evidence of bacteria, may be observed in individuals harboring a gumma in the corresponding epiphysis, and may even result from fracture involving the joint with partial dislocation of the articular facets. It may therefore be inferred that the proliferative type of arthritis is induced by a great variety of irritants which, for the most part, continue to act for a long time, but only in some cases can the active cause be identified.

As to the various theories advanced to assign an active cause in explanation of the joint lesions of this type, the author is inclined toward that of focal infection; but whether the immediate cause of the lesion is a bacterium emanating from a focus of infection too attenuated to permit of its cultivation from the joint tissues, or of such a character that it defies our present means of detection, cannot be stated. That the joint lesions are, in a large percentage of cases, a manifestation of a toxemia whose source is a focus of infection, appears to the author obvious, also that the irritant is in most cases produced by some cause acting over a long period of time.

Another hypothesis offered is that of "faulty metabolism," *i.e.*, abnormal physiological processes of certain tracts or organs of the body, or abnormal cellular changes. This theory of faulty metabolism has support in certain clinical facts, viz., its long duration with constant remissions; the amelioration of joint symptoms by sterilization of the intestinal canal and by diuresis; the association of organic intestinal lesions or anomalies (such as Meckel's diverticulum). Additional support of this theory is offered by the chronic inflammatory nature of the lesion, as evidenced by involvement not only of the joint tissues but also those of the adjacent epiphysis, indicating the action of some soluble irritant of low degree of irritability operating over a long period. However, the above clinical facts and the theory of some soluble irritant fit equally well the theory of an endotoxin or exotoxin of bacterial origin arising from a focus of infection.

This type is of universal distribution and is commonest among the most civilized peoples. It is an affection of adult life, women being more frequently affected than men. It is rare before the fifteenth to the twentieth years. Goldthwaite believes that cases of deforming arthritis occurring prior to fifteen are instances of Still's disease, which he considers does not belong to the type of arthritis under consideration.

Goldthwaite has observed the association of such factors as grief, fear, severe nervous shock, and great physical or mental strain in a very large aggregate of patients. He also believes that the preponderance of women as victims of the disease points to the close relationship between the joint condition and nervous exhaustion (ref. "Diseases of the Bones and Joints," Goldthwaite, Painter, and Osgood, 1909, p. 294). In the social scale, the lower and middle classes are chiefly affected. According to Goldthwaite, the disease is apparently more prevalent in individuals of neurotic temperament with feeble vital resistance.

General Pathological Process.—The *synovial membrane* presents the most marked change, while secondary changes occur in the capsule. The synovial membrane proliferates and forms a layer of vascular granulation tissue, beginning at the periphery of the joint. The membrane becomes thickened and produces a thin layer of pannus which spreads from the margins of the joint over the surface of the articular cartilage. This pannus usually

extends downward into the cartilage and causes disintegration and dissolution of the latter, so that often the entire cartilage is destroyed and the bone completely denuded of it. The bone ends are then separated only by a layer of pannus in the form of vascular granulation tissue or dense non-vascular fibrous tissue. In the early stages of the disease the destruction of cartilage is not complete but is most marked at the periphery. In some cases the opposed layers of pannus on the articular ends of the bones are not adherent to one another, while in others they are coalesced by a thick mass of adhesions which diminishes the joint cavity and restricts motion.

The entire synovial membrane often proliferates, and if any portion of it comes into prolonged contact with the articular cartilage, adhesions occur, and the synovial cavity is thus subdivided into intercommunicating loculi.

Further destruction of the joint cartilage may occur from its epiphyseal surfaces by the formation of a zone of edematous, vascular granulation tissue in the marrow spaces of the epiphysis which may penetrate the zone of provisional calcification and erode the cartilage from below.

But in the majority of cases the *peripheral ingrowth* of *synovial pannus* is the predominating feature, while destruction of the cartilage is of minor importance. In other cases, the two processes are of equal severity and advance synchronously, when, after destruction of the cartilage, the two layers of synovial pannus become amalgamated, and foci of the original disintegrated cartilage may be found in the thick layer of granulation or fibrous tissue.

Usually, as a sequel to synovial proliferation, there occurs *proliferation of the perichondrium of the articular cartilage*, and of the *endosteum of the epiphysis*, resulting in the formation of new cartilage or bone, which appears as a layer of fibrous tissue on the joint surface. This fibrous tissue is transformed into cartilage in a manner analogous to the formation of the callus in fractures. Often transformation into true bone occurs. The initial stage of this transformation of perichondrium into cartilage or bone is marked by roughening of the surface of the joint on account of the projection of cartilaginous or bony masses.

Proliferation of the endosteum of the epiphysis results in the formation of trabeculæ of osteoid tissue which later may become fused with the proliferating layers of the perichondrium.

Summary.—In the proliferative type of arthritis deformans, then, the pathological changes are briefly as follows:

The formation of two layers of granulation tissue, one from the synovial membrane (pannus) and one from the connective tissue of the epiphyseal marrow; and the formation of two layers producing new cartilage or new bone, one from the perichondrium of the joint surface, the other from the endosteum of the epiphysis. All four layers may proliferate together so that, synchronously, destruction of cartilage and new formation of cartilage or bone may be going on in the joint; while in the epiphysis, destruction of cartilage and the formation of new trabeculæ are taking place. The intervening layers of cartilage having been destroyed, these two proliferative layers on either side of the joint become fused. The same process takes place in both of the adjacent bones of the joint, and the result of their approximation varies with the character and origin of the new tissue; hence varying degrees of ankylosis occur. If the synovial pannus predominates, ankylosis is fibrous; if perichondrium predominates, it is cartilaginous; if trabecular proliferation predominates, ankylosis is bony. In the latter event (excessive trabecular proliferation) all traces of the original joint are obliter-

ated, so that fusion of the two bones occurs with the production of a continuous marrow canal. In the majority of cases, all three processes are co-operative in the same joint, particularly the large joints, pannus, erosion of cartilage either from above or below, with fibrous, cartilaginous, or bony ankylosis in evidence.

Changes in the Bones.—No atrophy or resorption of bone has been observed. Changes in the marrow often involve the entire epiphysis. The connective tissue of the marrow proliferates to such an extent that the normal marrow disappears and its place is taken by fibrous, edematous connective tissue of increased vascularity.

The bony trabeculæ may show no change. Occasionally they are diminished in number and size. This change in the density of the bone is apparently due to the removal of calcium salts from the matrix without resorption of the bone by osteoclasts. These osseous changes, moreover, are secondary and are due to disuse of the involved bone, which is further attested by the fact that bones which are longest ankylosed are the most permeable to the *x*-rays. Bony formation at the periphery of the joint is rare (in contrast to the degenerative type), while thinning of the cortical bone in advanced cases may be extreme and eburnation not occur (due to interposition of pannus).

Changes in the Capsule.—There is more or less thickening of the entire capsule, due to the proliferation of connective tissue, and at the margins of the joint this proliferation is continuous with the proliferation of the synovial membrane. This thickened capsule may eventually undergo conversion into dense fibrous tissue, and interfere seriously with joint motion.

Synovial Tags.—Papillary and polypoid masses are not so common in this as in the degenerative type, because early ankylosis with obliteration of the joint cavity usually allows no time for their formation. When they do form, they arise in one or all of three ways, viz., from (1) synovial membrane, (2) synovial pannus, or (3) granulation tissue from the marrow. Their structure consists of connective tissue with fat spaces, or in some instances entirely of fatty tissue. These tags become detached as "joint mice" (foreign bodies), less often than in the degenerative type.

Luxations.—Partial dislocations are common. They are caused by several factors: changes in the shape of the articular facets from destruction of their cartilage; or changes in the shape of the bones on account of new formation of bone or cartilage from proliferation of perichondrium and endosteum. Luxations are always associated with a tendency to ankylosis, rather than to the formation of peripheral bone as in the degenerative type. Ankylosis, when it does occur, is actual and in contrast to the obstruction of motion due to extra-articular deposit of osteophytes which is observed in the degenerative type of lesion.

Gross Appearances.—The gross appearance of a joint of this type is readily distinguishable from one of the degenerative type. In the early stages the cartilage appears practically normal, the only apparent change being hyperemia, thickening, and slight encroachment on its surface at the margins. In some cases the thickening of the cartilage is extreme, the synovial membrane purple, and associated with the presence of a small amount of clear to cloudy effusion in which small coagula may appear.

The first real changes in the cartilage are that it appears slightly redder than normal and is thinner in spots; its surface is roughened, red, lusterless, and hyperemic; a thin layer of granulation pannus encroaches upon it at its periphery; this pannus is either smooth or papillary. In the later stages a thin layer of synovial pannus completely covers the cartilage and is either

much injected or exists as a thin white, bloodless, fibrous layer with isolated patches of white, shining, normal cartilage remaining in and beneath it. This encroachment of pannus reduces the joint cavity, or by adhesions it becomes subdivided into small intercommunicating cavities or else completely obliterated; in any event, limitation of motion results, with areas of bony or cartilaginous ankylosis. By forcible avulsion of the joint, such ankylosed areas may be readily disrupted, leaving behind eroded, vascular bony areas. Occasionally there exists complete obliteration of a joint, its place being occupied by a continuous marrow canal communicating with the marrow canals of the bones above and below the erstwhile joint.

Localized proliferation of perichondrium often results in irregular bosses of cartilage on the original joint cartilage. These nodules consist entirely of cartilage, or of a bony base with a cartilaginous surface.

The apparent enlargement of these joints is due to thickening of the capsule and not to peripheral growth of new bone, as in the degenerative type.

The *x*-ray shows increased permeability due to absorption of lime-salts from the matrix in acute cases, while at a later stage it is due to slow osteoclasis from disuse and hence is a secondary change.

Luxations are very common, may be extreme, and are due to muscle spasms and contractions, and to erosions, the formation of new tissue, and to ankylosis of different varieties. There is a great variety of gross appearance, varying with the amount of damage to the joint, the duration of the lesion, and the ratio between retrogressive and proliferative changes.

Pathology in Relationship to Clinical Symptoms.—As has been noted by Nichols and Richardson, "although only two general types of pathological changes (proliferative and degenerative) occur in these joints, the variety of stages in either type is very great, since both types are progressive" and hence there is "a corresponding variety in clinical symptoms of different patients affected with the same general pathological type of joint." This multiplicity of symptoms and conditions in one general type of deforming arthritis has caused the great confusion in nomenclature and classification of these affections which has hitherto existed.

In approaching a case of deforming arthritis, the surgeon should be careful to ascertain, if possible, three factors of paramount importance to the intelligent management of the case, viz.: First, which of the two general pathological types (proliferative or degenerative) is present; second, the stage of that particular pathological process in the affected joint; and, third, the *active cause* operating in the case at hand; and every possible site of a focal infection should be studied with the aid of specialists and of every known diagnostic method.

In considering the relationship of clinical phenomena to pathological processes, the surgeon should constantly bear in mind "the variability in anatomical conditions in each type and the variability of symptoms in different stages of the same type," and, as Nichols and Richardson further note, "it should be remembered that this attempt to associate symptoms with pathological conditions is not an attempt to represent two different diseases, because we believe very strongly that many different causes may produce each of these pathological changes."

Clinical Features.—Any joint, large or small, may be affected. The distribution is usually polyarticular but may be monarticular.

Age.—Although individuals of any age may be affected—children (exemplified by Still's disease), adolescents, adults, and the aged—it is commonest in the relatively young. Nichols and Richardson state that of

18 cases at the Long Island Hospital in Boston, the onset in 10 occurred before fifty, and in 7 before forty years of age.

Onset.—In some instances the sudden onset with slight hyperpyrexia and rapid pulse, with joints enlarged, tender, painful, and in some cases reddened and exhibiting elevation of surface temperature, makes the resemblance to acute articular rheumatism so close that it is sometimes impossible to differentiate the two diseases. The difficulty is increased by the evidence of pain during rest as well as during motion; in the latter event it is sometimes excruciating. In other instances, the onset, instead of being acute, is insidious, and the first signs are slight stiffness or lameness, gradually increasing in degree, with remissions, and enlargement of the joint is perceptible only after a long period.

Although the involvement may be monarticular at first, at a later period other joints, and occasionally every joint in the body, are involved. The characteristic changes in the joint consist of enlargement, fusiform swelling, more or less effusion into the cavity (usually, however, small in amount), and thickening of the capsule. *X*-ray examination shows great permeability to the rays, particularly of the bone in the neighborhood of the joint. This increased permeability is due to halisteresis (loss of lime-salts) and not to resorption of bone.

The gross appearance of an acute joint is as follows: The synovial membrane is thickened and injected to a variable degree. Pannus extends over the articular surface and diminishes its area; the rate of extension of the pannus varies, in some cases it is slow, in others rapid. Central portions of the articular cartilage which are not covered with pannus exhibit areas of injection, roughening, or thinning; the roughened areas are produced by perichondrial proliferation, while the red, injected areas are due to beginning erosion by upward extension of the phagocytic granulation connective tissue of the marrow. In some instances, however, the joint may show no gross change although the patient may be suffering intense pain.

The process is progressive with remissions, whether treatment has been administered or not. Following the acute attack, slight deformity and limitation of motion persist. The latter is due to the diminished area of the articular facet and more or less amalgamation of the two layers of pannus. After the joint has been subjected to a long series of such attacks, it occasionally diminishes in size, suffers great deformity, distortion or dislocation, and marked restriction of movement. The gross appearance of a joint at this later stage varies markedly, depending on the relative proportion of destructive changes of the synovial pannus and marrow granulation tissue, and of the hyperplastic process in the perichondrium and endosteum. In some cases the cartilage is completely overgrown by a layer of pannus of varying degrees of thickness, and in structure varying from vascular granulation tissue to pinkish fibrous tissue. In other cases the cartilage is only partially covered by pannus, while the uncovered areas are either intact or exhibit marked erosion from below. The joint space is usually greatly decreased by amalgamation of the opposed layers of pannus and proliferating perichondrium, as by bands of adhesions between the synovial membrane and the cartilage, subdividing it into multilocular cavities. Adhesions occur between the opposed articular surfaces or between the capsule and the articular surfaces. In the former case, the adhesions may be so dense as to obliterate the joint cavity and practically inhibit motion, or they may be long and permit a good range of mobility. These adhesions are the result of repeated exacerbations. Marked deformity usually accompanies dense adhesions, and is increased by destruction of cartilage

and muscular contractions. Within certain limits, deformity follows no mechanical rule, and may in some instances be of any type. During the subacute stage pain may be absent for considerable intervals, even though function be greatly restricted or absent, but in some instances swelling, redness, and acute pain may accompany the recurrent attacks.

In the chronic stage of the proliferative process, deformity is increased and may be extreme. Function is increasingly limited and may be entirely suspended. In incising the joint, the cavity is smaller than formerly and is subdivided by fibrous adhesions with which are associated cartilaginous adhesions between contiguous areas of proliferating perichondrium. These cartilaginous adhesions may become converted into true bone, inhibiting any joint motion, although by avulsion such osseous adhesions may be readily sundered. In the intervals between the adhesions, the joint cartilage may be normal or undergoing erosion from below or covered with synovial pannus. In still other cases, extreme in character, all trace of the original joint cartilage is lost, its place being taken by spongy bone-marrow obliterating the joint cavity and forming a connecting link between the marrow cavities of the two adjacent bones, and converting their two shafts into one continuous shaft.

A characteristic feature of the proliferative type of deforming arthritis is its polyarticular nature. The small joints of the hands are usually the first to be affected, while the process invades the other joints with varying degrees of rapidity. Monarticular lesions are rare and the large joints are the last to be involved. The progressive order of involvement is usually as follows, in the order given: Fingers primarily, followed by wrists, elbows, knees, tarsus, metatarsus, shoulder, jaw, and spine.

The initial symptom is usually (1) *slight stiffness* or (2) *lameness*, accompanied by (3) *localized sweating of the hands and feet*, and (4) *decrease of surface temperature*, the last two phenomena being due to circulatory derangement. (5) Deformity takes place slowly, is usually permanent, and tends toward *flexion* or *subluxation*, and this tendency (in contrast to the lateral distortions which characterize certain other types of arthritis) is a feature of some diagnostic value. These flexions and distortions are due to thinning and erosion of the joint cartilages, villous thickening of the synovial membrane, and the greater strength of the flexor muscles. Lateral distortions are less common than flexion deformity or subluxation, but do occur as ulnar deviation of the hands and as genu valgum, the latter being usually consequent upon subluxation of the tibia. (6) *Pain*, usually slight at first, is due to thinning of the cartilage or to actual erosions. (7) *Crepitus* is dependent upon friction of the eroded cartilages during movements of the joint and also, possibly, to rubbing together of synovial tags. (8) *Limitation of motion* is due to the causes discussed in the section on pathology. (9) *Ankylosis* of varying degree and of different varieties may occur. (10) *A jerky sensation* on manipulating the joint in advanced cases, is the result of patchy destruction of the cartilage. (11) *Constitutional derangement* is manifested by muscular atrophy; enfeebled circulation; sallow, thickened, dry skin; physical inertia; while the facial expression is indicative of the chronic distress of mind and body. (12) *Associated atrophic changes* affect the skin, which becomes dry and glossy on account of disturbance of the sweat-glands; while the nails become hypertrophied, striated, and may undergo exfoliation.

The blood remains normal, although one would naturally anticipate a secondary anemia. There is generally no elevation of the general body temperature or the pulse, although localized tenderness may be extreme

and associated with slight increase of surface temperature, but usually without local redness of the skin.

The course of the pathological process varies in different individuals; some recover spontaneously; in others, proper treatment will check the lesion; while certain cases resist all treatment. The resemblance of this proliferative form of arthritis to chronic gout is sometimes striking, and is evidenced not only by the *x*-ray but by the thinning of the joint cartilage and the presence of gouty deposits which already have been described in the section on pathology.

Prognosis.—Individuals below forty, under hygienic conditions and with freedom from worry and physical stress, present the most favorable outlook for improvement and, occasionally, cure. Their prospects are enhanced by nourishing diet, good local treatment, and outdoor life and exercise, and according to the degree of response which they exhibit to endocrines, autogenous vaccines and sera, etc. Synovial tags may thus undergo resolution, eroded cartilage may be partially restored or replaced by fibrous tissue, and the progress of the disease in these responsive cases retarded and modified.

However, the prognosis in every case should be guarded. Much of the outlook depends upon the discovery of the cause of the disorder and, if of bacterial nature, to the individual reaction to an autogenous serum or specific serum. The regenerative power of cartilage is slight, and, even when it proliferates, tends to increase the deformity. The surgeon should not be misled into considering a prolonged remission as a cure of the disease. Again, it often happens that destruction of the joint cartilage is so extensive that, even if the cause of the disease is discovered and removed, local distortion persists. Some of these proliferative cases progress rapidly and entail extreme suffering and deformity in spite of all treatment.

Treatment.—The old régime of dietetic stringencies and drugging the victim with salicylates and iodides has been displaced in recent years by a therapy which aims to properly nourish the patient, improve his personal and general hygienic status, to stimulate all his metabolic and immunizing machinery, and to apply local treatment, both palliative and operative, with due regard to the fundamental pathology of the joint involved.

Diet.—A full, free, mixed diet is recommended, avoiding only indigestible articles of food and those promoting flatulency, with the object of maintaining the highest standard of physical efficiency.

Endocrine Therapy.—The treatment of these arthritides by endocrines is based on the assumption that there is a physiological lack of balance among the ductless glands in chronic joint disease. The two endocrines most frequently employed in this connection are the extracts of thymus gland and of the pituitary gland.

(*a*) *Pituitary Extract.*—In reporting cases of proliferative arthritis treated by the extract of pituitary body (following the suggestion of Wallace), Whitbeck (ref. Amer. Jour. Orth. Surg., 1914–15, xii, pp. 484–501) noted from his experiments that, in the 13 cases reported, only 2 failed to show improvement under treatment. About the first sign of benefit was the relief of pain to a greater or less degree. Absorption of fluid and increased mobility also occurred. Pituitary extract also has a tonic effect, as was indicated by improvement in color, increase of weight and physical energy, and renewed stability of the nervous system. The blood pressure was raised in cases of low blood pressure and, conversely, was lowered in cases of hypertension. Retardation of the usually rapid pulse with improvement of its quality was also noted.

Whitbeck administers 1 c.c. of a 1 per cent. solution daily for two to three weeks, or longer, and then increases the dose to a 2 per cent. solution daily or every other day, or, in some cases, less frequently. In preparing the 1 per cent. solution, 0.3 g. of powdered extract of pituitary and 0.15 g. of chloretone are mixed with 30 c.c. of normal salt solution. This is allowed to stand for seven hours and is then filtered through the best filter papers until the filtrate is absolutely clear. The filtrate is then brought to a boil, when it is put in a sterilized bottle and corked or rubber-capped. When used, it is injected into the deltoid muscle in the appropriate dose.

(*b*) *Thymus Extract.*—In the treatment of what he terms "metabolic osteo-arthritis" (another contribution to our heterogeneous nomenclature), which corresponds to the proliferative type of arthritis, P. W. Nathan (ref. Jour. A. M. A., 1911, lvi) assumes that the affection is dependent upon a gradual deterioration of the general nutrition, and to improve this malnutrition he has advocated the use of the extract of thymus gland. He states that the improvement occurs only after the thymus has been taken for several months. Nathan believes that a short period of rest in conjunction with the administration of thymus and a nutritive diet will nearly always relieve the more active symptoms in the milder cases. This period of rest must be prolonged in severer cases, and in those cases which have hitherto had more active treatment (active and passive motion, etc.) several months or a year may be required to bring the condition to quiescence. Nathan advocates that active joint movements and locomotion be begun gradually and only after quiescence has been obtained.

The author employs thymus extract in 5-grain tablets, prescribing one tablet three times a day after meals for the first week, and thereafter giving two tablets three times a day. The results vary widely, both with this agent and with pituitary extract.

Medicinal Treatment.—As has been said, drugs are of little value in this condition. There is no specific medication. The salicylates and iodides merely provoke dyspepsia and have no effect on the course of the disease. Aspirin in 5-grain doses 3 times a day, is frequently used, but its effect is merely analgesic. Tonics and laxatives, however, are indicated in this as in all other debilitating affections.

Local Treatment.—The prevention or correction of deformity is about all that can be expected of local treatment in the proliferative type of arthritis. The knees and feet demand particular attention on account of their mechanical importance in weight-bearing and locomotion. Hence a useful position is of paramount importance in view of possible ankylosis.

The caliper splint (see Chapter VII on Tuberculosis of the Knee) is very useful in correcting flexion contraction of the knee, although plaster-of-Paris is less expensive and many times less troublesome. Instead of its constant use, whatever correction apparatus is employed may be worn only at night and omitted during the day. Manipulation and massage of the joints are effective in some instances but should be interdicted in the acute stages in the event of villous hypertrophy with progressive swelling and elevation of temperature.

Local stimulation of the joint is valuable and may be obtained by alternating douches of hot and cold water systematically administered by a nurse or other competent attendant. Baking and electric light baths with the arc or incandescent lamps are useful methods of stimulation. The use of the high-frequency current is favorably regarded by Goldthwaite, Painter and Osgood (ref. Diseases of the Bones and Joints, 1909, p. 317).

Operative Treatment.—(*a*) *Brisement Forcé.*—Forced disruption of adhesions under an anesthetic is particularly indicated in the case of a knee-joint flexed to 45° or more. Great conservatism should always be practised and this procedure should not be done until all evidence of activity of the arthritis has subsided. If manual correction of the deformity is impossible, then a genuclast or Thomas wrench may be used with success. If the hamstring tendons are shortened, tenotomy should be performed, although they and contracted portions of the capsule often yield to prolonged extension. After brisement forcé, a plaster-of-Paris dressing is used to maintain the correction until no tendency to a relapse is manifest. This requires one week or more. After removal of the cast, massage and passive motion are administered and the caliper splint is worn during the day, the split cast at night. Weight-bearing may be practised in the third or fourth week, followed soon by walking with the splints and crutches, but the apparatus should be retained until there is full voluntary extension of the knees.

(*b*) In cases of long standing, where the capsule has become permanently shortened with the joint in flexion deformity, a cuneiform or Osgood osteotomy may be performed and the deformity overcome, thus making the most of the existing limited motion with the limb corrected. For example, flexion deformity, with motion limited to 5°, if converted by osteotomy into extension even with the same limited motion, affords a more serviceable limb.

(*c*) *Arthrotomy.*—If hypertrophied synovial villi or floating particles of cartilage or bone cause pain and tend to lock the joint by encroaching on its articular facets, they should be removed.

Vaccine and Serum Therapy.—The rôle of focal infection in this proliferative type of arthritis is believed by the author to be such an exceedingly important one that a chapter has been devoted particularly to that subject elsewhere in this book (see Chapter IX). There will be found discussed the treatment of focal infections and of the acute and chronic infectious arthritides resulting therefrom, especially by the application of serum and vaccine therapy and the therapeutic use of non-specific protein antigens injected intravenously.

II. Degenerative Arthritis

Synonyms.—Spondylose rhizomelique; osteo-arthritis; hypertrophic arthritis of Goldthwaite.

Definition.—A chronic constitutional disease, probably of infectious origin with local joint manifestations.

General Considerations.—The affection may or may not be polyarticular. Localized lesions heretofore regarded as separate entities (Heberden's nodes, morbus coxæ senilis, etc.) are all incidental to the one degenerative process.

The joints most commonly involved are, in their order of frequency, fingers, hip, knee, spine, elbow, and feet.

The general symptoms are few and consist mainly of flatulency and constipation. It is a disease chiefly of middle life and old age and affects women more frequently than men, and in them the larger joints bear the brunt of the attack. It is rare in the very young. In general, it begins at a more advanced age than does the proliferative type.

Etiology.—Traumatism is an important factor, as is also exposure. The nature of the injury is often continuous stress incidental to occupation, especially when slight but continuous strain is put upon one particular joint, or the injury may be so severe as to have produced a fracture near the involved joint. In other cases (notably in the hip) a sudden, severe, single

traumatism will provoke the degenerative process. Sudden, extreme fluctuation in temperature and other atmospheric changes have a predisposing influence, notably in the case of stationary engineers and firemen exposed to sudden changes of temperature in going from a hot boiler-room to "cool off" in the outside air; teamsters continuing their work in wet clothing. Longshoremen, on account of carrying heavy wet loads upon their backs, are particularly disposed to spinal lesions of the degenerative type.

The effect of repeated slight traumatism is exemplified by (*a*) the frequency of involvement of the finger- and knee-joints in housemaids; (*b*) the occurrence of Heberden's nodes on the thimble-finger of seamstresses; (*c*) the frequency of knee-joint involvement in stout women who are obliged to frequently climb stairs, thus putting constant strain on the marginal surface of the articular cartilages of the knee; (*d*) obese individuals in general, by constant slight flexion of the knees, subjecting the latter to abnormal strain, are subject to localization of the disease in this joint. The effect of greatly prolonged pressure over a localized area has been noted in (*e*) bed-ridden individuals, in whom no evidence of inflammation could be obtained in the affected joint, the lesion being entirely degenerative. A striking feature is the persistence of these areas of degeneration of cartilage after the patient has been relieved of his invalidism, when they may be the beginning of further joint degeneration. (*f*) Severe mechanical strain in an abnormal position, for instance, in the case of a hallux valgus, is often accompanied by degenerative changes in the joint cartilage. Again (*g*), sudden deformity, the result of dislocation, may initiate the degenerative process.

The influence of trauma in localizing the lesion is evidenced by the preponderance of spinal and hip lesions in males, and again by the not infrequent affection of the elbow in baseball and tennis players. Fibrillation of the cartilage occurs in cases of *Charcot's joint*, particularly of the hip and knee. The fibrillation is at right angles to the joint surface and occupies large areas where denudation occurs, while in other places irregular thickening of the perichondrium occurs with resulting irregularity of the joint surface. These areas of proliferated perichondrium often undergo true ossification, while great deformity of the joints and early partial or complete dislocation are common.

Another explanation of the origin of arthritis deformans is the mechanical theory of George Preiser, who maintains that arthritic changes are due to disturbances in the static relations of the joint surfaces to one another; for instance, that arthritic changes in the hip are due to slight deviations in the pelvic obliquity, which throw an unusual strain upon the head of the femur and the corresponding portion of the acetabulum. Preiser has founded this theory upon thousands of measurements showing the presence of variations from the normal in individuals who give no symptoms of static disturbances until joint symptoms have manifested themselves.

The rôle of arteriosclerosis in this degenerative arthritis is not understood, but its possible influence should be considered, particularly in connection with the ligamentous thickenings at their insertion into the joints in the case of elderly persons. A similar ligamentous thickening about the vertebral joints in younger subjects in whom no definite cartilaginous or bony changes are demonstrable is suggestive of a similar analogy.

It has frequently been observed that localization of this diathesis in an arthritis of several small joints or one or two large ones, usually confers immunity from a flagrant polyarticular involvement. In some instances, Goldthwaite, Painter and Osgood (*loc. cit.*, p. 325) have observed proliferative and degenerative lesions co-existent in the same patient, although the period

of onset and the clinical course of each separate process is differentiated by the patient.

Pathology.—*General Process.*—The primary lesion consists of fibrillation and degeneration of the hyaline cartilage, which results in softening and erosion of the cartilage and exposure of one or both bone ends. The cartilage is eroded at first in patchy fashion, so that only circumscribed areas of bone are exposed. Compensatory overgrowth of bone or cartilage of the opposing surface accompanies the destruction of one articular cartilage, and this results in a very irregular indented line of articulation. This destruction of cartilage may eventually be complete, so that the ends of both bones are entirely denuded of cartilage, while at the same time, on account of the irregular

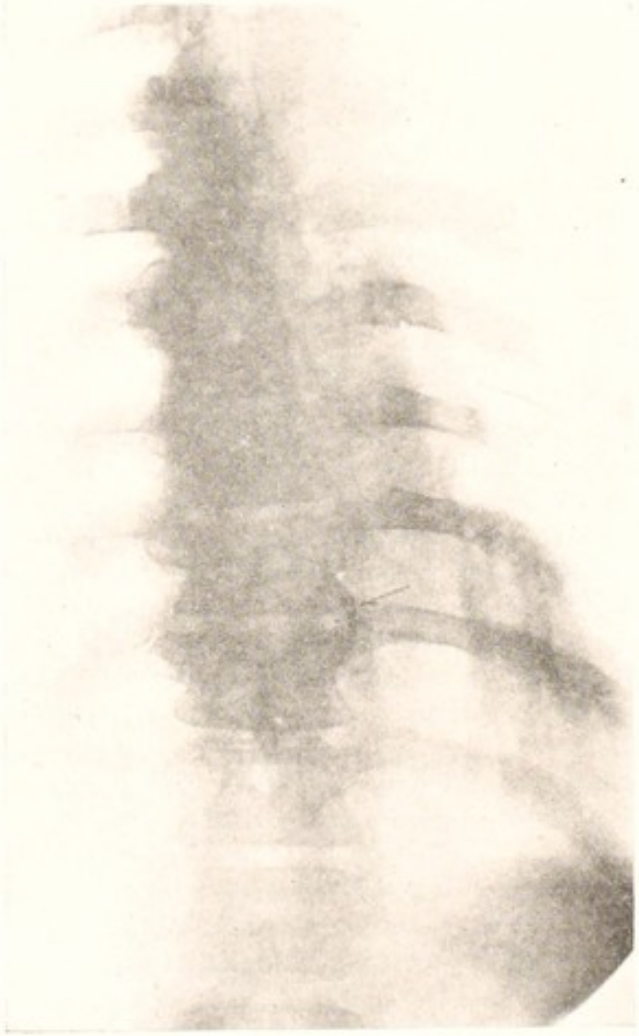


FIG. 147.—Localized arthritis deformans of the spine. The arrow indicates the formation of a bony bridge between two adjacent vertebræ.

character of the compensatory hypertrophy of cartilage, their surfaces become extremely notched and irregular.

Joint movement in this degenerative type is maintained for a long period on account of the slowness of destruction of the cartilage. Marked thickening of the bony trabeculæ and almost complete obliteration of the marrow spaces of the articular ends of the bones occur, resulting in conversion of the exposed bone end to osseous tissue equal in density to normal cortical bone, or even exceeding it in density, and this solid bone, as the result of friction, becomes highly eburnated.

Secondary changes in the joint accompany the above process and consist of subluxations, slow in development and due to the altered shape of the articular surfaces. *True ankylosis of adjacent joint surfaces never occurs*, but, on account of the great irregularity of the surfaces, interlocking of the two bones may occur and alteration of the plane of motion may follow remodelling of the articular surfaces, as exemplified by the change in shape of the femoral head from a sphere to that of a cylinder (see illustrations and text on "osteo-arthritis of the hip," Chapter XIV).

Secondary changes in the shafts of the bones consist of hypertrophy of the perichondrium at the joint margin, at the junction of cartilage and capsule (Heberden's nodes). At this point the cartilage may be converted



FIG. 148.—Osteo-arthritis (degenerative type of arthritis deformans) of the knee-joint. Particularly noteworthy are the large deposits of osteophytes at the upper border of the patella and in the superior aspect of the anterior and posterior regions of the femoral condyles.

into true bone, the hypertrophy is irregular and nodular, and there is increase of width and circumference of the articular ends. This peripheral new growth of cartilage is within the joint and hence actually increases the size of the articular surface. Irregular deposit of new cartilage on the articular surface increases the unevenness due to primary degeneration of the joint cartilage. This peripheral growth of perichondrium may more or less completely fill the joint space and produce partial or complete luxation. The peripheral bone-growth is composed of thick, dense trabeculæ.

Eburnation of the articular ends involves only a thin layer and not the entire epiphysis, nor is there much resorption of bone. Eburnation is explained on the supposition that new bone is developed to functionate as did the original joint cartilage; or, it has been suggested, eburnation represents

a reaction to repeated traumatism from within. Whatever resorption of trabeculæ of the shaft occurs, is probably incidental to old age or disease.

The capsule is usually not much increased in thickness, although in cases where destruction is rapid and severe (as in association with organic lesions of the central nervous system) there may be enormous thickening. The same is true of the synovial membrane except that proliferation of a high grade affects that portion of the capsule which is thrown into folds at the periphery of the joint, and, as a result of this proliferation, papillary or sessile masses are developed in the synovial membrane. These masses consist of granulation tissue or edematous connective tissue and are occasionally converted into cartilage, bone, or adipose tissue, the latter as "lipoma arborescens." The papillary masses are occasionally disrupted and freed in the joint cavity as loose foreign bodies. The synovial membrane does not extend in a pannus over the joint surface as it does in the proliferative type and, moreover, fibrous ankylosis never occurs.

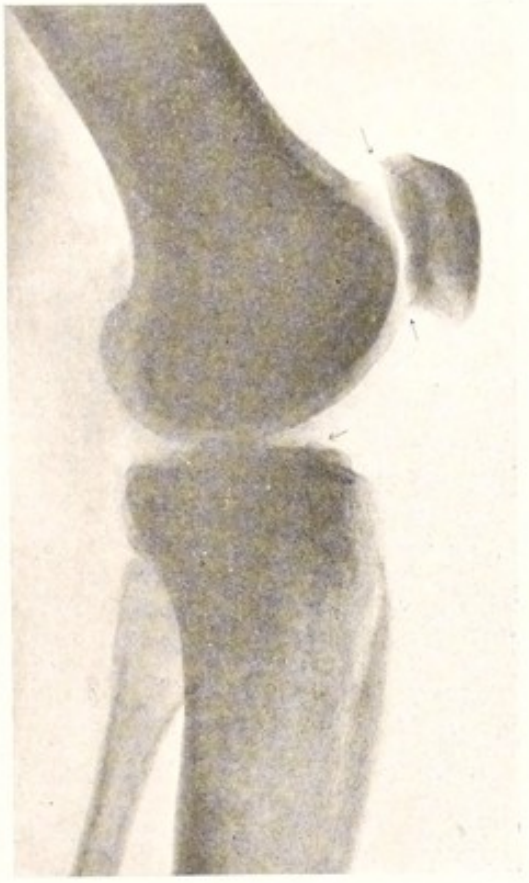


FIG. 149.—Osteo-arthritis (degenerative type of arthritis deformans) of the knee-joint. Early case. The arrows point to the sharp protuberant osteophytes at the upper and lower margins of the patella and on the upper articular surface of the tibia.

Changes in the Epiphysis.—In the event of complete destruction of the cartilage and exposure of the denuded ends of the bones, with retention of joint motion, there occurs great thickening of the trabeculæ immediately underlying the cartilage. This thickening of the trabeculæ occurs *only* when the bone is exposed, thus exciting a reaction of the connective tissue of the marrow spaces and of specialized endosteal osteoblasts. There ensues a formation of osteoid tissue and edematous connective tissue. This osteoid tissue may later be converted into bone. Reduction in size and eventually complete obliteration of the marrow spaces occurs as the result of encroachment of these overgrown trabeculæ, thus explaining the condensation of the bone ends.

Coincidently with the formation of new bone, there occurs a re-arrangement of trabeculæ by osteoclasis with the apparent purpose of endowing the bone ends with the greatest mechanical efficiency in their new rôle as articulating agents. New bone is also laid down by preformation of cartilage in the marrow spaces. This new dense bone, under the influence of attrition and joint motion, becomes highly polished, "eburnated." The thickness of this eburnated bone end varies with the extent of bone area exposed and with the amount of weight-bearing and motion required; in most cases it is no thicker than the original joint cartilage, although in some instances eburnation may affect the entire epiphysis. Reduction of the number and size of the trabeculæ of the shaft is due to inhibition of function of the bones, and the resulting resorption may be in part affected by osteoclasts and in part by the edematous granulation tissue which fills the marrow spaces.

Perichondrial New Bone.—The earliest indication of the formation of new peripheral bone in degenerative arthritis is at the junction of perichondrium and capsule and begins *inside* the joint capsule, as a rule, and arises either by transformation of the attached fibers of the capsule into fibrocartilage and thence into bone, or else by hyperplasia of the perichondrium itself with subsequent formation of true cartilage, and then bone. This results in actual enlargement of the articular area, the enlargement being *within* the capsule. The periosteum, as a rule, contributes nothing to the formation of this new bone. The cartilage which at first covers this new formation is disposed in an irregular manner. Eventually the entire mass of peripheral cartilaginous tissue may be converted into bone, usually of a very dense structure. The cartilage covering its surface may be eroded as in the case of the articular cartilage, leaving exposed peripheral spurs of eburnated bone, increasing the irregularity and size of the articular end of the bone.

Changes in the Capsule.—These are very slight. The fibrous tissue of the capsule is denser than normal but not infiltrated and, at its point of attachment to the margin of the joint, may be transformed into fibrocartilage or hyaline cartilage. In exceptional instances (as in the case of large joints or disease of the central nervous system) the capsule may become greatly thickened, hyperemic, with a tendency to obliterative *endarteritis*, and contain masses of cartilage or bone. The latter may arise at a part of the capsule far away from the joint and may never encroach on the joint. In some cases, however, bony nodules appear under the surface of the synovial membrane or projecting into the joint cavity. These bony masses may be sessile or polypoid and pedunculated, and in the latter case may be set free as foreign bodies ("joint mice"), and may, by lodgment between the articular bone ends, cause interference with motion or locking of the joint.

Changes in the Synovial Membrane.—Alterations in the synovial membrane are purely secondary to degeneration of the cartilage and usually occur in cases of extensive destruction of cartilage, and then chiefly in the large joints. Overgrowth of the synovial membrane takes place at the periphery of the joint, with the production of polypoid masses projecting into the joint in this locality. The structure of the masses consists of a central stem of connective tissue with a main vessel, or they are composed of granulation tissue entirely. They may be sessile or pedunculated, in the latter case sometimes forming foreign bodies analogous to those arising from the capsule. By compression between the articulating bone ends, these foreign bodies may suffer infarction, and necrosis may occur, leading to acute symptoms in the joint. Again, they may undergo hyaline or fibroid degeneration, which may affect the attached as well as the floating polypoid masses. These polypi, then, consist of granulation tissue, fibrous tissue, fatty tissue, cartilage, or bone. Obliterating endarteritis often affects the vessels of these polypoid masses, especially in Charcot's arthropathy of the larger joints. Another source of origin of polypoid masses is conversion of the fibrillated articular cartilage into a shaggy mass of polypoid tissue whose structure is cartilage which has undergone hyaline degeneration. Even if freed in the joint cavity, these are such minute bodies that they do not seriously interfere with joint motion. Still another source of these polyps exists in the projecting tags of granulation tissue of the marrow which becomes exuberant through the denuded end of the bone.

Luxations, Dislocations, Erosions.—The slow development of degeneration and erosion of the cartilage with new formation of cartilage and bone predisposes to luxations. Increase of the articulating area occurs from the peripheral deposit of osteophytes with the resulting enlargement of the extremity

of the bone. The end result of this process is merely deformity, if the joint area is relatively large (as in the phalanges); while, on the other hand, in a ball-and-socket joint (like the hip) peripheral growth at the margins of the deep socket diminishes and occasionally obliterates the cavity, and at the same time the femoral head is eroded and its shape becomes cylindrical or conical instead of spherical, or else flat and mushroomed. Hence, subluxations and even complete dislocations occur, with extreme limitation of motion which, however, is due to the distortion and *not to ankylosis*.

Pathology in Relationship to Clinical Symptoms of the Degenerative Type.—Subjects of this type of lesion are usually old, although the disease is occasionally encountered in the young, particularly in those affected by disease of the central nervous system. The onset is insidious and consists of gradually increasing lameness or stiffness in one or more joints without much constitutional disturbance. The gross appearance of the joint reveals circumscribed areas of roughening of the cartilage over one or both articular facets without any other apparent gross change in the joint in the early stage of the lesion.

At a later stage, pain and disability increase and the joints enlarge. The enlargement is due to *bony deposit* (in contrast to the character of the enlargement in the proliferative type), producing a *nodular* and not a fusiform swelling as occurs in the proliferative lesion. The *x*-ray shows the presence of perichondrial deposit within the capsule. Motion is restricted and the joint is tender and painful in this stage. The gross appearance on opening the joint consists of erosion of the cartilage so marked as to expose portions of the underlying bone-marrow, with eburnation of the latter from thickening of its trabeculæ by proliferation of the endosteum. Irregularity and grooving of the articular surface are noted along the line of motion, with depression in one bone end to accommodate elevation of the opposing bony extremity. These outgrowths are formed of cartilage resulting from proliferation of the perichondrium to compensate for erosion of the opposite bone end, and in most instances these cartilaginous outgrowths become converted into dense eburnated bone. The corresponding gutters in which these overgrowths move during joint motion are produced by the erosion of cartilage or bone.

Further modifications in the articular ends of the bones are apparent in the enlargement of the articular facets within the capsule, the result of proliferation of the perichondrium at their periphery, and this proliferated perichondrium frequently becomes converted into true bone, the enlargement being thus rendered nodular and not uniform like the fusiform swellings of the proliferative type. The dense bony enlargements and eburnated joint surfaces are well seen in *x*-ray examination. The familiar "Heberden's nodes" of the fingers are characteristic examples of this process, while the changes in the other joints are not so characteristic and the resulting deformities are more irregular. The production of deformity is a slow process in most cases, though in exceptional cases it may be rapid. The progress of the disease may be steady and continuous, or characterized by remissions, after each of which a more or less acute attack occurs with pain, tenderness, and increased swelling in some cases.

Peri-articular changes involving the synovial membrane and occasionally the capsule consist of proliferation of the synovial membrane to form the overgrowth projecting into the joint, as previously described. The consistency of these outgrowths varies, as already stated; they may be composed of granulation tissue which gradually becomes transformed into fatty tissue (*e.g.*, lipoma arborescens), or the synovial tags may contain cartilage or bone,

while other masses of bone or cartilage may form in the capsule and thus be extra-articular. Detachment of bony or cartilaginous synovial tags gives origin to the "joint mice" above described.

As has been previously stated, the result of the growth of these papillary projections from the synovial membrane is the production of more or less functional disturbance. Repeated traumatisms and constriction of the soft-tissue tags cause recurrent attacks of acute synovitis, a common event in degenerative arthritis. If strangulation of a synovial tag occurs, the ensuing infarction and necrosis may cause such disturbance as to make their removal by operation necessary. In other cases, "locking" of the joint in the case of cartilaginous or bony tags, pedunculated or free, may occur with sudden pain and the production of an acute traumatic synovitis. In other



FIG. 150.—Osteo-arthritis (degenerative type of arthritis deformans) of hip-joint. Hip dislocated, with "wandering" acetabulum. Old acetabulum filled up with new-formed bone.

instances, these papillary masses may cause no disturbance whatever. Joints in which these synovial protuberances are present are subject to chronic effusion or to recurrent attacks of synovitis, and the effusion, together with the presence of these masses, gives a doughy sensation on palpation, when the masses can sometimes be felt. Occasionally these fungous growths are the predominating feature of the lesion and their removal is attended by great relief of symptoms and improvement of the joint function. In other cases, erosion of cartilage and deformity are the outstanding features. As a rule, the larger the joint the larger are the masses.

The *x*-ray appearance of a very advanced lesion of the above character is variable. The line of articulation is often toothed and irregular; the ends of the bones are much enlarged and relatively impermeable to penetration by *x*-ray; increased joint space, due to effusion; foreign bodies attached or free, in the former case giving the picture a cloudy appearance, and in the latter event appearing as discrete spots in the joint space.

The most extreme degree of lesion of this type presents merely an exaggeration of the foregoing changes. Increased irregularity of the articulation finally causes such stretching and destruction of ligaments that the joint-motion may become flail-like. The deposit of peripheral perichondrial new bone (osteophytes) enlarges and deforms the articular facets so greatly that subluxation or actual dislocation occurs. This is most strikingly seen at the hip-joint (Fig. 150), where the acetabular cavity may be completely filled, and the dislocated femoral head forms a new articulation with the pelvis, and the head becomes flattened to a mushroom-like structure by erosion and attrition, and broadens laterally by osteophytes at its periphery. The degree of deformity varies with the cause of the affection and according to other incidental elements varying with different joints. Although extreme deformities frequently occur, shortening, malposition, etc., it is remarkable that considerable functional power often remains, and in no case does true ankylosis or absolute suspension of function occur, although in many instances function is greatly impaired. Pain bears no definite relationship to the degree of deformity, being sometimes great in cases with slight distortion and again inappreciable where the deformity is extreme.

Clinical Features.—Constitutional derangement is so slight that in most instances the lesions become well advanced before any joint symptoms are manifested. Pain is variable and is elicited not only by trauma applied directly to the affected joint or extreme movements of the degenerated joint, but in many cases by ordinary locomotion or function.

The disease develops so slowly and insidiously that a period of years is sometimes required for an advanced lesion to be developed. Subjective distress and discomfort are usually outweighed by the disability from stiffness and distortion. The self-limited character of the disease is evidenced by the fact that in some instances after the lesion has run its course the cartilaginous or osseous monuments erected to its memory are the only residual signs of the malady. Discomfort and stiffness on movement frequently remain, and, in the case of the lower limbs, permanent lameness, especially if there is much distortion present. The only constitutional disability of any note relates to the alimentary tract, and consists of flatulency and constipation and occasionally discomfort after meals and headache. The toxemia following constipation in these cases is almost invariably recorded by the joints and manifested by exacerbations of symptoms.

Prognosis.—The facts that the lesions are self-limited and that they produce no profound secondary changes of local or constitutional character, make the outlook much more favorable than in many other forms of arthritis. In the small joints of the hands and feet, the acute painful process yields favorably to proper nursing and support. The new formations of cartilage or bone are permanent, but their interference with function varies. There is very little interference with function in the small joints of the hands and feet, while more or less restriction of motion always remains in the joints of the spine, although the painful stage of the process can be considerably mitigated by proper treatment.

The hip- and knee-joints offer the worst prognosis. In the case of the hip, this type of arthritis is capable of producing worse distortions and functional restrictions than any other lesion. Particularly disabling is the synchronous involvement of the lumbar spine and both hip-joints.

It can be reasonably assured to the patient that proper protective treatment, systematically followed for a sufficient length of time, will, in most early cases, have the following effects: (1) modification of the symptoms; (2) preservation of sufficient motion to permit more or less function.

Treatment.—*General Measures.*—On general principles, stimulation of all the *emunctories* is indicated, the *skin*, by bathing, rubbing, friction, massage, alternating douches of hot and cold water; the *bowels* kept free by a suitable laxative, and the gastric hyperacidity counteracted by bicarbonate of soda; the *kidneys* kept active by drinking freely of pure water whose mineral content is low.

Local Treatment of the Joints.—*Support* and *protection* should be afforded the diseased joint, prohibiting the extremes of motion, in view of the well known rôle of repeated slight traumatisms in producing and perpetuating the degenerative type of lesion and because of the danger of breaking off and setting free in the joint one of the overgrowths of synovial tags, cartilaginous or bony masses. In lesions of the fingers, a loose glove of heavy type with light steel stays in their flexor surfaces is a useful means of support. Aluminum or other metal gauntlets with flexible wire extensions, permitting them to be moulded, may be used to support and protect a carpal lesion.

Massage directly applied to the joints is inadvisable, although very beneficial when administered to the skeletal muscles of the limb in question. For the *relief of pain* which is sure to follow overactivity of an affected limb, and to overcome muscle-spasm, fixation of the joint by some sort of apparatus is necessary, such as plaster-of-Paris or leather splints especially made to fit the joint involved. *Crutches*, in the case of lesion of the joints of the lower limbs, may be advisable in the acute stage. In all cases of the degenerative type, manipulation and forcible correction of the deformity are contraindicated.

Diet.—There is no object in restricting any but the most highly seasoned and indigestible foods.

Local Heat.—Baking, hot water stupes, electricity, etc., are satisfactory means of applying local heat, and may be provocative of good results. High frequency and static electricity often act as an anodyne.

Endocrine Therapy.—The use of pituitary extract and thymus extract is indicated in the manner and dosage recommended for the proliferative type (see p. 328, this chapter).

Serum and Vaccine Therapy.—Every case should be studied from the viewpoint of focal infection and upon the intelligent appreciation of this factor rests the whole fabric of treatment by vaccines, serums, etc., which is considered in detail in the section on focal infections (see p. 295).

Operative Treatment.—Several operative procedures are in vogue which are applicable to the degenerative type of arthritis.

1. *Arthrotomy* is particularly applicable to the knee-joint for (*a*) the removal of obstructive spurs, (*b*) to obtain greater motility, and (*c*) for the removal of foreign bodies locking the joint, etc., and is most satisfactorily performed by median section of the patella (Jones) (see Chapter XV). Arthrotomy of other regions is more fully described elsewhere in this book.

2. *Osteotomy* may be necessary to correct deformity, relieve strain on the joint or make the most of the existing limited motion. The technic of the various procedures will be found in the chapters dealing with the joint in question.

3. *Arthrodesis* (in the case of a degenerative joint lesion) is, as a rule, performed only in those cases with extremely painful advanced processes, and is particularly favorable in the hip and knee, although it affords great relief in any joint which is particularly sensitive. (See Chapter VI, p. 215, for technic of author's arthrodesis of hip.)

4. *Arthroplasty*, for mobility in obstructive lesions, is preferably performed by means of the free fat fascial flap or Baer's interposition of mem-

brane from pig's bladder. (See Chapter XXVIII on arthroplasties and special chapters for technic of arthrodesis of individual joints.)

Conclusions

The conclusions drawn by Nichols and Richardson at the close of their publication (*loc. cit.*) on the subject of arthritis deformans are so eminently fitting that they are herewith quoted:

"1. In non-tubercular deforming arthritis, there are two pathological types of joint change: (1) the proliferative type, which tends to destroy joint cartilage and lead to ankylosis of adjacent joint surfaces, and (2) the degenerative type, which tends to destroy the joint cartilages and produce a deformity without ankylosis.

"2. These two types do not correspond to two definite diseases, but each type represents reaction of the joint tissues to a considerable variety of causes.

"3. In neither type, if the original injury is sufficiently severe or if the causative factor continues to act, is there likelihood of the regeneration of a perfect joint.

"4. A joint injury of a sufficient degree, even if the primary cause ceases to act, may of itself continue to act in a vicious circle as a cause of continued joint change.

"5. Clinically, the aim should be to recognize the type and stage of the lesion present, and then to determine and remove the active cause.

"6. The prognosis should be guarded because of the difficulty in determining the active cause, because of the unlikelihood of complete regeneration of a severely injured joint, and because of the known clinical history of many of the cases.

"7. The nomenclature used in this article (Note: and adopted by the author) is suggested because it describes the pathological process without any assumption that the etiology is known in any given case.

"8. Further advance in the study of these processes may be expected from a study of their etiology."

Still's Disease

This is a peculiar polyarthritis of childhood, related clinically to arthritis deformans. It was first described in 1899 by Dr. G. F. Still, whose name it bears. It is a condition of arthritis deformans of special symptoms and is not to be confused with the ordinary types (just described) of arthritis deformans which affects children, but without splenomegaly or lymphadentis.

The cause is unknown, although enlargement of the lymph-glands and spleen points strongly to an infectious origin. The process begins acutely or insidiously, and usually before the second dentition. Although creaking of the tendons in their sheaths is a marked feature, there is no bony irregularity and no grating. Tenderness and limitation of motion characterize the affected parts. The lesions are polyarticular, but exhibit neither suppuration nor bony ankylosis. Enlargement (occasionally to the point of visibility) and tenderness of the lymph-glands, particularly those draining the involved joints, occur synchronously with the onset of joint symptoms and, *pari passu*, disappear with the joint disturbance. Splenic enlargement begins at the same time with the glandular swelling and may progress until the spleen is palpable 1 to 2 inches below the costal border.

Sweating, mild intermittent fever, and occasionally exophthalmos, have

also been noted. Arrested growth is a striking phenomenon. Although the affection does not endanger life, various degrees of crippling, to the point of hopeless invalidism, may ensue, *e.g.*, fibrous adhesions of joints but without osteophytes or fibrillation of the articular cartilages.

Thus far, the treatment has been purely empirical, viz.: arsenic internally plenty of good food, and a dry, warm, equable climate.

REFERENCES

ARTHRITIS DEFORMANS

NICHOLS AND RICHARDSON: "Arthritis Deformans." Jour. of Med. Research. N. S., xvi, September, 1909.

BAUDOUIN, M.: "L'ostéo-arthrite déformante à l'époque de la pierre polie." Compt.-rend. Acad. d. Sci., Paris, cliv, 1361–1363.

BAUDOUIN, M.: "Les Maladies des animaux préhistoriques; la spondylite déformante chez l'ours des cavernes (Ursus speloeus Bl. J.)." Compt.-rend. Acad. d. Sc. Paris, 1912, cliv, 1822.

BAUMAN, G. I.: "Chronic Deforming Arthritis Developing During the Course of a Tuberculous Infection of the Ankle." Cleveland Med. Jour., 1912, xi, 33–35.

BEITZKE, H.: "Über die Sogen Arthritis deformans atrophica." Ztchsr. f. klin. Med., Berl., 1912, lxxiv, 215–229.

BOORSTEIN, S. W.: "Abstract of Treatment of Arthritis Deformans in Montefiore Home, with Report of Cases." New York Med. Rec., 1912, xxxi, 265–267.

BOORSTEIN, S. W.: "Institutional Treatment of Arthritis Deformans." New York Med. Rec., 1912, lxxxii, 469–473.

CLOTET, B.: "Tractament de les artropaties seques deformants per l'optérapia ovarica." An. Acad. y lab. d. cien. méd. de Cataluña, Barcel., 1912, vi, 1–7.

DELÉARDE AND FONTAN, CH.: "Polyarthrite déformante chez une fillette de 14 ans." Echo méd. du nord., Lille, 1911, xv, 597–600.

ELY, L. W.: "Arthritis Deformans; Preliminary Paper." Am. Jour. Surg., N. Y., 1912, xxvi, 49–52.

EWALD, P.: "Über arthritis deformans." Berl. Klinik, 1911, cclxxxii, 1–17.

FERNANDEZ SANZ, E.: "El Signo de Babinski en el reumatismo crónico deformante." Rev. clin. de Madrid, 1911, vi, 91–96.

FRANK, P.: "Über den Rheumatismus nodosus mit besonderer Berücksichtigung des pathologisch—anatomischen Befundes." Berl. klin. Wchnschr., 1912, xlix, 1358–1361.

GREENE, H. M.: "Arthritis Deformans. Successful Treatment by an Auto-bacterin." N. Y. Med. Jour, 1912, xcvi, 421.

HICKLING, G. N. G.: "The Blood Pressure in Rheumatoid Arthritis and the Effect of Bath Treatment Thereon." Med. Chron. Manchester, 1912–13, lvii, 25–41.

HARDER, T. J.: "Vaccine Therapy in Rheumatoid Arthritis." Lancet, London, 1912, i, 1053.

JORDAN, W.: "Rheumatoid Arthritis in a Child." Brit. Med. Jour., London, 1912, i, 363.

KÜNNE: "Arthritis Deformans im Kindesalter." Deutsch. med. Wchnschr., Leipzig u. Berlin, 1912, xxxviii, 337.

LEDDERHOSE, G.: "Arthritis deformans und Unfall, Aertzl." Sachverst.-ztg., Berlin, 1912, xviii, 345–349.

LUFF, A. P.: "The Diagnosis and Treatment of Rheumatoid Arthritis and Other Forms of Infective Arthritis." Practitioner, London, 1912, lxxxviii, 22–33.

MORRIS, E. H.: "Observations on the Uric Acid Excretion in one Normal Person and in Four Cases of Rheumatoid Arthritis." Bull. Comm. Study Spec. Dis., Edinburgh and London, 1912, iii, 57–66.

NOBEL, E.: "Ein Fall von Arthritis Chronica Progressiva." Wien. med. Wchnschr., 1912, lxii, 527.

OPPENHEIM, R., AND LAMY, P.: "Essai de traitement du rheumatisme déformant par la Tuberculin." Clinique, Brux., 1912, xxvi, 599–607.

PARKER, F. H.: "Rheumatoid Arthritis; a Personal Experience of the Disease." Brit. Med. Jour., London, 1911, ii, 1351–1353.

SALOMON, H.: "Deformierende polyarthritis mit nervösen Symptomen." Mitt d. Gesellsch. f. inn Med. u. Kinderh. in Wien., 1912, xi, 20.

SAUNDERS, A.: "A Case of Rheumatic Nodules." West. London Med. Jour., London, 1912, xvii, 39.

SENISE, T.: "L'azione terapeutica degli ioni e l'etiologia dell' artrite deformante amiotrofica." Studium, Napoli, 1912, v, 90–98.

SMITH, P. H.: "The Incidence of a History of Vaginal Discharge in 115 Cases of Rheumatoid Arthritis." Bull. Comm. Study of Spec. Dis., Edinburgh and London, 1912, iii, 92–96.
SMITH, J. S. K.: "Arthritis Deformans and a Purin-free Diet." Med. Press and Circ., London, 1912, N. S., xciv, 56–58.
TAYLOR, A. E.: "Rheumatoid Arthritis." Australas. Med. Jour., Melbourne, 1911–12, N. S., i, 477–480.
TUBBY, A. H.: "Two Lectures on Arthritis Deformans." Clin. Jour., London, 1911–12, xxxix, 1, 21.
WILLIAMS, C.: "*X*-rays in the Treatment of Rheumatoid Arthritis." Practitioner, London 1912, lxxxviii, 141–144.
WILSON, H.: "Thyroid Extract in Rheumatoid Arthritis." Therap. Med., N. Y., 1911, xxv, (v), 381.
WOODWARK, A. S., AND WALLACE, R. L. M.: "The Relation of the Gastric Secretion to Rheumatoid Arthritis." Lancet, London, 1912, ii, 942–944.
ABELS, H.: "Eine seltene Erscheinungsform von Rheumatismus nodosus." Wien. klin Wchnschr., 1913, xxvi, 440.
AXHAUSEN: "Über das Wesen der Arthritis deformans." Berl. klin. Wchnschr., 1913, i, 126–128.
BARR, SIR. J.: "An Address on Rheumatoid Arthritis." Brit. Med. Jour., London, 1913, i, 753–755.
BARR, SIR. J.: "Rheumatoid Arthritis." Brit. Med. Jour., London, 1913, i, 911.
BAUDOUIN, M.: "La polyarthrite alvéolaire depuis le quaternaire jusquà l'époque romaine." Arch. prov. de chir., Paris, 1912, xxi, 738–749.
CAMERON, W. H.: "Radium Emanation Therapy in Arthritis Deformans." Radium, Pittsburgh, 1913, i, 3–5.
CANNEY, L.: "The Cause of Rheumatoid Arthritis." Brit. Med. Jour., London, 1913, ii, 833.
CASSIDY, M. A.: "A Case of Rheumatoid Arthritis." Proc. Royal Soc. Med., London, 1912–1913, vi, Clin. Sect., 131.
CROWE, H. W.: "A Contribution to the Etiology of Rheumatoid Arthritis." Lancet, London, 1913, i, 1377–1379.
DAVY, P. C. T.: "Vaccine Treatment in Subacute and Chronic Arthritis." Jour. Roy. Army Med. Corps, London, 1913, xx, 53–55.
ELY, L. W.: "The Etiology of Chronic Non-tuberculous Arthritis, the Miscalled Arthritis Deformans." Am. Jour. Orth. Surg., Phila., 1912–13, x, 171–177.
ELY, L. W.: "Chronic Arthritis." Jour. Am. Med. Ass'n, Chicago, 1913, lxi, 670.
GARRY, T. G.: "The Cause of Rheumatoid Arthritis." Brit. Med. Jour., London, 1913, ii, 1185.
HICKLING, G. H. G.: "Notes on the Clinical History of Rheumatoid Arthritis." Med. Chron., Manchester, 1912–13, lvii, 317–341.
HILLEBRECHT: "Zur klinik des Rheumatismus nodosus." Med. Klin., Berlin, 1913, ix, 208–210.
IPATOFF, K. V.: [Fibrolysin in Arthritis Deformans] Vrach." Gaz., S. Petersb., 1913, xix, 1219–1256.
JONES, J. J.: Rheumatoid Arthritis with Exhibit of Cases." Delaware State Med. Jour., Wilmington, 1912–13, iv, 1–8.
LAUMONIER, J.: La diététique de la polyarthrite deformante." Gaz. méd. de Paris, 1912, lxxxiii, 318–320.
LINDSAY, J.: "Vasomotor Phenomena as a Premonitory Symptom in Rheumatoid Arthritis." Clin. Jour., London, 1913–14, xlii, 268–271.
VON MANTEUFFEL: Über experimentelle Arthritis deformans." Deutsch. Zeitschr. f. Chir., Leipzig, 1913, cxxiv, 321–327.
MIDELTON, W. J.: "The Cause of Rheumatoid Arthritis." Brit. Med. Jour., London, 1913, ii, 772.
MIDELTON, W. J.: Some Notes of Arthritis Deformans, with an Analysis of 50 Cases Treated by Means of Continuous Counter-irritation." Med. Press and Circ., London, 1913, N. S. xcvi, 422.
PALMER, F. S.: A Case of Rheumatoid Arthritis, with Bursal Complications." West London Med. Jour., London, 1913, xviii, 45.
PORTER, F.: Notes on a Case of Rheumatoid Arthritis Treated with Subcutaneous Injections of Rheumatism Phylacogen." Lancet, London, 1913, i, 1588.
SOLTAN, A. B.: A Note on the Use of Vaccines in the Treatment of Rheumatoid Arthritis. Lancet, London, 1913, i, 1379.
STAFFEL, A.: "Zur Casuistik der Arthritis deformans des Hüftgelenks als Berufskrankheit." Arch. f. klin. Chir., Berlin, 1912–13, c, 593–596.

STOUTENBURGH, J. A.: "What Can be Done for the Relief of our Arthritic Patients?" Am. Med., 1913, N. S. viii, 259–263.
THOMSON, F. G.: "Some Problems Connected with Rheumatoid Arthritis." Brit. Med. Jour., London, 1913, i, 335–337.
WAGNER, K.: "Zur Aetiologie der Arthritis deformans." Wien. med. Wchnschr, 1913, lxiii, 1907–1910.
WATSON, T. A.: "The Cause of Rheumatoid Arthritis." Brit. Med. Jour., London, 1913, ii, 704.
WOLLENBERG, G. A.: "Zur Therapie der Arthritis deformans." Zeitschr. f. orthop. Chir., Stuttg., 1913, xxxii, 442.
AXHAUSEN, G.: "Über das Wesen der Arthritis deformans." Ztschr. f. orth. Chir., Stuttg., 1913, xxiii, 223.
AXHAUSEN, G.: "Neue Untersuchungen über die Rolle der Knorpelnekrose in der Pathogenese der Arthritis deformans." Arch. f. klin. Chir., Berlin, 1914, civ, 301–346.
AXHAUSEN, G.: "Die Entstehung der freien Gelenkkörper und ihre Beziehungen zur Arthritis deformans." Ibid., 581–679.
BAUDOUIN, M.: "L'osteo-arthrite déformante chronique à l'âge de la pierre polie, dans l'ossuaire de Bazoges-en-Pareds (Vendée)." Bull. Soc. franc. d'hist. de la méd., Paris, 1914, xiii, 96–102.
BILLINGS, F.: "Clinical Aspect and Medical Management of Arthritis Deformans." Illinois Med. Jour., Chicago, 1914, xxv, 14–17.
BROWN, D. D.: "Rheumatic Arthritis." Brit. Med. Jour., London, 1914, ii, 666.
CHLOUPEK, C. J.: "Arthritis Deformans." Wisconsin Med. Jour., Milwaukee, 1913–14, xii, 221–225.
CROWE, H. W.: "The Primary Cause of Rheumatoid Arthritis." Lancet, London, 1913, ii, 1460–1464.
DAVIS, D. J.: "The Etiology and Pathologenesis of Rheumatoid Arthritis." Illinois Med. Jour., Chicago, 1914, xxvi, 156–163.
DONALD, J.: "The Cause of Rheumatoid Arthritis." Brit. Med. Jour., London, 1913, ii, 1647.
ELLIOTT, G. R.: "The Operative Treatment of Contracted and Deformed Hands in Multiple Arthritis; a preliminary paper." New York Med. Jour., 1914, c, 957–959.
FULLER, E.: "The Cure through Genito-urinary Surgery of Arthritis Deformans and Allied Varieties of Chronic Rheumatism." Trans. Am. Ass'n Genito-Urin. Surg., N. Y., 1913, viii, 121–134.
GEIST, E. S.: "Chronic Multiple Arthritis." Journal-Lancet, Minneapolis, 1914, xxxiv, 128–131.
HASTINGS, T. W.: "Complement-fixation Tests in Chronic Infective Deforming Arthritis and Arthritis Deformans." Jour. Exp. Med., Lancaster, 1914, xx, 52–71.
HILLER, K.: "Arthritis Deformans (Chronic Infective Arthritis)." Med. Jour. Australia, Sydney, 1914, i, 341–344.
HIRSH, A. B.: "Deforming Arthritis and Intestinal Stasis." Jour. Advanc. Therap., N. Y., 1913, xxi, 432–442.
HODGE, E. H. V.: "Nodular Subacute Rheumatism in an Adult." Indian Med. Gaz., Calcutta, 1914, xlix, 19.
JONES, R.: "On the Treatment of Arthritic Deformities." Brit. Med. Jour., London, 1914, ii, 741–745.
LEDDERHOSE: "Arthritis Deformans." Deutsch. med. Wchnschr., Leipzig, u. Berlin, 1913, xxxix, 2437.
MURPHY, J. B.: "Rheumatoid Arthritis." Surg. Clin., Chicago, 1913, ii, 531.
OSGOOD, B.: "Certaines types d'arthrite déformante et leur traitement." Orthop. et tuberc. chir., Paris, 1914, i, 93–124.
PEMBERTON, R.: "The Metabolism, Prevention, and Successful Treatment of Rheumatoid Arthritis; second contribution." Am. Jour. Med. Sci., Phila. and New York, 1913, cxlvi, 805; 1914, cxlvii, 111; 265; 423.
PEMBERTON, R.: "The Nature and Successful Treatment of Rheumatoid Arthritis." Internat. Clin., Phila., 1914, 24, s. iii, 55–61.
ROBERTS, P. W.: "The Practical Management of Chronic Osteo-arthritis." Med. Rec., New York, 1914, lxxxv, 829–833.
ROSENOW, E. C.: "Etiology of Arthritis deformans; preliminary note." Jour. Am. Med. Ass'n, Chicago, 1914, lxii, 1146.
SCHANZ, A.: "Zur Aetiologie und Therapie der Arthritis deformans." Verhandl. d. Deutsch. orthop. Gesellsch., Stuttg., 1913, xii, 177–183.
SILVER, D.: "Our Present Conception of Arthritis Deformans." Penn. Med. Jour., Athens, 1913–14, xvii, 615–621.
VON STUBENRAUCH, L.: "Die deformiererende Gelenktentzündung (Arthritis deformans) im Lichte neuerer Forschungen." Münch. med. Wchnschr., 1914, lxi, 1404; 1505.

SWAIM, L. T.: "A Study of 15 Cases of Hypertrophic Arthritis." Clifton Med. Bull., Clifton Springs, N. Y., 1913, I, 54–59.
WOLLENBERG, G. A.: "Zur Therapie der Arthritis deformans." Verhandl. d. deutsch. orth. Gesellsch., Stuttg., 1913, xii, 190.
YAKUNIN, N. N.: "The Thyroid Gland and Arthritis Deformans." Med. Obozr., Mosk., 1913, lxxx, 731–737.
AXHAUSEN: "Die Entestehung der freien Gelenkkörper und ihre Beziehung zur. Arthritis deformans." Verhandl. d. deutsch. Gesellschl f. chir., Leipzig, 1914, xliii, 1, Teil. 182–186.
BOORSTEIN, S. W.: "Chronic Progressive Polyarthritis or Arthritis Deformans, with a report of 105 cases." Med. Rec., N. Y., 1915, lxxxvii, 1009–1019.
BRACKETT, E. G.: "Operative Treatment of Osteo-arthritis." Am. Jour. Orth. Surg., Phila., 1914–15, xiii, 46–58.
BURT, J. B.: "The Production of Osteophytes and Exostoses in Chronic Gout and Arthritis Deformans." Proc. Roy. Soc. Med., London, 1913–14, vii, Balneo. (etc.) Sect., 45–48.
COMSTOCK, A.: "The Treatment of Rheumatoid Arthritis." Am. Med., Burlington, Vt., and N. Y., 1915, N. S. x, 420–422.
CROWE, H. W.: "The Primary Cause of Rheumatoid Arthritis." Proc. Roy. Soc. Med., London, 1913–14, vii, Path. Sect., 25–36.
DAVIDSON, P.: "Rheumatoid Arthritis." Liverpool Med. Chir. Jour., 1915, xxxv, 305.
ELLIOTT, G. R.: "Arthritis Urica; the Relationship of its Arthritic Findings to those of Certain Other Types of Chronic Multiple Arthritis." Am. Jour. Orth. Surg., Phila., 1915–16, xiii, 179–191.
GOADBY, K.: "Arthritis of Mouth Origin." Tr. Internat. Cong. Med., 1913, London, 1914, Sect., xvii, Stomatol. Pt. 2, 191–197.
HASTINGS, T. W.: "Complement Fixation Tests in Infective Deforming Arthritis and Arthritis Deformans." Boston Med. and Surg. Jour., 1915, clxxii, 558.
HEAD, J.: "Osteo-arthritis in its Relation to Mouth Infection." Am. Jour. Orth. Surg., Phila., 1914–15, xiii, 71–85.
HEWLETT, R. T.: "The Bacteriology of Rheumatoid Arthritis." Am. Med., Burlington, Vt., and New York, 1915, N. S. x, 349–351.
KÖHLER, H.: "Die Arthritis deformans bei Subluxatio coxæ: eine statische Erkrankung." Ztschr. f. orth. Chir., Stuttg., 1915, xxxv, 89–109.
LANE, W. A.: "Some Remarks on the Causation and Treatment of Rheumatoid Arthritis." Am. Med., Burlington, Vt., and New York, 1915, N. S. x, 385–390.
LEDDERHOSE, G.: "Die Arthritis deformans als Allgemeinerkrankung." Strassb., 1915, K. J. Trübner, 40 pp. 80.
LLOYD, S.: "The Surgical Treatment of Rheumatoid Arthritis." Am. Med., Burlington and New York, 1915, N. S. x, 456–461.
MEYER, A. W.: "The Effect of Arthritis Deformans (?) on the Tendon of the long Head of the Biceps." Am. Jour. Orth. Surg., Phila., 1915–16, 91–95.
MIDELTON, W. J.: "Two Cases of Arthritis Deformans treated by Continuous Counter-irritation." Proc. Roy. Soc. Med., London, 1913–14, vii, Clin. Sect., 19–21.
MORRISON, J. R.: "Remarks on Arthritis Deformans and so-called Rheumatoid Arthritis." Louisville Month. Jour. M. and S., 1914–15, xxi, 271–276.
NATHAN, P. W.: "The Mechanical Treatment of Deforming Arthritis." Am. Med., Burlington, Vt., and N. Y., 1915, x, 612–621.
POMMER, G.: "Mikroskopische Befunde bei Arthritis deformans." Denkschr. d. k. Akad. d. Wissensch. Math.-naturw. Kl., Wien., 1914, lxxxix, 65–316.
POMMER, G.: "Zur Kentniss der Ausheilungs befunde bei Arthritis deformans, besonders im Bereiche ihrer, Knorppelusuren, nebst einem Beitrag zur Kentniss der lakunären Knorpelresorption." Virchow's Arch. f. pathol. Anat. (etc.), Berlin, 1915, ccxix, 261–278.
POMMER, G.: "Die Chronische deformierende Gelenksentzündung (Arthritis deformans) vom Standpunkte der neuzeitlichen Forschung aus." Ber. d. naturw.-med. Ver. in Innsbruck, 1915, xxxv, 1–36.
PORTER, J. L.: "The Treatment of Rheumatoid Arthritis of the Hypertrophic Type." Am. Jour. Orth. Surg., Phila., 1914–15, xii, 718–721.
ROBINSON, B.: "Rheumatoid Arthritis." Med. Rec., N. Y., 1915, lxxxvii, 206.
ROSENBAUM, J.: "A Study of the Urinary Nitrogen and Sulphur Partition in a Case of Rheumatoid Arthritis Treated with Intravenous Injections of Radium Salts." Am. Jour. Med. Sci., Phila., 1915, cxlix, 718–722.
SNOW, W. B.: "Rheumatoid Arthritis, a Distinctive Form of Multiple Arthritis of Toxic Origin." Jour. Advanc. Therap., N. Y., 1915, xxxiii, 336–340.
STEADMAN, F. St. J.: "A Case of Rheumatic Arthritis Twice Cured by the Removal of Septic Teeth." Proc. Roy. Soc. Med., London, 1913–14, vii, Odont. Sect., 21–28.

Weber, F. P.: "Rheumatic Nodules (rheumatismus nodosus) associated with Rheumatic Torticollis." Proc. Roy. Soc. Med., London, 1913–14, vii, Clin. Sect., 21–25.
Butler, G. F.: "Arthritis Deformans." Illinois Med. Jour., Chicago, xxix, 103–108.
Butler, G. F.: "Further Observations on Arthritis Deformans." Chicago Med. Recorder, 1916, xxxviii, 611–621.
Carroll, J.: "The Diagnostic Importance of the Estimation of Uric Acid in the Blood in Cases of Chronic Arthritis." Med Rec., N. Y., 1916, lxxxix, 389.
Lorenzini, A.: Morbo o sindrome di Still?" Bull. d. sc. med. di Bologna, 1916, 9s, iv, 311–324.
MacCrae, T.: "Chronic Arthritis." Penn. Med. Jour., Athens, 1915–16, xix, 501–507.
Nathan, P. W.: "The Neurological Condition Associated with Polyarthritis and Spondylitis." Am. Jour. Med. Sc., Phila., 1916, cli, 667–688.
Saunders, A.: "A Case of Rheumatic Nodules." West. London Med. Jour., London, 1916, xxi, 118–120.
Senger, E.: "Über die Arthritis deformans und ihre Beurteilung nach Unfällen." Berl. klin. Wchnschr., 1916, liii, 244–246.
Tyler, G. T.: "Some Remarks on Chronic Arthritis with Report of a Case." South. Med. Jour., Birmingham, 1916, ix, 983–985.
Axhausen, G.: "Die deformierende Gelenkentzündung (arthritis deformans) im lichte neuer Forschung. Berl. klin. Wchnschr., 1915, lii, 1205–1209.
Elliott, G. R.: "The Present Status of Chronic Multiple Arthritis, with Special Consideration of Infection as an Etiological Factor." Med. Rec., N. Y., 1916, xc, 666–672.
Murphy, J. B., and Kreuscher, P. H.: "A Clinical and Experimental Study of the Metabolic Arthritides. N. Y., Med. Jour., 1916, civ, 904.
Pietro, E.: "I noduli sottocutanei nel reumatismo articolare acuto." Policlin., Roma, 1915, xxii, sez. prat. 1550–1554.
Ritchie, L. C. P.: "Arthritis Deformans in Relation to Industrial Conditions." Jour. State Med., London, 1916, xxiv, 300–309.
Shropshire, C. W., and Watterston, C.: "The Relation of the Prostate Gland and Seminal Vesicles to the Arthritides." South. Med. Jour., Nashville, 1916, ix, 911–914.
Silver, D.: "The Rôle of Visceroptosis in the Etiology of Arthritis Deformans." Am. Jour. Orth. Surg., Phila., 1916, xiv, 513–521.
Vipond, A. E.: "Recent Work on the Bacteriology of Rheumatoid Arthritis and its Treatment." Am. Med., Burlington, Vt., and N. Y., 1915, x, 894–898.
Ward, A. R.: "Bacterium Pyogenes Associated with a Case of Multiple Arthritis in a Hog." Jour. Bact., Baltimore, 1916, i, 114.
Wharton, E. L.: "The Teeth as a Possible Causative Agent of Arthritis Deformans." N. Jersey Dent. Jour., Newark, 1916, v, 291–295.
Carothers, R.: "Arthritis Deformans from the Surgical Standpoint." Ohio Med. Jour., Columbus, 1916, xii, 89–91.
Hirsh, A. B.: "An Advance in Treatment of Deforming Arthritis (Infectious, Toxic, or Metastatic Arthritis)." Jour. Advanc. Therap., N. Y., 1915, xxxiii, 428–450.
Midelton, W. J.: "Continuous Counterirritation as a Therapeutic Measure in Rheumatoid Arthritis, etc." Practitioner, London, 1916, xcvii, 371–376.
Miller, J. L., and Lusk, F. B.: "The Treatment of Arthritis by the Intravenous Injection of Foreign Protein." Jour. Am. Med. Ass'n, Chicago, 1916, lxvi, 1756.
Pemberton, R.: "The Metabolism and Treatment of Rheumatoid Arthritis." Third paper. Am. Jour. Med. Sci., Phila., 1916, cli, 351–377.
Phillips, J.: "Arthritis Deformans from the Medical Standpoint." Ohio Med. Jour., Columbus, 1916, xii, 91–94.
Rowlands, M. J.: "The Radical Treatment of Rheumatoid Arthritis." Lancet, London, 1916, i, 133–135.
Zeublin, E.: "Radiotherapy in Chronic Arthritis." Med. Jour., N. Y., 1916, civ, 355–360

Arthritis Deformans in Children

Anderson, A. V. M.: "A Case of Subacute Infectious Arthritis (Still's Disease) Treated by Vaccines." Austral. Med. Jour., Melbourne, 1911–12, N. S. i, 421.
Chenhall, W. T.: "Still's Disease." Australas. Med. Gaz., Sydney, 1912, xxxi, 547.
Eden, R.: "Über Osteo-arthritis Deformans Coxæ Juvenilis." Deutsch. Zeitschr. f. Chir., Leipzig, 1912, cxvii, 148–175.
Gibney, V. P.: "A Case of Still's Disease." Med. Rec., N. Y., 1912, lxxxii, 93–96.
Jordan, W. R.: "A Case of Rheumatoid Arthritis in a Child." Brit. Jour. Child. Dis., London, ix, 502–505.
Young, J. K.: "Arthritis Deformans in Children." Pediatrics, N. Y., 1912, xxiv, 276–279.
Bolt: "Juvenile Arthritis Deformans." Deutsch. med. Wchnschr., Leipzig, u. Berlin, 1913, xxxix, 972.

Dock, G.: "Defective Development from Arthritis in Early Life." Trans. Ass'n Am. Phys., Phila., 1912, xxvii, 332–337.
Lindsay, J.: "Rheumatoid Arthritis in Children." Edinburgh Med. Jour., 1913, N. S. x, 332–346.
Stamm, C.: "Rheumatismus nodosus." Arch. f. Kinderh., Stuttg., 1913, lx–lxi, 706–709.
Bade, P.: "Über die Beziehungen der Arthritis deformans juvenilis zum., eingerenken kongenital luxierten Hüftgelenk." Verhandl. d. deutsch. orthop. Gesellsch., Stuttg., 1913, xii, 192–197.
Drehmann, G.: "Osteroárthritis deformans juvenilis (Perthes) Eine typische Belastungsdeformität." Beitr. z. klin. Chir., Tübing., 1914, xci, 642–652.
Holden, O.: "A Case of Still's Disease." Birmingham Med. Rev., 1914, lxxv, 83–90.
Klar: "Beiderseitige Arthropathia deformans coxæ juvenilis (Arthritis deformans juvenilis, Perthes)." Deutsch. med. Wchnschr., Leipzig, u. Berlin, 1914, xl, 1750.
Manning, J. B., and Fassett, F. J.: "Some Considerations Concerning Still's Disease and Arthritis Deformans." Arch. Pediatr., N. Y., 1914, xxxi, 414–418.
Lance, M.: "La poliartritis reumática en los niños (enfermedad de Still)." Clin. mod., Zaragoza, 1914, xiii, 662–668.
von Meyenburg Hanns: "Kasuistische Beiträge zur Frage der Arthritis deformans juvenilis idiopathica. Zürich, 1914." G. Leeman & Co., 28 pp. 3 pl., 8o.
Parkinson, J. P.: "A Case of Rheumatoid Arthritis in a Boy." Proc. Roy. Soc. Med., London, 1913–14, vii, Sect. Stud. Dis. Child., 6–8.

CHAPTER XII

TRAUMATIC AND OTHER AFFECTIONS OF THE SPINE

TRAUMATIC AFFECTIONS OF THE SPINE

The following conditions may properly be regarded as traumatic:

1. Contusions.
2. Rupture or sprain of spinal ligaments.
3. Railway spine, traumatic neurosis.
4. Coccygodynia.
5. Traumatic spondylitis, Kümmell's disease.
6. Spondylolisthesis.
7. Dislocation of the spine.
8. Simple fracture of the spine.
9. Fracture-dislocation of the spine.
10. Gunshot and stab wounds.

1. Contusions

The importance of contusions lies in the occasional damage to the spinal cord which follows: in some cases, severe hemorrhage with disintegration of the involved segment of the cord has resulted. Mild cases without hemorrhage present prolonged stiffness of the back, which may be temporarily incapacitating.

2. Rupture or Sprain of the Spinal Ligaments

Rupture or sprain of the spinal ligaments is not infrequent, especially of the flava or subflava ligaments that bind the laminæ of the vertebræ. Undoubtedly, a large number of the cases that complain of sharp pain in the back and stiffness following excessive movements and after the lifting of heavy weights are due to the stretching and tearing of these ligaments. According to the degree of injury, we may have symptoms ranging from mere stiffness and local tenderness to rigidity and severe pain. Even shock and later swelling, ecchymosis, and hematoma may be present. In the very severe cases it is unusual to get extensive tear of the ligaments without an associated fracture or dislocation of the vertebræ. It is of interest to note that several cases have been reported in which the spinal cord has been seriously injured without any evidence of either a fracture or a dislocation. These cases are all practically due to hyperextension of the spine. It is not improbable that a good many functional nervous disorders have their origin in slight traumata of the spine. These are the so-called railway spines.

Treatment.—The treatment consists of rest, either simple recumbency in bed or by supporting the spine with plaster jacket. Massage intelligently applied is of benefit. The surgical treatment in these cases is limited to the relief of pressure on the cord, which may be produced either by a blood-clot or by the rupture of a ligament.

3. Railway Spine, Traumatic Neurosis

This consists of functional disturbance of the nervous system without demonstrable lesion of the spinal cord, and is dependent upon railroad or

similar accidents. There may be sprain of the lumbar muscles but without anatomical disturbance of the spine or cord. The chain of symptoms ensuing is due simply to autosuggestion from the mental image of the accident.

In some cases, persons have extricated themselves from a wreck, assisted in giving aid to others, walked a considerable distance, and then collapsed, passing gradually into a state of hypochondriasis or even melancholia, without manifesting any sign of physical disturbance of the spine or cord.

Treatment is largely by psychotherapy, but contusion of the lumbar muscles, if present, is treated by friction, massage, electricity, etc.

Hysterical and Neurotic Spine.—These conditions (closely related to railway spine) are merely manifestations of a morbid psychology and will be found fully discussed in works on that subject.

4. Traumatic Spondylitis, Kümmel's Disease

This is a non-tubercular rarefying osteitis of the vertebral bodies, first described by Kümmell in 1895. The softening and collapse of the bodies give rise to deformities not unlike Pott's disease. After a more or less severe sprain or injury to the back, causing very little suffering, the patient soon returns to his work, and only after weeks or months does severe pain call his attention to a rounded kyphosis, generally in the dorsal region.

The vertebræ from the third to the seventh dorsal are usually affected, although the lumbar and the cervical vertebræ may be attacked. There is always a history of injury, several authorities maintaining that the condition is essentially that of fracture with subsequent softening of the callus from a too early use of the spine.

Symptoms.—The symptoms are first those due to injury, and after a varying interval of rest, pain occurs at the seat of the lesion, with a gradually developing round kyphosis usually involving several vertebræ. It is most frequent in adults. The cord, as a rule, escapes compression.

Treatment.—The prognosis is good, and the best results are obtained by fixing the spine either by plaster jackets or, if the case is severe, by the author's operation as done for Pott's disease, described in this work elsewhere (see operation for Pott's disease).

5. Coccygodynia (Coccydynia)

Coccygodynia is a painful condition in the region of the coccyx. It is far more common in females than in males. In the severe cases there is usually a history of a blow, such as striking on the end of the spine or from a kick. It has also been brought on by long-continued horseback riding. In some cases no cause can be found and no lesions of the coccyx discovered. The coccyx is usually displaced either forward, backward, or laterally. In some cases a nodule from overgrowth of bone is found on the tip or side of the coccyx, and pressure at this point causes severe pain. Walking, defecation, and riding over rough pavements, increase the pain; pressure from finger in the region elicits severe pain, which is referred to the fifth sacral and coccygeal nerves. The contour and position of the bone are readily ascertained by the *x*-ray and external and rectal examination. Patients suffering with coccygodynia are apt to be highly neurotic.

Treatment.—Treatment consists of sedatives applied locally, as oleate of morphia. Counterirritants are contra-indicated because of proximity to the anus and the danger of setting up a dermatitis in the gluteal cleft. The bowels should be kept well open and the patient advised to sit on an air

cushion or forced to lie on the side for a few weeks. High frequency electricity applied by means of special electrodes has been found efficacious in the hands of the author. If the symptoms do not subside under conservative methods, and there is evidence of pathological changes in the bone from trauma or disease, an operation should be performed and an excision of the whole or a portion of the bone resorted to.

Operation is simple. The incision should be made near the midline, and the knife should be kept close to the bone so as to avoid injurying the sacral and coccygeal nerves. When the fascia is removed from the tip of the coccyx, the anus becomes somewhat dilated because of the attachment of the external sphincter muscle to this bone. This patulous condition can be overcome and the anus restored to the normal appearance by placing deep sutures from the periosteum of the sacrum through the tendinous portion of the external sphincter. After the operation, the legs should be fixed together and the patient directed to lie upon the side. Cathartics are given on the third or fourth day. Every precaution should be taken to avoid operating upon a neurotic patient.

6. Spondylolisthesis

This is a chronic dislocation at the lumbosacral junction or between the fourth and fifth lumbar vertebræ, whereby the lumbar vertebral column slides

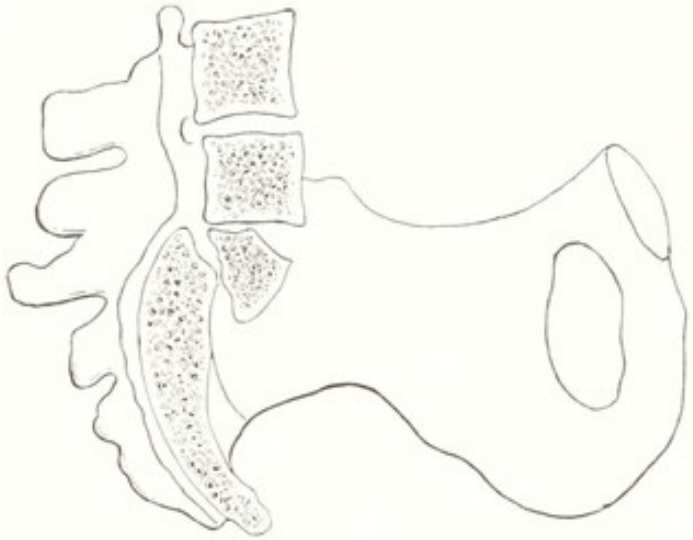


Fig. 151.—Spondylolisthesis produced by fracture of the upper segment of the sacrum and its dislocation forward and downward.

forward on the pelvic inlet (Fig. 151). Partial spontaneous reduction of the deformity on recumbency, with recurrent dislocation on resuming the erect posture, is a common and distinctive feature of the condition.

Mechanics of Production.—The amount of displacement varies from a very slight luxation to a dislocation so extensive that the fifth lumbar vertebra slips forward and downward through 90° until its normally inferior surface is opposed to the anterior surface of the first or first and second sacral segments, with subsequent synostosis in this position. Thus the normal anterior surface of the fifth lumbar vertebra faces downward, and the articulation between the fourth and fifth lumbar replaces the normal lumbosacral angle. This causes more or less blocking of the pelvic inlet. The pedicles are thinned and elongated or actually severed, the laminæ and spinous processes being forced backward. The affected vertebral body becomes wedge-shaped; its lower disk is absorbed and it may fuse with the sacrum. The

sacral promontory is now replaced by the prominence of the fourth, third, or second lumbar vertebræ.

Neugebauer makes the following classification of spondylolisthesis;

1. Neural arches separated from bodies.
   (*a*) Defective development, congenital.
   (*b*) Traumatic form, from pressure.
2. Change in form of the vertebral body from
   (*a*) Disease.
   (*b*) Superimposed weight and pressure changes.

Causation.—Injury may precipitate the condition. The female sex, aside from the relaxation of ligaments incident to *pregnancy*, is particularly subject to the disorder.

Clinical Features.—Displacement of the spinal column downward and forward, with consequent forward displacement of the whole trunk, is the distinctive feature. In compensation for this, the pelvic inclination is decreased, so that the symphysis pubis is on a level with the first sacral segment, or even on a higher plane. These changes result in a vertical shortening of the entire trunk in the abdominal region, which is strikingly evident in the front view, on account of the high position of the symphysis pubis. Diminished inclination of the pelvis causes broadening and flattening of the gluteal region and prominence of the posterior inferior iliac spines. The iliac crests stand out sharply from the loins. The condition has been adequately named "saddle-back," the lumbar region and loins appearing to fall away. The buttocks are small, and the posterior pelvic outline is quadrilateral.

The lumbar lordosis, diminution of the pelvic inclination, and vertical shortening of the trunk are almost pathognomonic of spondylolisthesis when combined with the detection of the marked angularity between sacrum and lumbar vertebræ on vaginal or rectal examination. Associated with these changes are partial flexion of hips, knees, and ankles when the patient stands.

Diagnosis.—Congenital dislocation of the hip can be differentiated by the fact that the legs and not the trunk are shortened and the gluteal region is not flattened but prominent; in dislocation, too, the trochanters are above Nélaton's line and the heads of the femora are displaced.

From Pott's disease, by the *flattening* of the lumbar spine and subsequent *prominence* of the spinous processes: the reverse of this takes place in spondylolisthesis, with muscular and bony rigidity, and serves to distinguish the two affections.

Rickets can be eliminated by the *increase* of the pelvic inclination and the fact that lordosis is exceptional.

Treatment.—The former treatment of this condition proved most unsatisfactory. It consisted of prolonged rest in bed with extension applied to the legs, followed by the wearing of a long plaster-of-Paris or steel spinal support reaching well down over the buttocks. In some instances, even laminectomies have been performed in an effort to relieve paralytic symptoms. One such case was reported by Sir Arbuthnot Lane, of London. In cases of great deformity, permanent external support has been necessary, although unsatisfactory.

The bone-graft, applied as in the treatment of Pott's disease, has solved this hitherto most difficult problem. The graft is inserted by precisely the same technic as that employed by the author for lumbar Pott's disease (see Chapter II). As a rule, the lordosis is readily corrected under an anesthetic, by placing the patient on the operating table in the prone position. If this should not produce sufficient correction, further flexion of the spine can be accomplished by placing a firm pillow under the lower portion of the

abdomen. The bone-graft offers the only means effecting a permanent cure in the severer cases.

An illustrative case is that of a young man, eighteen years of age who had a year and a half previously, while boxing, sustained a severe injury to the lumbar spine by being knocked against the ropes, a trauma which could readily produce such a displacement. Soon after, the patient noticed muscu-



FIG. 152.



FIG. 153.

FIG. 152.—A case of spondylolisthesis in a young man of 18 following an injury in a prize fight. Deformity reduced and reduction maintained with bone graft.

FIG. 153.—Illustrating a case of the application of the bone graft for marked spondylolistheses of the lumbar vertebra on the sacrum. A strong graft removed from the tibia has fixed this segment of the spine to the sacrum correcting the lordosis and relieving all symptoms.

lar weakness, numbness, and prickly sensations in the legs when standing or walking for any length of time. These symptoms increased until he was obliged to give up his occupation. He also noticed the increasing deformity of his lumbar spine. The recumbent position relieved this symptom.

Under full anesthesia, prone upon the operating table, the displacement was easily corrected, and an unusually strong graft, spanning the third, fourth, and fifth lumbar spines and the first and second segments of the

sacrum, held this portion rigidly fixed in its corrected position. The patient was kept on a fracture bed for five weeks, after which a long plaster-of-Paris jacket, moulded over the buttocks, was applied and worn for two



FIG. 154.—Lateral rontgenogram of spondylolisthesis between the third and fourth lumbar vertebræ after reduction and fixation by author's spinal bone graft in spinous processes. The dislocation forward of the third lumbar vertebra on the fourth, in this male patient of 18 years of age, occurred in the boxing ring from being knocked through the ropes. Pressure on the spinal cord resulted which has been entirely relieved by the operation.

months (see Figs. 152, 153 and 154). The symptoms were completely relieved.

Ryerson also has reported a very successful case treated by this method.

7. DISLOCATION OF THE SPINE

Dislocation of the vertebræ without fracture is not infrequent. Keen states that about 20 per cent. of injuries of the spine are pure dislocations;

another 20 per cent. being simple fractures, and the remaining 60 per cent. being the so-called fracture-dislocation. Pure dislocation is practically limited to the fourth, fifth, and sixth cervical vertebræ, and consists of a unilateral or bilateral dislocation forward, or a bilateral dislocation in opposite directions. Associated with the dislocations, the ligaments, particularly the intervertebral disk and the ligaments of the arches and their processes, are badly torn.

Symptoms.—The symptoms depend upon whether the cord has been injured or not. Sometimes the vertebræ may be displaced to such an extent that the cord will be torn by the displaced vertebræ, which are then pulled back into their original positions by the elasticity of the surrounding soft structures. Deformity is the most important symptom in dislocation. The pain, tenderness, rigidity, and deformity all help to make the diagnosis certain, even without the *x*-ray.

Very slight injuries may cause a dislocation of the cervical spine, which is illustrated by a case that came under the author's care. A boy, fifteen years of age, while hurriedly lacing his shoes for school, pulled rather violently, causing the lace to break, and his head to be thrown back with such force as to dislocate an upper cervical vertebra unilaterally. His head was inclined toward the right shoulder with the chin slightly to the left side. This position persisted for three days, associated with slight discomfort, when he was brought to the clinic by his parents. He was anesthetized in the dispensary, and the head was pulled further to the right and the chin rotated to the midline. Reduction occurred immediately, and the discomfort and torticollis were quickly relieved.

Treatment.—In the treatment of dislocation, which is practically limited to the cervical region, the question of reduction is important. The unilateral dislocation forward is produced by abduction and rotation of one vertebral articulating surface over the one beneath it. This is usually the condition met with, and in these cases it is best to try Walton's method of reduction. This consists of retrolateral flexion toward the non-dislocated side with rotation toward the midline. If this fails, strong traction followed by rotation backward may succeed, but in these manipulations the cord is in great danger.

Many cases have been reduced successfully by operative procedures, and as many have been spontaneously reduced under ether and during sleep, when the ligaments and muscles were relaxed.

The bilateral dislocations both forward and backward are rare. These are probably best treated by retrolateral flexion and rotation on one side, and repetition of the manipulation for the other side.

Rarely the occiput is dislocated from the atlas, and occasionally the atlas from the axis, with very grave results. In dislocation of the atlas from the axis, the spine of the axis is felt prominently behind, and the arch of the atlas is felt in the pharynx, whereas the head is markedly flexed, the chin resting on the chest. The head may either be held rigid or be very mobile. Successful reduction in which the cord escapes injury is nearly always followed by rapid and complete recovery. Little or no treatment is required after reduction, and as a rule the symptoms all cease (with the exception of slight soreness) within a few days.

8. Simple Fracture of the Spine

Simple fracture of the spine occurs as often as dislocation of the spine. This constitutes about 20 per cent. of all spinal injuries. The two common

sites of fracture are the spinous processes and the posterior arches. The fractures are nearly always due to direct violence and they are usually hard to differentiate from other injuries without an *x*-ray.

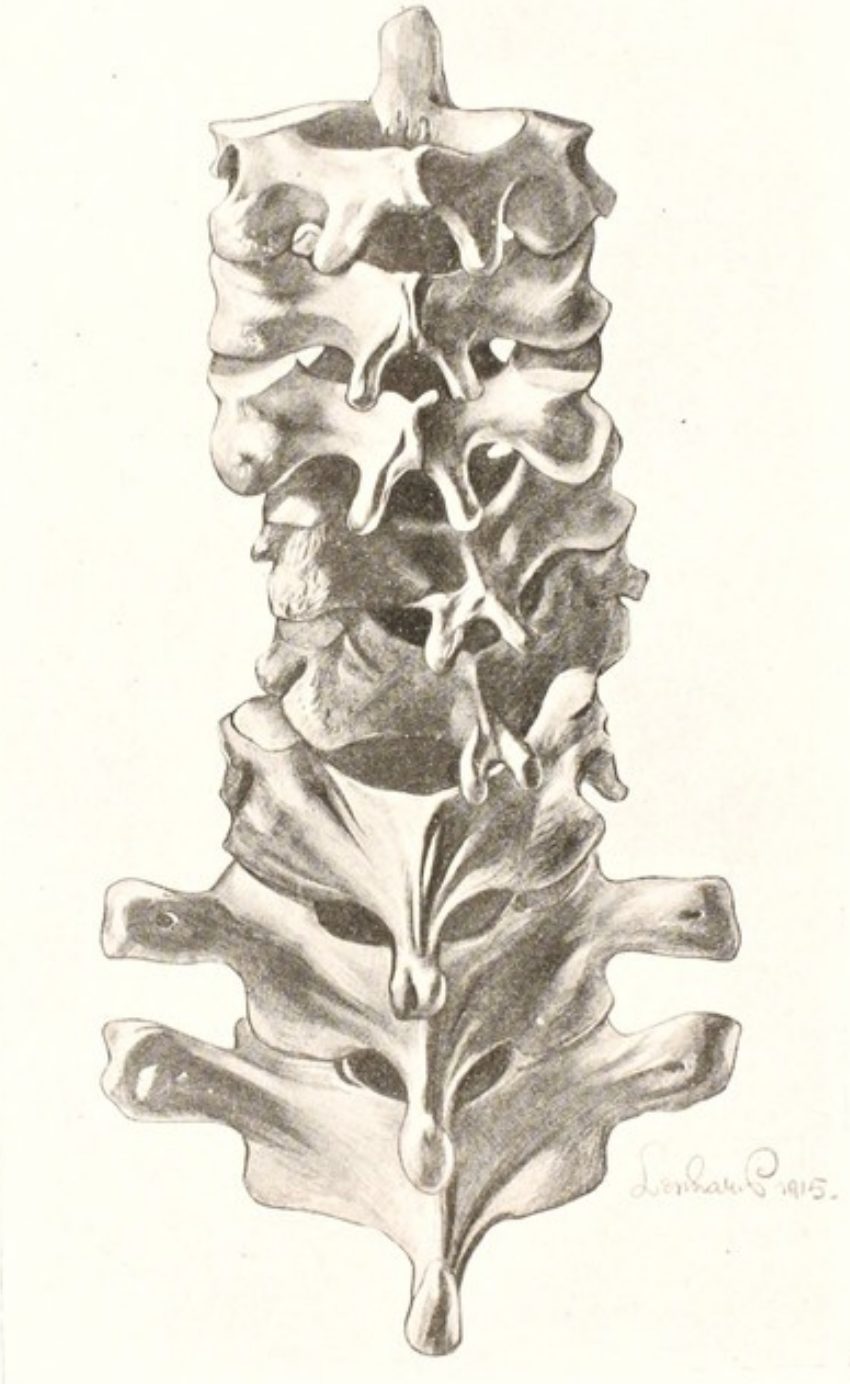


FIG. 155.—Fractured dislocation of the fourth and fifth cervical vertebræ. (Elsberg.)

Treatment.—These cases have to be treated either by plaster jackets or by operation. Removal of the portion causing the pressure is the usual procedure; otherwise, rest and spinal support for a period of six or more weeks is advisable. Occasionally in these cases the pressure is due to callus and exudate; in these cases the paraplegia occurs at a later date.

9. Fracture-dislocation of the Spine (Figs. 155, 156, 157, 158 and 159)

The so-called fracture-dislocations comprise by far the majority of spinal injuries, probably 80 per cent. of all injuries to the spine, and in Stimson's table 0.5 per cent. of all fractures are of this type. They may be simple or compound, and occur more frequently in males than in females. They

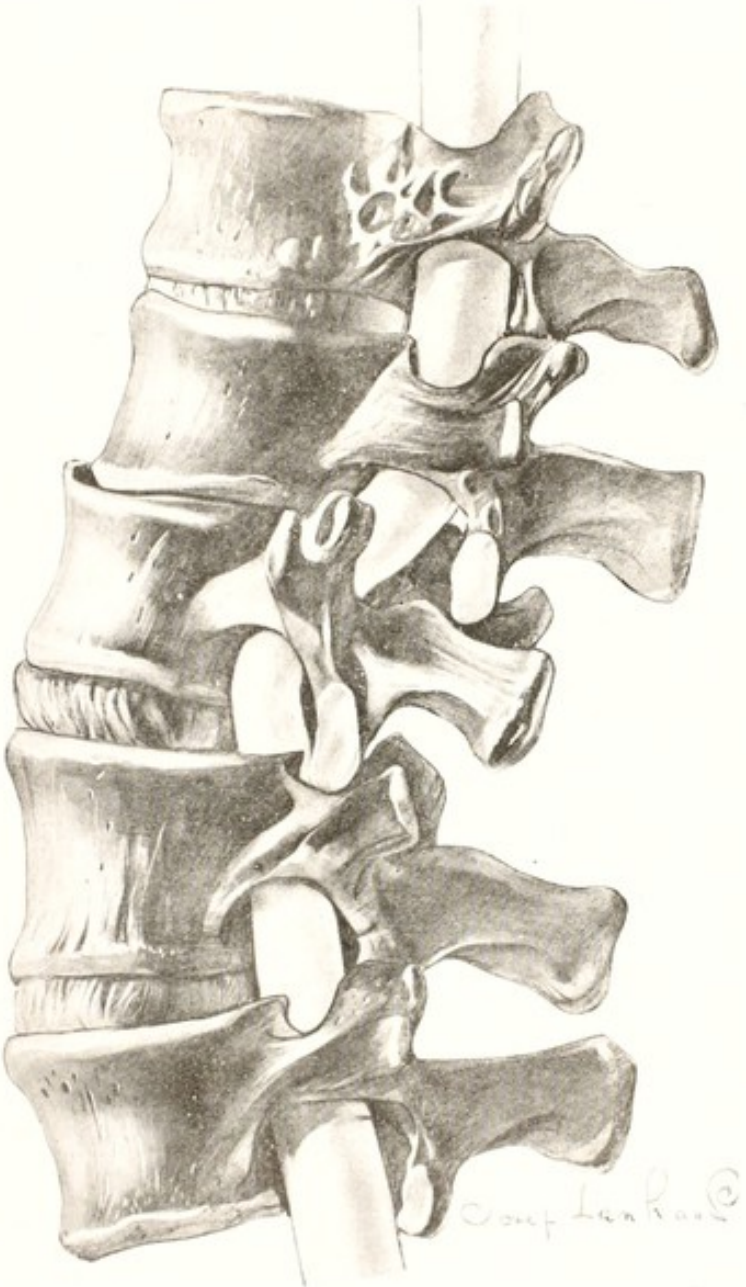


Fig. 156.—Lateral view to show the angulation of the cord in fracture dislocation. (Elsberg.)

may be produced by direct or by indirect violence, and even by excessive muscular action. The most frequent location is in the region of the fourth, fifth, and sixth cervical vertebræ and the last two dorsal and first lumbar vertebræ. Practically all the cases are caused by hyperflexion, whereas fractures of the spinous processes and posterior arches are usually due to direct violence. The bodies of the vertebræ are fractured more frequently than the arches.

The fractures occurring in the cervical region are in the majority and average from 25 to 35 per cent of the total, those in the other regions being: lower dorsal, 23 to 30 per cent; upper dorsal, 14 to 28 per cent; and lumbar region 10.5 to 28 per cent.

In these cases, the point of greatest interest and importance relates to the damage done to the cord, and it is usually best to separate the cases into groups from this standpoint, recognizing: first, the possibility of complete destruction of the cord at a particular level; second, those cases in which doubt exists as to whether the cord is completely destroyed; and, lastly, those cases in which there is reasonable assurance that the cord is only slightly damaged or not harmed at all.



FIG. 157.—Fracture of the spine with crushing of the first lumbar vertebra.

Considering these cases from this standpoint, the question arises of the advisability of operative interference in the various groups, and also as regards the most opportune time in which to operate.

It is generally agreed that no good can be accomplished in those cases of complete transverse lesions of the cord associated with fracture. Suturing of the cord has been done in a few cases, but even though some of the results seem to show evidences of regeneration, surgeons generally consider that the results so far hardly justify the operation. Mickulicz has shown that, experimentally, at least, in the lower animals, it is not successful, and hence we could hardly expect to get results in human beings where the different nerve tissues are so highly specialized.

In those cases where doubt exists as to the condition of the cord, it is probably better to operate as soon as the patient's condition will allow it; for in these cases there is not infrequently pressure on the cord from fragments of bone, blood and inflammatory exudate, and the longer they compress the cord the more irreparable is the damage. Then, too, we have first hand information as to the actual condition of the cord. Not infrequently in

fractures the cord symptoms are due to a hematoma alone which is entirely extradural. Then again, the hematoma may be within the cord, the fracture of the spine being of minor importance.

Lloyd, however, objects to immediate operation, as he thinks that many failures will be charged to the operation which were really not due to it. Then, too paralysis and anesthesia often result from so-called concussion of the spine, and in the first few hours one cannot determine with any degree of accuracy how severe the injury really is; nor can it, as a rule, be localized. Hence he thinks that operation should be postponed until it becomes apparent

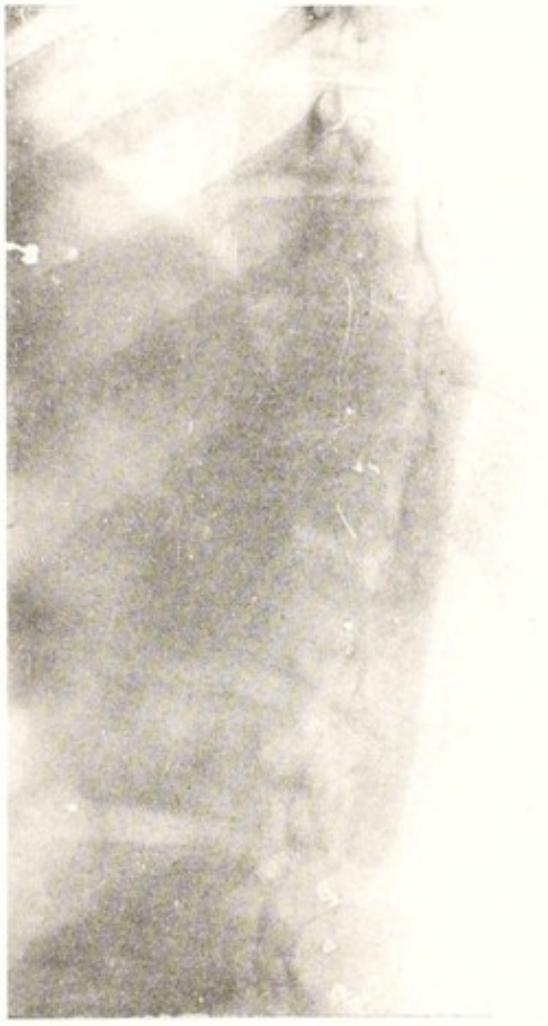


FIG. 158.—Fracture of the body of the twelfth dorsal vertebra without pressure. Symptoms completely and immediately relieved by the insertion of a tibial bone graft into spines of two vertebræ above and two below.

that spontaneous recovery, complete enough to make life endurable, is out of the question. This is usually evident by the seventh to the fifteenth day.

Those cases in which we are reasonably sure the cord is not injured require no operative interference until pressure symptoms arise. Upon the first evidence that pressure is present, an operation should be done at the earliest possible moment. On account of callus formation, this sometimes occurs quite late. Expectant treatment is best for this type of spinal injury. This consists of keeping the patient fixed on a Bradford frame, or supported by sand-bags, spinal jackets, or plaster jackets for a period of three to six weeks, prohibiting violent exercise and strain for several weeks longer.

Diagnosis in Transverse Lesions of the Cord Following Fracture-dislocation of the Spine.—A total transverse lesion of the cord may be deduced from the persistence of complete paralysis; loss of sensation in its various forms, particularly sharply defined anesthesia; total loss of reflexes below the lesion, especially the knee-jerk; retention of urine; priapism; incontinence of feces; vasomotor paralysis, with severe sweating in the paralyzed parts; tympanites; and the absence of irritative phenomena, such as pain. But most important of all is the variation in these symptoms. Thus, not infrequently the plantar reflex is retained where all other reflexes are lost.



FIG. 159.—Dislocation of the fourth cervical vertebra on the fifth causing pressure on the spinal cord and complete paralysis.

Prognosis.—The mortality in the cases of complete transverse lesion is almost in direct proportion to the height of the segment of the cord injured. Thus, in injuries of the cervical region above the fourth vertebra, death is almost instantaneous. This may be due to injuries of the vital centers in the medulla, but it is chiefly due to injury to the phrenic nerve. Practically all cases of injury to the cord from fractures about the fourth, fifth, and sixth cervical vertebræ result in death within eight months after injury. The lower the segment of cord injured, the longer the duration of life. Death

in most cases that do not succumb to the initial shock of the accident is due to ascending pyelonephritis. For this reason, every effort must be made to prevent the almost inevitable cystitis incidental to catheterization and the lowered resistance of the bladder walls. Because of this, many surgeons



FIG. 160.—A third grip for reduction. This is the strongest and usually the best grip of those shown. (Cotton.)

advocate a suprapubic cystotomy with drainage, as it can be done through a very small incision without anesthesia and does away with the necessity of frequent catheterizations, and is less likely to produce cystitis. The introduction of a retention catheter will relieve the distension and it answers the purpose very well. The bladder should be irrigated often with saturated boric acid solution; this is especially required after each catheterization.

Another very frequent cause of death is pneumonia, to which these patients are particularly susceptible.

Bed-sores are a great annoyance. In some cases it seems almost impossible to prevent them. However, at the very first sign of redness, pressure at this point should be relieved. Air or water mattresses should be used, also air cushions. In places where the skin has not broken, dusting powders should be used, but after the skin sloughs an astringent ointment (such as scarlet red, zinc oxid) or balsam of Peru should be tried. The tendency of pressure sores is to increase in size and they heal with great difficulty, because of trophic disturbances in the affected tissue.



FIG. 161.—For the right-sided luxations the head is abducted to the left (1) and rotated down and back on the right (2). (Cotton.)

HISTORY OF SPINAL SURGERY

The history of spinal surgery begins at a very early date. In the seventh century Paul, of Aegina, is accredited with some sort of spinal surgery.

Louis, in 1762, first operated for a fracture caused by a gunshot wound: this consisted probably of only a superficial operation on the arches. Operation in which the cord was exposed proved universally fatal until the middle of the nineteenth century. Sir Astley Cooper, in 1823, advocated operation in fractures. Rogers, in 1835, in speaking of a case of fractured spine with depression of a spinous process and the operation for its removal, says: "Although all the cases of depression of the spinous processes in which an operation has been performed have proved fatal, I think that in a case of simple depression of spinous process without any injury of the spinal cord we have a reasonable prospect of success in an operation; at all events, it is the only chance for the patient, and under such circumstances I recommend it." This attitude was probably in advance of the times, for as late as 1867, John Ashhurst, Jr., gathered statistics to show why operation should not be done; and even in 1893 Cheever and Manley published a paper advising against operation in fractures of the spine.

It was between the years 1885–1890 that a great deal was written pro and con concerning operative interference, the great tendency being to advocate operative procedures in certain cases.

At the present time, spinal surgery has made immense strides, and new instruments, particularly those driven by electric power (author's electro-operative outfit) and improved methods of procedure have simplified and extended the field of spinal and cord work.

LAMINECTOMY

Laminectomy consists of resection of portions of the laminæ from one or both sides of the neural arches of one or several vertebræ. When the operation is performed on both aspects of the neural arch, the term *bilateral laminectomy* is applied; when on one side only, *hemilaminectomy* or *unilateral laminectomy*. For reasons stated below, the author prefers the latter procedure in nearly all instances.

Indications for Laminectomy.—Resection of the vertebral laminæ is indicated chiefly for the purpose of *decompression*, but occasionally for certain other conditions, viz.: (1) simple dislocation; (2) new growths; (3) pressure symptoms from angulation of the spine in Pott's disease, Kümmell's disease, etc.; (4) for exploratory work; (5) nerve-root work; (6) removal of tumors, foreign bodies (bullets, shrapnel, etc.), and for other allied conditions of the vertebræ, cord, and membranes.

1. **Hemilaminectomy.**—In every condition accompanied by weakening of the spinal column, it is believed that hemilaminectomy is preferable, because it does not weaken the spine to nearly the degree that the bilateral laminectomy does and also because preservation of the spinous processes permits of insertion of the bone-graft at once or at some future date if necessitated by some such condition as fracture of the spine which fails to firmly unite. In several cases the author has found it necessary to insert the bone-graft on account of failure of union.

In the case of Kümmell's disease (which, it should be added, is not actually a disease but a microscopic disintegration or a comminuted condition of the vertebral body, severe enough to cause compression of the cord), a combined operation would be indicated, that is, treatment from two standpoints, viz.: (1) decompression, and (2) support and immobilization by the bone-graft to prevent further deformity. Again, in cases of Pott's disease complicated by compression of the cord, similar conditions are present and should be met by a combination operation, hemilaminectomy for decom-



FIG. 162.

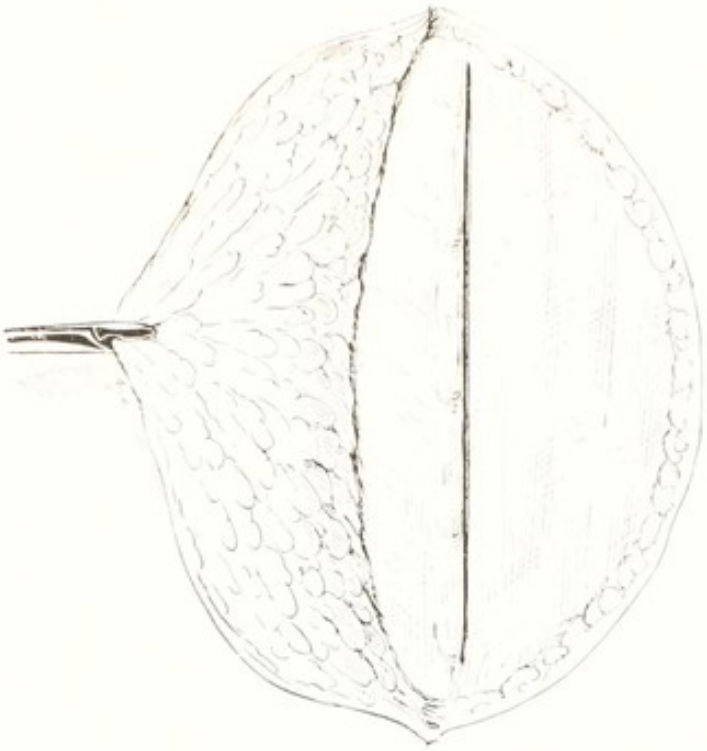


FIG. 163.

FIG. 162.—Right hemilaminectomy. Semi-circular incision, for purpose of turning up subcutaneous flap, so that line of sutures on closure will not directly overlie the site of excision of the laminæ.

FIG. 163.—Right hemilaminectomy. Subcutaneous flap reflected. Incision in fascia. Erector spinæ muscles separated by blunt dissection from spinous processes and interspinous ligaments at the site of proposed laminectomy.

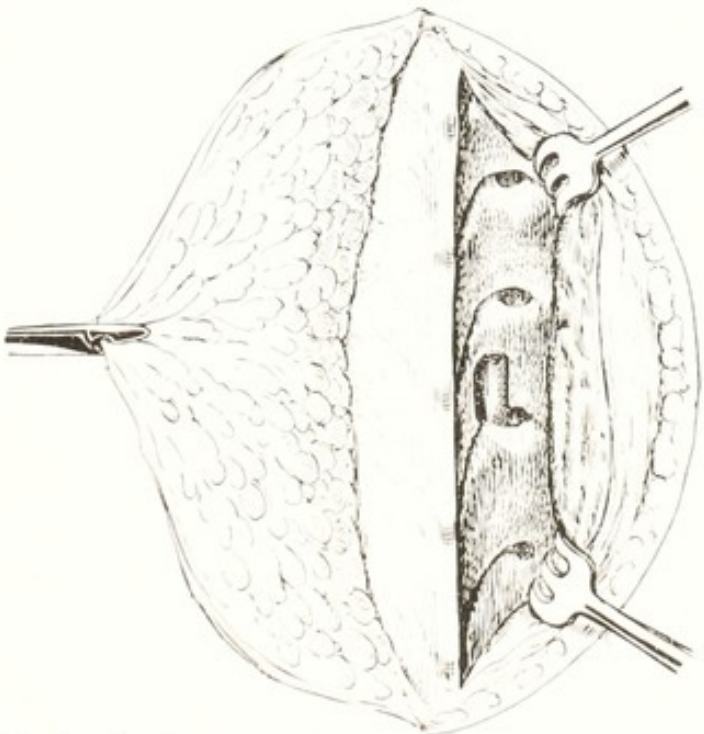


FIG. 164.—Right hemilaminectomy. Erector spinæ muscles retracted, exposing neural arches of vertebræ. A section has been removed from one lamina by means of oone forceps and rongeur, to permit of introduction of the author's laminatome.

pression of the spinal cord, and inlay bone-grafting for stability and treatment of the Pott's disease.

Technic of Hemilaminectomy.—Alfred S. Taylor of New York (Unilateral Laminectomy, Annals of Surgery, li, 1910, pp. 529–40) claims originality and priority in the performance of unilateral laminectomy, which he first performed in 1908, and which consists of the removal of portions of the laminæ of one or more vertebræ on one side of the spinous processes only. The use of the author's electrically-driven laminatome (see Fig. 165) and his

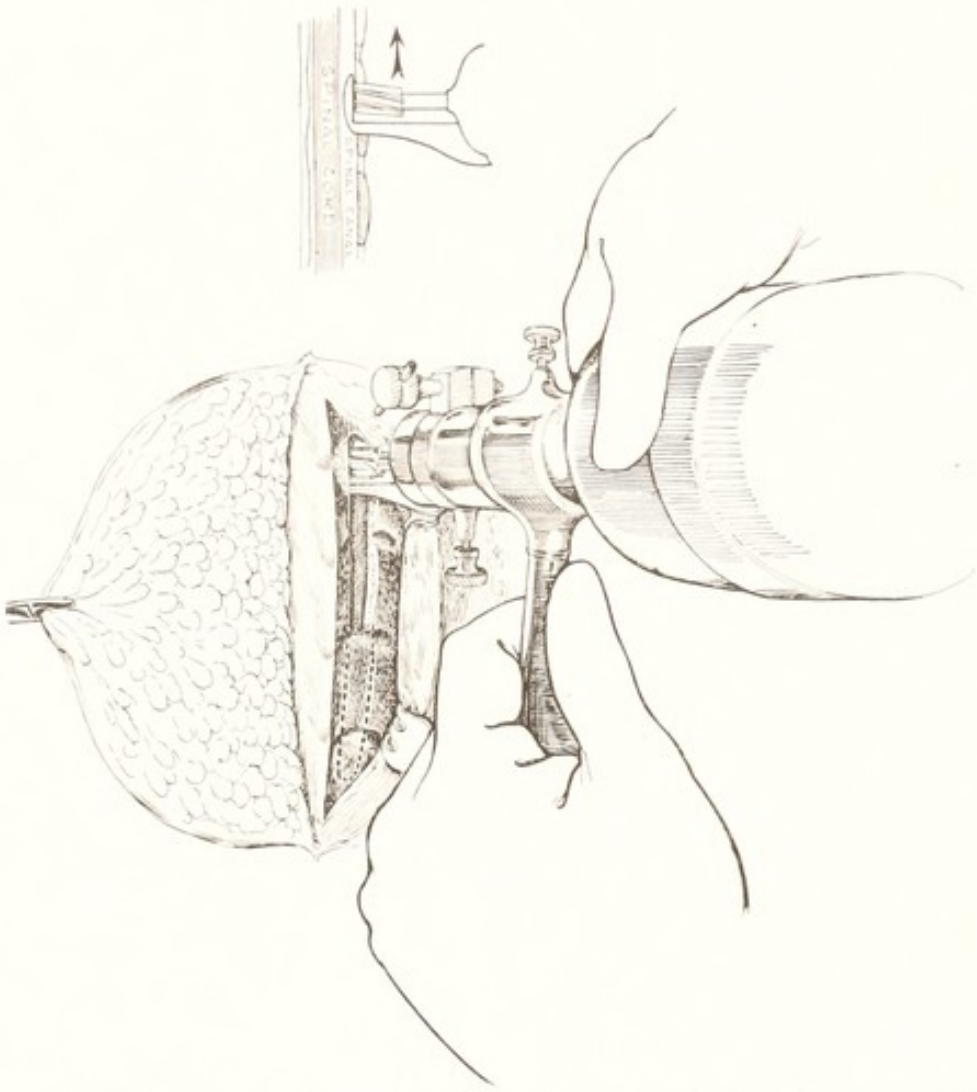


FIG. 165.—Right hemilaminectomy. The author's motor-driven laminatome has cut a path through the two laminæ shown in the upper portion of the field. The instrument will next be reversed to cut through the laminæ in lower part of the field, along the dotted lines. The details of the laminatome are shown in the small upper figure.

other motor-driven instruments have greatly simplified the performance of this operation.

The site of the proposed laminectomy is exposed by a long curved incision (Fig. 162) such as used by the author in his operation for Pott's disease (*q.v.*). The incision should be carried as high as possible above the site of lesion because of the frequent impairment of the circulation below that level; in depth, it should extend down to the supraspinous ligament. By retracting outward and by blunt dissection and the use of the periosteal elevator, the muscles are separated from the lateral aspects of the spinous processes and the

dorsal surfaces of the laminæ (Fig. 164). Hemorrhage, if troublesome, is best controlled by hot saline compresses. The neural arch is then pierced (Fig. 164) by means of a spinal rongeur or the Martel motor-drill attachment which drills a hole of sufficient size to admit the author's electrically driven laminatome (see Fig. 166), with which a path is cut through the desired number of laminæ above and below the original hole. By this method the author finds that the spinal canal can be quickly and safely entered within a very short time and with a minimum amount of hemorrhage.

After completion of the operation, the muscles are sutured to the perispinous and interspinous tissues with interrupted sutures of No. 1 chromicized catgut; the aponeurosis is closed with a continuous suture of the same material,

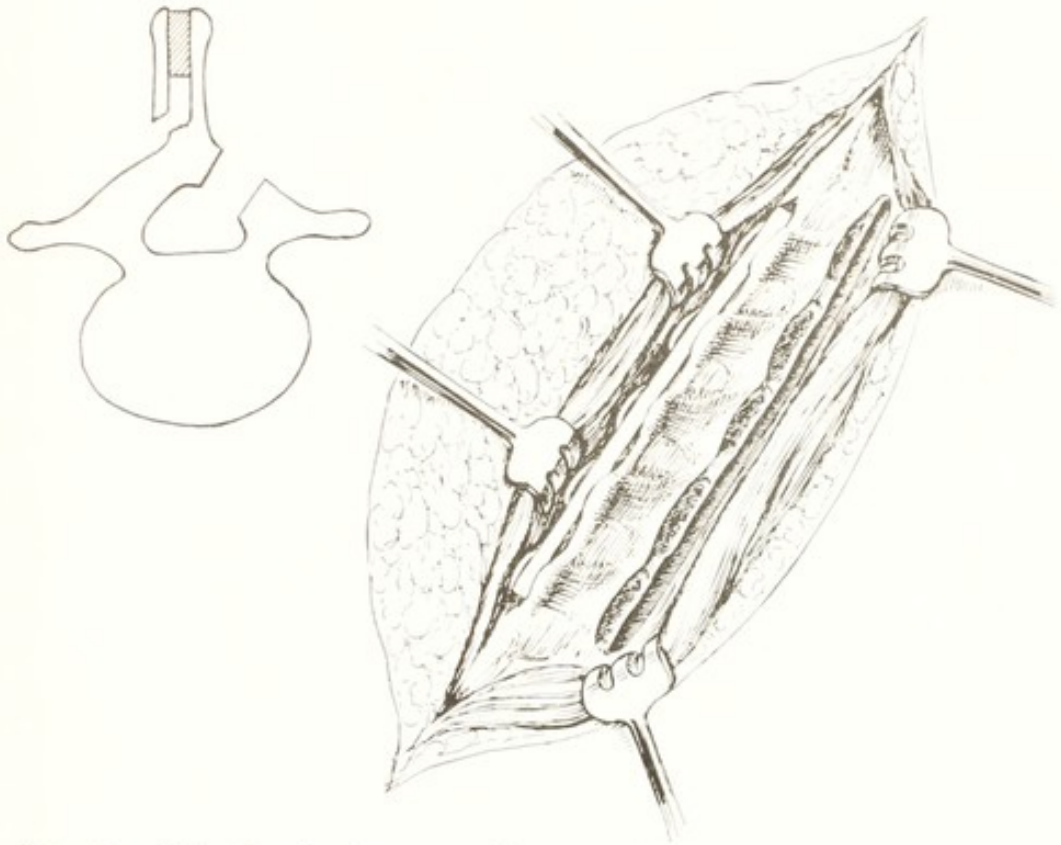


FIG. 166.—Right hemilaminectomy of five vertebræ, with a tibial bone graft inserted into the corresponding spinous processes. The spinous processes are split and the halves broken on opposite side (left) and graft inserted as for Pott's disease at the turn of the hemilaminectomy or later if found necessary to support or immobilize the spine.

and the skin with a continuous suture of No. 1 plain catgut. No drainage is employed. A large, firm, sterile dressing is applied and retained by adhesive strips and the binder, and the patient is kept in a lateral or prone position during the postoperative period. If the laminectomy has involved many vertebræ and there is danger of collapse of the spine, a graft may be inserted for support (see Fig. 166).

2. **Bilateral Laminectomy.**—This is the procedure employed by a majority of spinal surgeons at the present time, although the author believes that it entails the removal of an unnecessarily large amount of bone and is therefore, because of its tendency to weaken the spinal column, less desirable a procedure than hemilaminectomy. Where a wide exposure of the cord is imperative, a bilateral operation may be necessary.

After exposure of the field of operation, the spinous processes are removed

in toto from the vertebræ selected for operation down to the neural arches, by means of a large rongeur or bone forceps (see Fig. 168). The author's electrically driven laminatome is applied to the laminæ through a hole made as directed for the unilateral procedure, and two paths cut up and down, one on either side of the spinous processes, and the intervening strip of bone,

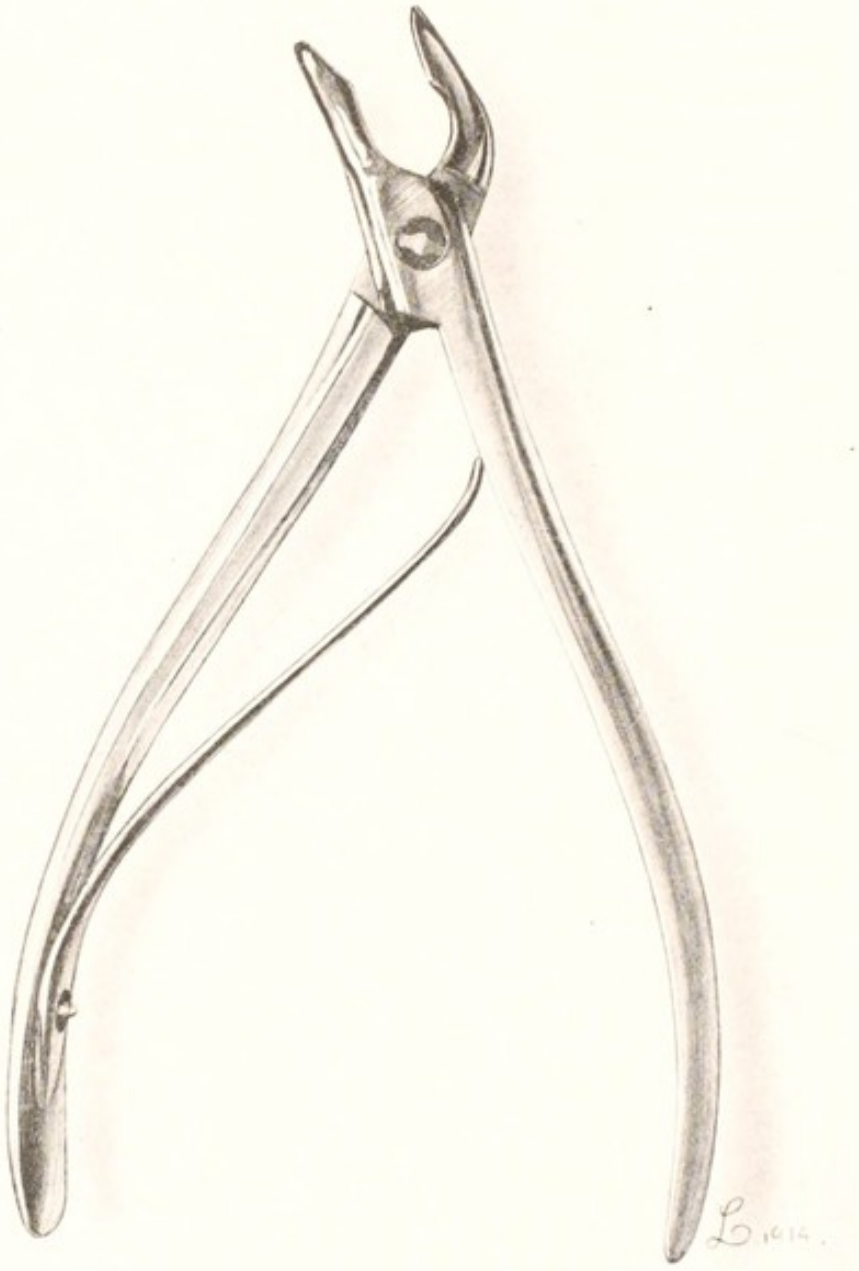


FIG. 167.—Rongeur for widening the spinal opening. $\times\frac{3}{4}$. (Elsberg.)

consisting of the bases of the spinous processes and the adjoining portions of the laminæ, is removed, or the bases of the neural arches and the stumps of the spinous processes may be removed by one cut of the laminatome and then the opening enlarged laterally by means of rongeur bone cutters, to expose the cord or its membranes sufficiently (Figs. 170 to 175). After completion of the operation, the superimposed soft tissues are reunited and

the postoperative management is conducted as in the case of hemilaminectomy.



FIG. 168.—Large rongeur forceps for the removal of the spinous processes. $\times\frac{2}{3}$. (Elsberg.)

10. GUNSHOT AND STAB WOUNDS OF THE SPINE

The subject of gunshot and stab wounds of the spine is a very general one and will be dealt with briefly. In so far as gunshot wounds affect the vertebræ the points to be considered are whether the spinal canal has been opened, and if opened, whether the contents have been injured. In many cases in which

the canal has not been opened, the patient is nevertheless subjected to a very severe concussion, from which, however, he usually recovers. In these cases, too, a large vessel is frequently torn and fatal hemorrhage results.

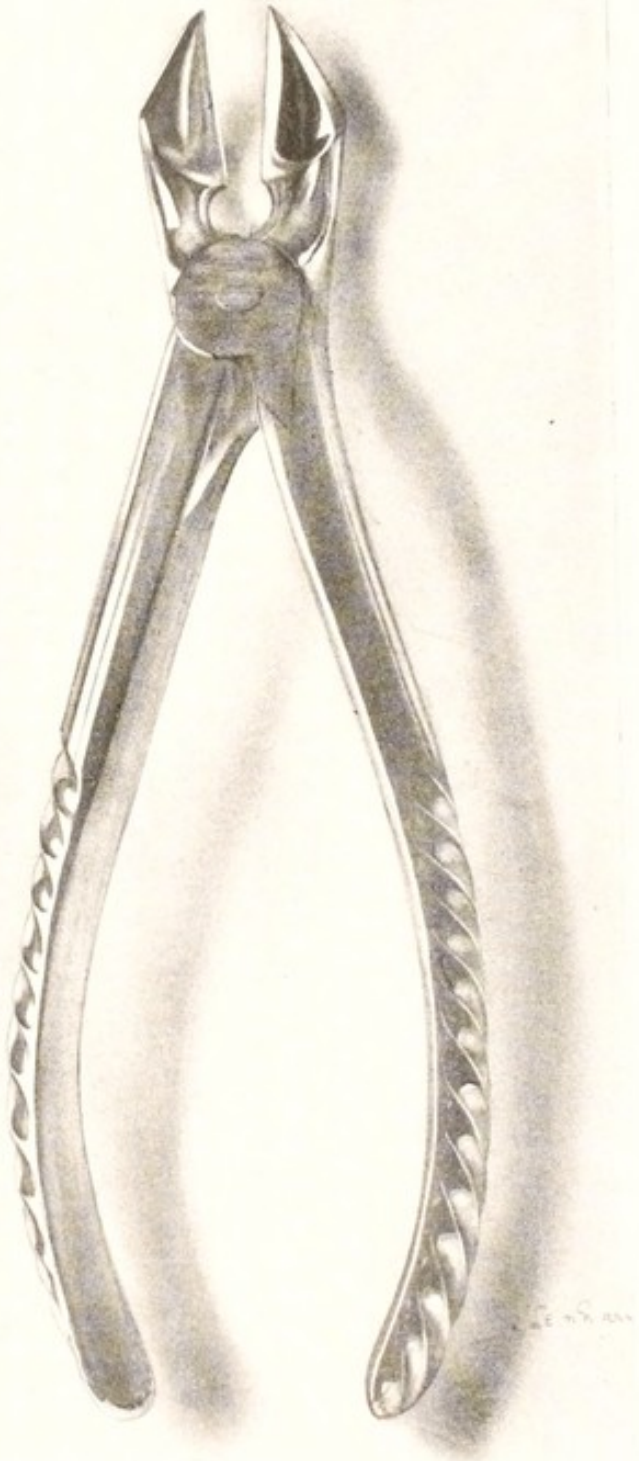


FIG. 169.—Horsley spine forceps. $\times\frac{2}{3}$. (Elsberg.)

Vertebral fracture from a bullet is usually compound and accompanied by all the dangers of an infection. Occasionally the canal is opened without endangering its contents. In such cases, however, the ultimate danger of

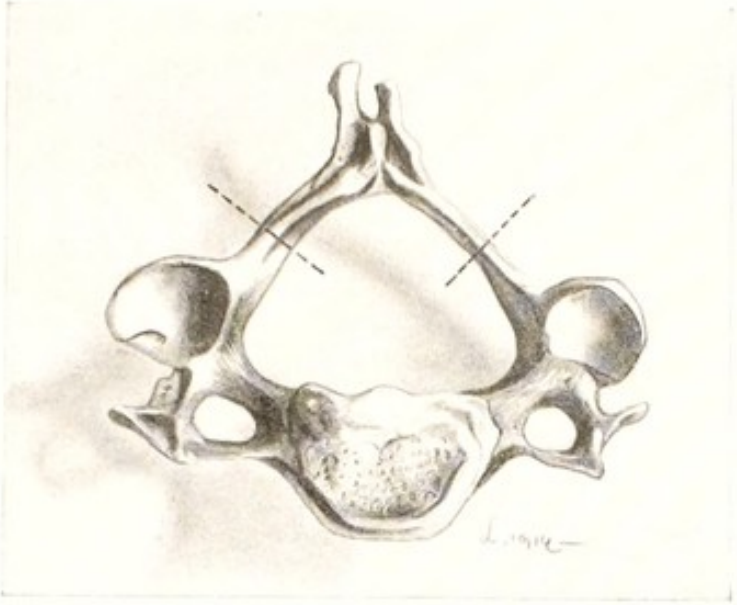


FIG. 170.—A cervical vertebra. The broken lines show the amount of bone removed in order to widely open the spinal canal (compare with Figs. 171 and 172). (Elsberg.)

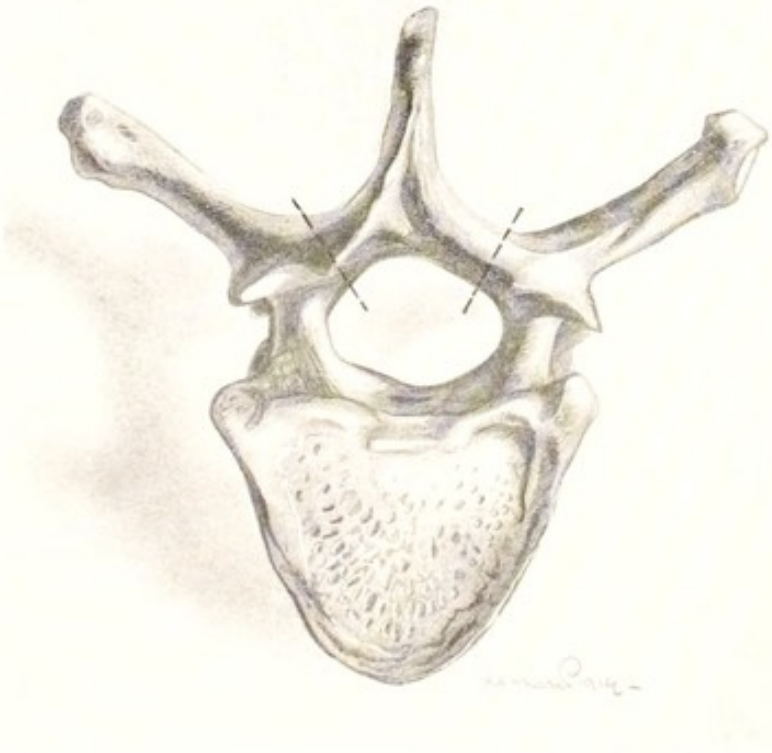


FIG. 171.—A dorsal vertebra (broken lines as in Fig. 175). (Elsberg.)

meningitis and hemorrhage is quite apparent. In the majority of instances the cord is more or less damaged by the bullet.

It is important to recognize the point of entrance and the course of the projectile, and to appreciate how readily the bullet becomes deflected after entering the body. From the medicolegal standpoint, it is well to note the size of the bullet, the points of entrance and exit, and the presence or absence of powder marks.

During our Civil War, 642 cases of gunshot wound of the spine were observed with a death-rate of 55.5 per cent. The survivors were almost exclusively those in whom the fracture was limited to the spinous processes and the transverse processes, although in a few cases the bodies of the vertebræ were injured.



FIG. 172.—A lumbar vertebra. (Elsberg.)

Treatment.—Modern military surgeons agree that it is best to leave the bullet wound alone, simply painting the surrounding skin with iodin and applying a sterile dressing to avoid contamination. If there is evidence of nerve-trunk injury, it is advisable to wait until the wound is completely healed before attempting to suture the nerve. A radiograph should be taken in every case, and if it reveals the presence of bone splinters and signs of compression of the cord, operation should be performed. The question of advisability of operation on such cases before the wound has healed is entirely an individual one; but as a general rule, in the absence of urgent necessity, it is better to defer operation. If the cord is not in danger, it is preferable to leave the bullet *in situ*, in the absence of untoward symptoms. If the cord is destroyed, it is advisable to remove the bullet, together with splinters of bone and exudate. The prognosis depends directly upon the extent of damage to the cord and the incidence of infection.

Stab Wounds.—Stab wounds penetrating the spine are rare, although it occasionally happens that a sharp instrument fractures portions of the vertebræ, even entering the canal and severing the cord. Each case, from the operative standpoint, presents an individual problem. A radiograph is of prime importance, while lumbar puncture is also of value in revealing the presence or absence of blood in the spinal fluid. A few cases of osteomyelitis resulting from bullet and stab wounds have been reported.

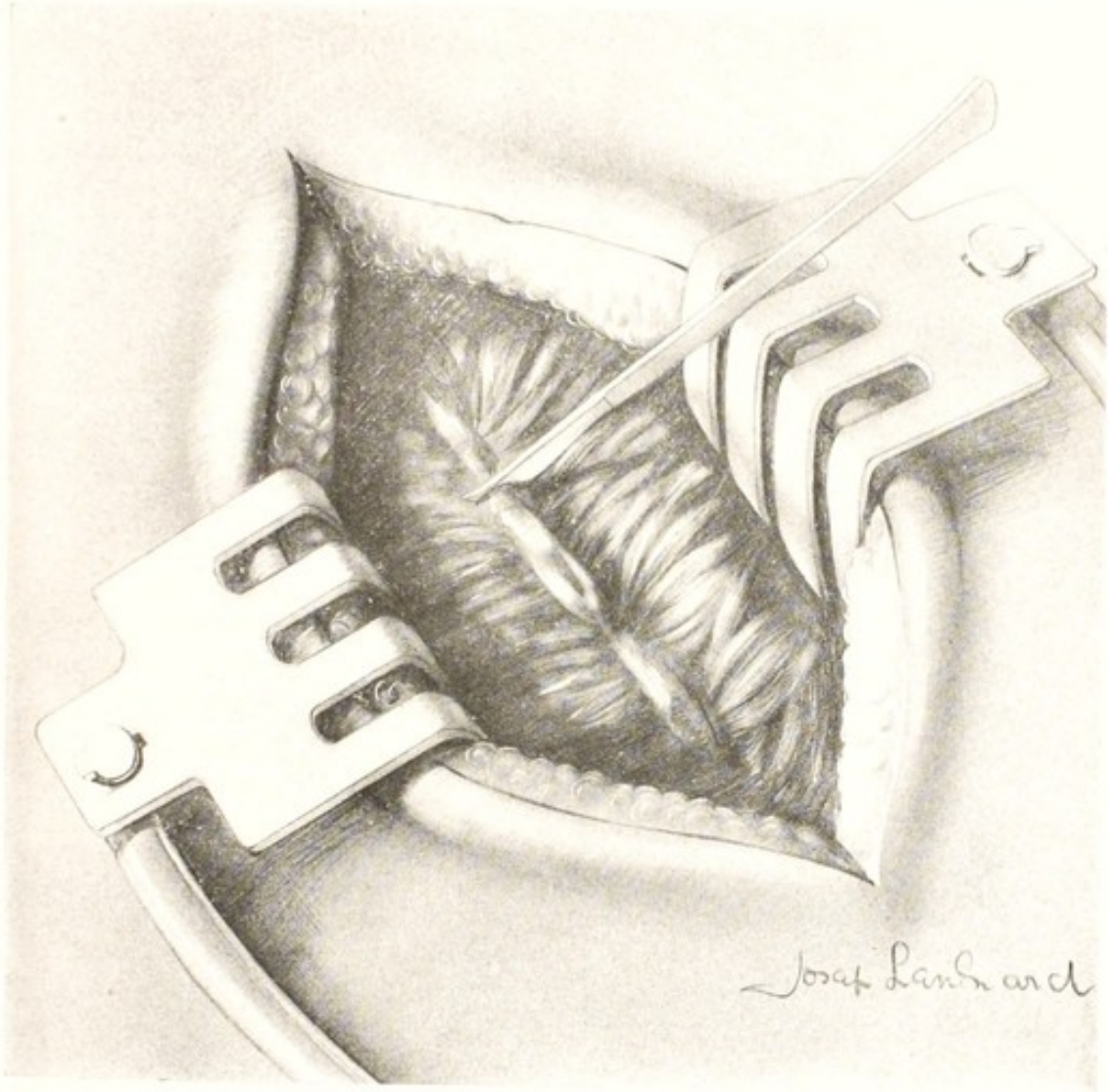


FIG. 173.—Laminectomy. The division of the interspinous ligaments. (Elsberg.)

MISCELLANEOUS AFFECTIONS OF THE SPINE

I. SYPHILITIC SPONDYLITIS

This condition is not unusual in children, but is rare in adults. All regions are susceptible, but the cervical region, because of its proximity to the pharynx, is the commonest localization. All the component parts of the vertebræ (bodies, ligaments, intervertebral disks, transverse and articular processes, etc.) may be involved. The syphilitic vertebral lesions differ in no respect from the disease in other joints, although it may be difficult to make an accurate diagnosis, because the condition is frequently associated with tuberculosis. The disease produces periostitis and hyperplasia rather than a degeneration, and the pain from motion and compression about the

nerves is often distressing. Abscess is not the rule, but may occur. The deformity may simulate that of Pott's disease, from which it must be differentiated. Spondylitis in children under three years of age, when associated with other chronic joint lesions, is usually syphilitic rather than tuberculous. The history of syphilis in the parents, the presence of brownish red crusts and cutaneous eruptions, especially about the genitalia and anus, Hutchinsonian teeth, nasal catarrh, suppurating otitis, interstitial keratitis, etc., all aid to differentiate the two. The Wassermann and *x*-ray examinations should confirm the diagnosis.

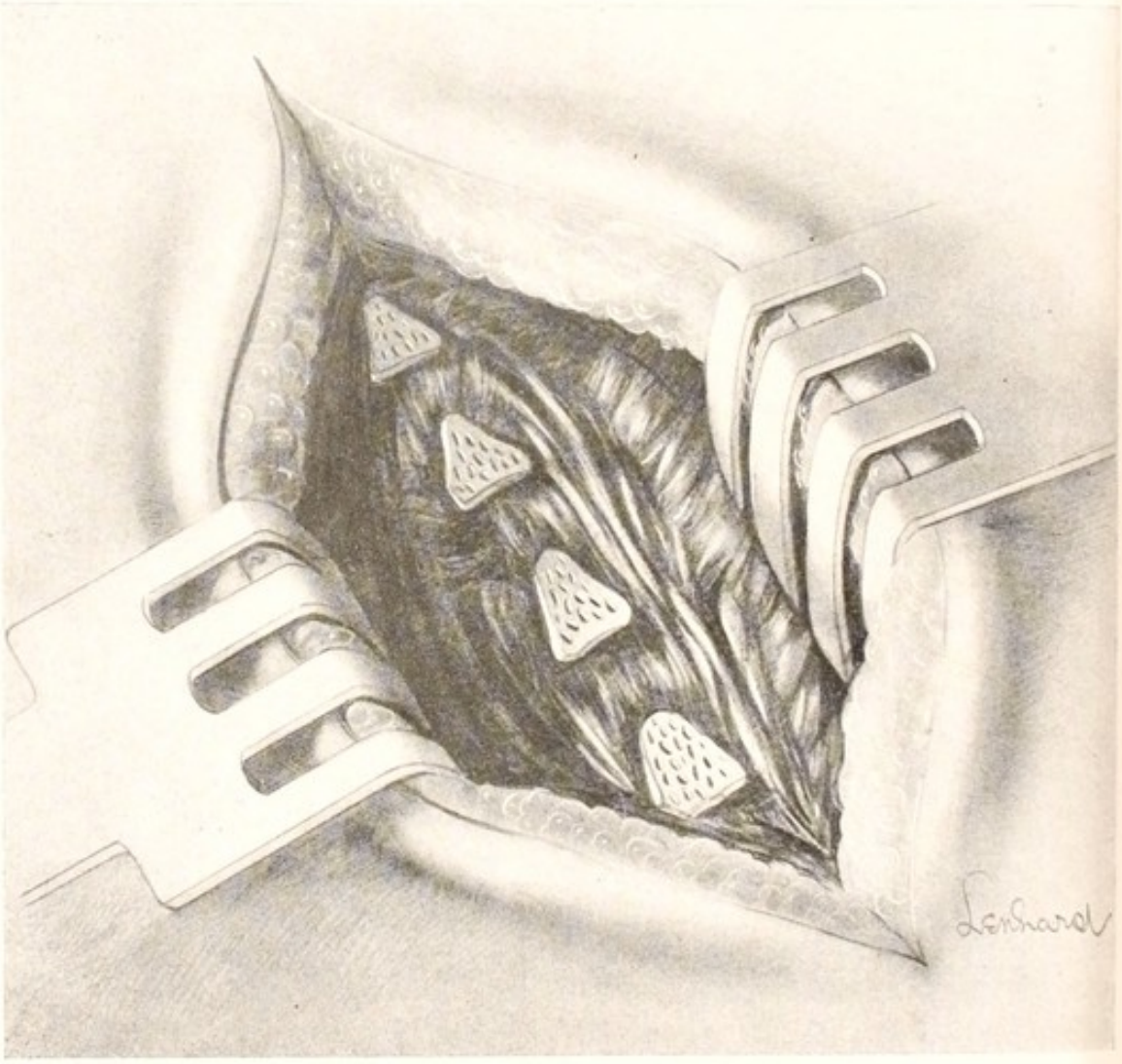


FIG. 174.—Laminectomy. The removal of the spinous processes. (Elsberg.)

Syphilitic aneurism of the aorta frequently attacks the adjacent vertebræ, which become involved in the inflammatory mass.

Frank, of Vienna, collected 27 cases of tabetic osteo-arthropathies. In general, the vertebral bodies are thickened, with extensive arthritic development. Ankylosis and ossification of the ligaments may occur. The spinous processes are thickened and roughened. The patients sleep on the side with the head bent toward the knees, probably in an attempt to relieve discomfort in the legs. Spontaneous fractures of the involved bones are common, and pain is of less consequence to the sufferer than disturbance of locomotion. The tendency is toward lateral deviation.

Treatment.—The treatment of syphilitic spondylitis should be mechanical and medicinal. Rest, spinal support in the acute stages, and supplementary treatment by iodids and mercury and some of the newer arsenical preparations (salvarsan and neosalvarsan) will occasionally benefit the patient. It is essential that the treatment be prolonged for a year or more.

In many cases, because of adverse mechanical conditions, the symptoms persist and the bone-graft, as applied by the author in Pott's disease, may be used in conjunction with antisyphilitic treatment as an immobilizing and supporting agent. An illustrative case is that of a young woman with a marked kyphosis in the dorsal region, with severe symptoms associated with

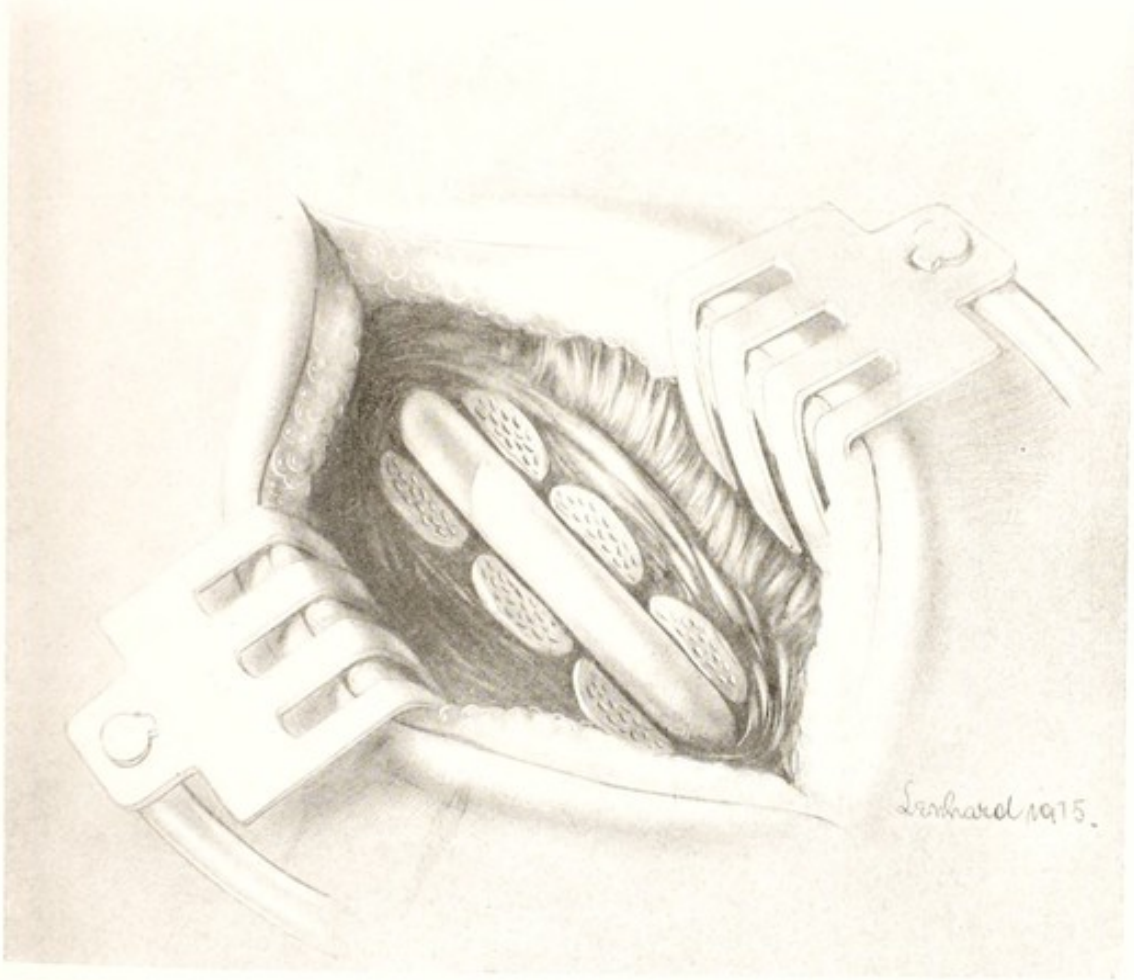


FIG. 175.—Laminectomy. The dura exposed. (Elsberg.)

lesions at the jaw and sternoclavicular joints. The spinal symptoms were immediately and entirely relieved by a bone-graft, while at the same time the lesions in the jaw and sternoclavicular regions resisted for a long time the most strenuous antisyphilitic treatment.

II. ACUTE OSTEOMYELITIS OF THE SPINE

Although acute osteomyelitis invades the spine very rarely, the subject has received considerable attention in the literature. Numerous cases of perivertebral abscesses were recorded by English, German, and French writers as early as 1833. Delafield reported a case of acute osteomyelitis of the spine in 1874, before the New York Pathological Society. The spinal

lesion is more or less similar to acute osteomyelitis in other parts of the body, occurring either as a periostitis of very mild course, or as a periostitis and superficial osteitis of moderate degree, or as a very virulent process with extensive pus formation. Like Pott's disease, it is encountered most commonly in the mobile parts of the spine (*e.g.*, the lumbar region) (Fig. 177) but is frequently seen in the cervical and dorsal regions. There are few cases on record in which the coccyx was involved. In Frohmer's statistics, published in 1889, only 1 case was reported in 545 cases seen in other regions. It is probably more common than this, and cases are being reported with increasing frequency. It is seen twice as often in males as in females,

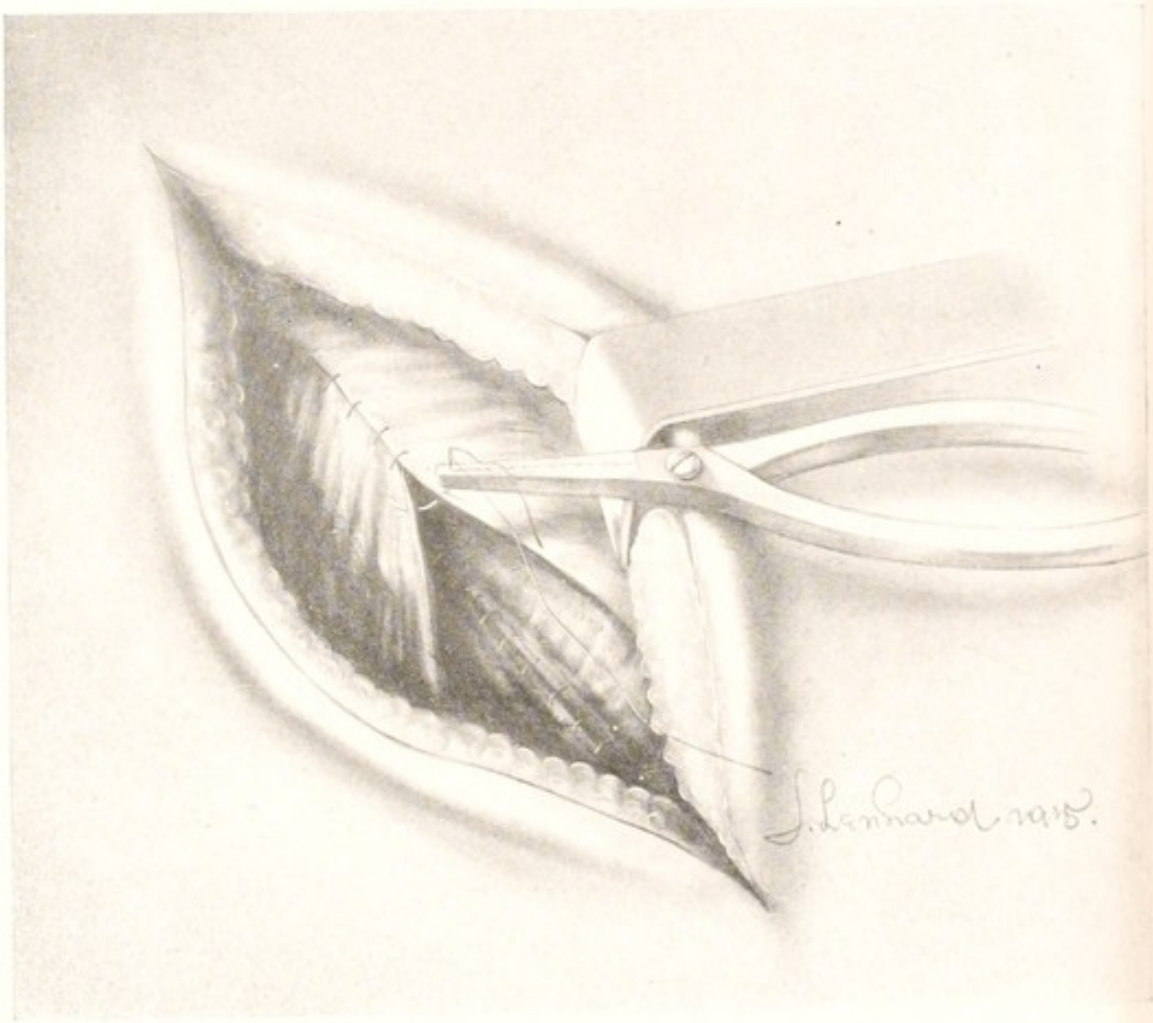


FIG. 176.—Laminectomy. The suture of the muscles and fascia. (Elsberg.)

and whereas any age is susceptible, the majority of cases occur at the period of greatest bone-growth.

The exciting causes are: injury to the spine, exposure, fatigue, and the presence of some localized septic process, but the largest number of cases are of pyogenic origin and caused chiefly by the staphylococcus pyogenes aureus.

The symptoms depend upon the degree of involvement. Thus in cases of simple periostitis, stiffness, slight pain, fever, and local tenderness may be the only complaints; while in the severe cases it is not unusual to encounter large abscesses with visceral and cord complications. The onset is sudden, with high fever, chills, vomiting, and other manifestations of a severe acute infection; the patient soon complains of intense pain in the spine, at which

point local tenderness is extreme. The suddenness of onset, the extreme tenderness, and the acute symptoms, with almost uniform absence of pain on jarring, form a symptom-complex presented by no other disease of the spine, with the possible exception of acute articular rheumatism, which, however, rarely affects the spinal joints. An abscess rapidly forms, and although rarely penetrating the dura, it frequently gives rise to an accumulation of pus in the loose areolar tissue about the spine. The inflammation and edema frequently occasion symptoms of pressure on the cord, and the

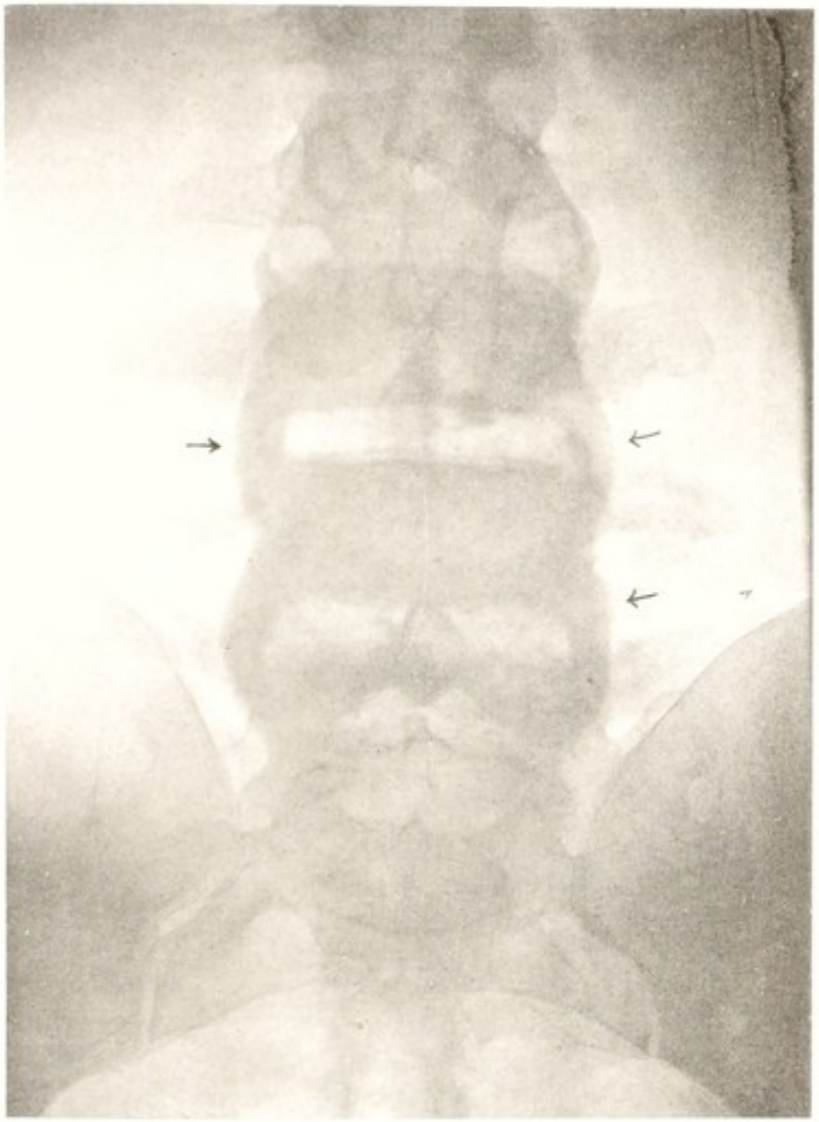


FIG. 177.—A case of infectious ostitis of the lumbar spine. The arrows indicate the large amount of new bone formation which is in such marked contrast to the absence of bone proliferation in tuberculosis of the spine. Ultimate telescoping of the vertebral bodies can be prevented in such cases by conservative splint treatment because of the active bone proliferation.

patient rapidly shows evidence of pyemia. The course of the disease is too rapid to allow the occurrence of deformity, but visceral complications are not unusual. The radiographic appearance and the very high leukocytosis are of aid in the diagnosis. The mortality is over 50 per cent. The condition is strictly a surgical disease, recovery being reported in only two cases in which operation was not performed.

Operation consists of the immediate evacuation of the abscess, thorough

opening of all pus pockets in the vertebræ, the removal of dead bone, and the establishment of good drainage. In cases of deeply seated pus formation, it may be necessary to resort to costotransversectomy or laminectomy for complete evacuation, particularly in the event of disease of the vertebral bodies.

III. Typhoid Spine

Attention was first directed to this condition by Gibney, in 1889. The fact that there are approximately about 70 cases reported in the literature, indicates its infrequency as a sequel of typhoid fever. The specific bacillus has been isolated from the pus in very rare instances. The condition is encountered at all ages, but far more frequently in males than in females. Traumatism is of considerable etiological importance. Over half the cases were encountered during convalescence, and all but two within a few months afterward, 90 per cent. before the end of the first month of the disease. The lumbar region is the usual seat of the lesion.

Pain is the most constant symptom, and is aggravated by movement; referred pains are not unusual. Other clinical phenomena are local swelling, redness, tenderness, spinal rigidity and kyphosis, as well as cord symptoms which may be merely irritative or may result in complete paralysis. The Widal reaction is almost universally positive. Although the usual lesion is spondylitis or perispondylitis, osteitis and osteomyelitis may occur. The pathological changes in typhoid spondylitis are more or less similar to those occurring in the vertebral manifestations of arthritis deformans. The prognosis in these cases is good. The lesion rarely progresses to pyogenesis.

Treatment comprises recumbency, immobilization of the spine in a plaster jacket or brace, massage, and the actual cautery. This usually suffices for the average case. In case, however, the lesion remains active, the advisability of immobilizing the affected segment of the spine by an inlay bone-graft, as applied to Pott's disease, should always be considered.

It has long been recognized that, following many of the acute infectious diseases, particularly typhoid, gonorrhea, tonsillitis, scarlet fever, diphtheria, and measles, pain, tenderness and rigidity of the spine are occasionally encountered. The sequence of events is similar to that observed in osteomyelitis of the long bones complicating the infectious diseases.

IV. Gonorrheal Spine

While gonorrheal infection of the joints is not infrequent, gonorrheal spine is even more rare than typhoid spine. There are very few distinguishing features to differentiate this from any other acute spinal condition. The diagnosis can safely be made in the presence of spinal pain and stiffness, following chronic urethritis, especially if other joints are involved, and if a gonorrheal fixation test is positive. The spine is usually stiff, and ankylosis is the rule. Bradford has reported a case in which gradual ankylosis followed gonorrheal disease of the spine, extending from sacrum to occiput.

Treatment.—As stated in Chapter X, treatment of the spinal condition must be preceded by elimination of the primary focus in the genito-urinary tract. Local treatment comprises rest in bed, or on a Bradford frame, support of the spine, and local applications of heat or cold. An ice-bag frequently affords great relief. Vaccines are of debatable value in this connection. Immobilization in a plaster-of-Paris jacket is indicated upon subsidence of the acute symptoms, and should be continued as long as active symptoms persist. The jacket may be supplanted by a spinal brace after

its removal, if there appears to be need of additional support. Massage and the electric light bath may also be employed at this time.

Prognosis.—In the severer forms stiffness and occasionally ankylosis of the involved segment of the spine may occur. The condition may subside in a few weeks or, in spite of all treatment, persist for many months.

V. Actinomycosis and Echinococcus Disease

There are only a few recorded cases of actinomycotic infection of the spine, and in all the spinal condition was secondary and of minor importance as compared with the primary growth. The vertebræ may be deeply eroded and the cord may be affected. The diagnosis in each instance depends upon the microscopic findings. Histologic examination is made either of the granulation tissue or of the pus in the abscess accompanying the growth.

Echinococcus cysts of the spine have been recorded in a few instances. In one case, an echinococcus cyst ruptured through the back. Treatment consists of operative removal of the growth, followed by immobilization in a plaster-of-Paris jacket or spinal brace.

VI. Tumors of the Vertebral Column

The neoplasms of the spine are either benign or malignant. They are very rare, constituting, according to Schlesinger, only 1½ per cent. of all tumors, over 90 per cent. of them malignant. There are a few cases of primary carcinoma and sarcoma, but the majority of spinal newgrowths are metastatic, and not a few are direct extensions of gastric and esophageal tumors.

Secondary carcinoma is more common than secondary sarcoma, and more frequently found in women, in whom it is probably due to metastasis from the breast. Several vertebræ are involved, as a rule, and the lumbar and dorsal regions of the spine are the commonest locations. Carcinoma can rarely be palpated or a diagnosis made except in those cases in which the spinal nerves are compressed and in which bony displacement and cord symptoms arise during the course of well-defined new growths elsewhere.

Sarcoma develops in the bone or periosteum, and usually causes a softening of the vertebral body, the superincumbent body-weight gradually producing such extensive erosion that two intervertebral disks become approximated. This "settling," as it is called, causes the most intense pain. The diagnosis can be made more readily in the case of sarcoma than of carcinoma, because of the tendency of the former to grow beyond the limits of the initial lesion. Primary sarcoma is more common than carcinoma in this locality.

A few cases have been recorded of a very rare tumor resembling red bone marrow, known as *myeloma*. Myelomata are always multiple, and usually cause no metastases, but tend to cause erosion of the vertebral body. The characteristic feature in cases of myelomata is the presence of albumose in the urine.

Exostoses are not infrequently found in the spine, particularly the cartilaginous form of exostosis. *Osteomata* and *enchondromata* are of no particular interest in this connection, and require no treatment as long as they produce no pressure or pain. Large dermoid cysts of the sacral region may be mistaken for neoplasms originating in the vertebræ or sacrum (Figs. 178, 179 and 180).

The chief symptoms of spinal tumors in general are pain and deformity. Over half the cases complain of neuralgia from pressure on the nerve-roots

and on the cord. The deformity is a gently rounded kyphosis. Death generally ensues within a year after the appearance of a malignant neoplasm of the spine.

Treatment consists of relieving the pain and pressure. In a few cases reported by Coley, a primary sarcoma was removed and the patient recovered without metastases, an unusual event. Coley's fluid may be tried in the case of sarcoma, but should be administered with due regard to the prescribed technic.

VII. Rickets

Rachitic deformity of the spine is produced partly by hypertrophy and partly by pressure or weight-bearing upon the malleable vertebral bodies.



Fig. 178.—Dermoid cyst at the sacral region. Such a tumor may cause confusion with a neoplasm of vertebral or sacral origin. (Author's case.)



Fig. 179.—Same case as Fig. 178. Shows child's habit of always sitting on the tumor, which was so large that it served for this purpose very well.

The spinal condition is always associated with the manifestations of rickets elsewhere and is characterized by absence of rigidity and the disappearance of the deformity when the child is prone, with the weight borne by the chest and thighs (Fig. 181). The conformation of the spine is usually a part of the general attitude, in which the body is inclined forward and the spine bent in a slightly rigid posterior curve which is most marked at the junction of the dorsal and lumbar vertebræ (Fig. 182).

The diagnosis of rachitic spine is usually easy, since it is associated with distortion of the lower epiphyses of radius and ulna, enlargement of the ankles, and overgrowth of the junctions of ribs and costal cartilages, together with delayed dentition, open fontanels, "pigeon-breast," etc.

The treatment is hygienic, dietetic, and medicinal. It is not necessary to support the spine, except in the more advanced cases, in which a simple

brace or brief recumbency upon a Bradford frame may be advisable. With proper care and treatment, the prognosis is excellent. Deformity is avoidable, except in those cases which are not seen until ossification of the spine in its distorted position has occurred.

VIII. Osteomalacia

This disease of the spine is characterized by absorption and disappearance of lime-salts. It is a disease of adults, chiefly females, and in them it is incident to pregnancy and prolonged lactation.

Pathology.—The lesions are characterized not only by absorption of lime-salts but by congestion of the bone-marrow, with increase of its lymphoid and fatty constituents. A thin shell of bone which bends or breaks, represents the cortex. Spontaneous fractures, often marked by malunion, are common.



Fig. 180.—Same case as Fig. 179 after removal of tumor. Excellent cosmetic result.

Clinical Features.—Constant pain, increased on exertion, is experienced in the spine and pelvis. There is difficulty in walking, typified by a waddling gait. Muscular weakness is evident, the knee-jerks are accentuated, while ankle clonus and muscular tremors are present. The pelvis is the first to suffer deformity by extreme lateral flattening, producing a sharp anterior beak. The spine becomes kyphotic or scoliotic. The ribs are laterally compressed. The long bones are bent or suffer spontaneous fracture.

Prognosis.—The progress of the disease in general, or the spinal lesion in particular, is unaffected to any appreciable extent by treatment.

Treatment.—Sanitary, hygienic surroundings, salt baths, cod-liver oil, phosphorus, bone-marrow, etc., have been separately and collectively employed, but with uniformly disappointing results. Double oöphorectomy in nonpregnant women has been credited with checking the disease in some instances.

IX. Scorbutic Spondylitis

The spinal involvement is but one of many manifestations of scurvy, is rare, and of little importance. It usually affects bottle-fed infants six to eighteen months of age. The first symptoms are discomfort on spinal movement or distress in the joints of the extremities. The spine is very tender but presents no evidence of redness or swelling. The condition can frequently be recognized by examination of the gums after dentition, and of the mucous membranes and skin for the presence of small repeated hemorrhages. An effusion of blood may occur about the joints, while epiphyseal separation is not unusual. The treatment is essentially dietetic; any citrous fruit (orange juice) appears to be almost a specific. The substitution of fresh modified cow's milk for the patented foods and artificially prepared milks (common etiological factors) may serve to cure the disease.



FIG. 181.—Same as Fig. 182; showing disappearance of kyphos in prone posture. (Taylor.)



FIG. 182.—Rachitic spine in a child one year old. (Taylor.)

During the period of pain, the spine should be immobiled on a Bradford frame or in a Phelps' cuirass.

X. Arthritis Deformans

Virchow was the first to pay much attention to spinal rigidities. His classification was undisputed, until Bechterew (1892) described several cases of spinal rigidity which he considered as an entity. Virchow (1867) divided the cases into what he called arthritis deformans and osteo-arthritis. Those cases in which there was bone formation between the vertebræ with loss of tissue and intervertebral substance, he named arthritis deformans, while those in which the ligaments were ossified he designated osteoarthritis of the spine.

The tendency at this time is to consider all cases of rigidity of the spine of unknown origin as manifestations of the same pathological process, and to term them arthritis deformans (or spondylitis deformans) (see Chapter XI).

The spinal condition may occur independently of any other joint involvement, or it may be associated with one or more joint disturbances. The cases with and without other joint involvements are about equally divided. Thus, Bechterew (1892) described conditions in which the spine alone was involved, while the Marie-Strümpell type was associated with ankylosis of the larger joints, such as the shoulder, hip, and knee. This pathological process in the spine is apparently identical with those observed in other (both large and small) joints in the body which have been classified generally as arthritis deformans. It is not unlikely that the etiological factors are the same in the spine as in the other joints, and that possibly one or more organisms or their toxins are the underlying factors in each.

Although the exact cause of the arthritis is not known, it is probably secondary to some local septic process elsewhere in the body, such as the septic foci so often encountered about the bases of the tonsils and about the teeth; or the spinal manifestations may be secondary to intestinal, prostatic, or skin disturbances. The organism may be present in the joints in an attenuated form, or the products of its metabolism may produce toxic changes here, as elsewhere. Traumatism, by lowering the resistance, would produce a locus minoris resistentiæ and present a nidus of infection. Not infrequently the spinal symptoms follow a severe infectious disease.

As in other joints of the body, the spinal changes may be essentially degenerative, proliferative, or simply inflammatory, without evidence of bone destruction; frequently the process is a combination of the three, depending, however, upon the resistance of the individual and upon the virulence of the irritant. Thus, a proliferation of bone may occur in the form of exostoses, which may gradually tend to fuse with each other; then, again, atrophy of the cartilages may result with or without bony replacement, and the spinal ligaments, especially the anterior lateral ligament, may undergo osteophytic changes. The extent of the involvement also varies. There may be only slight inflammation about a few vertebral joints, while in other cases portions of the spine may become ossified, the process being so extensive as to include all the vertebræ. The transverse processes are frequently involved.

While other manifestations of arthritis deformans affect males and females with almost equal frequency, spondylitis deformans, on the other hand, is far more prevalent in males. While most cases occur in the middle period of life, the affection is occasionally encountered in children, and ankylosis of the spine is sometimes observed during adolescence and in the

aged. The disease is insidious, and usually progressively chronic. The chief complaint is pain, which is due to nerve involvement or muscle spasm, and is usually of the referred type. It may be thoracic, abdominal, sciatic, or neuralgic. The formation of new bone not only interferes with motion, but is gradually productive of more or less rigidity of the spine. The character of the deformity depends largely upon the nature and the extent of the changes in and about the vertebræ, viz.: in those cases in which there is destruction of cartilage without restoration of bone, the straight, stiff "poker-back" is the rule. In other cases, marked bowing (flexion deformity) with ankylosis constitutes the distortion. The essential cause of the distortion in either case is ossification of the ligaments. The mental effect of the deformity and the physical effect of pain may proceed to such an extent as to undermine the health, the patients frequently appearing weak, worn, and haggard, with body bowed forward, head projecting, and eyes protruding. Muscular wasting is frequently noted in the back and leg muscles. Sensory disturbances are common. Radiography frequently demonstrates deposits of bone, characterized by extreme irregularity of conformation and in some cases localized chiefly on one side or in the ligaments.

The clinical features in the cases of general involvement of the spine are so characteristic that they need but little elaboration, but in those cases marked by stiffness, interference with motion, indefinite pains (the so-called "lumbago"), and weakness, differentiation is occasionally difficult. There may be nothing striking in the examination of the spine, with the exception of tenderness and slight limitation of motion, or slight evidence of muscular atrophy. The administration of tuberculin, when used in combination with radiography, may serve to exclude early Pott's disease.

The results of treatment are exceedingly disappointing. In the early acute cases, the keynote of treatment is rest, and in these cases the results of the use of spinal supports and plaster-of-Paris jackets are occasionally gratifying. Aside from these mechanical measures, the treatment is purely symptomatic. However, septic foci should be sought as etiological factors, and autogenous vaccines prepared from such foci are occasionally found to be of unexpected benefit. In the event of failure to demonstrate a pyogenic focus and hence to obtain an autogenous vaccine, a complement fixation test may be made and the corresponding stock vaccine employed. Radiotherapy has been employed with little success. The salicylates in large doses, with twice the amount of sodium bicarbonate seem to afford relief in certain cases. In very rare instances, the process may be limited and confined to a very few vertebræ, in which event the implantation of a bone-graft may serve to control the symptoms and the pathological process. The prognosis is not very hopeful for correction of the deformity although, if the case is seen early, deformity may be largely prevented. Excluding the cases of extreme nervous exhaustion, the limit of life is apparently not influenced to any great extent by the disease.

XI. Acromegaly

Acromegaly bears a superficial resemblance to Paget's disease because of the enlarged head, thickened long bones, and the kyphosis, the latter usually affecting the cervical region. The bony lesions of acromegaly are symmetrical and are accompanied by hypertrophic changes in the soft tissues. The chief osseous lesions are changes in the bones of the face, which are hypertrophied and give a typical leonine character to the facies. There is no procedure known to affect the disease, with the exception of

occasional temporary retardation by the administration of the extract of pituitary body; the dose of the dried gland averages $\frac{1}{4}$–$1\frac{1}{2}$ grains, although the amount depends upon what portion of the gland is used and the kind of preparation employed.

XII. Paget's Disease

The spine is only a part of the general bony involvement, and shows marked kyphosis and often partial ankylosis. A full description of Paget's disease will be found in Chapter XIX.

XIII. Congenital Deformities of the Vertebral Column

Congenital deformities of the spinal column are thus classified by Perrone (Zeitschr. f. Orth. Chirurg. xv, 2 bis 4 Hefte, 1906).

(*A*) Vertebral deformities without malformation of other parts:

1. Increase in number of vertebræ.
2. Deficiency of them or of parts of them (spina bifida and occulta).
3. Synostosis.

(*B*). Vertebral deformities with malformation of other parts:

1. Fusion of the ribs.
2. Suppression of portions of the ribs.
3. Sprengel's deformity of the shoulder.
4. Cervical ribs.

(*A*) **Vertebral Deformities Without Malformation of Other Parts.**—1. **Increase in Number of Vertebræ.**—The following are among the instances on record: (*a*) Four supernumerary half-vertebræ; (*b*) thirteen dorsal vertebræ but the third and fourth lumbar vertebræ were only half developed and were synostosed; (*c*) imperfect vertebra between the first and second lumbar, etc. These anomalies are of practically no clinical importance.

2. **Deficiencies of Whole or Parts of Vertebræ.**—The only important clinical instances of this group are the various forms of spina bifida and spina bifida occulta, in which portions or the whole of one or more arches are defective. Spina bifida is the commonest of all these congenital anomalies of the spinal column.

Spina bifida is a condition in which a considerable gap occurs in the posterior vertebral wall, due to faulty development of the bony lamellæ, which permits a protrusion of the spinal membranes or cord, or both. The hernial protrusion is sometimes covered by skin, but usually by a film-like structure of variable thickness, which is usually attenuated and likely to rupture. The protrusion varies in size, from a small sac to that of a walnut, or to a rotund mass occupying much of the lumbar region of the back. It is sometimes pedunculated. Other anomalies often co-exist, such as talipes, hydrocephalus, exstrophy of the bladder, and imperforate anus (Figs. 183 and 184).

Spina bifida is classified according to the structures entering into its formation, viz.:

1. *Meningocele.*—A protrusion of the dura mater and arachnoid, but containing no nerve elements. A pedicle whose narrow lumen sometimes closes, obliterating the sac, usually accompanies this form.

2. *Myelocele.*—Here the posterior wall of the involved vertebræ is entirely absent, exposing the medullary groove.

3. *Meningomyelocele.*—The sac contains spinal cord (which is not distended but adherent to its walls) spinal nerves, and fluid. The walls consist of dura mater and thin epithelium.

4. *Syringomyelocele.*—The distended cord with spinal membranes and nerves forms the wall of the sac. This variety is rare.

Infants afflicted with the two last-named varieties are either stillborn or die very soon after birth.



FIG. 183.—Spina bifida and congenital talipes equinovarus, both relieved by operation.

Prognosis.—The great majority of infants with spina bifida propria do not reach puberty. Frequently the sac leaks on account of sloughing, the fluid escapes, infection occurs, and death ensues from meningitis or myelitis.

Occasionally rupture is followed by shrinkage and spontaneous cure. Even after "cure" of a spina bifida spontaneously or from surgical inter-

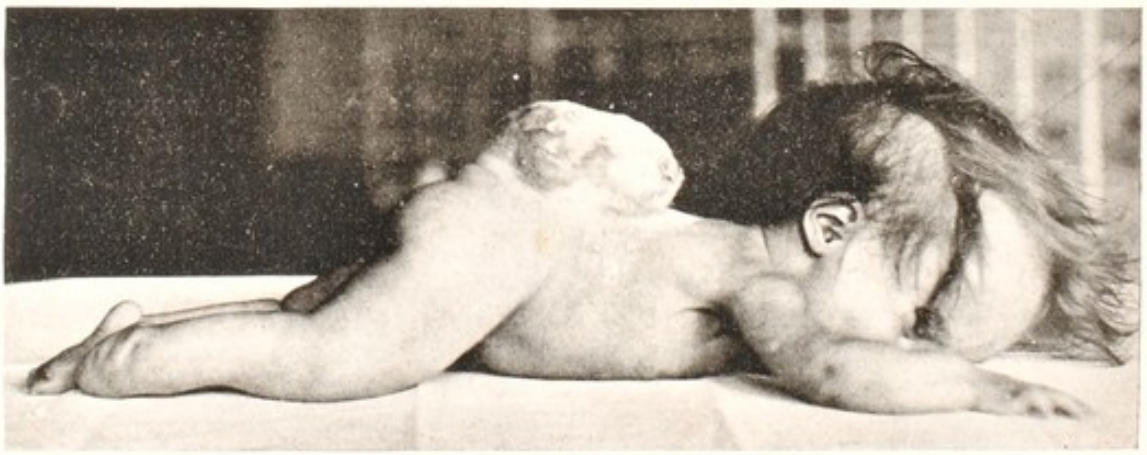


FIG. 184.—Spina bifida with associated hydrocephalus and left talipes equinovarus.

ference, many cases subsequently succumb to hydrocephalus or other sequelæ of increased intracranial pressure, or die from paralysis or a trophic lesion.

Treatment.—(1) *Palliative treatment*, which is in no wise curative, consists of protecting the sac by a compression pad of gauze and cotton (with an astringent ointment to prevent sloughing) retained by adhesive strapping.

2. *Operative Treatment.*—In cases of spina bifida in which the meningocele has been controlled and a large deficiency of vertebral bone exists together

with considerable weakness, as evidenced by lordosis or other deformity, the bone-graft offers an excellent means for strengthening the spine.

(*a*) *Radical Operation for Spina Bifida.*—Two lateral incisions are made vertically and extending well above and below the tumor. The sac is opened in a line with these incisions and the fluid is released *gradually* or with the patient in Trendelenburg's position but on the face, or in Babcock's position (to avoid cerebral anemia from too sudden reduction of intracranial tension) (Fig. 185). The sac is turned inside out, the nerves dissected out and the spinal cord freed, and these structures are then returned into the spinal canal, and the sac cut away. The neck of the sac is then freed from the bottom of the wound, and as much more tissue as is advisable is resected.

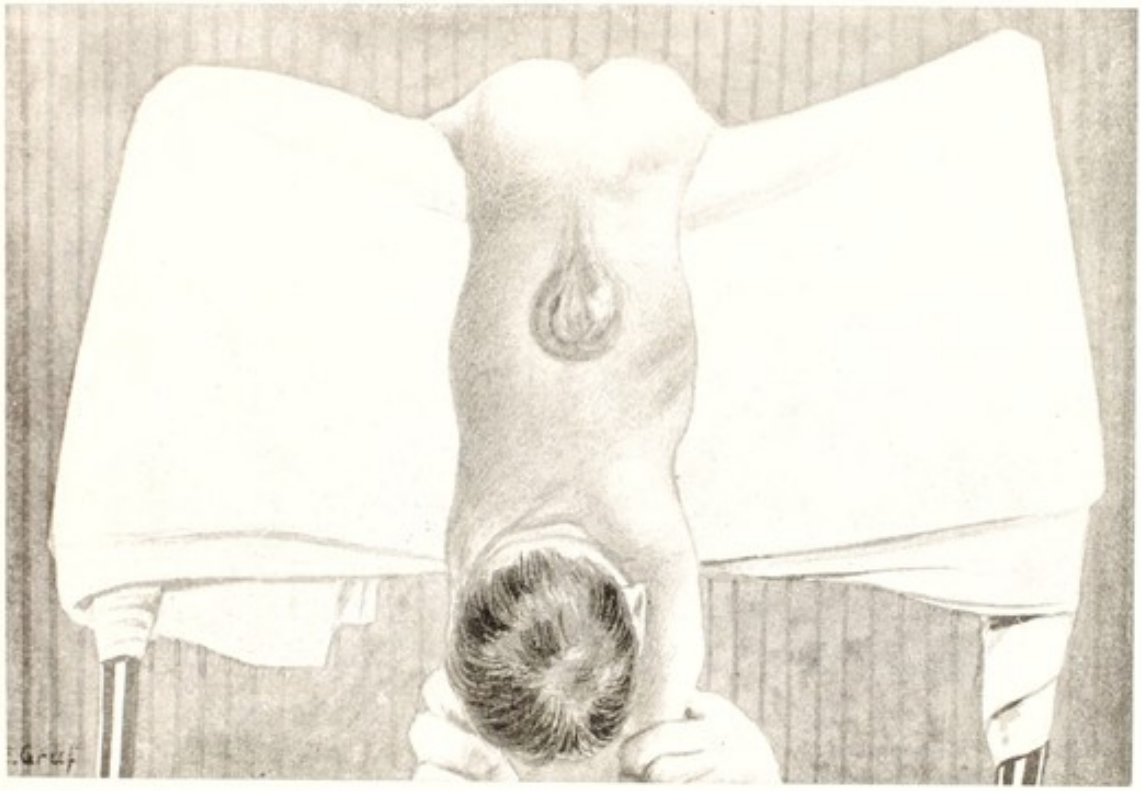


FIG. 185.—Babcock's position in operations for spina bifida. (The object of this position is to obviate the danger of too-sudden reduction of intracranial tension.) A blanket is fastened firmly between the upright rod leg-holders on an ordinary operating-table. The child is hung over this by its groins. The legs being fastened by bandages to keep it from slipping. A hot-water bottle is placed in front of the blanket, over the child's abdomen, to prevent chilling. (After Babcock.)

The neck is then closed with a purse-string suture. Quadrilateral flaps are made with their bases toward the median line, and consist of muscle, fascia, and periosteum. The flaps are sutured with their raw surfaces opposed, forming a ridge near the midline. The skin is closed with silkworm gut. Tension must be avoided by removing sufficient of the redundant superficial tissues, or by undercutting, or by making lateral incisions in the flanks.

Results of Radical Operation.—The immediate postoperative mortality is about $33\frac{1}{3}$ per cent.; the secondary mortality (from hydrocephalus, convulsions, etc.) is equally great, bringing the ultimate mortality from radical operation to 60 to 70 per cent.

(*b*) *Inlay Bone-graft for Spina Bifida* (Albee).—The technic is somewhat similar to that employed in Pott's disease, although modification is necessary

on account of the absence of spinous processes and portions of the neural arches. The spinous processes above the cleft and the remnants of the neural arches, or the lateral masses of the last lumbar vertebra and the first part of the sacrum, are reached from each side by two curved skin incisions, as it is undesirable to interfere with the nerve tissue which is usually involved in the cicatrix, following the operative reduction of the meningocele. The second spinous process above the cleft is split longitudinally, and a green-stick fracture, produced in each half. The first spinous process above the cleft is denuded of its muscular and ligamentous attachments, and both sides are freshened. Below the cleft, the lateral masses of the fifth lumbar vertebra (or the congenitally deformed stumps of the neural arches, if sufficiently prominent) and the first segment of the sacrum, which is usually congenitally hypertrophied, are split with the osteotome, and the halves are separated to receive the lower ends of the two grafts.

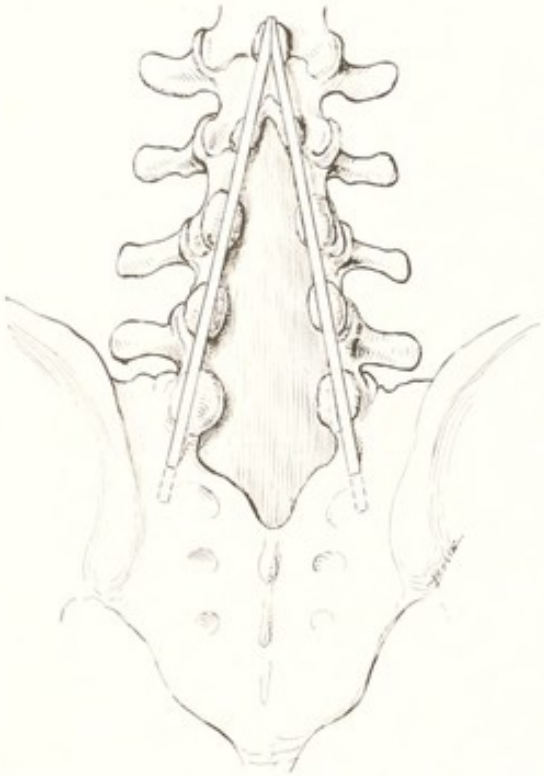


FIG. 186.—Drawing illustrating author's technic of inserting a tibial graft to straighten and support a lordotic bifid spine (spina bifida).

The wounds are packed with saline compresses, and the two grafts are removed from the crest of the tibia, being long enough to reach from the split spines above to the sacrum below. The upper ends are bevelled, so that when these bevelled surfaces come together the grafts form an acute angle like an inverted V. The grafts are placed at this angle in the beds prepared for them, and are held firmly in place in their bony contacts by drawing the split ligaments over them, with interrupted sutures of medium kangaroo tendon (see Fig. 186). The skin wounds are closed, and the patient placed on a fracture-bed for six weeks.

Spina Bifida Occulta.—This is a simple and relatively unimportant variety of spina bifida. Its usual location is the lumbar, sacrolumbar, or dorsolumbar regions. It is rarely encountered elsewhere.

The lesion is represented by a small scar or a depression, often pigmented, and exhibiting hypertrichosis. (Side-show freaks, with a "mane" are examples of spina bifida occulta).

The bony defect varies in size; sometimes it is exceedingly small and its presence is counteracted by the membrane, so that no protrusion occurs. J. W. Seaver (Bost. Med. & Surg. Jour., clxi, No. 12, pp. 388–392) reports 11 cases and states that there may accompany this condition other congenital defects and various trophic disturbances, dependent upon the bifid spine. Seaver states that the pain which sometimes accompanies these cases is due to pressure by a firm band of connective tissue joining the skin over the cleft and the lower end of the spinal cord, and causing anesthesia and hyperesthesia in the lower trunk and legs, and insufficiency of the bladder and rectum.

Treatment is, as a rule, uncalled for in cases of spina bifida occulta, but Seaver recommends division of the above-mentioned constricting band when

pain is severe. Where the bone deficiency is marked, resulting in pain and weakness, a bone-graft inserted into the spinous processes above and below the defect (in the manner of the operation for Pott's disease, *q.v.*) will strengthen and support the defective vertebræ.

3. **Synostosis of Vertebræ.**—This is one of the possible causes of "congenital scoliosis," particularly when there is fusion of the transverse process of one side of the fifth lumbar vertebra with the sacrum, the so-called sacralization of the last lumbar vertebra (Fig. 187). Similar synostoses of adjacent vertebræ in the lumbar and dorsal regions have been reported.

(B) **Vertebral Deformities with Malformation of Other Parts.**—(1) and (2) **Abnormalities of Ribs and Clavicle.**—*Fusion* of two or more ribs or failure of development have been recorded, but are of little practical importance.

Defects of the clavicle, such as partial absence, have been noted, usually associated with peculiarities of the cranial bones, palate, and teeth. The clinical features are slight drooping and falling forward of the shoulders,



FIG. 187.—Sacralization of fifth lumbar vertebra, more marked on left side. The specimen to the right is more completely sacralized and has only four lumbar vertebræ. (From specimens in Cornell Medical College.) (Taylor.)

which can sometimes be approximated to actual contact by the use of a little force.

3. **Cervical Ribs.**—Eisendrath (Am. Med., Aug. 28, 1904) distinguishes four types, viz.:

(*a*) Complete and articulating with the sternum.

(*b*) Rib 3 to 4 inches in length, articulating with the first thoracic rib or connected with the sternum by a ligament.

(*c*) Rudimentary rib about 1 inch long.

(*d*) Rudimentary structure represented by a tubercle projecting from the transverse process.

Cervical ribs probably represent a reversion in type to some elementary form. The longer the rib grows, the broader it becomes. It occasionally forms a bony projection in the posterior triangle of the neck. Sometimes the scalenus anticus (rarely the scalenus medius) is inserted into it.

Clinical Features.—The physical effects of the presence of cervical rib are arterial and nervous (rarely venous) obstruction. The veins are seldom compressed, hence edema of the arms is rare.

The location of a cervical rib is behind and beneath the branches of the

brachial plexus or between its cords, carrying forward and compressing the subclavian artery and the nerve cords against the external and posterior border of the scalenus anticus; the vein lies in front of the muscle and out of the way, and thus escapes compression.

Arterial Effects.—(*a*) Narrowing and constriction of the vascular lumen with the arm hanging, relieved by its elevation; (*b*) endarteritis and thrombosis; (*c*) aneurismal dilatation; (*d*) gangrene.

Nervous Effects.—Hyperesthesia, anesthesia, weakness, paresis, motor paralysis, and muscular atrophy.

Symptoms.—(*a*) *Nervous.*—Tingling and numbness of the arm and forearm (the latter following the distribution of the ulnar nerve); at a later period, a boring pain, muscular weakness, succeeded by anesthesia, paralysis, and muscular atrophy. The subjective symptoms are relieved by raising the arm above the head, elevating the shoulder, or by leaning on the elbow.

(*b*) *Vascular.*—The arm is white, and its surface cold, especially during muscular exertion. Diminution of the brachial and radial pulses, which may disappear with the arm hanging to re-appear on its elevation, is commonly observed. Actual aneurism or flattening of the artery to simulate aneurism, may occur at the point of its compression; this may disappear after resection of the offending rib. Endarteritis, sometimes obliterating in character, followed by thrombosis and gangrene, may occur.

(*c*) *Tumor.*—Immediately above the clavicle or in the neck, a bony mass may be palpable in the posterior triangle. Pulsation may be detected over it. In later life, the broadened distal extremity feels like an exostosis, occupying the whole subclavian triangle.

Diagnosis.—A cervical rib usually escapes detection except by accident, unless it is causing symptoms of arterial or nervous compression, when the symptom-complex given above is conclusive, particularly when substantiated by radiography.

Prognosis.—The presence of a cervical rib is of no importance unless it causes pressure, when the chief danger is gangrene or permanent paralysis unless the cause of the compression should be removed.

Treatment.—Resection of the offending rib is the only means of relief. The technic of the operation depends upon the location of the rib, and is often exceedingly complex when the ribs pass through the cords of the brachial plexus or if the artery is dilated or attenuated, or if aneurism is present.

Operation for Excision of Cervical Rib.—The operation may be performed from in front or from behind.

1. *Operation from in Front.*—The rib can be approached through various incisions, viz.: (*a*) vertical, over the most prominent point of the rib; (*b*) oblique, following the anterior edge of the trapezius; (*c*) transverse, about 1 inch above the clavicle and extending from the trapezius to the sternomastoid.

After the platysma and superficial fascia have been divided, a double ligature is placed on the external jugular vein, and the vessel severed. Having divided the deep fascia, the great vessels and the brachial plexus are developed (by blunt dissection through the loose areolar fatty tissue above them), and they are retracted from the cervical rib. By blunt dissection, aided by cautious use of the knife, the soft tissues are separated from the rib. The near presence of the pleura must be borne in mind and care must be taken to avoid injuring it. It is best to excise the rib extraperiosteally. After exposing and developing a small portion of the rib, it is followed to its spinal origin and there amputated with bone forceps, and

the stump carefully rounded off with rongeur forceps to avoid leaving a protruding spicule of bone. The anterior attachment of the rib is then divided and the rib removed. After all bleeding points have been checked, the deep and superficial wounds are closed.

2. *Operation from Behind.*—Streissler advocates an incision beginning three-quarters of an inch lateral to the spinous processes of the vertebræ and a hand's breadth above the vertebra prominens, thence passing downward parallel with the spinous processes to a hand's breadth below the vertebra prominens. After having divided the trapezius, both rhomboids, serratus posticus, and the splenius, the fibers of the complexus and semispinalis colli are separated, exposing the transverse processes of the two lower cervical and two upper thoracic vertebræ and the junction of the cervical rib with the transverse process of the seventh cervical vertebra. The transverse process is removed with bone forceps, bringing the thin neck of the rib into view. A curved periosteal elevator or other guard is passed above the neck of the rib, and the latter divided, avoiding the nerve roots which lie just anterior to it. With the rib held in lion-jaw or other strong forceps, it is developed by sharp and blunt dissection as far as possible. If the anterior connection is too firm to be broken sufficiently to permit removal of the rib, an anterior incision (which has already been described) is made, and the rib removed in that manner.

4. **Congenital Elevation of the Scapula** (Sprengel's Deformity).—This is a rare condition. According to Neuhof (Am. Jour. Dis. of Children, 1914, vol. vii, pp. 357–379) a considerable number of unilateral and about 14 cases of bilateral elevation of the scapula have been reported.

The etiology, symptoms, pathology, and operative treatment are fully considered in Chapter XV, *q.v.*

Associated Abnormalities.—(*a*) Ribs and Vertebræ.—Cervical ribs, spina bifida, spina bifida occulta, deficiencies of ribs and vertebræ, displacement of spinous processes with fusion, fused and irregular ribs, and absence of ribs have all been noted in connection with Sprengel's deformity.

(*b*) *Muscles.*—Defective development of the muscles is common. The trapezius is the muscle usually affected, is weak in all cases, and may be absent. The serratus, pectoralis major, and sternomastoid muscles are less commonly involved.

(*c*) *Humerus and Clavicle.*—Shortening of both these bones has been observed.

Treatment.—*Conservative Treatment.*—Active and passive movements of the affected arm, gymnastics, massage, etc., form the basis of conservative treatment.

Operative removal of plates of bone, division of the scapulovertebral muscles, excision of the vertebral portion of the scapula if actually overlying the spinous processes, followed by exercises, have all been practised with varying success. In certain cases, where a fibrous band joins the spine and the scapula, an extensive division may be necessary to allow correction of the deformity.

XIV. Chronic Backache

The frequency of chronic backache, the confusion in diagnosis, and the great impetus which this ailment has given to the patent medicine vendors, make it imperative that the subject be treated at some length. The confusion attending the subject may be appreciated by a review of the commoner designations by which the affection is known, as recorded by Lovett, in a very instructive paper (Jour. A. M. A., vol. lxii, 1914, pp. 1615–1620):

"Neurasthenic spine, hysteric or irritable or railroad spine, chronic lumbago, uterine backache, static backache, relaxation of the sacro-iliac joint, sacro-iliac strain, rheumatism of the spine, chronic back strain, etc."

Symptoms.—(1) Subjective discomfort, constant or intermittent dragging, or greater or less acute pain, usually in the lumbar region may be present. It may be unilateral or bilateral, increased on standing or walking, and often radiating to the buttocks or backs of the thighs. (2) Lameness on forward bending. (3) Tenderness in the lower lumbar region and over the sacro-iliac joints. (4) Relief afforded by a cushion under the small of the back. (5) Coccygodynia. (6) Commoner in women than in men, and particularly in the following three types of figures, according to Lovett (*loc. cit.*): (*a*) flat-backed, round-shouldered type; (*b*) type with prominent buttocks and sharp forward lumbosacral curve; (*c*) cases with slight lateral curvature.

Etiology.—Lovett recognizes three well-established etiologic classes, and a fourth less definite variety, viz.:

1. Disease or displacement of the pelvic organs, due to direct reflex influences or, more probably, to postural causes (*e.g.*, forward bending) assumed in order to relieve pressure on the pelvic viscera.

2. Traumatism, such as sprain, with resulting chronic irritability.

3. Arthritis of the spine, of traumatic or spontaneous origin, co-existent with arthritis elsewhere or existing as an independent affection.

The above varieties may be independent, interrelated, or influenced by the following:

4. Defective balance, due either to (*a*) static causes from overstrain of the posterior musculature, the pain arising from irritation of the muscles, ligaments, and fasciæ, or to (*b*) strain or relaxation of the sacro-iliac joints.

Clinical Features.—Lovett goes on to describe the clinical features of these various forms as follows:

1. *Backache of Pelvic Origin.*—The discomfort is generally sacral and associated with a history of pelvic disturbance. The similarity of back symptoms in static and pelvic cases tends to support the theory that pelvic backache is usually due to the forward bent position so often assumed by these patients.

2. *Backache Following Traumatism.*—There is often a history of a blow or strain, as of heavy lifting. Postoperative backache is included in this class.

3. *Backache Due to Arthritis.*—The symptoms are stiffness and lateral deviations of the spine, pain in the back and legs (often attributed to "sciatica"), loss of the lumbar curve, disturbances of sensation in certain areas of the legs, with occasionally some loss of motion in certain muscles; pain on movement, "catch" in the back on movement, recurrent lumbago. *X*-ray examination shows in some cases osteophytes on the vertebræ and "lipping" of the vertebral edges.

4. *Backache Due to Defective Balance.*—(*a*) *Lateral Defects in Balance.*—One leg is longer than the other, the pelvis is obliquely tilted, and the spine curved to one side on standing, the muscles on the converse side therefore undergoing strain. Discomfort is greatest on standing and walking, and is marked over the sacro-iliac region of one side.

(*b*) *Defective Anteroposterior Balance.*—The commonest cause is an abdomen so large as to constitute a serious anterior load. Another common cause is flatfoot and its allied conditions, which induce back strain by producing abnormality of the base of support. One of the commonest types is due to a relaxed and "slumped" attitude of body.

Treatment.—1. *Pelvic Backache.*—This usually requires the services of the gynecologist. Very often, however, the static element predominates,

and hence it is always advisable to try mechanical supports before resorting to operation.

2. *Arthritis of the Spine.*—A canvas corset, reinforced with steel straps, or a leather corset, or a steel back-brace, will very often give marked relief. In severe cases, a plaster-of-Paris jacket may be required.

3. *Traumatic Cases.*—In the severe forms, the treatment is the same as for arthritic cases; in the lighter cases, the treatment outlined for the static variety should be employed.

4. *Static Backache.*—The treatment of this variety consists of correction of unilateral defects of balance by elevating one heel; the proper treatment of pronated or otherwise deformed feet; the treatment of deficiencies in the general condition (such as overstrain, faulty habits of attitude, etc.), and the enforcement of as much recumbency as can be secured.

The mechanical treatment of static backache has been elaborated by Reynolds and Lovett (*loc. cit.*) and has been demonstrated to be most effectively accomplished by a properly fitted corset, supplemented by high-heeled shoes. The corset can be fashioned by any intelligent corset-maker, and should meet the following requirements enumerated by Reynolds and Lovett: (*a*) tight at the bottom and loose at the top, thus combining abdominal support with constriction of the gluteal region; (*b*) straight in front; (*c*) the corset should support the hollow of the back, but not press foward against the back at the top. The efficacy of the corset depends upon the cut of the cloth and the lines of strain, and does not need heavy steel supports. For men, a heavier canvas with light steel stays is best. The heels of the shoes are raised $\frac{1}{8}$ to $\frac{1}{4}$ inch. Gymnastics and massage should be instituted on subsidence of the symptoms.

REFERENCES

MISCELLANEOUS AFFECTIONS OF THE SPINE

Tumors

Bland-Sutton: "Tumors, Innocent and Malignant," p. 95.
Thomas, J. J.: "Myeloma," Bost. Med. & Surg. Jour., Oct. 3, 1901.
Davies-Colley: "Primary Sarcoma." Tr. Clin. Soc., xxv, 103.
Monroe: "Myeloma." Jour. A. M. A., Oct. 22, 1904.
Keen, W. W.: "Surgery," vol. ii, 833.

Syphilis

Ridlon: "Syphilitic Spondylitis in Children." Tr. Am. Orth. Ass'n, vol. iv, 1891, 118.
"System of Syphilis."
Watkins: Am. Jour. Orth. Surg., January, 1908.

Actinomycosis

Ewing: J. H. H. Bull., November, 1902.

Blastomycosis

Brewer, George: Ann. Surg., December, 1908.

Osteomyelitis

Delafield: N. Y. Med. Jour., 1875, xxi, 53.
Warren: Bost. Med. & Surg. Jour., May 7, 1903.
Tubby: Brit. Med. Jour., September, 1905.
Hunt: N. Y. Med. Record, April 23, 1904.

Paget's Disease

Osler's System of Medicine.

History of Spinal Surgery

Prewitt: Ann. Surg., 1898.
McCosh: J. A. M. A., Aug. 31, 1901.
Sherman: J. A. M. A., March 9, 1907.
Cheever: Bost. Med. & Surg. Jour., Sept. 28, 1893.
Thornburn: "Contributions to Surgery of Spinal Cord."
Murphy: Surg. Gyn. & Obst., April, 1907.

Rickets

Whitman: Orth. Surgery, 1918.
Gillette: St. Paul Med. Jour., March, 1905

Scurvy

Gillette: St. Paul Med. Jour., March, 1905.

Typhoid

Gibney: Tr. Am. Orth. Ass'n, 1889.
McCrae: Am. Jour. Med. Sci., December, 1906.
Silver: Am. Jour. Orth. Surg., October, 1907.
Fluss: Centralbl. f. D. Grenzgeb. d. Med. u. Chir., 1905, Bd. 8, p. 17.

Gonorrhea

Marie: Rev. de Med., No. 18, 1898, p. 285.
Raymond: Semaine Med., No. 1, March, 1899.
Bradford: Ann. Anat. Surg., vol. vii, No. 6.

Osteitis Deformans (Spondylitis Deformans)

Elliott: Am. Jour. Orth. Surg., 1906.
Crispin: N. Y. Med. Jour., July 30, 1910.
Epstein: Med. Record, Jan. 29, 1902.

Osteo-arthritis

Goldthwaite: Bost. Med. & Surg. Jour., vol. 146, p. 299.
Feiss, H.: Cleveland Med. Jour., June, 1905.
Sachs: Jour. Nerv. & Ment. Dis., Jan, 1900.

Congenital Deformities of Vertebral Column

Bland-Sutton: Trans. Roy. Med.-Chir. Soc., 1884, p. 157.
Fleury: "Scoliose Congénitale." Diss., Paris, 1901.
Athanassow, P.: "Über kongen. Skoliose." Archiv f. orth. Mechan., 1903, Heft 3.
Coville: "De la scoliose congén." Rev. d'orth., 1896.
Rédard: Traité pratique de chir. orth. Paris, 1892.
Guérin, J.: Recherches sur les difformitiés congén., Paris, 1880.
Maas: "Ein Fall von angeborener Skoliose." Zeitschr. f. orth. chir., 1903, Bd. vii.
Bonnaire: Bull. Soc. Obstét. de Paris, 1894.
Fitzwilliam: Proc. Roy. Soc. Med., December, 1908, vol. ii, No. 2.
Allison, Nathaniel: Amer. Jour. Orth. Surg., November, 1908, p. 286, with skiagram.
Böhm: Boston Med. and Surg. Jour., November 22, 1906.
Bardeen: "Numerical Variation in the Human Adult and Embryo." Anat. Anz., 1904, Bd., xxv.

LOVETT: "Lateral Curvature of the Spine and Round Shoulders," p. 20.
CLARKE, J. JACKSON: Amer. Jour. of Orth. Surg., vol. iv, p. 100. "A Case of Congenital Deformity of the Spine." Thirteen ribs were present, including a cervical rib, also a double lateral curve, to the left in the cervical, and to the right in the upper dorsal region; and fusion of the last cervical and first dorsal vertebræ.
KIRMISSON: Rev. d'orthopédie, September, 1906.
BONNAIRE: Bull. Soc. Obstét. de Paris, 1901, iv, p. 161.
CORNER AND HARNETT: St. Thomas's Hosp. Rep. (1904), 1905, xxxiii, p. 190.

SPINA BIFIDA

ROBSON MAYO: Clin. Soc. Trans., vol. xviii.
ROBSON MAYO: Annals Surg., 1895, xxii.
LOVETT: Amer. Jour. Orthopedic Surgery, October, 1907, vol. v, No. 2.
LAFERTE, DANIEL: "Spina Bifida, Its Relation to Orthopedic Surgery." Amer. Jour. Orthopedic Surgery, May, 1910, vol. vii, No. 4.
HILDEBRAND: Verhandl. d. deutsch. Ges. f. chir., 1893. Archiv f. klin. chir., Bd. xxvi.

CERVICAL RIBS

MURPHY: Annals of Surgery, vol. xli, p. 401.
EISENDRATH, D. N.: Amer. Med., Aug. 20, 1904.
KEEN: Amer. Jour. Med. Sci., February, 1907, gives a review of 42 operations.
MURPHY, J. B.: Surg. Gyn. and Obst., October, 1906.
SZOKOL: Chirurgie (Russian), 1907, S. 23; also abst. Zentralbl. f. Chir. and mech. Orth.
RUSSELL, C. K.: Med. Rec., Feb. 16, 1907.
FARR, C. B.: Amer. Med., May, 1907.
BROADBENT, W.: Brit. Med. Jour., May 5, 1906.
VON RUTKOWSKI: Zeitschr. f. klin. Med., Bd. lx, Nos. 3 and 4.
SPILLER AND GITTINGS: N. Y. Med. Jour., Oct. 6, 1906.

CONGENITAL DEFECT OF CLAVICLE

DOWSE, T. S.: Path. Soc. Trans., vol. xxvi, 1875, 166.
SCHORSTEIN: Lancet, Jan. 7, 1899.
CARPENTER: Lancet, Jan. 7, 1899.
WALSHAM: B. M. J., 1888, vol. ii, p. 994.
SHERMAN: Trans. Am. Orth. Ass'n, vol. xv, 1902.
KLAR, MAX. M.: Zeitschr. f. orth. Chir., 1906, Bd. xv, 2 bis 4 Hefte, p. 424.
MARTIN: Jour. de méd. et chir., etc., Paris, S. xxiii, 456.
STAHMANN, F.: Zeitschr. f. med. Chir. u. Geburtshilfe, Magdeburg und Leipsic, 1857, Bd. ii, 433.
GEGENBAUER: Jena'sche Zeitschr. f. Med. u. Naturwissenschaft, Leipsic, 1864, p. 1 et seq.
NIEMEYER: "Bericht. über die xl. Versammlung deutscher Naturförscher u. Ärzte." Hanover, 1866, p. 236.
SCHEUTHAUER: Wien. med. Zeit., 1871, p. 293.
KAPPELER: Arch. d. Heilk., 1875, Bd. xvi, p. 265.
GUZZONI, DEGLI AUCARANI: Bulletino scientifico, Pavia, 1887, anno 9, p. 72.
BUSSCHE: Inaug. Dissert., Freiburg, 1890, Amsterdam, 1890.
PIERRE MARIE ET PAUL SAINTON: "Sur la dysostose celido-cranienne héréditaire." Rev. neurologique, 1898, vol. vi.
PIERRE: "De la dysostose celido-cranienne héréditaire." These, Paris, 1898.
GIANETTASIO: "Assemza congenita delle clavicole."
SACHS: "Über angeborene Defekte des Schlüssell blattes." Inaug. Dissert., Leipsic, 1902.
GROSZ: Münch. med. Wochenschr., 1903, No. xxvii.
PRELEITNER: Wien. klin. Wochenschr., 1903, No. iii.
DUNCAN, C. L. FITZWILLIAM: Lancet, Nov. 19, 1910, with full bibliography.

CONGENITAL ELEVATION OF SCAPULA

(SPRENGEL'S DEFORMITY)

ARNOLD: American Journal of Orth. Surgery, July, 1906.
BEELY: "Scoliosis capitis." Zeitschr. f. orth. Chir., 1892, Bd. xi.

BENDER: "Zur Etiologie des Schulterblatthochstandes." Münch. med. Wochenschr., 1903, 7.
BENDER: Münch. med. Wochenschr., 1903, i, 293.
BOLTEN: "Über den angeborenen Hochstand des einen Schulterblattes." Münch med. Wochenschr., 1892, 38.
BOURRET: "Sur un cas d'élévation congénitale de l'omoplate." Rev. d'orthop., Paris, 1907, 2 s., viii, 47–50.
BRADFORD AND SOUTTER: "Elevation of the Scapula." Boston Med. and Surg. Jour., Jan. 22, 1903.
BULOW-HANSEN: "Ein operierter Fall von angelborenem Hochstand der Scapula." Nordiskt Medicinski Arkiv, 1901, 3.
CAPELLE: "Ein Fall von Defekten in der Schultergürtelmuskel und ihre Compensation." München, 1905, Inaug. Diss., Kastuber and Callavey, 38 pp.
CAUTURE: Rev. d'orthop., 1892.
CHIEVITZ: "A Research on the Topographical Anatomy of the Full-term, etc." Copenhagen, 1899.
COLLIER: Transactions of the Society for the Study of Disease in Children, 1902.
DAMSCH: "Über anatomische Befunde bei sogenannten kongenitalen muskeldefekten." Verhandl. d. Kongresses f. innere Med., 1891, p. 519.
EHEHART: "Über angelborenen Schulterhochstand." Beitr. z. klin. Chir., Tübingen, 1904, xliv, 470, Heft 2.
EULENBURG: "Beitrag zur Dislokation der Scapula." 37. Versammlung deutscher Naturforsch. und Ärzte, Karlsbad, 1868.
EULENBURG: "Hochgradige Dislocation der Scapula, bedingt durch Retraktion des Musculus levator scapulæ." Archiv für klin. Chir., Bd. iv.
FAIRBANK: "Cases of Sprengel's Shoulder." Trans. Clin. Soc., London, 1905, xxxviii, 200, 2 pl.; Lancet, Nov. 5, 1904.
FREIBERG: "Malposition of the Scapula." Annals of Surgery, May, 1899.
FRÖHLICH: "Ein Fall von kongenitalen Hochstand der Scapula." Zeitschr. f. orth. Chir. Bd. xi, 1, vii.
GIBNEY: Trans. Am. Orth. Ass'n, 1901, p. 308.
GOLDTHWAIT AND PAINTER: "Congenital Elevation of the Shoulder." Boston Med. and Surg. Jour., 1901, 2.
GOURDON: "Quatre cas de surélévation congenitale de l'omoplate." Annales de chirurgie et d'orthopédie, 1901, 2.
GOURDON: "Surélévation congénitale de l'omoplate droite." Jour. de méd. de Bordeaux, 1905, xxxv, 83–85.
GOPPERT: Zentralbl. f. die Grenzgeb. f. Med. und Chir., 1900.
GRAETZER: "Congenital High Shoulder." Mitteilungen a.d. Grenzgeb. d. Med. u. Chir., Jena. Third Supplementary number, memorial to Mikulicz.
HAROUTIOUN: "De la luxation congénitale de l'omoplate ou maladie de Sprengel." Thesis, Nancy, 1904, E. Claude, p. 145.
HEINECKE: "Eine seltene Verschiebung des Schulterblattes." Zentralbl. f. Chir., 1886, 2.
HIBBS: Med. Rec., N. Y., 1903, lxiv, 168–171. Archiv für Orthop., Wiesbad., 1904, ii, 40–50.
HIRSCH: "Über einen Fall von doppelseitigem angeborenem Hochstand der Schulterblätter." Zeitschr. f. orth. Chir., xiii, xv.
HOEDLMOSER: "Sprengel'sche Difformität mit Cucullarisdefekt." Wien. klin. Wochensch., 1902, 52.
HOFFA: "Ein Fall von angeborenem Hochstand des einen Schulterblattes." Würzburger phys. med. Gesellschaft, 1892, 7.
HOFFA: Orthopadische Literatur, 1904.
HOLZ: "Angeborene Verschiebung des Schulterblattes nach oben. Med. Korrespondenzblatt d. württembergischen ärzt. Landesvereines," 1896, 33.
HONSELL: "Doppelseitiger Hochstand der Schulterblätter." Beiträge z. Klin. Chir., 1899, Bd. xxiv.
HORWITZ: Amer. Jour. Orth. Surg., vol. vi, No. 2, pp. 260–311.
HUTCHINSON: "Deformity of the Left Shoulder Girdle." Trans. Path. Soc., London, 1894, vol. lxv, p. 224. Brit. Med. Jour., 1894, i, p. 634.
JEDLICKA: Wien. klin. Rundschau, 1904, xviii, 508.
JONES: "Two Cases of Congenital Elevation of the Scapula." Med. Press and Circular, London, 1901, p. 654.
JOUON: "Nouvel exemple de refoulement congenital de l'omoplate par en haut." Rev. d'orthop., 1899, 3.
JOACHIMSTAL: Fortschritte a.d. Gebiete d. Röntgenstrahlen, No. 2.
KAUSCH: Mitteilungen a.d. Grenzgeb. d. Med. u. Chir., 1902, ix, 3.

KAUSCH: "Cucullarisdefekt als Ursache des kongenitalen Hochstandes der Scapula." Zentralb. f. Chir., 1901, 22.
KAYSER: "Über Hochstand der Scapula mit kongenitalen Hals- und Schultermuskeldefekten." Deutsche Zeitschr. f. Chir., 1903, Bd. lxviii.
KEYSER: "Congenital Elevation of the Shoulder." Trans. Clin. Soc., London, 1903–1904, xxxvii, 230.
KEYSER: Lancet, London, 1905, i, 1333.
KILVINGTON: Intercolon. M. J. Australas., Melbourne, 1904, ix, 47.
KIRMISSON ET JOUON: "Nouvel exemple de refoulement congenital de l'omoplate." Rev. d'orthop., 1899.
KIRMISSON: "De. quelques malformations congénitales de l'omoplate." Rev. d'orthop., 1893, 5.
KIRMISSON: "Nouvel exemple de malformation congénitale de l'omoplate." Rev. d'orthop., 1897, 5.
KIRMISSON: Rev. d'orthop., Paris, 1904, 4, s. 2, pp. 31–46.
KIRMISSON: Comp. rend. Soc. d'obst., etc., Paris, 1903, v, 112–115.
KÖLLIKER: "Bemerkungen zum Aufsatz von Dr. Sprengel." Archiv f. klin. Chir., 1891, Bd. xli, S. 925.
KÖLLIKER: "Zur Frage des angeborenen Hochstandes des Schulterblattes." Zentralblatt f. Chir., July, 1895.
KÖLLIKER: "Die operative Behandlung der Sprengel'schen Deformität bei Funktionsstörungen des Schultergelenks." Verhandl. d. deutschen Gesellschaft f. Chir., 1902.
KONING: Verhandl. d. deutschen Gesellschaft f. Chir., 1893, 22. Kongress, Berlin.
KRECKE: "Chirurgische Demonstrationen im ärzlichen Verein zu München." Münch. med. Wochenschr., 1896, S. 509.
LAMERIS: Archiv f. klin.Chir., Berlin, 1904, xviii, 517–535.
LAMM: "Über die Kombination von angeborenem Hochstand des Schulterblattes mit muskularem Schiefhals." Zeitschr. f. orth. Chir., Bd. x, Heft 8.
MCBURNEY: N. Y. Med. Jour., 1888.
MAYDL: Sborn. klin. v. Præze, 1903–4, v, 73–146, 3 plates. (Study of elevation of scapula.)
MERCIER: Bull. Soc. d'obst. de Paris, 1904, vii, 148–150.
MILWARD: Brit. Med. Jour., London, 1904, ii, 1636.
MILO: "Ein Fall doppelseitiger Sprengel'schen Deformitat." Zeitschr. f. orth. Chir., 1899, Bd. xi, Heft 6.
MILO: "Een geval von dubbelsijdige Sprengel Difformitat." Weekblad voor Geneeskunde, 1897, p. 695.
MOHR: "Zur Kasuistik des Beiderseitigen angeborenen Schulterblatthochstandes." Zeitschr. f. orth. Chir., 1903, xi, 2.
MOLLIER: "Über die Statik und Mechanik des menschlichen Schultergürtels." Festschrift für Kupfer, June, 1899.
MONNIER: "Sur un nouveau cas de déplacement congénital de l'omoplate." Rev. d'orthop., 1899, 2.
MOUCHET: Gaz. des Hôp., Paris, 1903, lxiv, 985–991.
MÜLLER: "Über den angeborenen und erworbenen Hochstand des Schulterblattes." Diss., Leipzig, 1902.
NEUMAN: "Zu Frage einer ätiologischen Bedeutung des Cucullarisdefektes für den Schulterblatthochstand." Wien. klin. Wochenschr., 1903, 36.
NOVÉ-JUSSERAND: "Position élevée de l'omoplate." Lyon méd., 1899. "Contribution à l'etude de la position élevée de l'omoplate." Revue mensuelle des maladies de l'enfance, Mars, 1900.
NOVÉ-JUSSERAND: "Anomalie de position de l'omoplate par contracture du rhomboide." Gaz. hebdom. de méd. et de chir., 1900, xlvii, p. 510.
OBERSTEINER: "Rückgratsverkrümmungen, etc., bei Muskeldefekten." Wien. klin. Rundschau, 1902, 16.
PANKOW: "Über den angeborenen, insbesondere beiderseitigen Schulterblatthochstand." Diss., Leipzig, 1900.
PARISIL: "De la surélévation de l'omoplate congénitale." Jour. de chir. et Ann. Soc. belge de chir., Brux., 1907, vii, 58–63, 2 pl.
PERMAN: "Tvanne fall af medfood fortsgutning uppot af Skulderblat." Nordiskt. Medicinskt Arkiv., 1892, xxiv, N. F. LL.
PISCHINGER: "Drei Falle von angeborenem Hochstand der Scapula." Münch. med. Wochenschr., 1897, S. 1471.
PITSCH: "Ein Fall von angeborenem Hochstand der Scapula." Zeitschr. f. orth. Chir., 1899, Bd. vii.
PORT: Münch. med. Wochenschr., 1899, p. 814.

RAGER: Drei Fälle von angeborenem Hochstand des Schulterblattes." Zeitschr. f. orth. Chir., Bd. ix, 1901, Heft. 3.
ROBINSON: Trans. Society for Study of Disease in Children, 1902.
SAINTON: "Sur un nouveau cas de déplacement congénital de l'omoplate." Rev. d'orthop., 1898, 6.
SAINTON: "Note sur un cas de surélévation congenitale de l'omoplate." Ibid., 1899, 1.
SANDS: N. Y. Med. Journ., 1888, p. 582.
SCHLESSINGER: "Zur Lehre von angeborenem Pectoralisrippendefekt und dem Hochstand der Scapula." Wiener klin. Wochenschr., 1900.
SCHLANGE: "Demonstration von angeborenem Hochstand der einen Hälfte der Scapula." Berl. klin. Wochenschr., 1892.
SCHLANGE: "Über Hochstand der Scapula." Verhandlung d. deutschen Gesellschaft f. Chir., 1893. Archiv f. klin. Chir., Bd. xlvi.
SICK: "Über angeborenen Hochstand des Schulterblattes." Deutsche Zeitschr. f. Chir., Bd. lxvii.
SPRENGEL: "Die angeborene Verschiebung des Schulterblattes nach oben." Archiv f. klin. Chir., 1891, Bd. xlii.
STEELE: Trans. Amer. Orth. Assoc., 1902, p. 18.
STILES: Lancet, May 28, 1904, p. 1905.
TILANUS: "Over Sprengel's Diffortmiteit." Ned. Tijdschrift voor Geneeskunde, 1897, Deel ii, 5.
TRIDON: Rev. d'orthop. Paris, 1904, v, pp. 435–489.
TRIDON: Rev. d'orthop. Paris, 1905, vi, p. 71.
VIRDEN: "A Case of Congenital Displacement of the Scapula." Pediatrics New York, 1899, vii.
VOROBYEFF: Russk. Vrach. St. Petersb., 1904, iii, 1179–1183.
WACHTER: "Über angeborenen Hochstand des Schulterblattes." Diss. Strassburg, 1901.
WATERMAN: Acad. of Med., N. Y. Orth. Section, April, 1902. Rev. d'orthop., 1903.
WIESSINGER: "Demonstration im ärzlichen Verein zu Hamburg." Münch. med. Wochenschr., 1896, S. 664.
WILLETT AND WALSHAM: Trans. Royal Med. and Chir. Soc., 1880–1883.
WILSON AND RUGH: "Two Cases of Anomalous Spinous Process of the Seventh Cervical Vertebra Articulating with Scapula." Annals of Surgery, April, 1900, Philadelphia.
WINKEL: Münch. med. Wochenschr., 1896, S. 389.
WITTFELD: "Über den angeborenen Hochstand der Scapula." Diss., Bonn, 1901.
WOLFHEIM: "Über den angeborenen Hochstand der Scapula." Diss., Berlin, 1895. Zeitschr. f. orth. Chir., Bd. iv, xvii.
ZESAS: "Über den angeborenen Hochstand des Schulterblattes." Zeitschr. f. orth. Chir., Bd. xv., Heft. 1.

CHRONIC BACKACHE

LOVETT, R. W.: "The Causes and Treatment of Chronic Backache." Jour. Am. Med. Ass'n, May 23, 1914, lxii, 1615–1620.
DICKENSON, R. L., AND TRUSLOW, W.: "Averages in Attitude and Trunk Development in Women and their Relation to Pain." Jour. A. M. A., Dec. 14, 1912, p. 2128.
REYNOLDS, EDWARD: "The Etiology of the Ptoses and their Relation to Neurasthenia." Jour. A. M. A., Dec. 3, 1910, p. 1943.
KLEIN: Zeitschr. f. Geburt. u. Gynäk., 1891, xxi.
WALCHER: Verhandl. d. Deutsch. Gesellsch. f. Gynäk., Bonn, 1891.
STRASSER: "Lehrbuch der Muskel und Gelenk." Mechanik, Berlin, 1913.
DIEULAFÉ AND ST. MARTIN, C. R.: Ass'n d. Anat. 14 Reunion Revues, 1912.
REYNOLDS, EDWARD, AND LOVETT, R. W.: "An Experimental Study of Certain Phases of Chronic Backache." Jour. A. M. A., March 26, 1910, p. 1033.
MEISENBACH: Monatschr. f. Unfallheilk., 1909 (account of 8 cases of Traumatic luxations), Surg., Gyn. and Obst., May, 1911, p. 411.
GRIMBACH: Deutsch. Zeitschr. f. Chir., October, 1908.
PITFIELD: Am. Jour. Med. Sc., June, 1911.
MORILL: Cleveland Med. Jour., October, 1910.
SWETT: Yale Med. Jour., October, 1908.

SPINA BIFIDA OCCULTA

SEVER, J. W.: "Spina Bifida Occulta." Bost. Med. and Surg. Jour., clxi, No. 12, pp. 388–392, Sept. 16, 1909.
BOETCHER, T.: Beitr. z. klin. Chir., Tübingen, liii, No. 3.
PORTER, M. F.: Jour. Ind. State Med. Ass'n, January, 1908.

GATES, B. B.: Boston Med. and Surg. Jour., clviii, No. 5. January, 1908.
JONES, R.: Brit. Med. Jour., 1891, vol. i, 173.
INTERNATIONAL Text-book of Surgery.
HOLT: "Infancy and Childhood."
AMERICAN Text-book of Surgery.
KEEN, W. W.: "Keen's Surgery," vol. ii.
LANDON: Königsburg, 1897.
WAUJURA: Berlin, 1892.
GRAY: "Gray's Anatomy."
QUAIN: "Quain's Anatomy," vol. i, No 1.
DENNIS: "Dennis' Surgery," vol. ii.
BRUNNER: Virchow's Archiv, cvii, 1887.
JAEGER: "Ein weiterer Beitrag z. Casuistik der Spina Bifida Occulta mit lokaler Hypertrichosis." 1899.
JOACHIMSTHAL: Virchow's Archiv, cxxxi.
KELLNER: Zentralbl. f. Chir., 1901, p. 22.
LACAYO: Zur Kas. d. sp. bf. oc., 1897.
MAAS: Deut. Med. Wochenschr., 1897, p. 47.
REINER: Wien. klin. Rundschau., 1901, p. 19.
RIBBERT: Virchow's Arch., vol. cxxxii.
SAINTON: Rev. de Orthop., 1891, p. 6.
SCHON: Berl. klin. Wochenschr., 1894, p. 5.
KATZENSTEIN: Centralbl. f. Chir., 1901, p. 57.

CERVICAL RIBS

HENDERSON, M. S.: "Report of 31 Cases of Cervical Rib." Trans. Am. Orthop. Ass'n, May, 1913.
BORCHARDT: Berl. klin. Woch., 1901, xxxviii, 1265.
EHRICH: Beitr. z. klin. Chir., 1895, xiv, 199.
GALEN: Quoted by Hunwauld, Mem. Math. und Phys. d'Acad. Royal des. Sci., 1740, Paris, 1742, Tome 57.
GRUBER: "Neue Anomal." als Beitrage z. Phys. Chirurg. u. Pathol. Anatomie., Berlin, 1849; also "Ueber die Halsrippen de Menschen," St. Petersburg, 1869; also Mem. de l'Acad. Imperial des Sci., vii Series, Tome 13, No. 2.
HIBBING: Berl. klin. Woch., 1905, xliii, 1451–1480.
HIRSCH: Wien. klin. Woch., 1896.
HOWELL: Lancet, June, 1907, p. 1702.
HUNT: Brit. Med. Jour., Aug. 7, 1909, 314–315.
HUNWAULD (see Galen, above): Mem. Math. und Phys. d'Acad. Royal des Sci., 1740, Paris, 1742, Tome 57, 377.
JONES: Lancet, March 1, 1913, 609.
KEEN: Am. Jour. Med. Sci., February, 1907, 173–218.
KRABBE: Ugeskrift for Laeger, Nov. 7, 1912, 1633–1668.
LEVI: Neurol. Centralbl., Nov. 1, 1904, 9881.
MARBURG: Wien. klin. Rundschau, 1906, No. 13.
MURPHY: Annals of Surg., 1905, xli, 404; also Surg., Gynec. & Obst., October, 1906, 519.
OPPENHEIM: Berl. klin. Woch., 1905.
PILLING: "Halsrippen des Menschen." Inaugural Dissertation, Rostock, 1894.
SCHÖNEBECK: "Beitrage z. Kenntniss der Halsrippen." Inaugural Dissertation, Strassburg, 1905.
SPILLER AND GITTINGS: New York Med. Jour., Oct. 5, 1906, 683.
TODD: Lancet, August 10, 1912.

CHAPTER XIII

STATIC DEFORMITIES OF THE SPINE

(A) SCOLIOSIS

General Consideration

Definition.—Scoliosis is a permanent lateral deviation with rotation away from the sagittal (anteroposterior) plane, of the whole, or a portion of the spinal column.

Frequency.—According to *Tubby* (Deform., incl. Dis. of Bones and Joints, vol. i, p. 404), Fisher encountered scoliosis in 11.76 per cent. of 3000 orthopedic cases. Whitman (Orth. Surg., 1904, p. 162) places it next to bow-legs in order of frequency. Of school children, only 1.3 per cent. of those of Denmark, according to Drachmann (quoted by Tubby, *loc. cit.*) were affected, while in Switzerland 24.6 per cent. of school children were scoliotic. Tubby (*loc. cit.*) states that the affection is particularly prevalent in large towns.

Sex.—Scoliosis is far more frequent in girls than in boys over five, although below that age the distribution is more even.

Age.—Scoliosis is an affection of adolescence. More than 50 per cent. of the cases appear between the ages of seven and fourteen.

Heredity.—There is unquestionably a hereditary factor in a certain proportion of scoliotics.

Physiology of the Spinal Column

It must be borne in mind that the vertebral column consists of two parts, two vertical pillars of multiple segments, an anterior column composed of the vertebral bodies which is distinctly weight-bearing in function, and a posterior column composed of the neural arches, whose function is multiple, *i.e.*, protection for the cord, and attachment for the spinal muscles and ligaments.

Physiological Curves

The spine has four normal, physiological curves—two kyphotic, sacral and dorsal, and two lordotic, cervical and lumbar. These normal curvatures vary with the race, age, individual, muscular condition, adiposity, vocation, etc., and, although hereditary in origin, they are nevertheless influenced by muscular action incident to standing, walking, etc. It is assumed that these curves produce changes in the shape of the intervertebral disks, those in the lordotic regions becoming wedge-shaped and higher in front than behind. These disks are elastic and compressible, and the greater their total quantity in any given portion of the spine, the greater the freedom of movement of that segment; hence, the widest range of movement is observed in the cervical and lumbar regions.

Normal Spinal Movements

The movements possible in a normal healthy spine are *flexion*, *extension*, and *hyperextension* in the sagittal plane; *lateral flexion* in the frontal plane; and *rotation* or *torsion* on the long axis of the vertebral column.

Pathological Curves

Tubby (*loc. cit.*, p. 400) quotes Schulthess as laying stress on the following factors in the production of abnormal spinal curvatures:

(*a*) Resisting powers of the vertebral column—its shape, elasticity, firmness and tension.

(*b*) Body-weight and alterations of its center of gravity.

(*c*) Muscular tension and its variations.

(*d*) Additional loading.

Mechanical changes acting asymmetrically are powerful primary factors in the production of scoliosis. Functional or structural asymmetry in the spine or elsewhere (as in limbs or pelvis), occupational peculiarities of movement, unilateral infantile paralysis, faulty attitudes, etc., are likewise influential in producing lateral curvature of the spine. Derangement of proper muscular co-ordination in maintaining the body "balance," and a faulty attitude in sitting are contributing etiological elements.

Clinical Features

Varieties.—Two clinical varieties of scoliosis are recognized, viz.:

(*a*) *Functional*, in which the structural changes are incipient and remediable.

(*b*) *Structural*, in which the organic changes are well-established in the vertebræ, disks, ribs, shoulder-girdle and pelvis.

Kinds of Curves.—A soft, anilin blue pencil should be used to mark the tips of the spinous processes properly to appreciate the extent, location and character of the curvature. The following kinds of curves are the most frequently encountered:

(*a*) C-shaped curve, of the whole spinal column to the left.

(*b*) S-shaped curve, denominated left or right according to the side toward which the convexity inclines, and qualified according to the spinal segment involved, *i.e.*, right dorsal-left lumbar scoliosis.

(*c*) Three or more curvatures combined.

(*d*) Scoliosis with an angular projection of the spinous processes at the junction of the upper and lower curves.

(*e*) Kyphosis complicating scoliosis.

Location of the Curvature

According to Schulthess (ref. Lüning and Schulthess, Orth. Chirurg., pp. 806–809),

1. The twelfth dorsal is the commonest location for the curvature.

2. Convexity to the left is the commonest, especially in men, in whom it is also higher up than in women. Lumbar scoliosis is commoner in women.

3. Convexity to the right is most frequent at the level of the seventh dorsal vertebra. Left-sided dorsal convexities, on the other hand, are more evenly distributed in the dorsal region.

4. Right-sided scoliotic convexities are more often accompanied by compensatory curves.

5. Left-sided scoliotic convexities have a less tendency to produce compensatory curves.

Pathology

In scoliosis the spine undergoes not only lateral curvature, but also torsion on its long axis. The different kinds of curves have been described above.

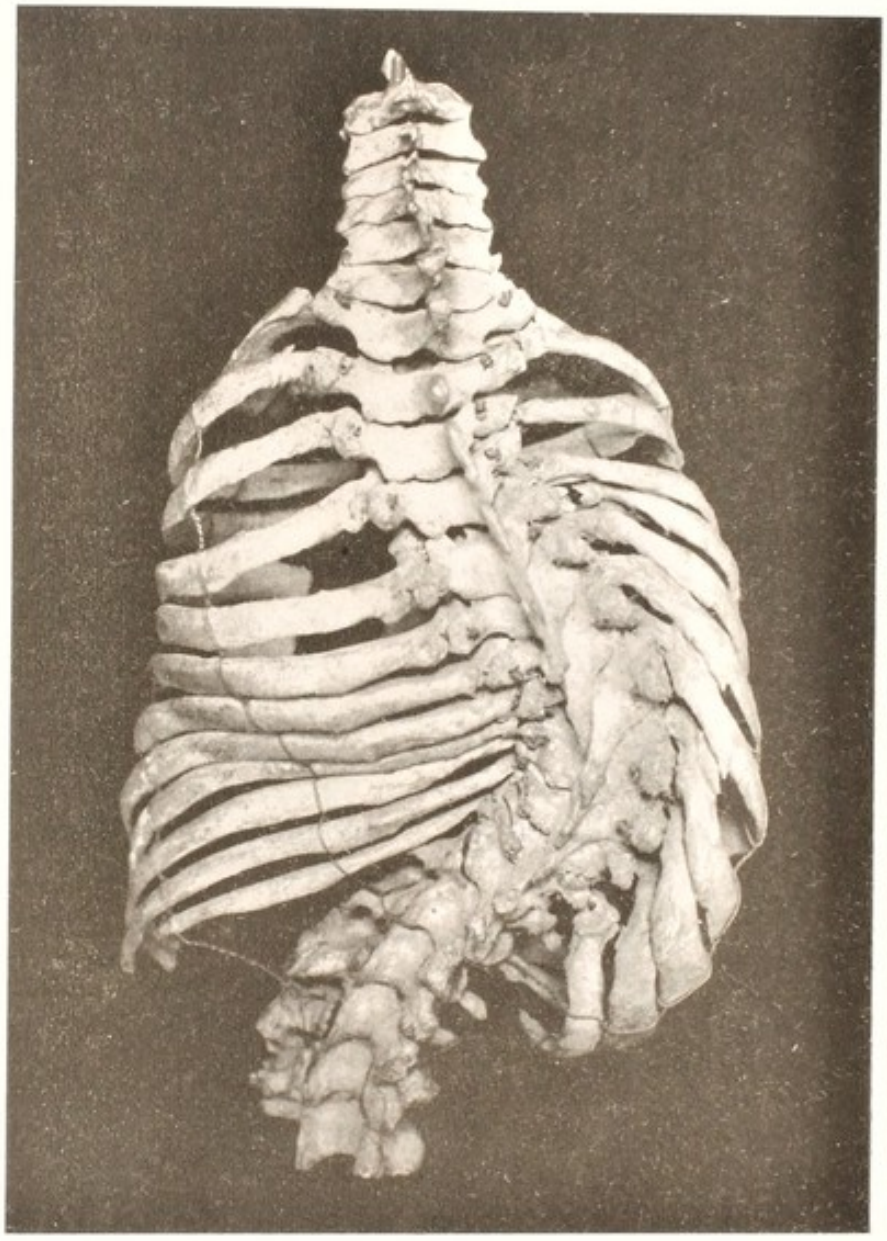


Fig. 188.—Scoliotic spine; secondary changes in vertebræ and ribs. (Taylor.)

Torsion or *rotation of the vertebral bodies always takes place toward the convexity of the curve.* In scoliosis, the column of the bodies is more curved laterally than the line of the tips of the spinous processes (Fig. 188).

Changes in Individual Vertebræ

1. **Bodies.**—(*a*) *Wedge Vertebræ.*—These are compressed on the concave side and expanded on the convex side. The wedging is most marked at the point of greatest curvature or it may be evenly distributed in all the in-

volved vertebræ. The intervertebral disk is squeezed out toward the concave side, allowing synostosis of the adjacent vertebræ to occur; this synostosis may involve several vertebræ.

(*b*) *Lozenge-shaped Vertebræ.*—This form is less common than the wedge-shaped variety. It is most marked at the junction of opposite curves and hence is most frequently seen in marked S-curves.

2. **Pedicles.**—The pedicles are directed more anteroposteriorly on the convex side, and more transversely on the concave side than in a normal spine.

3. **Vertebral Foramen.**—This becomes pointed in the concavity, rounded in the convexity.

4. **Transverse Processes.**—Those on the convex side are more anteroposterior than normal, hence the vertical furrows between the transverse processes and the spines are narrower on the convex side than on the concave side.

5. **Spinous Processes.**—In a general way, the spinous processes point toward the convexity. The arc of their tips describes the same curve as the curve of the bodies, although less marked. The spinous process itself is twisted so that its root is toward the concavity, its tip toward the convexity. It also becomes twisted on its long axis, and its inclination is altered.

6. **Articular Processes.**—Synostosis frequently occurs at the joints of the articular processes (where it makes its earliest appearance) and between the laminæ; the latter condition is due to ossification of the ligamenta subflava.

7. **Costovertebral Articulations.**—The joints between the ribs and vertebræ are deeper and more posteriorly located on the convex side, shallow and more anterior on the concave side.

8. **Ligaments.**—The anterior common ligament becomes a thick cord with a well-marked edge on its concave border, while the edge toward the convexity is greatly thinned.

9. **Muscles.**—Atrophy from disuse affects the muscles on the concave side. In those on the convexity, fibrous degeneration occurs, as the result of stretching. Occasionally, dislocation of the muscular bundles of the latissimus dorsi takes place away from the convexity and toward the concave side, spanning it and hence increasing its concavity.

Associated Anatomical Changes

1. **Thorax.**—In dorsal scoliosis, changes in the thorax are the most marked. On the convexity, the rib angles form a marked posterior ridge, (Fig. 189), while the ribs in the concavity fall away. In front, the mammillary region, corresponding to the concavity, is markedly prominent. On the convex side the ribs are inclined downward; on the concave side they extend horizontally. It is the rule to have but one rib prominence, but two or three may be encountered.

2. **Pelvis.**—Oblique deformity of the pelvis may occur. Lateral curvature of the sacrum is rarely marked. The important alteration in the sacrum is rotation or torsion, which alters the length of the oblique diameter and is a common cause of obstetrical dystocia.

3. **Viscera.**—(*a*) *Lungs.*—In the common right dorsal-left lumbar curves, decrease in volume of the right lower thorax tends to cause pleural adhesions, obliteration of the right pleural sac, and consequently collapse of the lung. Pulmonary tuberculosis is common in scoliotics and is the cause of death in a considerable proportion of them.

(*b*) *Heart.*—This diminution in pulmonary space overtaxes the heart, the handicap being further increased by kinking of the aorta and cardiac displacement, resulting in right-sided cardiac hypertrophy and dilatation with consequent venous stasis.

(*c*) *Trachea and Esophagus.*—These structures follow the direction of the concavity.

(*d*) *Liver.*—In right lower dorsal scoliosis, the liver is pushed to the left and its left side becomes overdeveloped.

(*e*) *Kidneys.*—The one on the convex side becomes dislocated or compressed between the spine and the crest of the ilium, and incidental to such compression, degenerative renal changes may take place.

(*f*) *Spleen.*—The spleen is often displaced upward and is commonly subject to pathological changes.

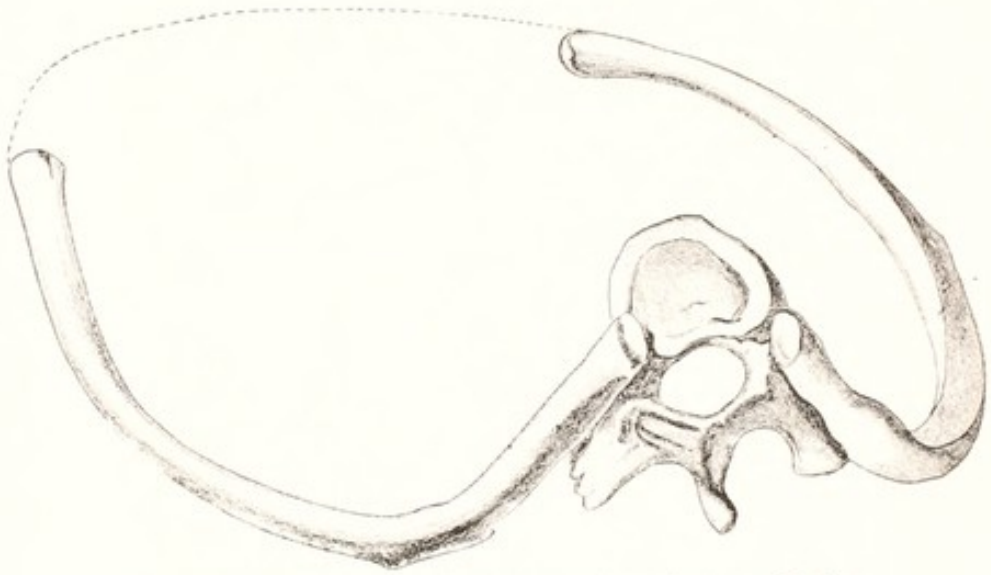


FIG. 189.—Deformity of the thorax in scoliosis. (Hoffa.)

(*g*) *Stomach.*—Its cardiac end is elevated, the pyloric end depressed.

(*h*) *Transverse Colon.*—As a result of displacement of the abdominal viscera, the transverse colon may become directed nearly vertically.

PHYSICAL EXAMINATIONS

History.—*Family History.*—Careful questioning may reveal a hereditary factor in the deformity.

Personal History.—The patient should be carefully questioned as to the following data:

The state of the *general health* during *infancy*, particularly as regards *rickets*. *Date* of *onset* of the curvature and whether it has *increased* or not. The *height* and *weight*. The general health at the present time—progress at school—does the patient become readily fatigued, etc.

General Physical Examination.—Much information may be gleaned by keen observation and intelligent deduction therefrom. Carefully observe the state of body nutrition—the color development of the chest, length of the legs, altitude, the existence of genu valgum or flat feet, the arrangement of the clothing (particularly in girls, whether the skirts are suspended from the shoulders or hang from the waist) and any evidence of neurasthenia.

Examination of the Back.—The patient should be *stripped* to the gluteal region. A good light is indispensable.

1. *Body Outlines.*—Is there asymmetry at any point? Is one flank more curved than the other? Do the arms hanging at the side make equal triangles with the trunk? Is one hip more prominent than the other?

2. *Shoulder Level.*—Is one shoulder higher than the other? If so, and the inequality cannot be readily corrected, it is suggestive of scoliosis.

3. *Scapulæ.*—Compare the two sides.

4. *Carriage of the head* should be noted.

5. *Anterior-posterior body curve* must be observed.

6. *Hands on opposite shoulders* and *the spine anteriorly flexed* cause any spinal deformity to be clearly delineated. This is the correct position for estimating the *amount* and *character* of *lateral curvature*. The tips of the spinous processes should be marked on the back with a soft, anilin blue

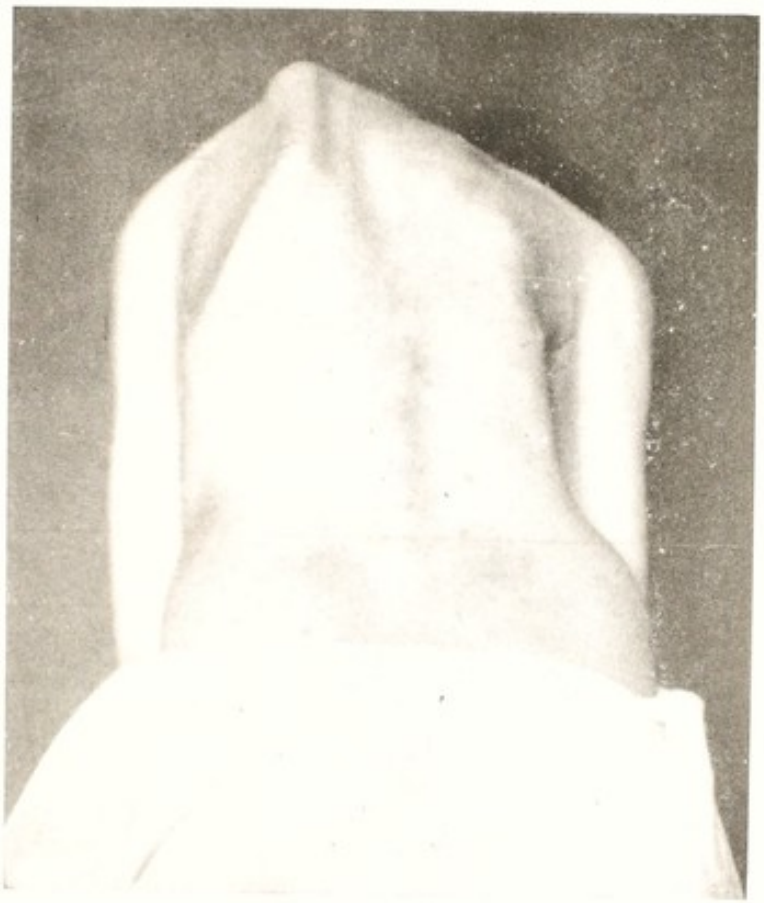


FIG. 190.—Keel-shaped projection of left ribs due to rotation unmasked by forward bending. (Taylor.)

pencil and a straight-edge or plumb-line applied to the back. Note the location of the region, and the extent of the curvature and its character (C-shaped, S-shaped, etc.) and record the findings in some graphic manner.

7. *Rotation.*—This is indicated by *posterior projection* of the *ribs* and *transverse processes* on the *convex side*. If this phenomenon is not readily apparent, have the patient cross the arms, thus pulling the scapulæ forward, and bend forward (with the knees straight) until the trunk is horizontal. Rotation is indicated by posterior projection or asymmetry, is due to lateral displacement of the vertebræ and is always convex-sided (Fig. 190).

8. *Flexibility.*—Have the patient practice lateral bending, first to one side, then to the other with the legs straight, and the surgeon fixing the pelvis with his hands on the iliac crests. Inequality of lateral flexion indicates incipient

scoliosis. It is more limited on the convex side. Suspension of the patient by the Sayre head sling, with just enough traction to take the weight off the spine, should next be practised. If suspension causes elimination of the lateral curvature, the outlook is good, and the case is probably one of postural curvature without structural vertebral changes.

9. The physical condition of the heart and lungs should be ascertained and evidence of *venous stasis* and *displacement* of the *thoracic* and *abdominal viscera* noted.

10. *X-ray*.—Last, but not least, an *x*-ray examination should be made in every instance.

Recording the Curvature

Although a very great number of appliances have been devised for scoliosiometry, a simple means of graphically recording the lateral curvature is by a photograph through a thread screen placed close to the patient's back, the tips of the spinous processes, the iliac crests and the angles of the scapulæ having been previously outlined with blue pencil.

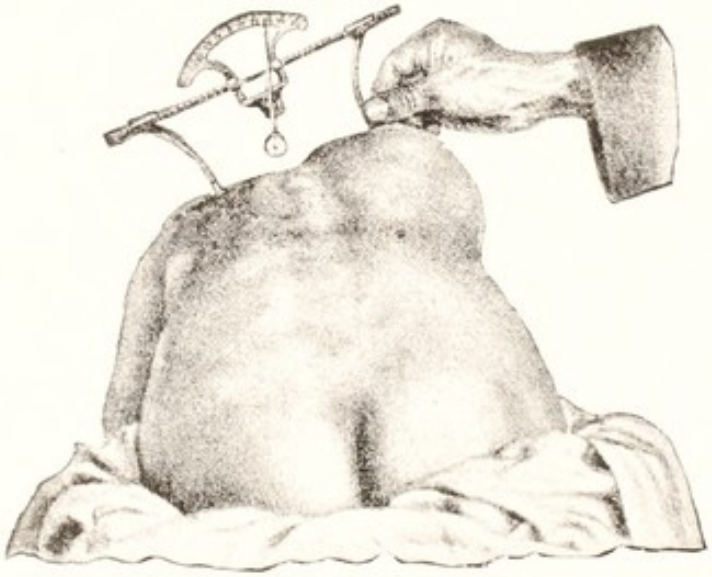


Fig. 191.—Scoliosis.—Measurement of rotation of the ribs in the horizontal position by the levelling trapezium. (Schulthess.)

Bucholz and Osgood (Am. Jr. Orth. Surg., 1914, xii, No. 1, p. 77) have devised a frame for standardizing photographic records of scoliosis. They advocate using a stereoscopic camera and inspecting stereoscopic prints of negatives. They also insist that in the back or front view, the plane of the patient's back or crest bears in successive photographs, the same relation to the lens and the plate. In photographing rotation by forward bending, they assert that the bend must always be to exactly the same extent if photographs of the slightest comparative value are to be obtained.

For recording the rotation, the most important indication of deformity, a direct tracing of the trunk with lead tape may be made with the patient recumbent.

Schulthess' level indicator (Fig. 191) affords a convenient and accurate means of recording the rotation of the ribs. The pendulum pointer of the apparatus remains vertical and indicates the number of degrees the levelling trapezium has to be inclined in order to be adapted to the patient's back.

Symptoms and Clinical Course

The clinical features will be considered in their stages of evolution, viz.:

1. Early stage.
2. Developmental stage.
3. Stage of arrest.
4. Stage of improvement.

1. **Early Stage.**—In its incipiency, the affection is frequently overlooked, particularly on account of the usual absence of symptoms. Symptoms in adolescence, suggestive of beginning scoliosis, are impaired vitality, general lassitude and aversion to prolonged exertion.

2. **Developmental Stage.**—*Pain* is a variable feature but is usually encountered in underdeveloped girls with scoliosis at puberty; the pain may range from slight discomfort in the lumbar region to incapacitating distress. *Muscular rigidity* in combination with pain, may at this stage, cause confusion with Pott's disease. In these border-line cases, where the diagnosis is not clear, the asymmetry should be corrected, rest enjoined, and frequent examinations made until the diagnosis has been established.

Hysterical girls with hyperesthetic areas, neuralgic pains, tenderness over the spinous processes, hysterical paraplegia, etc., may cause difficulty in diagnosis.

In case the deformity is extreme, considerable pain is experienced, both local and general in character. When localized, it is usually on the convex side, and in dorsal curvatures is most marked just below the angle of the scapula, and in lumbar curvatures near the transverse processes. Several factors are concerned in the production of this pain, viz.:

(*a*) Twisting and stretching of the muscles and ligaments over the convexity.

(*b*) Distortion of the thorax and displacement of the viscera.

(*c*) Compression of the lumbar nerves by the last rib, and of the tissues of the flank between the ribs and the crest of the ilium, or by the protrusion of the lower ribs into the iliac fossa.

(*d*) Pressure on nerve roots, especially in congenital cases.

(*e*) General hyperesthesia from lowered vitality.

(*f*) Rapidity of formation in the case of total curves.

(*g*) Slowly increasing curvatures in extremely rigid spines cause unusually severe localized pain.

Pregnancy often aggravates a pre-existing scoliosis in women. The retrogressive changes incident to senility may activate a previously quiescent scoliosis.

3. **Stage of Arrest.**—Lateral curvature may be arrested by treatment, or it may undergo spontaneous arrest at any stage. Or the arrest may be due to bony ankylosis with ossification of the ligaments, thus preventing further deformity.

4. **Stage of Improvement.**—Spontaneous improvement of a lateral curvature depends upon several factors, viz.:

General good health, with increased muscular development, favorable climatic and hygienic conditions, and the age of the patient when the process began, the outlook being more favorable the nearer the age to the terminal period of bone-growth. Spontaneous improvement is not uncommon in postural cases, if the cause be removed, provided no structural changes have occurred. But in scoliosis with definite bony alterations, spontaneous correction of the curvature is impossible. Apparent correction in such cases is due to the formation of compensatory curves.

Clinical Types

For convenience of description, scoliosis may be classified in the following manner:

1. Total scoliosis.
2. Lumbar scoliosis.
3. Dorsolumbar scoliosis.
4. Simple primary dorsal scoliosis.
5. Cervicodorsal scoliosis.
6. Compensated dorsal curvatures.

1. **Total Scoliosis.**—The whole vertebral column is involved in a continuous curve, with the convexity usually to the left and the pelvis is frequently oblique from shortening of a limb or other cause. It is most frequently encountered in early life, particularly in school children in whom it develops from abnormal postures. In these children it may undergo spontaneous cure, or develop into an S-shaped curve. The amount of curvature is usually not great, the deviation rarely amounting to more than 1 or 1 1/2 inches. The leading clinical features of these total scolioses (usually to the left) are as follows:

Convexity to the left, elevation of the left shoulder, the triangular space between the hanging arm and the body greater on the right than on the left side, the right loin and right thorax depressed, while they are raised on the left side (convex rotation).

2. **Lumbar Scoliosis.**—The curvature is usually most prominent at the second lumbar vertebra. In some cases, the spine does not return to the middle line above the lumbar region (the so-called "overhanging" cases), *i.e.*, the whole spine above the deformity, although straight, is deviated from the middle line. This type deviates to the right and to the left sides in about an equal number of cases. Compensatory curves are common. It occurs twice as frequently in females as in males, and is oftenest seen in the twelfth to fifteenth years. The curve is often short, sharp and resistant to treatment. The lumbar type is the usual one in "static" cases, viz., short limbs.

The most distinctive clinical feature of this variety is prominence of the hip on the concave side with depression of the loin and reduplication of the skin, while on the convex side the loin is full. Lateral bending is more free toward the concave side. The lumbar type comprises about 11.5 per cent. of all cases of scoliosis.

3. **Dorsolumbar Scoliosis.**—This type makes up nearly 1/5 of the total of scoliosis. The point of sharpest curvature is the junction of the twelfth dorsal and first lumbar vertebræ. There are more vertebræ involved than in lumbar scoliosis, which it very much resembles except that the sharp sacrolumbar angularity is absent. The curve may be slight and lordosis be present, or, in the severe variety (rachitic or paralytic) kyphosis may occur.

Compensatory curves are not marked. The convexity is usually to the left. Rotation occurs toward the convexity at the height of the curve, while it is apparently directed toward the concave side at the shoulder-girdle with depression of the shoulder on that side. Females are far more commonly affected with this type than males.

4. **Simple Primary Dorsal Scoliosis.**—The greatest curvature is opposite the sixth to eighth dorsal vertebræ in most cases. No compensatory curvature takes place above or below the dorsal curve. This type is commoner than the lumbar, and next to the dorsolumbar in order of frequency. The curvature may be slight or severe. In the severe form, rotation is great and kyphosis marked. In the milder form, lordosis occurs producing the flat-

backed type. As has been said, rotation in the severe form is extreme, is always convex and, in combination with the decreased height of the trunk, causes malposition of the viscera and pressure effects, *e.g.*, displacement, dilatation and right-sided hypertrophy of the heart with consequent pulmonary embarrassment, thus predisposing the patient to pneumonia, pleurisy, and pulmonary tuberculosis. Pressure symptoms from the abdominal viscera are common in this type of scoliosis. Cardiac dilatation with incompetency is a terminal event in most scoliotics of this type at the age of forty or fifty years.

The changes in outline and shape of the trunk are striking, viz.: in right dorsal scoliosis, the right side of the chest is prominent, the right shoulder is raised and thrust forward, anterior bowing of the clavicle is increased, the right arm hangs away from the side, the right flank is flattened, the lower right ribs are approximated to the iliac crest, compression of the soft parts producing constant severe pain; the right scapula is elevated, projecting and oblique or horizontal in direction, the angles of the ribs are more acute, the left shoulder droops and is carried backward, the left chest is flattened posteriorly and the left scapula hidden, while the angles of the left ribs are diminished and the ribs are less oblique.

In the spine, the tips of the spinous processes are twisted to the left, bringing the right transverse processes into the posterior midline in the position formerly occupied by the spinous processes.

The thorax in front view has its left side more prominent than the right. The tip of the sternum is displaced toward the convexity. The greatest diameter of the thorax is the right oblique instead of the transverse diameter as in the normal chest.

5. **Cervicodorsal Scoliosis** (Fig. 193).—This type is infrequent. The curve is directed to the right oftener than to the left, and the point of greatest curvature is the third or fourth dorsal vertebra. The clinical picture is characteristic. The curvature is short and sharp, the upper part of the trunk markedly overhanging, kyphosis is a prominent feature, and the head is thrust forward and inclined toward the concave side. The scapula on the convex side is very high and prominent and the anterior border of the trapezius stands out as a ridge extending from the head to the shoulder. The median border of the scapula on the concave side may over-ride the spinous processes. The neck is shortened, the arm on the concave side hangs far away from the side, and rotation is extremely marked, the upper ribs being so prominent as to give a hunch-back appearance. Some authors believe that this type is usually of rachitic origin.

6. **Compensated Dorsal Curves** (Fig. 192).—This is the commonest type of scoliosis, constituting nearly $^{1}_{3}$ of the cases. The most frequent combination of curves is right dorsal-left lumbar. It has been suggested that this localization of the curvatures is due to the universal employment of the right hand by school children, the dorsal deformity being aggravated by the left lumbar curvature, which is induced by faulty posture at the school desk. In the ordinary type the dorsal curve is the primary one except in the short-legged or static cases. The apex of the dorsal curve is at first always at the sixth to the eighth dorsal vertebrae but shifts to a lower level as the deformity increases.

Compensated dorsal curves are usually manifested as three types, viz.: (A) double, (B) overhanging, and (C) triple-curved. The double and overhanging types constitute the majority of adult cases. In general, multiplicity of spinal curves is an index of excessive malleability of the spinal column.

The clinical features of the commonest type (the right dorsal-left lumbar) are as follows: right shoulder higher than the left, right scapula elevated and abducted from the spinous processes, right hip more prominent, the triangular space between the hanging right arm and the body larger on the right than on the left side. The thoracic distortion is the same as in simple dorsal curvature.

Etiology

The fundamental factor underlying static lateral curvature is *spinal insufficiency*, a lack of resistance. This lowered spinal resistance includes the spinal muscles and ligaments as well as the bones. Schanz (Zeitsch.



Fig. 192.—Right dorsal scoliosis; girl of fifteen. (Taylor.)

f. orth. chirurg., Bd. xiv, Hefte 3 u. 4) graphically states this discrepancy between the load and the carrying (resisting) power, producing the deformity, by the following formula:

$$B > T = D$$

(B = the load; T = carrying power; D = deformity.)

Supplementing and augmenting this defective resistance, are often found many contributing forces, *e.g.*: (*a*) *adiposity*, (*b*) *heavy clothing*,

(*c*) the carrying of *loads*, (*d*) prolonged, *fixed attitudes* (occupational postural, as in school children), and (*e*) the relative *inflexibility* of the spine in *advanced life*. Also (*f*) *tilting* of the *pelvis*, (*g*) *excessive malleability* of the bones, as in rickets and osteomalacia, (*h*) prolonged *disuse*, as in protracted severe illnesses, (*i*) *paralysis*, and (*j*) *muscular weakness*.

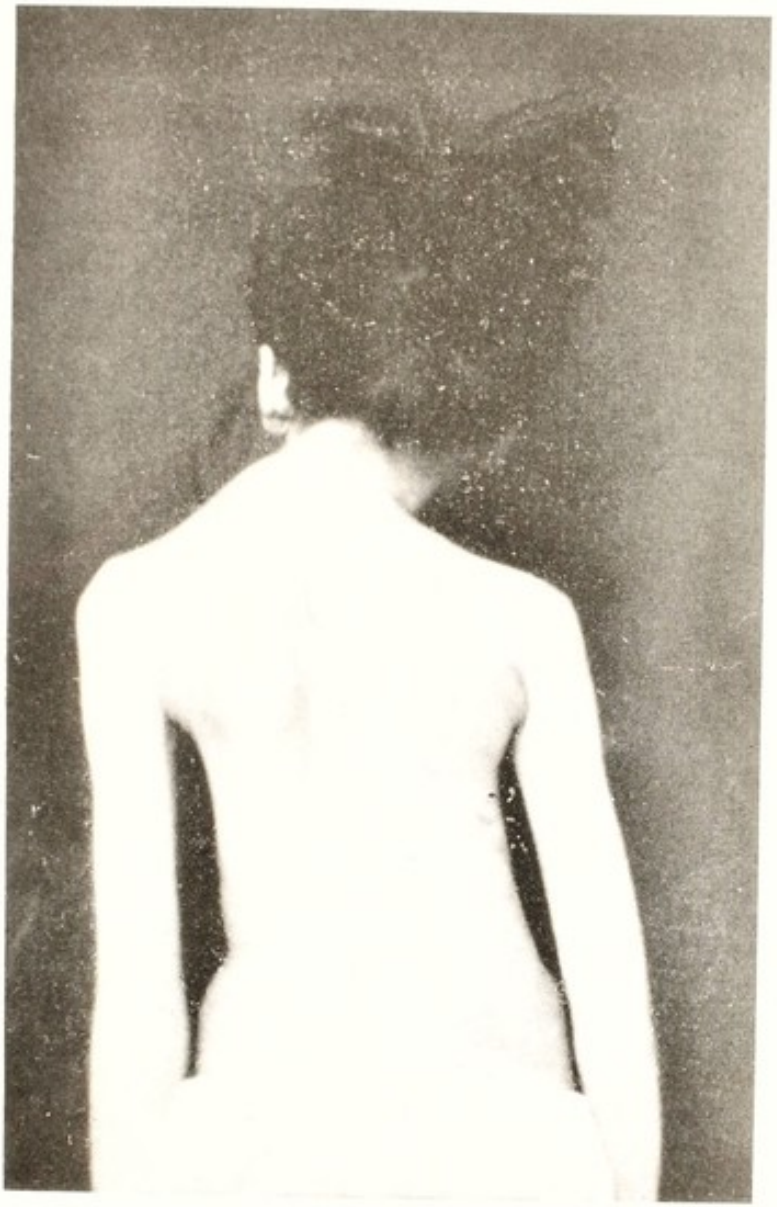


FIG. 193.—Cervicodorsal scoliosis to the left. (Taylor.)

ETIOLOGIC CLASSIFICATION

Tubby ("Deform. incl. Dis. of Bones and Joints," Vol. I, p. 460) makes the following very efficient etiological classification of scoliosis:

(A) **Congenital Scoliosis.**—1. Curvature arising from congenital anomaly of the spine, such as portions of supernumerary vertebræ, sacralization of the fifth lumbar, etc. (Fig. 194).

2. Curvature arising from some congenital extraspinal anomaly, such as deficiency of ribs.

3. Due to intra-uterine malposition.

(B) **Acquired Scoliosis.**—1. Constitutional or idiopathic, due to general insufficiency of the spine.

2. Due to processes of bone softening:

(*a*) Rickets.

(*b*) A few cases traceable to osteomalacia, osteomyelitis, gumma, tubercle, injury, arthritis deformans, newgrowths.

3. Occupation scoliosis.

4. Static scoliosis from pelvic obliquity, which in turn is due to a large number of causes, ranging from a short limb due to coxitis to unilateral flatfoot.

5. An asymmetrical position of the trunk, from diverse causes, *e.g.*, torticollis, unequal vision or hearing, loss of one arm.

6. Associated with certain nerve conditions:

(*a*) Infantile paralysis.

(*b*) A few cases due to hysteria, sciatica, locomotor ataxia, syringomyelia, Friedreich's disease.

7. Due to malformations or diseases of the soft parts. Pleurisy, empyema (Fig. 195), phthisis, heart disease, skin cicatrices from burns, and following the kyphosis due to nasal stenosis, adenoids, and enlarged tonsils.

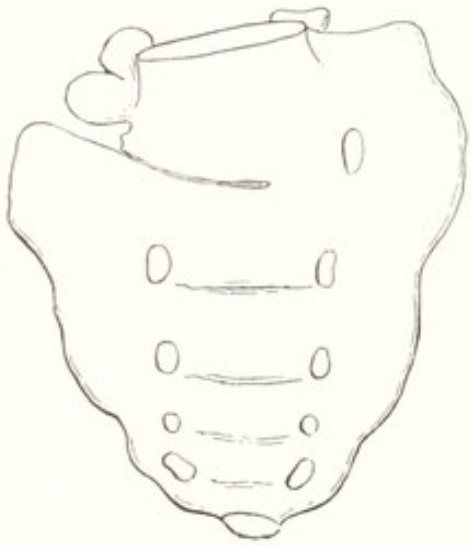


FIG. 194.—Unilateral sacralization of fifth lumbar vertebra which frequently leads to scoliosis.

(A) **Congenital Scoliosis.**—Congenital anomalies of the spine are quite common, particularly numerical variations in its constituent parts, viz.: reduction or increase of the vertebræ, unilateral sacralization of the fifth lumbar vertebra, a cervical rib on one side only, a supernumerary half-vertebra, etc. Very rarely a child is born scoliotic without bony anomalies, or with the scoliosis associated with more or less monstrosity and extraspinal anomalies; in both these rare groups of cases, the scoliosis exists as a well-defined clinical entity from birth. The usual behavior of congenital scoliosis, however, is a latent bony anomaly at birth without spinal deformity, the clinical picture appearing at a subsequent date.

(B) **Acquired Scoliosis.**—This group constitutes the vast majority of scoliotics.

1. *Constitutional Form.*—The curvature affects those in their early "teens," particularly city-bred girls of overgrown stature. Associated with a lack of resistance in the spine, there is usually relaxation of other joints, viz.: flatfoot or genu valgum. Muscular tonus is also defective, and the subjects are often apathetic, weak and anemic children. Rapidity of growth, and the changes incident to puberty out-distance the development of the musculo-ligamentous apparatus. Muscular and skeletal deficiency being mutually interdependent, it is difficult to determine which force predominates. It is notable that the spine in these cases is extremely mobile.

2. *Excessive Malleability of the Bones. Rickets.*—The primary deformity is an anteroposterior curvature developing later into a lateral curvature and eventually into an organic scoliosis. The common method of carrying infants on the flexed forearm tilts the pelvis and readily produces a total postural curvature of the rachitic spine. When fully developed,

rachitic scoliosis is manifested in three leading forms, viz.: (*a*) lumbodorsal or marked lumbar kyphotic scoliosis; (*b*) multiple curvature with serious deformity of the thorax; (*c*) high cervicodorsal curves.

Other forms of softening of the vertebræ leading to scoliosis are osteomalacia, osteitis deformans, syphilis, malignant disease and tuberculosis. Scoliosis may also occur incidental to dislocation of the vertebræ and following injury to the epiphyseal cartilages.

Arthritis Deformans.—A generalized kyphosis precedes the lateral curvature, which, if it occurs, is severe and intractable.

3. *Occupational.*—In this form there is often a mental as well as a physical basis. For instance, the peculiar mental state operative in young diffident



FIG. 195.—Collapse of right lung and secondary scoliosis following empyema at the age of five. Portions of two ribs were excised; the opening never closed and after eighteen years is still discharging. Patient is now twenty-three. (Taylor.)

girls at puberty is expressed by a certain shyness and by peculiar attitudes of body. The sense of balance or equilibrium in such individuals may be faulty. Again, fatigue, anemia and overwork in city dwellers, cause almost involuntary malposition from sheer exhaustion.

The following vocations are prone to induce spinal curvature:

(*a*) *Hod-carrier*, by raising the shoulder of one side, producing spinal convexity toward that side.

(*b*) *Nurse-maid*, particularly predisposed to scoliosis.

(*c*) *Joiners*, by continuous use of the right hand in pushing a plane, suffer a right dorsal curve.

(*d*) *School Children.*—The soft, plastic spines of school children are subject to several factors in their routine school work, viz.: primarily *fatigue* (incident to puberty and supplemented by mental and physical strain)

causes the assumption of the most comfortable position which later becomes a fixed attitude. Other forces predisposing to faulty attitudes are the monotony of routine school work, too long confinement, lack of air and exercise, and uncomfortable, unsuitable school furniture (Fig. 196).

4. *Static obliquity of the pelvis* frequently causes compensatory curvature of the spine. An underlying cause of the pelvic obliquity is inequality of the lower limbs. The convexity of the curve is usually toward the short limb, while displacement of the pelvis is toward the concave side, but variations of this order occur. Pelvic obliquity is not always accompanied by curvature of the spine provided the spinal muscles are in good tone and the patient's sense of the upright position is not defective. Obliquity of the pelvis is operative particularly in weakly girls, but even in their case, instinctive attempts are made by an equinus position of the foot on the short limb and by flexion of the knee on the longer leg, to compensate for the pelvic anomaly. Flatfoot, as an etiological factor in producing scoliosis, is of only slight clinical importance.

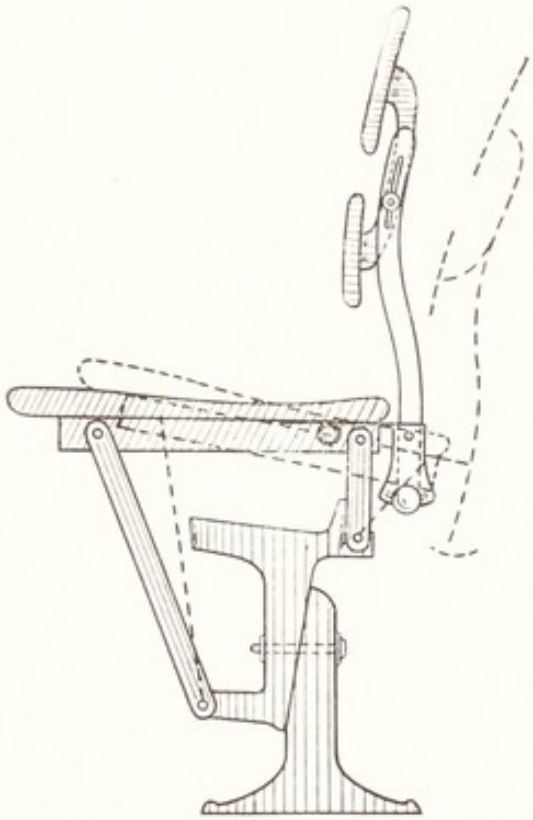


FIG. 196.—Adjustable school seat. (Miller and Stone.)

In the case of congenital dislocation of the hip, even after the pelvic obliquity has been overcome by reduction of the dislocation, the scoliotic spine often requires special additional treatment.

5. *Unequal vision* particularly astigmatism, by causing malposition, is an etiological factor in school children.

Unequal hearing necessitating torsion of the head, reacts on the vertebral column.

Torticollis (long untreated) may produce a cervicodorsal curve with its convexity on the side opposite the contracted muscle.

The *loss of one arm* tends to cause an asymmetrical position of the trunk and may produce lateral curvature of the spine.

6. *Neurological Affections.*—Unilateral weakness or paralysis of the intrinsic muscles of the back, or of those which normally maintain its equilibrium, are common causes of scoliosis. The following nervous disorders are potent factors in this respect:

(*a*) Anterior poliomyelitis; (*b*) Multiple neuritis; (*c*) Spastic paralysis; (*d*) Sciatica; (*e*) Progressive muscular atrophy; (*f*) Pseudohypertrophic paralysis; (*g*) Tabes dorsalis; (*h*) Friedreich's ataxia; (*i*) Syringomyelia; (*j*) Tumors of the cord and meninges.

(*a*) *Anterior Poliomyelitis.*—Poliomyelitis produces scoliosis in several ways, viz.: shortening or deformity of one leg, paralysis of one arm, unevenly distributed paralysis of the trunk muscles, and, most important of all, weakness or paralysis of the intrinsic spinal and abdominal muscles. The selection of the motor nerve cells of the anterior horns of the spinal cord which supply the spinal and abdominal groups of muscles is comparatively rare, excepting where there is a very general cord involvement. The

conduct of this affection is the same when the groups of spinal muscles are attached as when the disease has resulted in the paralysis of extremity muscle groups.

This deformity is a variable one, the severity of the lateral deviation depending largely upon the posture of the patient when in the erect or reclining position. The lateral deviation always diminishes in recumbency and increases in a varying degree in the erect posture, according to the severity of the paralysis. A certain degree of rotation of the vertebræ is always present, varying in amount also with the severity of the paralysis, but rarely reaching the same degree of rotation met with in static scoliosis.

Distortions similar to those of anterior poliomyelitis are encountered following *hemiplegia*, *progressive muscular atrophy*, and *pseudohypertrophic paralysis*.

(*b*) *Spastic Paralysis.*—The scoliosis in these cases is usually preceded by a kyphosis.

(*c*) *Ischias Scoliotica.*—This term is applied to a lateral curvature of the spine consequent upon an idiopathic neuralgia of the lumbar or the sacral plexus of nerves. The curvature is purposeful and postural and is not structural. Curvature is usually toward the affected side, with flexion at the knee and hip, with consequent tilting of the pelvis, the object being to relax tension on the lumbosacral cord. This malposition is the result of muscle-spasm. Similar functional curvatures occur in association with other painful affections, viz.: psoas ichor pocket, lumbago and rheumatic myositis.

(*d*) *Locomotor Ataxia.*—In rare instances, scoliosis may complicate this affection.

(*e*) *Syringomyelia.*—Spinal curvature occasionally complicates syringomyelia. The condition may be a trophic disturbance. The curvature is generally scoliotic with a slight amount of kyphosis. The curvature is usually painless and of a moderate grade, but the distortions are sometimes extreme.

(*f*) *Friedreich's Ataxia.*—Scoliosis with lumbar lordosis is occasionally a late complication of Friedreich's disease.

7. *Diseases of the Chest.*—(*a*) *Empyema and Pleurisy.*—As a result of cicatrization of the affected pleural cavity, scoliosis may be produced. The curvature is toward the healthy side. There is very slight or no vertebral rotation. The chest is large on the convex side, the opposite of the condition in the usual types of scoliosis.

(*b*) *Congenital Heart Disease.*—This disease in children is occasionally a factor.

(*c*) *Chronic pulmonary tuberculosis*, by reason of fibrosis and cicatrization of the lung, acts in a manner similar to empyema and pleurisy in producing scoliosis.

8. *Nasal Obstruction.*—Obstruction in the nasal or nasopharyngeal cavities, if persistent, often leads to contracted thorax, kyphosis and scoliosis, in the order given. Persistent spinal flexion in the kyphotic position weakens the muscles and allows scoliosis to occur. That the lateral curvature definitely depends upon the nasal obstruction in these cases, is abundantly attested by the spontaneous return of the spine to its normal position following correction of a deflected nasal septum, adenoids, etc.

9. *Cicatrices.*—Dense cicatrices, from extensive burns, followed by their contracture in the region of the upper arm and thorax, sometimes produce scoliosis with its concavity on the affected side.

Diagnosis

These cases of true scoliosis must be distinguished from the lateral curvature incident to Pott's disease. It must be borne in mind, however, that caries may supervene in simple scoliosis. A kyphosis, likewise, occurring at the junction of two scoliotic curves, is not necessarily tuberculous, although extreme cases may resemble Pott's disease. Non-tuberculous spinal curvature may be distinguished by the absence of pain and rigidity, and the presence of characteristic outlines of the body, and particularly by the presence of vertebral rotation.

Prognosis

In forming an opinion as to the outlook, each case should be judged on its merits and not by an inflexible rule. However, each case should be viewed from many angles, and the influence of each of the following factors kept constantly in mind: (1) cause, (2) age of onset, (3) sex, (4) mentality, (5) disequilibration, (6) physical condition, (7) rate of growth, (8) occupation, (9) nature, (10) location, (11) amount and (12) state of the curve, and (13) the effect of treatment.

1. **Cause.**—Rachitic curvatures tend to become worse with age, the added weight increasing the distortion. *Girls* with scoliosis at the age of *puberty*, offer a prognosis that must be tempered by several considerations, *e.g.*, the influence of heredity is unfavorable. If the case under observation presents a remediable cause (such as myopia, occupational curves, asymmetry of the lower limbs), the prognosis is far better than in cases in which the cause is irremediable (such as the paralyses, pleurisy, empyema, etc.). The degree of hardness of the bones, and the tension of muscles and ligaments must also be considered in rendering an opinion.

2. **Age of Onset.**—The earlier the onset, the greater, as a rule, is the deformity. In the cases of young children, the curvature, if structural, is sure to become worse. The effect on the general health, and particularly on the thoracic viscera from pressure, is not a negligible factor. Pulmonary tuberculosis, circulatory disturbances, etc., are likely to be engrafted upon the lowered vital resistance. A curvature in adolescents, although possibly slow in developing during childhood, is likely to increase with age.

3. **Sex.**—As a rule, deformity is worse in girls than in boys, on account of their inferior muscular development, and the lowered vital resistance consequent upon the establishment of the menstrual life.

4. **Mentality.**—The influence of an abnormal psychical attitude in shy, diffident girls is not to be disregarded. It is manifested by various awkward postures repeatedly assumed in sitting and standing, and these postures are intensified if there is lack of pride in the personal appearance, and rejection of advice as to change of the physical carriage. The outlook in such cases is unfavorable.

5. **Disequilibration.**—Loss of the sense of balance, if it cannot be restored by education, has an unfavorable effect on the prognosis.

6. **Physical Condition.**—Anemia (particularly chlorosis), dysmenorrhea, and a hysterical taint, by lowering the resistance impair the chances of correction. During pregnancy the curvature is sometimes increased.

7. **Rate of Growth.**—Long, narrow, yielding backs are readily malleable into abnormal curves; in such cases, when the rate of growth has been rapid, the outlook is relatively poor.

8. **Occupation.**—Vocational effects, which have been fully discussed, are less powerful the later in life the deterrent influence is assumed.

9. **Nature of Curve.**—Total or functional curves offer the best prognosis. If treatment is begun early and continued systematically, they may not progress to structural changes. But if neglected, a total C-curve may change to an S-curve with great rapidity (sometimes in a few weeks), in which case the prognosis is much more dubious.

10. **Location of Curve.**—Lumbar curvatures are less amenable to treatment than dorsolumbar or dorsal curves. Cervical and cervicodorsal curvatures are exceedingly difficult to treat because of the impossibility of getting proper pressure on the vertebræ, and the further handicap presented by the physiological kyphosis in those regions of the spine.

11. **Amount of Curvature.**—This is gauged by the degree of rotation of the vertebræ. A scoliosis in which the normal anteroposterior curves are reversed offers a very grave prognosis.

12. **State of the Curvature.**—Rigidity and fixation of a scoliotic spine in an adult confine the prognosis to the hope of staying its progress but without hope of permanent correction.

13. **Effect of Treatment.**—Generally speaking, the prospect of cure by any manipulative treatment is in inverse ratio to the patient's age. Total scoliosis with little or no structural changes can sometimes be cured if the patient is young and the spine plastic. Congenital bony anomaly or extensive intrathoracic disturbances are distinct obstacles to any form of treatment.

Paralytic scoliosis on the other hand, without structural changes and with plasticity of the spine, even with abdominal and spinal muscular weakness, offers a good prospect of relief, if not of permanent restoration of vertebral architecture, by means of the inlay bone-graft, as in Pott's disease when supplemented by external support, as practised by the author and which will later be described more fully in this chapter.

Treatment

The treatment of scoliosis falls naturally into two main divisions, (I) preventive and (II) corrective.

(I) **Preventive Treatment.**—Any predisposing factor should be eliminated at once upon recognition. *Rickets* demands prompt and systematic specific treatment and the avoidance of faulty attitudes particularly while the bones are in a malleable state. Especially to be avoided is the common method of carrying infants on the flexed forearm which tilts the pelvis and curves the spine.

The habit of careful and systematic observation of every child's physique for the detection of cryptic physical anomalies should be cultivated by parents. Too often the discovery of a beginning curvature is delayed until accidentally made by the dressmaker, the school-teacher or the school physician. It is likewise within the parent's province to correct bad habits of sitting and standing.

Harmful avocations, because of their tendency to produce asymmetry in the very young are violin playing, horse-back riding with the side-saddle in the case of girls, and bicycling, particularly bicycle racing with the spine hyperflexed.

In school life, frequent change of routine work, plenty of exercise and fresh air supplementing the working hours, and particularly the avoidance of too long periods of sitting or standing should be observed. The natural inclination of the spinal column to bend to the left should be borne in mind, and writing postures which favor this position should be avoided.

Associated deformities—short leg, flatfoot, genu valgum, coxa vara, etc.—should be immediately corrected. Corsets should never be worn by young children.

The general physical condition must be kept at a high standard. Sufficient sleep is essential, and general muscular weakness is to be met with ample exercise, frequent bathing with vigorous rubbing, walking and nourishing food. At puberty, the child must be protected against both mental and physical exhaustion.

(II) **Corrective Treatment.**—The history of corrective treatment of fully established structural scoliosis presents one of the gloomiest chapters in orthopedic practice. The result of treatment in a given case is always problematical, whatever the method employed.

The scoliotic deformity, being produced by the synchronous interaction of (*a*) abnormal postures, (*b*) their fixation by the constant operation of the fundamental cause, (*c*) increased by the superimposed weight of the upper trunk, shoulders, head, and neck and (*d*) loss of tone of the spinal muscles, local treatment must be directed at breaking simultaneously all links in this vicious chain of events. This corrective treatment is best applied in the following forms: 1. Maintenance of the general health. 2. Daily periods of recumbency. 3. Postural methods to give the patient an educated muscle sense to procure instinctively correct attitudes. 4. Exercises, both active and passive, supplemented by massage. If these methods, severally or collectively, after being given a fair trial, are unavailing, resort is had to 5. Rapid correction by (*a*) manipulation and fixation, supplemented by (*b*) operative correction by the inlay bone-graft in selected cases, to aid in maintaining the correction used in conjunction with a spinal brace. 6. Palliative spinal support in intractable cases.

1. *Maintenance of the general health* has been fully discussed above.

2. *Recumbency* is employed to prevent undue fatigue and *not* as a therapeutic measure aimed at correction of the deformity. Too long recumbency, as formerly used, tends to increase rather than to relieve the deformity. Employed as short rest periods at frequent intervals each day, in combination with passive correction, recumbency is a useful adjuvant to other forms of treatment. During sleep it is advisable to have the head low and a pillow under the convex side, but placed at a point away from the rib angles; if the pillow makes pressure at the point of greatest convexity, it is likely to increase the rotation of the vertebræ.

3. *Postural Methods.*—Proper methods of walking, standing and sitting should be taught, and the patient put through regular drills involving the simultaneous use of both arms. Standing "at ease," that is, with one hip relaxed, should be forbidden. If discrepancy in the length of the legs exists, it should be overcome by the addition of a cork sole to the boot of the short leg.

4. *Exercises.*—The object of formulated exercises is not only to increase the flexibility of the spine, but to increase the strength of the musculature which must be largely depended upon to retain the normal shape of the spine after correction. Exercise may be used as both active and passive. Exercise by means of apparatus is practised extensively by some, notably Lange, who has devised many ingenious though simple appliances for this purpose.

In the hands of the author, one of the simplest and most effective of these appliances has been found to be the lateral suspension apparatus of C. F. Taylor. The patient is made to grasp a pair of adjustable handle bars attached at right angles to an upright which can be inclined away

from the side of the deformity. A block is fixed on the upright so that, by adjusting the height of the handle bars, it can be made to impinge on the most prominent part of the convexity. With the patient hanging by the hands and with the feet clear of the floor, considerable side pressure is exerted on the deformity (Fig. 107).

Another useful means of exercise is by gymnastics (Fig. 108). No fixed rules or order of exercise can be formulated inasmuch as each case requires to be studied separately in this regard, and exercise must be prescribed which will best meet the conditions of the particular case at hand. However, it

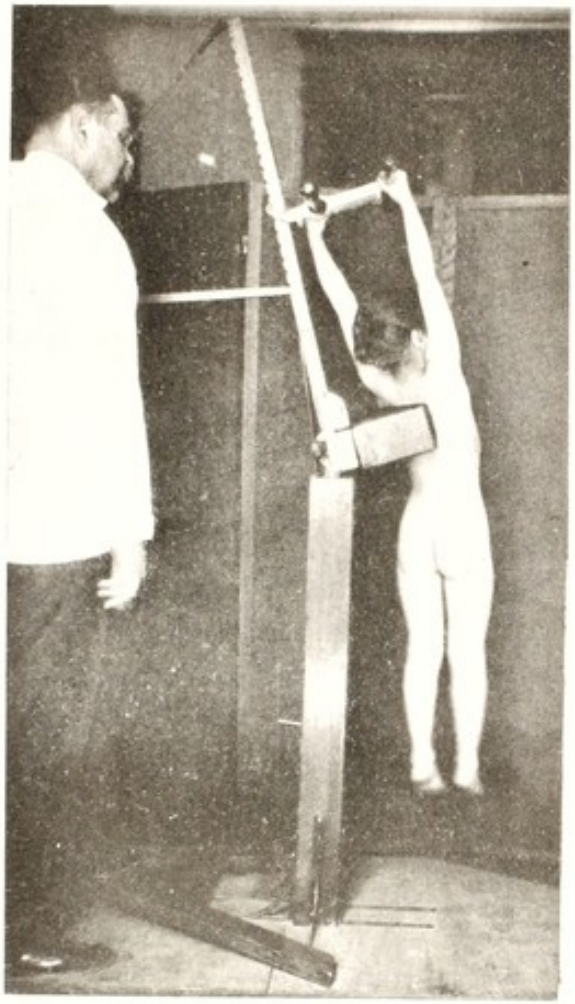


FIG. 107.—C. F. Taylor's lateral suspension apparatus for the correction of scoliosis. (Taylor.)

seems to be the prevailing opinion that gymnastics really accomplish very little in moderate and severe cases of scoliosis.

5. *Rapid Correction. Manipulation and Fixation.*—Sayre of New York in 1878 first advocated the treatment of scoliosis by suspension in a plaster-of-Paris jacket, but the real impetus to the modern methods of correction by plaster-of-Paris jackets was given by Wullstein's paper before the International Congress in Paris in 1900.

(I) *Author's Method* (Figs. 199 and 200).—In the case of young children from three to eight years of age, the author employs a frame, simulating a wide Bradford-Whitman frame, on which the child is kept for a period of from six to twelve months. By means of counter-straps of webbing 3 to

4 inches in width, a constant corrective pressure is kept up on the deformity. The results in this recumbent position are more rapid and complete than in the erect position, because the surgeon is not working against the superimposed body-weight, as is the case when the child is standing. Furthermore, the muscles and ligaments, after a time, become more supple from disuse and yield to the pressure, after which the case may be conducted as outlined below.

Among the methods now most commonly employed are those of Lovett, Abbott and Forbes which may be taken as types of this form of treatment.



FIG. 198.—Self-correction by side pressure. (Taylor.)

That the treatment of scoliosis is still very much unsettled is indicated by the diversity of various methods. Whereas Abott advocates flexion of the spine, Whitman and Lange employ the opposite method of hyperextension.

(H) *Lovett's Method.*—During the application of the jacket, the patient lies on the face on webbing strips running from end to end of a gas-pipe frame with the legs flexed at right angles to the body. Lateral pressure is made by means of lateral webbing straps running to the sides of the frame. Lovett believes (Bull. Dept. Surg., Harv. Med. Sch., May 20, 1915) that by his position he obtains greater correction of the vertebral column than by Ab-

bott's method, and that the lateral and unrotating pressure on the thorax is in this position more likely to be effective on the spine than on the thorax alone.

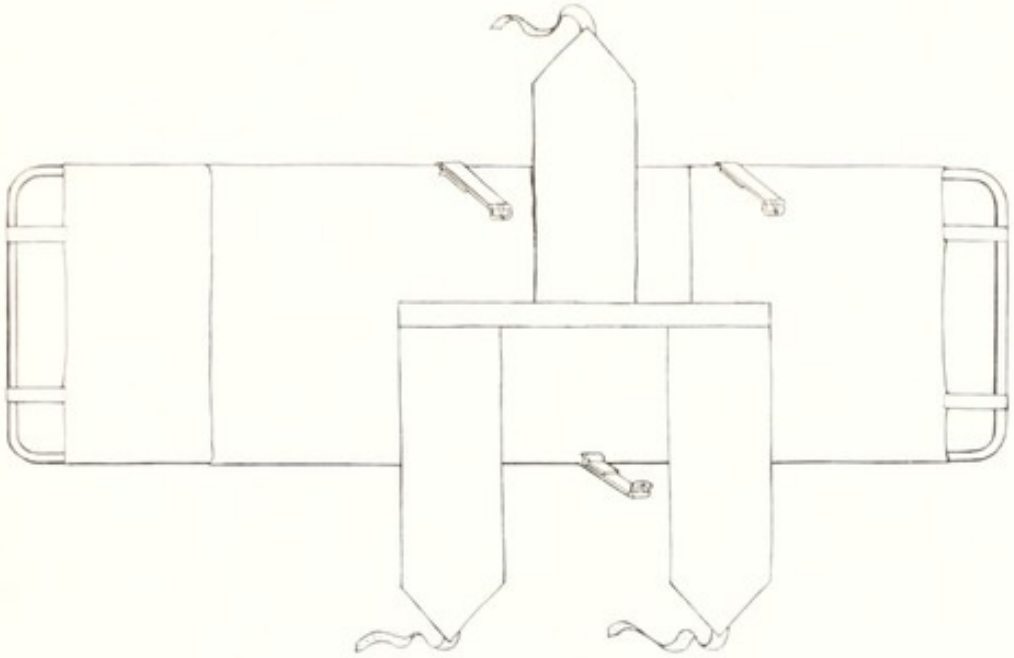


FIG. 199.—Author's modification of a Bradford frame for the correction of scoliosis in children with the patient in the reclining position. Two broad bands of heavy ducking are placed on one side, with one on the opposite side. Correction pressure is applied by buckles at ends of metal posts indicated. (See next figure.)

(III) *Abbott's Method.*—This method depends upon *flexion* of the spine, which tends to unlock the articular processes of the spine from one another and thus to allow greater facility of correction, especially with regard to rotation of the vertebræ.

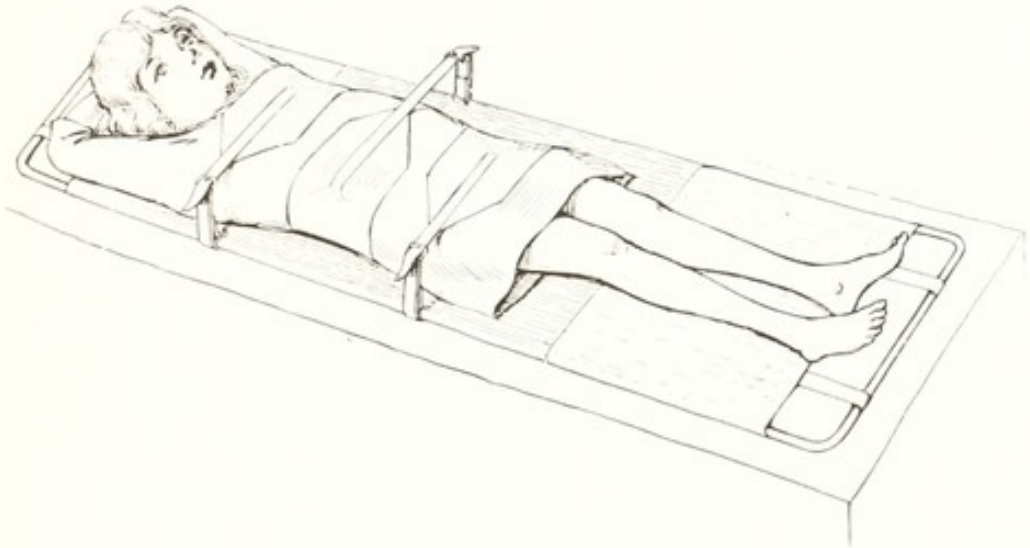


FIG. 200.—Same as Fig. 199.

To secure this flexion, the patient is put in an Abbott frame which consists of a series of superimposed frames joined together by uprights (Fig. 202). To the middle of the frame is fixed a canvas hammock of trapezoid shape so that when pulled out, one edge is tightly stretched, the other loose. The patient is put in the hammock with the convexity of the back resting on the

stretched part of the canvas. Then the feet are raised by a pulley, thus sharply flexing the spine Bands running from the sides of the frame permit traction to be made on the trunk to overcome rotation and the lateral curvature. A 3-tailed bandage makes lateral traction on the prominent region of the ribs, and downward traction on the trunk. A second 3-tailed bandage pulls the pelvis toward the concavity and upward. The arm on the concave side is drawn upward and forward, the other arm downward and backward. If hypercorrection by this means cannot be obtained at one sitting, other

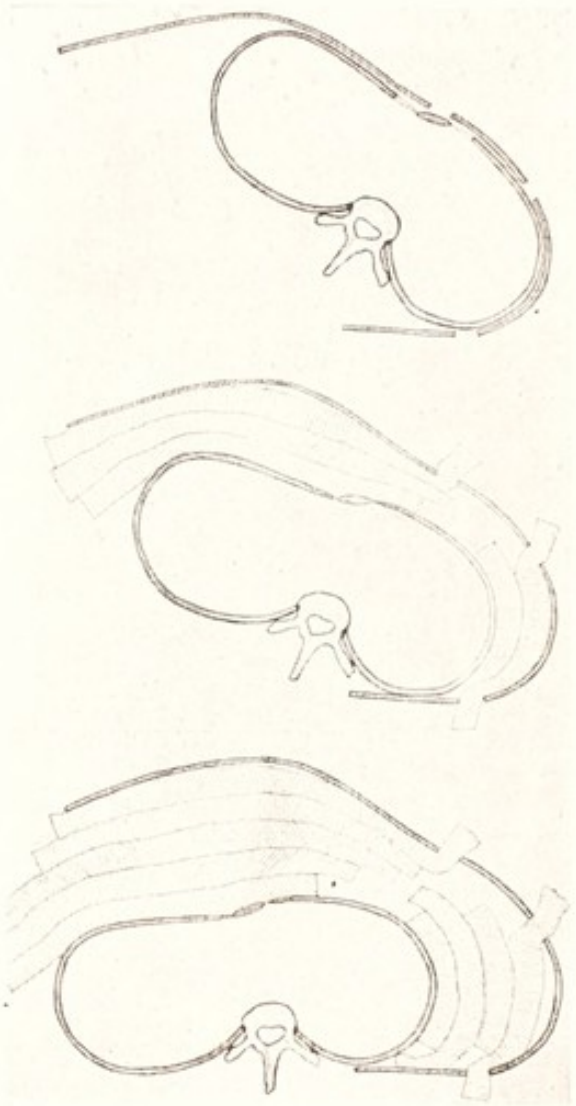


FIG. 201.—Diagram illustrating the changes which take place in the thoracic spine when felt is inserted through slits in the plaster. The same changes take place in the lumbar spine by this procedure but they are not so marked. (Abbott.)

trials are made. When hypercorrection is attained, the patient is put up in a plaster-of-Paris jacket. On the concave side of the curve a heavy felt pad is placed and a heavy plaster jacket is applied to the patient in this position. A large window for decompression is then cut out over the concave side behind, reaching beyond the middle line of the back. Smaller rectangular windows are then cut out on the corresponding side, one in the middle line in front, the other two at the anterior and posterior axillary lines, and heavy pads are pushed in, to press the thorax back into the large posterior hole in the jacket. The patient is thus held in the flexed position,

with one arm held away from the side—a rather unsightly and uncomfortable position.

Orr's Spinal Brace for the Rotation (Abbott) *Treatment of Scoliosis.*—H. Winnett Orr (Am. Journ. Orth. Surg., vol. xiv, No. 8, August, 1916) employs a specially designed brace for executing Abbott's rotation treatment. The Orr brace consists of a wide strong pelvic band, with a straight vertical cylindrical rod extending up the back. Over the rod little collars are dropped corresponding somewhat in size and position to the vertebræ, and each collar has a toothed edge so that it fits securely against its neighbor. Some of these collars carry "ribs," which may be placed at any level or in any position of rotation desired. Rotation pressure may thus be exerted upon the ribs

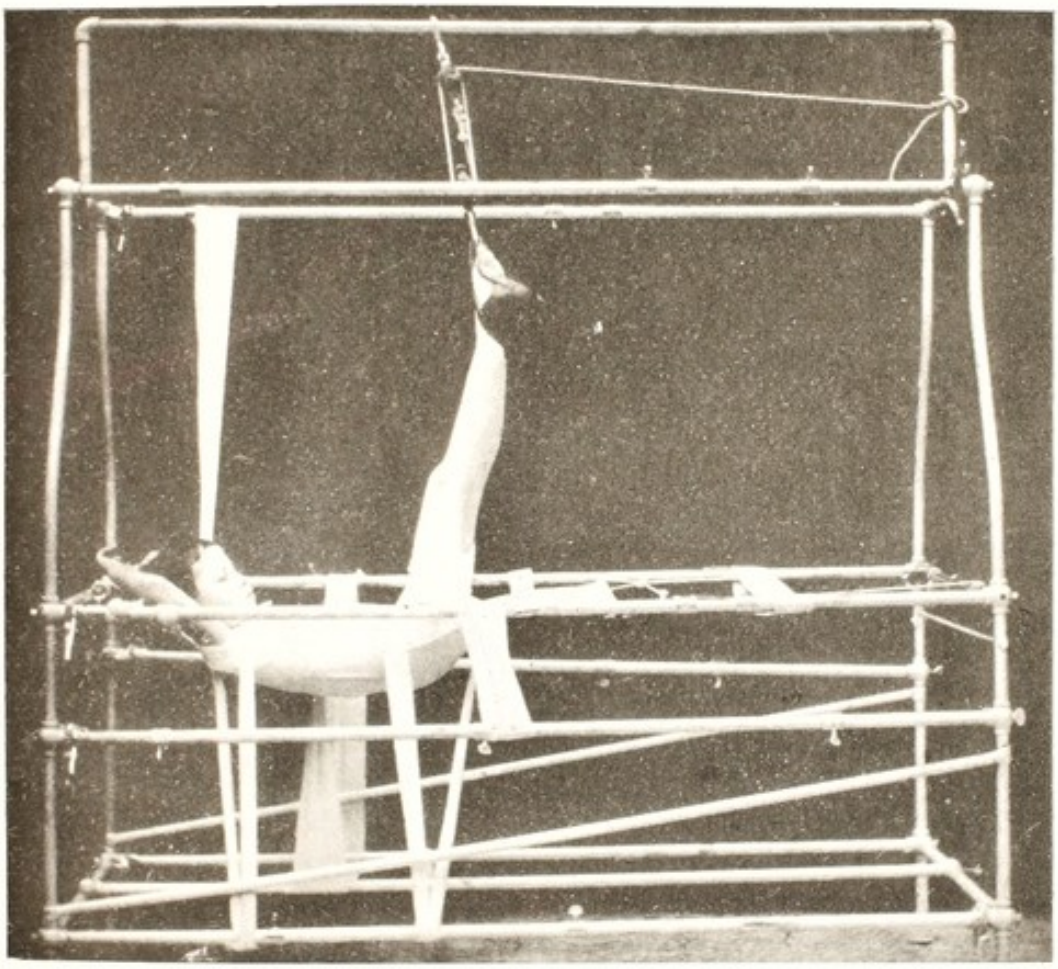


FIG. 202.—Figure illustrating method of placing patient in Abbott frame for the treatment of scoliosis. (Bradford and Lovett.)

at any point and in any degree. Near the top, two of the collars or "vertebræ" carry special pieces for supporting the shoulders. These, too, can be placed in any position desired. After all these parts have been placed in the desired position, a nut is turned securely down against the top "vertebra" and the entire brace is thus securely locked.

The three important advantages which Orr claims for his brace are that positive rotation correction may be obtained with it; that the brace is infinitely adjustable for position or growth at any time, for any patient, without actual alteration or weakening of any part; and finally, that there is no constriction of the chest.

Kleinberg's Spinal Brace for the Rotation (Abbott) *Treatment of Scoliosis.*—S. Kleinberg (J. A. M. A., vol. lxii, No. 17, April 25, 1914, p. 1325, has devised a spinal brace which he claims has all the advantages and none of the disadvantages of the Abbott jacket and which is especially applicable to fixed deformities where there is a long single curve. Kleinberg applies the method of Abbott in all its details, only replacing the jacket by a brace which is constructed as follows:

"The brace consists of pelvic and thoracic bands, 3 upright bars and an accessory bar to guide the direction of the three canvas bands used to exert pressure. The pelvic band (Fig. 203) grips the pelvis firmly, and is reinforced by curved bars (Fig. 203, *b*) fitted accurately over the crests of the ilia. On the side of the deformity in front, it is provided with a hinge (Fig. 203) to allow for opening up of the brace during its application or removal. The thoracic band (Fig. 203) is so constructed that on the side opposite the deformity it lifts the shoulder up as highly as possible, holding it



FIG. 203.—Anterior view of new brace for treatment of scoliosis. (Kleinberg.)

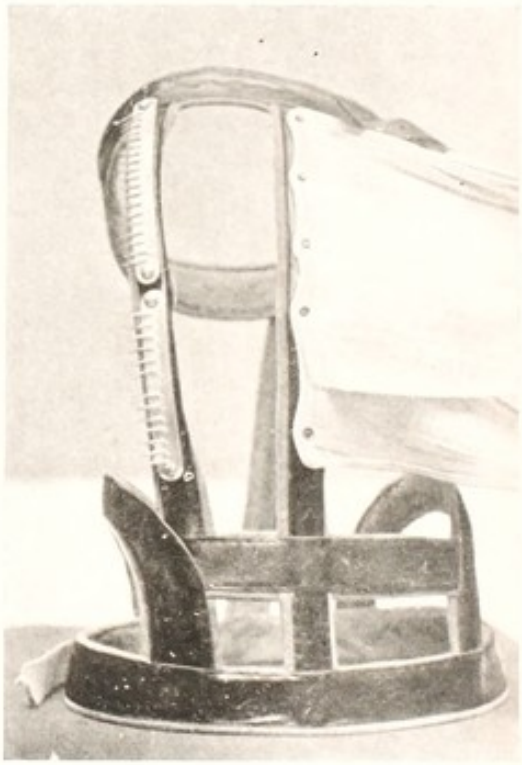


FIG. 204.—Lateral view of brace for treatment of scoliosis. (Kleinberg.)

forward also, while on the side of the deformity it is interrupted in its course across the axilla, allowing the shoulder to drop down, and is held here only by a buckle and strap; on the hollow side at the axilla, it is provided with a hinge (Fig. 203). The 3 upright bars connect the pelvic and thoracic bands and are distributed as follows: one along the middle of the back and another parallel with the posterior axillary line on the hollow side. It is essential that this bar be on a plane behind the most prominent part of the deformity, usually from 3 to 6 inches distant from the surface of the chest. The third bar (Figs. 203 and 204) is placed in front. It is fixed to the pelvic band and adjusted to the thoracic band by means of a screw lock, so that it is easily detachable. This bar is bent to conform to the fixed chest.

"The posterior lateral and anterior vertical bars are provided with steel teeth (Fig. 203) for the attachment of the canvas bands. The accessory bar (Figs. 203 and 204) extends upward from the pelvic band to the axilla

on the side of the deformity and serves as a guide for the canvas straps, preventing them from compressing the chest.

"To the median posterior bar are attached 3 canvas bands (Figs. 203 and 204). Two bands encircle the chest and are attached to the lateral posterior bar. Both, when pulled, push the ribs on the side opposite the deformity backward, tending to unrotate the spinal column; they take the place of the felt pads in the Abbott jacket. A band serves also by its pressure across the abdomen to maintain flexion of the body. A band equal in width to the area of the deformity, attaches to the anterior bar, and by hugging the deformity tightly helps the action of the other bands.



FIG. 205.—Demonstration that by rotation of the trunk superimposed on a fixed pelvis apparent correction of a spinal curve can be produced. Dotted line marked 1 shows the position of the spinous processes when the patient is turned to the left. Dotted line No. 2 demonstrates the position of the spinous processes when the patient is turned to the right. Lines 3 and 4 demonstrate the position of the angles of the ribs in these movements. (A. Mackenzie Forbes.)

"To make the brace, one places the patient in an Abbott jacket, being sure to adjust the pelvis and especially the shoulders, as taught by Dr. Abbott, and obtaining as much correction as possible. This jacket, when sufficiently hard, is cut off and filled with plaster for a torso, over which the brace is constructed. In the brace the body can be held well flexed."

(IV) *Forbes' Method* (N. Y. Med. Jour., July 6, 1912, vol. xcvi, No. 1, p. 1).—The aim and object of Forbes' apparatus are to cause physiological scoliosis on the reverse side. The effect is seen in Fig. 205. To cause physiological scoliosis by means of his apparatus, Forbes immobilizes the pelvis and rotates the thorax by means of the arms toward the side of the deformity. The power to create torsion by means of the arms seems to be transmitted

through it to the thorax by the serratus magnus and allied muscles. The trunk is flexed on the fixed pelvis on the assumption that rotation is made easier by flexion. Since lordosis usually accompanies scoliosis, the lower extremities are flexed.

The desired torsion having been obtained, the plaster jacket is applied to the patient on the Forbes frame. The plaster is maintained from the spinous processes to the angles of the ribs on the side of the deformity and increased if necessary or increasing pressure insured by inserting wadding between the trunk and the jacket. The plaster immediately opposite this remains intact, because all pictures of the deformity reveal a bulging here. The remainder of the plaster is fenestrated. To quote Forbes' own words (*loc. cit.*), "..... opposing quadrants of the thorax are treated in a similar manner. Plaster opposes plaster and window is opposite window. In the treatment of patients by this method in Montreal, so much plaster has been cut away that it has been found necessary to reinforce the remaining plaster by irons, as shown in the accompanying illustration" (Fig. 206). He further states: "Treatment by torsion by this method aims at the unfolding of the deformity with the production of physiological scoliosis on the side reverse to that of the greatest deformity. By twist there may be obtained correction without the lateral pressure which, theoretically at least, is so greatly to be deplored in the treatment of a compound deformity, of which a crushing, or should I say, a narrowing of the thorax is a most important part."

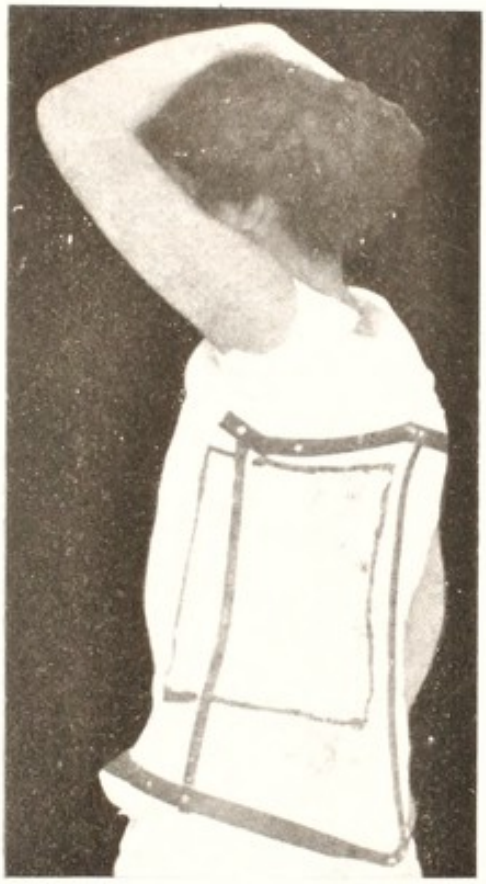


FIG. 206.—Photograph of a patient being treated for scoliosis by a plaster jacket, well fenestrated, window opposing window, and plaster opposing plaster. The strengthening irons are clearly seen. Such a jacket in many cases can be applied with advantage above the arms. The picture is to demonstrate the extent of the fenestration. (A. Mackenzie Forbes.)

The application of the first jacket is often followed by an increase in height of one or more inches in Forbes' hands. The jacket should be changed, as a routine, every six weeks.

Manipulation and Fixation Supplemented by the Inlay Bone-graft in Conjunction with a Spinal Brace in Paralytic Scoliosis.—The general rules of treatment applying to all types of infantile paralysis should be carried out during the initial febrile stage, namely, restraint in bed or on a gas-pipe frame, to restrict motion of the vertebræ of the involved area of the spine. Following the febrile stage, external supports, such as plaster-of-Paris corsets and metal frame braces, self-suspension by the Sayre apparatus (Fig. 209), etc., should be applied, together with corrective gymnastic exercises, until no further improvement can be attained, thus indicating that the paralysis still persists and the spinal deviation therefrom is a result of permanently destroyed motor nerve-cells.

It is difficult to maintain correction of this spinal deviation in the severer

cases by any external appliance, because the spine slumps into an S-curve inside of the brace, due to the lack of muscle support, whenever the patient assumes the erect posture. This difficulty in maintaining correction by any external support is due to a combination of the following factors:

1. Large size of the thoracic cage. 2. Its constant *movement*. 3. Its ever-changing volume under the influence of respiration. 4. The fluctuation in degree of *distention* of the abdomen and its contents. 5. The location of the spine in the extreme posterior portion of the trunk. 6. The physical impossibility of immobilizing individual vertebræ, one with another, on account of the aggregation of 26 moving vertebral bodies, each a unit of relatively small size.



FIG. 207.



FIG. 208.

FIG. 207.—A case of paralytic scoliosis before correction and insertion of graft.

FIG. 208.—Paralytic scoliosis; same case as Fig. 207, 1 year after the insertion of a graft into the tips of the transverse processes of the apex of the convex side of the worse curve. The graft included the thoracic vertebræ from the fifth to the twelfth inclusive. The marked straightened condition and increased stability of the back is most gratifying.

In this instance, on account of the unbalancing of muscle forces and the marked tendency of the deformity to relapse, it is impossible to maintain a general alignment of the vertebral segments.

After a lapse of two years it devolves upon the surgeon to decide whether the muscle weakness and the resulting curvature warrant the implantation of the more corrective and trustworthy bone-graft support.

Mechanics of Correction by the Bone-graft.—The bone-graft can be applied in two ways and only after correction by the various methods described elsewhere, either by the same technic as the author's operation for Pott's disease, or by placing the graft into the tips of the transverse processes of the vertebræ on the convex side at the apex of the sharpest curve, preference

being given to the thoracic region for the implant and six to eight transverse or spinous processes included by this graft.

From a mechanical standpoint, the transverse processes afford a much better leverage action to the correction of the lateral curvature than the spinous processes. In favor of the employment of the spinous processes as a graft bed is the presence of dense supra- and interspinous ligaments, prolongations from the powerful ligamentum nuchæ, which, when sutured over the graft, aid in fixing it in its bed. The selection of the transverse processes as the site of the graft appears, however, to have the greatest mechanical advantage; but there is, when the latter site is employed, danger of the graft becoming "sprung" from its bed by a tendency of the scoliosis to relapse before firm bony union has occurred. The latter danger can nevertheless be minimized by a properly adjusted external support and recumbency of from six to eight weeks, followed by a carefully moulded plaster-of-Paris jacket.

A lateral deviation in the spine causes a separation of the transverse processes of the convex side, coincident with the approximation of the transverse processes of the concave side. Much of this lateral deformity can be readily corrected by manual force under an anesthetic. This correction causes the transverse processes of the convex side to approach each other at the same time that the transverse processes of the concave side separate. The implantation of the graft with the spine so corrected acts in a like manner in preventing the relapse to lateral curvature, by controlling the separation of the transverse processes of the convex side, as does the graft implanted into the spinous processes for the control of the anteroposterior deformity of Pott's disease. The graft thus imbedded acts at a great mechanical advantage, in that it is pulled upon lengthwise, in preventing the separation of the transverse processes, which are arms of levers, at the same time acting as an internal fixation splint. Bearing in mind the mechanical and anatomical peculiarities of each of these two situations for the graft (the spinous and the transverse processes), it devolves upon the surgeon to select the method best suited to the exigencies of the particular case at hand.

Author's Technic of Operation.—A plaster-of-Paris bed with firm lateral walls should be moulded, before the operation, to the back and sides of the patient's trunk, and allowed to harden while the patient is held in the corrected position. This plaster splint is then removed and laid aside until the operation has been completed. The field of operation on the back, as well as the leg, is prepared by the iodin method. Six to eight transverse processes (or spinous processes, as the case may be) at the apex of the most acute curve are laid bare on the convex side by a curved skin incision, similar to the skin incision described in the bone-graft operation for Pott's disease. The muscles and ligaments over the tips and between the transverse processes are split into approximately equal halves with a scalpel. The transverse processes are split longitudinally into halves and at the same time the posterior half is set over to give room for the graft. With flexible probe and calipers the contour and length of the desired graft are determined. The tibia is flexed on the thigh and its antero-internal surface laid bare. The flexible probe pattern is applied to this exposed tibial surface, and the desired graft is outlined in the periosteum with a scalpel, its length being determined by the previous measurement with the calipers. The motor-saw is then made to cut along the periosteal outline and the graft is removed, including the full thickness of the cortex, and placed in its bed already prepared between the halves of the split transverse (or spinous) processes. While the patient is held in the corrected position, the ligaments and muscles

are drawn over the graft with interrupted sutures of medium kangaroo tendon.

The wound is closed by a continuous suture of No. 1 chromic gut, and a generous dressing applied. The patient is bandaged into the plaster-of Paris bed, previously prepared.

After six weeks of recumbency in this plaster bed, a well-moulded plaster case is applied to the spine to remain on for ten to twelve weeks. Following the immediate postoperative fixation, a well-moulded plaster-of-Paris jacket or corset brace is applied



FIG. 209.

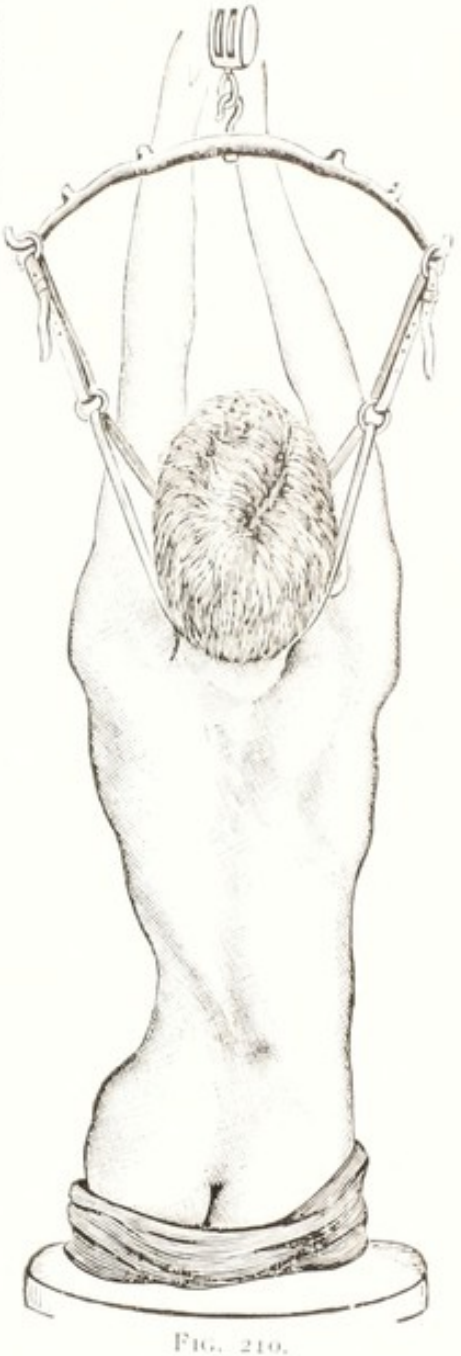


FIG. 210.

FIGS. 209 and 210.—Self-suspension, illustrating the effect of traction in lessening deformity induced by paralysis. (Gibney.) In such cases support is essential, and the tibial bone graft is of great value.

to those cases which need further support supplemental to the graft (Figs. 211 and 212). In the majority of cases external support is necessary because of the unbalanced muscle pull of the spinal and abdominal musculature and the strong tendency to a relapse of the deformity above and below that portion of the spine fixed by the bone-graft.

In closing the subject of scoliosis in general, attention is directed to the fourth report of the committee on the treatment of structural scoliosis to the

American Orthopedic Association, in May, 1917. This committee presents the following summary as the result of its investigation of the series of cases treated by the various methods:

"1. No case of overcorrection of the elements of deformity in structural scoliosis has been presented to the committee, in which they have been permitted to observe and record the condition of the patient from a time preceding the beginning of treatment.



FIG. 211.—Plaster-of-Paris corset. (Taylor.)

"2. The time allowed by the committee has been sufficient, in their judgment, for such a demonstration, were it possible, in the respective patients and by the respective methods.

"3. The same statements may be made with respect to complete correction of the elements of deformity.

"4. In mild cases of undoubtedly structural scoliosis, and perhaps in some moderately severe cases, considerable degrees of correction may be achieved by means of the method of Lovett, Abbott, and by Kleinberg's brace.

"5. It seems probable that greater degrees of correction may be obtained

with the flexed position of the spine than with the extended position of the spine.

"6. It does not appear that the use of extreme force is justified by the results which are to be obtained from it."

(B) KYPHOSIS

The following statements appertain to posterior curvature of the spine *exclusive* of that produced by destructive lesions such as tuberculosis, malignant disease and syphilis.

Following Tubby's excellent arrangement (Deform., Incl. Dis. of the Bones and Joints, 1912, Vol. I, p. 559), kyphosis may be conveniently grouped according to the age of the onset of the curvature.



FIG. 212.—The Van Winkle corset-brace adjusted in a marked case of scoliosis, low dorsal to right, lumbar to left. (Taylor.)

I. **Kyphosis of Infancy.**—This type is usually due to feeble muscular development in combination with rickets.

II. **Kyphosis of Childhood.** (*a*) *Rachitic.*—Kyphosis due to rickets may be confused with tuberculous kyphosis, from which, however, it may be differentiated by the flabby musculature, other stigmata of rickets, the freedom of spinal motion, the disappearance of posterior curvature on suspending the patient from the axillæ and by the fact that hyperextension

of the spine is possible to its full normal 90 degrees. Further discussion of rachitic kyphosis will be found elsewhere in this book (Chapter XII).

(*b*) *Neuropathic.*—This group includes the kyphosis following poliomyelitis, pseudohypertrophic paralysis, progressive muscular atrophy, sciatica, locomotor ataxia, idiocy, cretinism and allied paralytic conditions.

(*c*) *Hereditary Kyphosis.*

(*d*) *Kyphosis* associated with chest deformities such as complicate adenoids, etc.

III. **Kyphosis of Adolescents.**—The physiological anteroposterior curvature is subject to so many variations under normal conditions, depending upon age, sex, race, general conditions of the skeletal muscles, abdominal obesity, pregnancy, etc., that it is difficult to obtain a standard with which to compare deviations from the normal. However, there are several types of kyphosis in adolescents which are clinically recognized, viz.:

(*a*) "*Round Back.*"—Here the normal dorsal kyphosis is exaggerated and includes the cervical region which is inclined forward and the head thrust forward with it. The pelvis is pushed forward, carrying the upper ends of the femora with it. The thorax is tilted back, while the abdomen protrudes. In short, there are *flat chest, round back* and *prominent abdomen.*

(*b*) "*Flat Back.*"—The dorsal kyphosis and the lumbar lordosis are both diminished and the spine, in consequence, is nearly straight.

(*c*) "*Hollow Back.*"—This deformity is produced by increased pelvic inclination with backward dislocation and exaggeration of the sacrolumbar angle.

(*d*) "*Round and Hollow Back.*"—This double distortion is the result of increased dorsal kyphosis with lumbar lordosis and is often accompanied by hyperextension of the knees.

The commonest of these four adolescent deformities is the "round back." Next in frequency is the "round and hollow back" with wing-like projection of the scapulæ. These types usually are an indication of muscular weakness aided by visual defects, faulty attitudes in sitting, etc.

Treatment of Adolescent Kyphosis.—Flat-chest associated with dorsal kyphosis should be treated by reducing the kyphosis by spinal extension by means of appropriate gymnastics, breathing exercises, and exercises to pull back the shoulders and stretch the anterior part of the shoulder girdle. In resistant cases, forcible stretching may be indicated by some special apparatus such as Lovett's (ref. "Lat. Curvat. of Spine and Round Shoulders," 1916, p. 205). Stretching alone may be sufficient or may need to be supplemented by fixation in a brace or plaster case.

IV. **Kyphosis of Adults.**—There are several common etiological types of kyphosis in adults:

(*a*) Occupational (cobblers, tailors, porters, etc.). (*b*) Muscular and gonorrheal rheumatism. (*c*) Arthritis deformans. (*d*) Osteitis. (*e*) Osteomalacia. (*f*) Progressive muscular atrophy. (*g*) Bronchitis and emphysema.

V. **Senile kyphosis** due to the retrogressive osseous changes of old age.

(C) LORDOSIS

Increase of the normal anterior curvature of the spine is almost invariably compensatory. It is normally greater in the lumbar region in females than in males, particularly in Cuban women (according to Tubby—ref. Defor. Incl. Dis. of the Bones and Joints, 1912, Vol. I, p. 572) and in those with a distended abdomen from any cause (pregnancy, ovarian cysts, ascites, etc.).

In a few instances, lordosis is not compensatory, viz.: rickets, spondylolisthesis, and occasionally in the lordosis of infantile paralysis.

An illuminating and useful classification of lordosis is that of Tubby (op. sup. cit., p. 573):

I. **Total.**—The existence of this form is very doubtful.

II. **Partial.**—A. Exaggeration of curve in regions normally lordotic. (*a*) Compensatory to kyphosis. (*b*) Compensatory to increased pelvic inclination. (*c*) Static, *e.g.*, in abdominal obesity. (*d*) Paralytic. (*e*) Spasmodic. (*f*) Rachitic.

B. Reversal of a normally kyphotic curve. (*a*) In certain scolioses. (*b*) In some cases of caries of the spine. (*c*) Osteomalacia.

Treatment of Lordosis.—The treatment of increased anterior curvature of the spine is the treatment of its underlying cause rather than of the static deformity *per se*. Thus, rachitic lordosis demands general and specific treatment of the disease itself, local supports for the weakened musculature with systematic massage, electricity, etc., to increase muscular tone.

AFFECTIONS OF THE SACRO-ILIAC JOINT

General Considerations

Relatively little importance was attached to the anatomical structure or pathological affections of the sacro-iliac joint prior to the publication by Goldthwaite and Osgood, in 1905, of "A Consideration of the Pelvic Articulations from an Anatomical, Pathological and Clinical Standpoint."

However, it had long been known that increased mobility of the pelvic articulations occurs physiologically during pregnancy and even during menstruation entirely without the influence of pregnancy. A certain amount of motion in the pelvic articulations was also known to occur normally.

The sacro-iliac articulations are true joints, having all the common joint structures, and are therefore subject to the same diseases and injuries as the other joints (Albee: J. A. M. A., Oct. 16, 1909). Furthermore, unlike most true joints, exact apposition of the component bones is maintained almost entirely by the ligaments. Considering these facts, it is remarkable, not that abnormal mobility and disease of these joints ever occur, but that they do not occur more often.

Clinical Groups

Clinical manifestations of disturbance of the sacro-iliac joint may be considered in the following groups:

I. **Obstetrical** and **menstrual relaxation** of the joint, in which the disturbance is due to physiological hyperemia of the affected structures.

II. **Traumatic relaxation.**

III. **Postural relaxation** from abnormal attitudes assumed in standing, sitting or lying. In the latter instance, it occurs especially after prolonged postoperative recumbency.

IV. **Postoperative relaxation** after symphysiotomy, pubiotomy, etc.

V. **Infectious sacro-iliac arthritis,** from tuberculosis, gonorrheal, pyogenic, osteo-arthritic and rheumatic causes.

VI. **Constitutional and developmental** anomalies.

Etiology

Relaxations and affections of the joint are produced by a number of causes, viz.:

1. **Female Pelvis.**—The female pelvis is less firmly constructed, therefore abnormal mobility is more easily obtained than in the male variety; on the other hand, because of the greater size and strength of these articulations in man, when abnormal mobility does take place, disability is more marked than in woman.

2. **Hyperemia.**—Congestion incident to pregnancy and menstruation leads to physiological relaxation of the joint.

3. **Traumatism.**—(*a*) *Direct blows* such as "sitting down hard" and (*b*) *severe strains*, as in the "giving way" following heavy lifting, are often followed by relaxed ligaments at the sacro-iliac joint. The traumatic relaxation may be *sudden* (as in a fall from horse-back) or due to *constant strain* continued for a long period (as in a patient of the author's who was obliged to hold a heavy plate glass window in a stooped-over position over long periods of time). The influence of constant strain is also seen in the relaxed sacro-iliac joint following difficult labor in which the prolonged pressure of the fetal head in the case of disparity between it and the pelvic canal causes great strain on the joint. This obstetrical relaxation is easily repaired, as a rule, in nonoperative as well as in cases following pubiotomy, on account of the strong posterior ligaments, but it occasionally persists.

4. **Attitudes and Postures.**—Prolonged standing with extreme lordosis and sitting with the lumbar curve reversed (lounging) are predisposing factors.

5. **Obesity.**—The drag of a large, pendulous abdomen, causes lordosis and consequent strain of the pelvic joints.

6. **Corsets.**—Straight front corsets lead to increased lordosis and cause pressure on the anterior part of the iliac crests, tending to relaxation of the sacro-iliac joints.

7. **Atony** of muscles and peri-articular ligaments and visceral ptosis all favor relaxation.

8. **Tuberculosis.**—The process usually extends from the sacrum as a sequel to disease of the lower lumbar vertebræ.

9. **Gonorrhea.**—The gonococcus may invade the joint in systemic infection following urethral involvement.

10. **Osteomyelitis.**—Pyogenic infection of the contiguous sacrum or ilium may involve the joint.

11. **Infectious proliferative** (atrophic) and **degenerative** (hypertrophic) forms of arthritis may involve the sacro-iliac as well as other joints of the body.

12. **Developmental peculiarities,** where the origin is obscure, may be the etiological factor by lessening pelvic stability or result in frictional irritation from the misshapen bone rubbing against some part of the joint during normal or abnormal motion.

Anatomy

In 1909, the author reported the results of his researches on the anatomy of the sacro-iliac joint based upon the careful dissection of fifty specimens (*loc. cit.*).

It was found that each specimen presented a perfect joint composed of all its elements, such as synovial membrane and cavity and strong, well-formed capsule, all of which proved to be as constant in their size and relationships as those of any other joint.

The antero-inferior aspect of the capsules was found to be very thin, which accounts for the fact that infection of this joint is very prone to discharge by this avenue into the pelvis and rarely through the very thick part of the capsule posteriorly; also, this part of the capsule often ruptures in

symphysiotomy, and in case of puerperal sepsis opens the joint to infection. The lumbosacral cord passes in close proximity to the joint at its lower third, and undoubtedly is frequently involved in affections of this joint, thus explaining the presence of persistent pain in the distribution of this nerve, *i.e.*, sciatica.

The articulation is easily opened on the autopsy table by incising the anterior part of the capsule and forcing the pelvic bones apart in front, the pubic symphysis having already been divided. Hence the occasional interference with locomotion and permanent injury of this joint, following symphysiotomy.

In the author's dissections, the interosseous ligament always separated from the ilium and never from the sacrum. The round ligament sometimes ruptured and sometimes its bony attachment. The anterior or auricular portion of each articular surface was covered with a thin plate of cartilage which was thicker on the sacrum than on the ilium. It averaged, in the fifty specimens, in its greatest length 7 cm. ($2\frac{3}{5}$ inches) and in width 3 cm. ($1\frac{1}{8}$ inches). The largest joint area of hyaline cartilage was 8 cm. ($3\frac{1}{16}$ inches) in length, and 3 cm. ($1\frac{1}{8}$ inches) in width. The smallest was 6 cm. ($2\frac{1}{4}$ inches) in length and averaged in width $2\frac{1}{2}$ cm. ($\frac{15}{16}$ inch).

The posterior irregular part is the attachment of the interosseous and round ligaments, around the latter of which most of the motion occurs as about an axis.

Mechanics of the Articulation

The sacrum is an inverted key to an arch suspended principally by the posterior sacro-iliac ligament. The base of the sacrum, in the upright position, projects forward beyond the articular surfaces of the ilium, and has a tendency to tip down. This is prevented by the sacrosciatic ligaments which tie the lower part of the sacrum to the ischium. Here is a great articulation, placed at the cross-roads, so to speak, between the trunk and the thighs, and mechanically imperfectly constructed to sustain sprains and injuries.

Distinct motion was elicited and measured carefully in every specimen except one. Sixteen of the cadavers were placed in Walcher's hanging position and the true conjugate diameter of the pelvis averaged an increase of 8 mm. ($\frac{1}{3}$ inch). Walcher obtained 9 mm. on the living subject.

Under favorable circumstances, however, this joint will stand much abuse, as in the case of a symphysiotomy. Edgar reported 5 cases in which he obtained from 2 to $2\frac{1}{2}$ inches of separation at the symphysis, followed by firm union and without symptoms.

Pathology

1. **Relaxed Joint.**—Fluid from effusion may or may not be present, as in other traumatic joint affections, the condition being described as "moist" or "dry." Abnormal mobility may be demonstrated by moving the sacrum on the ilium or *vice versa*. *X*-ray examination reveals an increase of the sacro-iliac space.

2. **Infectious Sacro-iliac Joints.**—(*a*) *Tuberculosis.*—The disease may occur on one or both sides, but is usually unilateral. The primary focus is in the articular surface of the ilium or in the lateral mass of the sacrum, usually the latter, the disease often extending into this situation from the lower lumbar vertebræ. The synovial membrane is secondarily infected whence the disease may spread to the articular surface of the ilium. The detailed pathological process is the same as in osseous tuberculosis elsewhere in the body, except that ichor pockets (cold abscesses) are more common

than is usually the case elsewhere. Owing to the thin anterior ligaments the focalizing point is usually forward into the pelvis. The intrapelvic abscess may extend outward into or beneath the sheath of the psoas, appearing in the groin, or, extending further, may point more superficially, internal to the anterior superior iliac spine, or it may pass downward and appear on the buttock through the sacrosciatic notch and in the ischiorectal fossa.

(*b*) *Degenerative* (Hypertrophic) *Arthritis* (Osteo-arthritis).—This condition is usually unilateral, and is characterized by fusion of the joint. In one of the author's dissections the anterior part of the joint was obliterated with bony deposit which also extended into the posterior ligament.

(*c*) *Pyogenic and Gonorrheal Arthritis.*—The pathological character of the joint in these conditions is as it occurs elsewhere in the body. Externally the peri-articular tissues are swollen, tender, red and the surface temperature elevated. The joint cartilages are eroded in advanced cases and the joint may be distended with turbid fluid or pus.

3. **Malignant Sacro-iliac Disease.**—Although the author has never encountered a case of primary malignant disease of this joint, cases have been seen in which the malignant process had extended from the ilium or the sacrum into the joint.

4. **Congenital Anomalies.**—Congenital absence of the pubic bones may produce pathological relaxation of the sacro-iliac joints, while it is probably true that many disturbances of this joint of obscure origin depend upon developmental peculiarities, the exact pathology of which is as yet unknown. In many cases of exstrophy of the bladder a considerable portion of the anterior segment of the pelvic ring is absent and where the gait is much interfered with or the symptoms are severe enough, the operative restoration of the defective anterior segment of the pubic arch by a bone-graft may be justified.

Symptoms and Signs

The symptoms of disturbance of the sacro-iliac joint from relaxation or disease vary considerably, but certain ones are nearly always present and if properly interpreted should make the diagnosis easy. The most common symptom is the *limitation of motion* of the lumbar spine; the others are *pain*, *swelling*, *abnormal mobility*, and peculiar *attitudes on standing or walking*. Goldthwait (J. A. M. A., vol. xlix, pp. 768–774) describes these symptoms and signs as follows:

1. **Pain.**—Aside from the limitation of motion, pain, which may be localized at the joint or referred to the leg or foot, is the most important symptom. Pain is usually indicated by digital pressure over the posterior aspect of the joint. The referred pains may extend the length of the leg or may be referred to definite areas in the upper or lower leg or in the foot. They are definitely increased by motions which result in strain of the affected joint, but are not increased by pressure along the course of the nerves, as would be true of a neuritis. The pain is almost always worse at night, because of the strain on the pelvic joints by obliteration of the lordotic curve which results from recumbency, but is relieved by changes of position which overcome this strain, and is prevented by postures in which this strain is not present such as in the lateral position. In the day time it is not apt to be present unless the joints are strained, as may result after long sitting, standing, stair climbing, stooping, etc. It is always worse in one leg, but may be present in both. The local pain when present may be referred definitely to the sacro-iliac joints, but more often to the sacral region. This

is made worse by anything that results in strain of these joints, and in women is worse at the menstrual period, because of congestion and the increased mobility of the joints at that time and consequently the greater possibility of joint strain. Recumbency, long sitting or standing increases the pain, because of the strain of these joints possible at such times. Bimanual compression of the pelvis laterally may or may not produce pain.

Affections of the sacro-iliac joint are exceedingly rare in children, but when they do occur the pains usually take the form of legache or backache, rarely being acute, and while they may be present during the day and interfere with the normal activities, they are almost always present at night, awakening the child, and are often supposed to be growing pains or are confused with the night cry and pains met in disease of the spine or hip.

2. **Swelling.**—At times, usually in connection with the infectious processes, the sacro-iliac joints are swollen sufficiently so that the swelling is visible and can be palpated. The character of the swelling will depend on the nature of the lesion. If tuberculous, there is usually considerable infiltration of the tissues without definite fluctuation, unless the process is so far advanced as to result in abscess formation. With this there is also to be expected considerable atrophy of the buttock and this, with the history and slow onset, is usually enough to make the nature of the process clear. With the non-tuberculous processes the infiltration is less, and there can sometimes be made out a distinct sense of fluctuation. The muscular atrophy is slight, and this, together with the more acute onset and the usual involvement of some of the other joints, should make differentiation possible. Tuberculosis of this joint is usually metastatic.

3. **Abnormal Mobility.**—While in lesions of the pelvic joints there is almost invariably limitation of some of the motions, there also, in certain cases, is an increase of the normal motion. This increase will naturally be seen chiefly in the cases in which, as the result of long continued strain, the joints are much relaxed. To determine this, various tests may be made. Forced hyperextension of the thighs, one at a time, thus moving the ilia on the sacrum, may be sufficient. At other times, with the patient standing, if one hand is held over the sacrum while the pubic bones are held between the thumb and finger of the other hand, and the patient now raises first one knee, then the other, the motion is sometimes quite distinct. Again, if the crests of the ilia are grasped with the two hands, the thumbs resting on the sacrum, and the patient raises the legs as above, the mobility is also often apparent. Another method is to have the patient lie down and raise first one leg and then the other with the knee straight. With one or all of these the mobility is usually apparent, but it is to be borne in mind that while there is an abnormal amount of motion under certain conditions, there is also in these very cases, under other test, definite limitation of motion.

4. **Attitudes on Standing or Walking.**—Disease or weakness of the sacro-iliac joints frequently results in peculiarities in the use of the body that are suggestive. When standing, the body is usually inclined away from the joint chiefly affected, *i.e.*, an inclination of the entire spine to the opposite side. In rising, the spine is usually held rigid, and the hands are frequently used for support. In stooping, the flexion of the trunk is avoided. In walking, the motions are made guardedly if the condition is at all acute, or if the joints are much relaxed the gait is rolling or even waddling as the result of this pelvic instability. If the condition be acute, a long step in walking is impossible, owing to the spasm of the hamstring muscles, produced when the knee is straightened with the thigh flexed. In lifting the weight with the knee bent, as in stair climbing or rising from the sitting posture, the discom-

fort is increased, and the hands are frequently used for support. It is usually painful for the patient to sit on a hard-bottomed chair, and he seeks relief by sitting with his weight resting on the buttock opposite to the affected joint.

5. **Limitation of Motion.**—In any event, if the sacro-iliac joints are strained or diseased, motion of the body which causes strain of these joints is limited involuntarily, as is true in the disease of other joints. With the sacro-iliac joints, the limitation may show by motions of the body on the thighs or by the motions of the thighs on the body. In the first place, forward bending of the body with the knees straight will be limited if the lesion is one of any magnitude, since as soon as the hamstring muscles become tight, the motion, which up to that point had been made largely in the hip and spine, is then made by the sacro-iliac joints and the spine. When this point is reached, the spinal and trunk muscles contract reflexly to protect the irritated joint, and the motions are restricted. To determine whether this limitation of motion is due to disease of the spine or to the sacro-iliac joints, the tension of the hamstring muscles should be released, and this is the most easily accomplished by the patient being allowed to sit, and in this position the same motion tried. If the spine is involved, the limitation will be present in this test as when standing. If the sacro-iliac joints are at fault, however, the bending will be much more free, since with the hamstring muscles relaxed, the forward bending is performed almost entirely with the hips and the spine, the sacro-iliac joints under such conditions being used only in the extremes of motion such as are rarely made. While the forward bending is limited when the patient is standing, the lateral bending is also limited. In this, as one side is usually more affected than the other, the bending to one side may be more free than to the other, and not only is this more free but it is usually made with different segments of the spine. While with the forward bending the change from standing to sitting makes a very noticeable difference in the motions, in the lateral bending this difference is not as marked, since in this, the hamstring muscles play but little part. In backward bending, the motions are usually guarded, while in the extreme cases the body may even be drawn forward so that it is not possible to assume the erect position and under these conditions backward bending would naturally be entirely impossible.

Thus far in the consideration of the motions, the thighs are made the fixed point, and not only this, but the tests are made with the joints carrying the body-weight. These same motions can be tested without the latter feature being present, by having the patient lie down and the thighs held fixed. In this way, while lying on the back, the forward bending can be tested by raising the body, and when on the face the amount of backward or lateral bending can also be determined.

After these tests have been made, the leg motions should next be tried (with patient still on back), the body in this test becoming the fixed point. These knee motions should be free and with the knee bent, the hip motions should be free and without pain except when the disease or lesion of the joint is very acute, at which times the extremes of motions, especially outward rotation with abduction, may be associated with pain referred to the sacro-iliac joints. In making these tests, while the hip motions are free as long as the knee is flexed, if the knee be straightened and then flexion of the thigh is attempted, the limitation will be definite. In this position the hamstring muscles are stretched and since these muscles are attached to the ischia, then any motion made in which they are tense, as in the straight leg raising, will result in the innominate bone moving with the leg and in this way the motion and possible sensitiveness to the sacro-iliac joints will

be developed. In any case in which there is definite disease or weakness of these joints, the straight leg raising will be limited, and not only is the motion limited, but attempts to carry it farther will develop pain which will be referred either directly to the sacral region or to the legs. (Note: this is the so-called "Goldthwait symptom.") In applying this test, whenever there is severe trouble in one joint, not only will the straight leg raising on that side be limited, but also in a considerable percentage of cases there will be a similar limitation in the other leg, although naturally not as marked. This limitation on the opposite side is to be explained by the fact that in the motion made with the hamstring muscles tight, the ilium on that side is moved, the sacrum naturally moving with it, and, as the result of this movement of the sacrum, the affected joint, although on the opposite side, is strained. Not only is this limitation of motion present on this side away from the lesion, but the pain which is developed by this same test is referred to the seat of the trouble or to the leg on the side affected, so that whether one leg or the other is raised, the pain is referred to the one on the side of the lesion. These tests, which should be at first made passively, will be even more striking if attempted actively by the patient.

Diagnosis

The following symptom-complex when present is almost pathognomic of disturbance of the sacro-iliac joint:

(1) Pain in the region of the affected joint on turning over while in the recumbent posture. (2) Discomfort while lying on the back. (3) Pain produced by sitting on a hard chair and relieved by sitting on the opposite buttock. (4) Pain in the affected sacro-iliac joint on forward bending. (5) Pain on deep pressure over the affected sacro-iliac joint. (6) Listing of the whole spine to the side opposite the lesion. (7) Goldthwait's symptom (pain referred to sacro-iliac region or to the leg of the affected side when the thigh is flexed with the leg extended).

Differential Diagnosis

There are several conditions simulating sacro-iliac disturbance which may cause error in diagnosis: lumbago, sciatica, hip disease, Pott's disease and disease of the ilium.

Disease	Points of resemblance	Points of difference
1. Lumbago	Pain in the lower back. Limitation of motion.	Pain is bi-lateral and sharply stabbing in character. *Location* in lumbar *muscles* which are tender to pressure. Goldthwait's symptom absent.
2. Sciatica	Pain radiating down leg. Local sensitiveness to jars and to manipulation.	Pain confined to distribution of sciatic nerve. Very uncommon in children. Goldthwait's symptom absent, but pain may be elicited over sciatic nerve.
3. Hip disease	Limp. Faulty attitude. Pain on movement of thigh and on rising.	*Muscular rigidity* in the hip-joint. *X*-ray picture different. Limitation of motion in all directions.
4. Lumbar Pott's disease	Pain in back and down leg. Postural peculiarities. Limp.	*X*-ray picture different. No pain on bi-manual compression of iliac spines.
5. Iliac Disease	Local tenderness.	*X*-ray picture excludes sacro-iliac disturbance. Goldthwait's symptom absent.

Treatment

The essential principle of treatment is *protection* of the joint with previous *replacement* of the component bones in the case of luxation or subluxation, followed by *immobilization*, to be at first attempted by *external appliances* (strapping, belts, braces, plaster jacket, etc.) and, if the case remains intractable, by direct fixation by *bone-graft* after the methods devised by the author. In cases of tuberculosis or osteomyelitis it is occasionally necessary to remove portions of bone.

Treatment in detail depends on the extent of the lesion, and its pathological character and will be discussed under three heads, viz.: (I) Conservative treatment; (II) Operative treatment; and (III) The treatment of complications.

I. CONSERVATIVE TREATMENT

This comprises (1) the correction of displacement; (2) treatment of sprain of the joint; and (3) treatment of obstetrical and menstrual relaxation.

1. **Correction of Displacement.**—Displacement of the sacrum may be a true *luxation* or a *subluxation*.

A. *Luxation.*—This is very rare and is the result of severe trauma. It requires an anesthetic for complete reduction, followed by the application of a double plaster-of-Paris spica bandage and recumbency.

B. *Subluxation.*—This is a relatively common occurrence and usually consists of a true backward displacement of the upper part of the sacrum. The correction may be brought about in several ways, viz.:

(*a*) *Hyperextension* of the spine by a *firm pillow* under the hollow of the back. By raising the lumbar spine, this maneuver usually draws the sacrum into place.

(*b*) *Hyperextension* of the spine by placing the patient prone with the thighs and legs supported by one table and the head and shoulders by another, the body hanging entirely unsupported between the tables. The weight of the body drags the spine forward, favoring replacement of the sacrum. If successful, this maneuver should be followed, at the same sitting, by the application of a plaster-of-Paris jacket. (For details of application see below.)

(*c*) *Goldthwait Frame.*—This was primarily designed for the application of the plaster jacket in Pott's disease. Its flexible steel rods may be bent low down to bring pressure on the sacrum. The body-weight forces the sacrum forward. With the patient in the desired corrected position on the frame, a plaster-of-Paris jacket may be applied and the steel rods then removed.

(*d*) *Suspension* or *hyperextension* may be practised with the patient standing, and in this way the subluxation reduced.

Note.—The plaster-of-Paris jacket for the reduction of subluxation of the sacrum is applied well down over the buttocks and anterior part of the thighs, and, at the top, high upon the thorax. A single or double spica may be used if necessary. In any event, recumbency should follow the application.

2. **Sprain.**—In case of recent injury, the treatment is that of a sprain of any other joint, but on account of the character of the sacro-iliac articulation, complete fixation of the joint is necessary for a longer period. Rest in bed with as complete fixation as possible is necessary for three or four weeks, followed by the use of a removable jacket or some form of support for two or three months, the latter treatment to be supplemented by appropriate exercises and massage.

Moderate Relaxation.—If the relaxation is moderate in amount, some form of support may be used without subjecting the patient to the recumbent posture. Of the various supports in common use, the author prefers the use of adhesive strapping with a felt pad over the sacrum.

1. *Strapping.*—A thick pad of felting measuring 5 × 6 inches is applied to the sacrum. Two-inch adhesive straps (usually 5 or 6 are required) are made to half-encircle the pelvis *tightly* just below the anterior-superior iliac spines. They should extend from the extreme anterior part of the ilium on one side around the buttocks to a similar point on the other side and carried up and down until the buttocks and lower lumbar spine are covered. The pad and strapping should be re-applied every five or six days until the symptoms are relieved, and then the wide webbing belt (described below) worn, for not less than six months. After the symptoms have been relieved, a short Van Winkle corset—short above, long below, well down over the buttocks, with the same sacral pad as above, and with a surcingle—should be worn (Fig. 213). This corset can be most satisfactorily made by the intelligent co-operation of the surgeon and a competent brace-maker; several fittings should be made under the direct supervision of the surgeon.



FIG. 213.—Van Winkle corset support for relaxation of the sacro-iliac joint. A felt pad 5 by 6 inches in diameter and 1 to 1½ inches in thickness is shown over the sacrum with a broad surcingle over it.

2. *Plaster-of-Paris Jacket.*—This should come well down over the trochanters to firmly hold the pelvis and should be applied with the patient standing with the arms raised shoulder high, the hands holding some support, and with the lumbar spine moderately hyperextended.

3. *Stiff Leather Jacket.*—This may be applied to the patient standing in the position outlined above, or may be moulded to a plaster model.

4. *Goldthwait's spring steel back brace* consists of a pelvic band with two uprights for the back fitted well in at the bottom so as to make firm pressure over the upper part of the sacrum.

5. *Wide webbing belt* attached to the base of a long corset in women, reinforced with light steels to prevent wrinkling and with a firm pad over the sacrum, often gives relief.

6. *Woven elastic trunks* may be fitted about each thigh and then about the buttocks.

7. *Osgood's Brace.*—This consists of a sacral pad with a spring steel crib which crowds the pad against the sacrum. It may be used in connection with the elastic trunks for greater support.

Night Supports.—It is even more essential to support the bones during recumbency than in the waking hours, for at night the pain is often the most severe. For this purpose the following are useful:

1. *Hard pillow* fitted under the hollow of the back to prevent flattening of the lordotic curve or transferred to the side when the patient assumes the lateral position, supplemented by another pillow below the knees.

2. *Woven elastic trunks* (see above).

3. *Plaster-of-Paris Bed.*—In very obstinate cases with great pain, a

plaster bed may be made so that the back, sacrum, buttocks, and thighs are supported.

Extreme Relaxation.—If the patient is subject to extreme pain and no relief has been obtained from strapping or any of the appliances above mentioned, more urgent measures are indicated, viz.:

1. *Traction by Weight and Pulley.*—This should be applied in the most severe cases on the limb of the affected side until acute symptoms subside.

2. *Recumbency* in *plaster-of-Paris jacket* or similar appliance should be enjoined, particularly in the case of stout women.

3. *Double plaster-of-Paris spica*, with or without weights and pulley, should be applied if no relief is obtained by the weights alone or with the simple plaster jacket.

3. **Obstetrical and Menstrual Relaxation.**—Although the treatment of relaxed sacro-iliac joints is the same during pregnancy and menstruation as under other conditions, there are several special factors to be borne in mind.

(*a*) *Preliminary pelvic examination* should be made in the case of multiparous women, in view of the fact that uterine fibromata and old lacerations of cervix and perineum have been found to be the etiological factor in several instances of symptoms referred to the sacro-iliac joints, their correction being rapidly followed by relief of the joint disturbance.

(*b*) *Acute Relaxation Incident to Pregnancy.*—If the relaxation is a *complication* of pregnancy, the patient may be allowed out of bed with a pelvic support three weeks after labor, the support to be worn until two or three menstrual periods have occurred. If nursing inhibits menstruation, the support should be worn for at least three months.

(*c*) *Menstruation without Pregnancy.*—In relaxation incident to menstruation alone, a support may be required for an indefinite period.

(*d*) *Pregnancy with Pre-existing Relaxation.*—When the relaxation is already established prior to conception the pelvis must be supported throughout pregnancy.

II. OPERATIVE TREATMENT

If the case is intractable, resisting all treatment by external supports, absolute fixation of the sacro-iliac joint must be secured, and to obtain this the author has devised three operations, viz.: (1) Bridge bone-graft from sacrum to posterior wing of ilium; (2) inlay graft into the joint surfaces themselves; (3) inlay bone-graft from spinal inlay graft to wing of ilium for combined tuberculous disease of lumbar vertebræ and sacro-iliac joint.

1. **Bridge Bone-Graft from Sacrum to Wing of Ilium.**—(Specially Indicated for Tuberculosis or Some Other Infection).—For bony fixation of this joint the following technic has been devised by the author.

With the patient on the face in the prone position, and both spinal and tibial fields of operation prepared, the posterior wing of the ilium and the upper portion of the sacrum are approached by a curved incision so placed that the line of skin sutures will not directly overlie the graft.

The first spinous process of the sacrum is split *en masse* with its enveloping ligaments and soft tissues, the cleft being made not vertically, but at right angles to the long axis of the spine. The upper half of the split process is left attached to the sacrum and unbroken; the lower half is fractured at its base and displaced downward. On account of its small size, the first sacral spinous process may be fragmented by repeated attempts to split it in equal halves, but this interferes in no way with the ultimate result if the fragments are left attached to the enveloping ligaments.

The periosteum of the posterior surface of the sacrum where the *graft*

is to be contacted is split in line with the cleft in the spinous process and peeled downward with the sharp periosteal elevator. The underlying bone is then scarified over a considerable area for contact with the graft.

The mesial surface of the posterior wing of the ilium projecting beyond (toward midline) the sacro-iliac joint is developed and a cleft is made by driving a $\frac{1}{2}$-inch osteotome into it in a plane parallel with the prepared

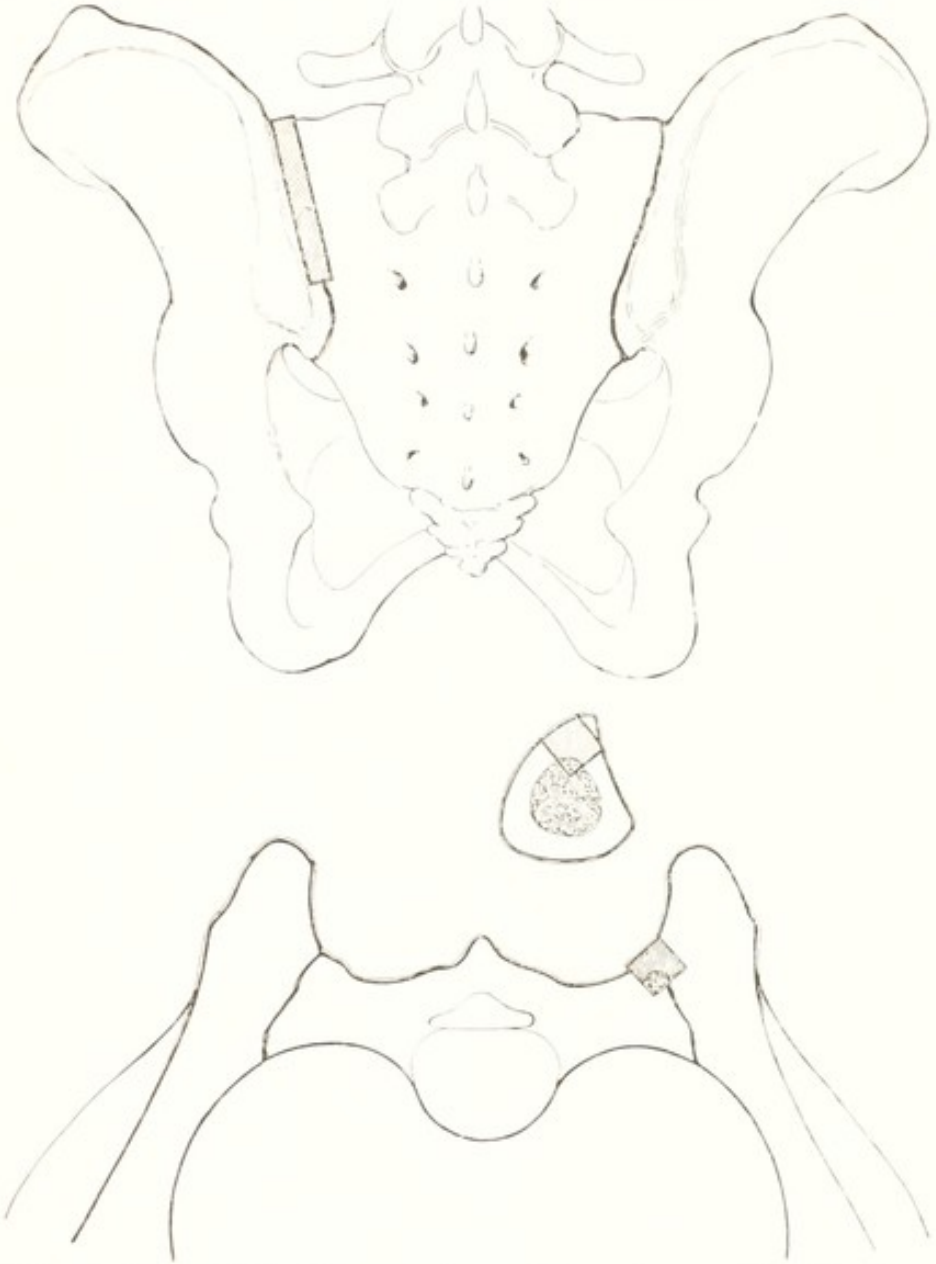


FIG. 214.—Indicates tibial inlay graft inserted into the sacro-iliac joint for support and immobilization of a relaxation of this joint, failing to be relieved by conservative treatment.

posterior sacral surface for the reception of the distal end of the graft. In making this cleft the handle of the osteotome is pressed down as tightly as possible against the posterior surface of the sacrum. The distal end of the graft is bevelled in such a way that, on being forced into its bed in the ilium, its proximal (sacral) end is tightly coapted to the posterior surface of the sacrum (see Fig. 216). The field of operation is then temporarily packed with hot saline compresses while the graft is being prepared.

The leg from which the graft is to be removed is flexed and the site of the

proposed graft exposed by a wide curved incision so placed that the line of subsequent sutures will not overlie the site of the graft removal. A bone-graft $\frac{1}{2}$ inch or more in width is removed from the antero-internal surface of the tibia as described under the operation for Pott's disease. Its distal (iliac) end is bevelled on its periosteal side (which is to be the posterior side) so that it may be driven tightly into the cleft in the ilium by means of the author's bone-peg set. As much of the marrow substance as possible is left on the graft. Numerous fragmented grafts obtained from bevelling the

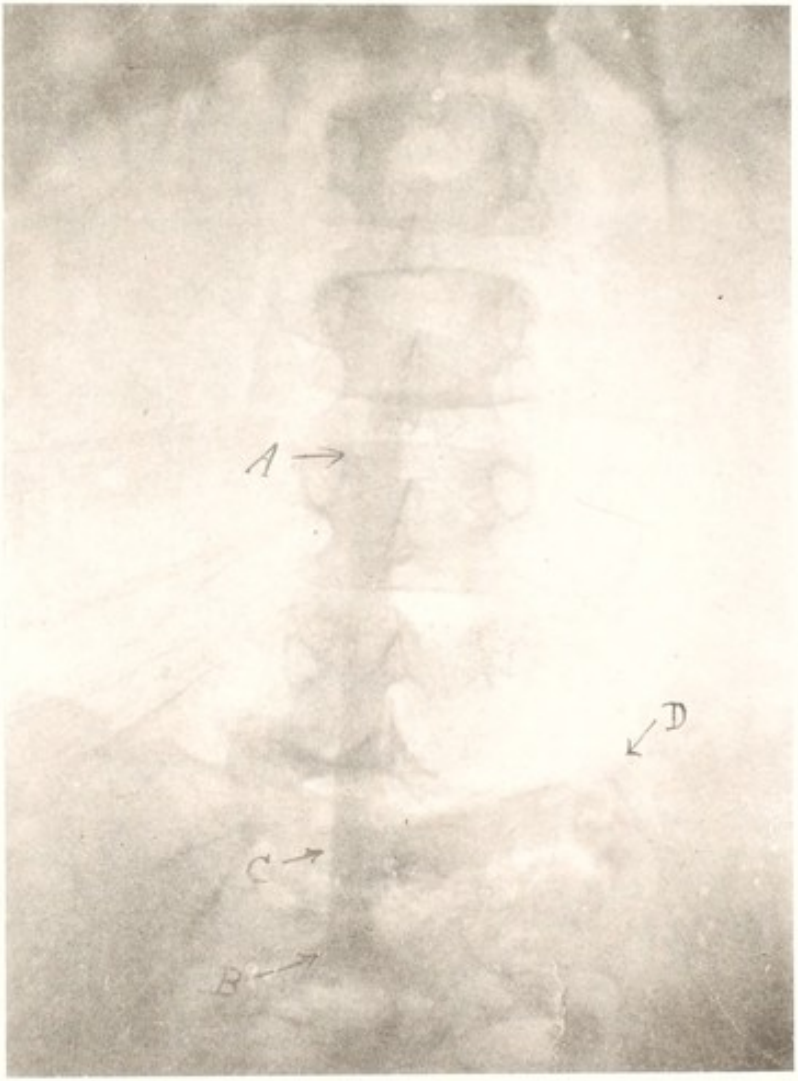


FIG. 215.—Rontgenogram of case of tuberculosis of last lumbar vertebra and sacro-iliac joint of which Fig. 216 is a drawing.

AB is spinal graft; *CD* is graft for fixation of sacroiliac joint.

iliac end of the graft and from the edges of the tibial gutter are placed about the points of junction of the graft with the sacrum and ilium.

Ligaments and soft tissues are now united over the graft by medium-sized kangaroo tendon and chromic catgut sutures, and the wound is closed with a continuous suture of No. 1 plain catgut in the usual manner.

Postoperative treatment consists of recumbency in bed for six weeks or longer.

2. **Inlay Bone-graft into the Sacro-iliac Joint Itself.**—(Indicated for Non-Infectious Relaxation of the Sacro-iliac Joint).—The joint is reached through its posterior ligaments just to the inner side of the posterior wing of the ilium.

The cartilaginous surfaces of the joint with the underlying cortical bone are thoroughly removed by the osteotome and the author's motor burr or end-mill. The dimensions of the gutter thus formed are accurately obtained by means of compasses or inside calipers. The graft is obtained from the tibia in the manner described in the preceding operation. The graft usually measures about $\frac{1}{2}$ inch in width and 2 to 3 inches in length. The graft is then driven into place by means of a mallet and the author's bone-peg set, and requires no retaining fixation sutures (Fig. 216).

Postoperative treatment consists only of recumbency in bed for five to six weeks or longer.

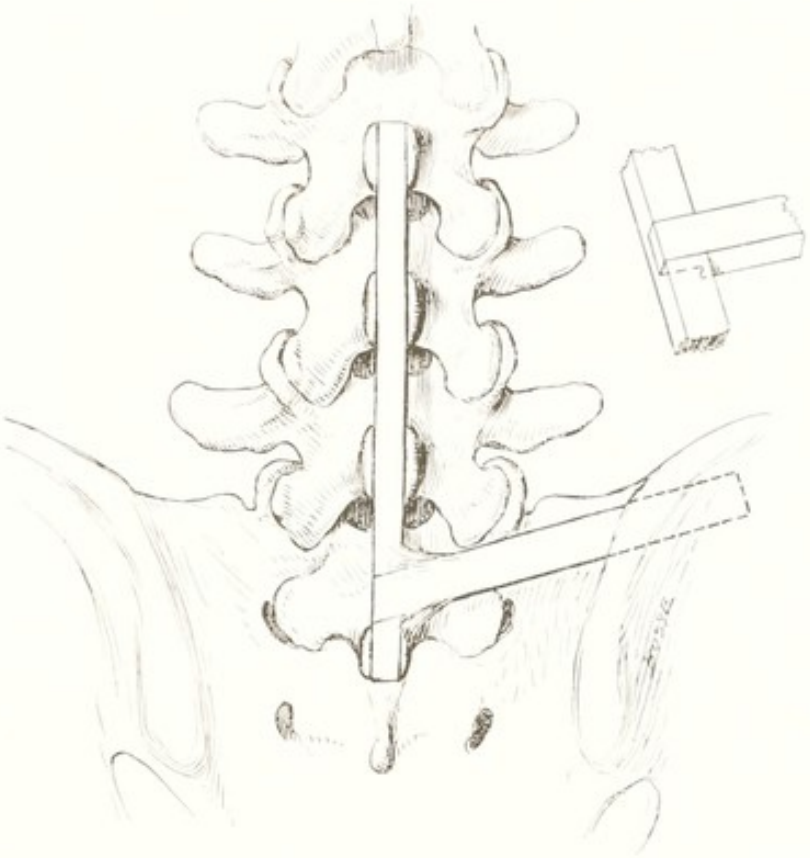


FIG. 216.—Diagram from the roentgenogram of an actual case of tuberculosis of the last lumbar vertebræ and the right sacro-iliac joint. The spinal graft was inserted by the author's regular technic for Pott's disease. The graft controlling the sacro-iliac joint was joined by a carpenter's half mortise to the spinal graft (see small upper right-hand drawing). The callus uniting the two grafts is indicated. The graft was joined to the posterior wing of the ilium by shaping it into a wedge end which was forced into a split in the ilium made by an osteotome.

3. **Inlay Bone-graft from Wing of Ilium Mortised into a Previously Inserted Spinal Inlay Bone-graft, for Combined Tuberculous Disease of Lumbar Vertebræ and Sacro-iliac Joint.**—*Author's Operative Technic.*—The posterior-superior spine, the wing of the ilium and first spinous process of the sacrum are reached by a curved incision. The spinous processes of the last one or two lumbar vertebræ are split, with their attached ligaments, by the author's thin, wide osteotome, forming a gutter to receive the ends of the graft. A cleft is made in the posterior wing of the ilium by driving a thin osteotome $\frac{1}{2}$-inch in width into it just anterior and mesial to its posterior-superior spine (Fig. 216) and in a direction laterally from within outward. The lateral graft, which is later secured, is formed with a wedge end to be

driven into this cleft, the other end being joined by a carpenter's half mortise to the spinal graft.

If practicable, a surface of the sacrum is denuded to furnish additional contact with the graft. The wound is packed with a saline compress and with the patient still in the prone position, the leg is flexed and a graft of sufficient length removed from the crest of the tibia by the motor-saw (as described in the use of the bone-graft in Pott's disease, except for the just mentioned wedge end) to furnish material for the spinal graft and the lateral bridge to the ilium. The width of the graft should be 3 times the thickness of the cortex. The thickness should include the whole cortex, periosteum, endosteum, and a small amount of the adhering marrow. The spinal graft is placed in its prepared bed and the ligaments are drawn over it by interrupted sutures of medium kangaroo tendon.

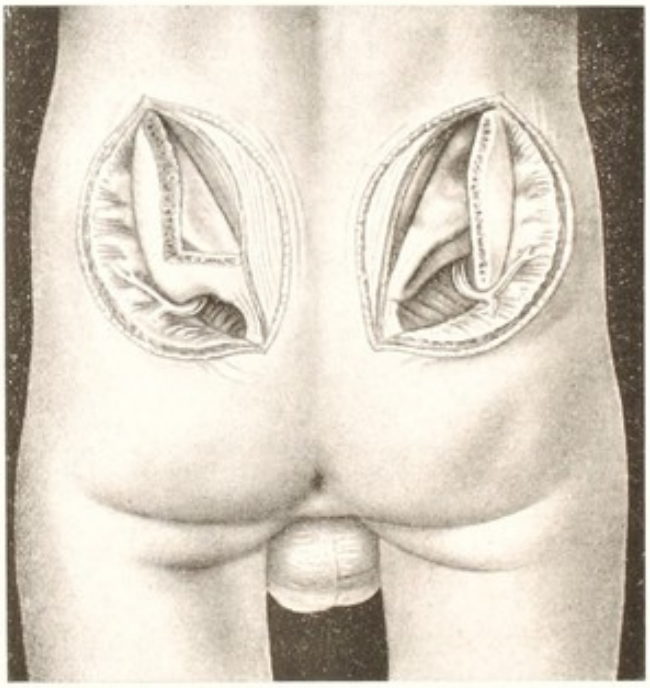


FIG. 217.—Pique's exposure of sacro-iliac joint.

A curved incision is made along the posterior third of the iliac crest and continued down the border of the sacrum to the level of the third posterior-external tubercle. After the periosteum and overlying soft parts have been reflected from the outer surface of the posterior portion of the ilium, the iliac bone is divided, with an osteotome, vertically from the crest down to the outer and upper corner of the great sciatic notch. If partial exposure only is desired, the vertical incision may be made shorter and supplemented by a transverse one, thus leaving the sciatic notch intact.

Before the kangaroo tendon sutures are drawn over the lower end of the spinal graft a segment is removed from its uppermost surface and into it one end of the lateral graft is half-mortised, and the other wedge-shaped end is driven into the cleft in the ilium prepared for its reception.

The skin wound is closed and the patient placed on the back on a fracture bed for a period of not less than five weeks. There should be no necessity for further mechanical treatment.

(If both sacro-iliac joints are affected, a lateral graft is inlaid from sacrum to ilium on each side after the manner described above for unilateral relaxation.)

III. TREATMENT OF COMPLICATIONS

1. **Local Abscess.**—In the case of an abscess pointing posteriorly, or sequestration in osteomyelitis, incise, curette and drain. If necessary, to secure thorough drainage, cut away the overhanging wing of the posterior part of the ilium (Figs. 217 and 218).

2. **Intrapelvic Abscess.**—In case an abscess points anteriorly into the pelvis it should be treated according to the rules laid down in works on surgery.

PROGNOSIS

The outlook varies with the pathological character of the sacro-iliac lesion, as follows:

(*a*) **Traumatic Relaxation.**—The prognosis is favorable. Relief should be permanent after six to twelve months of adequate treatment.

(*b*) **Tuberculosis.**—The outlook is better in children than adults. The prognosis is more grave with abscess formation, especially in mixed infection. Tuberculous sacro-iliac disease is an extremely chronic affection and this treatment prolonged.

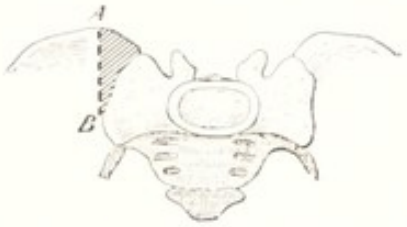


FIG. 218.—Pique's exposure of sacro-iliac joint.

This figure shows that the sacro-iliac joint is so situated that to reach it a portion of the ilium (*AB* and shaded portion) must be removed. (Binnie.)

(*c*) **Gonorrhea.**—The outlook for complete restoration of the integrity of the joint and relief of symptoms is very unfavorable, unless the infection is severe enough to produce amalgamation of the joint.

(*d*) **Pyemic** and **osteomyelitic** disease is accompanied by as unfavorable a prognosis as in the case of gonorrhea.

(*e*) **Rheumatic affections** as a rule offer a favorable prognosis.

REFERENCES

SCOLIOSIS

MECHANISM

FEISS: Amer. J. Orth. Surg., iv, 1, 37.
WULLSTEIN: Zeitsch. f. orth. Chir., x, 2.
ARNDT: Archiv f. orth. Chir., i, 1, 2.

CLINICAL FEATURES

SCHULTHESS: Zeitsch. f. orth. Chir., vi, 399–566, 1902, Ibid., x, p. 489.
REINER AND WERNDORFF: Verhandl. Deut. Gesell. f. orth. Chir., 1910, p. 232.
LÜNING AND SCHULTHESS: Orth. Chir., 1901.

PHYSICAL EXAMINATION

FITZ, J. W.: Boston M. & S. J., Nov. 16, 1905.
HOVORKA: "Ueber die Messmethoden des Rückens." Wien, 1904.

PATHOLOGY

FAUCONNET: Zeitsch. f. orth. Chir., xvii p. 201.
BACHMANN: Bib. med., Abt. 1, Heft 4, 1899.
MOSSE: Zeitsch. f. klin. Med., xli, pp. 1–4.

V. Zade: Deut. Arzte Zeit., 1902, xx.
Hacker: Wien. Med. Woch., 1887, p. 46.

Etiology

Hoffa: Lehrbuch der orth. Chir., 1894.
Hirschberger: Zeitsch. f. orth. Chir., vii, 1.
Kirmisson: Rev. d'orth., 1910, 21.
Mouchet: Rev. d'orth., 1910, No. 4.
Seibert: Zeitsch. f. orth. Chir., 1911, xxviii, 415.
Schmidt: "Allg. Path. und path. Anat d. Wirbelsaüle." Lübersch's Ergeb. zur allg. Path., 4, 1897.
Colville: Revue d'orth., 1896, 7.
Drehmann: Verhandl. d. deutsch Gesell. f. orth. Chir., 5th Congress, 1906, p. 12.
Eckstein: Zeitsch. f. orth. Chir., 1908, xx, 177.
Cramer: Verhandl. d. deutsch. Geo. f. orth. Chir., 1908, 68.
Breuss and Kolisko: "Pathologische Beckenformen."
Adams: Am. J. Orth. Surg., July, 1914.
Gould, G. M.: Amer. Med., May 21, 1904.
Wilson, H. A.: N. Y. Med. Jour., June, 1906.
Kirsch: Verhandl. d. deutsch. Gesells. f. orth. Chir., 1900, p. 94.
Böhm: Ibid., p. 49.
Cordet Boise: Rev. d'orth., 1910, 5, 381.
Stein: Zeitsch. f. orth. Chir., xxv, 1910, 479.
Binswanger: "Hysterical scoliosis." Deutsch. med. Wchnschr., Vereinsbeil., 1902, 5.
Walther: Zeitsch. f. orth. Chir., 1910, xxv, 401.

Occurrence

Härtel: Deutsch. Ztschr. f. Chir., 98, 277.
Rievel: "Knochenpathologie der Tiere." Luborschs and Ostertags Ergebnisse, xi, 1907.
Schanz: Verhandl. d. deutsch. ges. f. orth. Chir., 1910, p. 454.
Grönberg: Ztsch. f. orth. Chir., xviii, 130.
Haglund: Ibid., xxv, 649.
Lubinus: Verhandl. d. deutsch. Geo. f. orth. Chir., 1910, 469.

Influence of School Conditions

Kronecker: "Ueber die Ermüdung und Erholung der gest. Muskeln." Leipzig, 1871.
Warner: "The Nervous System of the Child." London, 1900.
Scudder: "Determination of the Muscular Strength in Growing Giris." Boston, M. & S. J., Nov. 6, 1890.
Fahrner: "Das Kind und die Schultisch." 1865.
Myer: "Die Mech. des Sitzens." Virch. Arch. f. path. Anat., xxxv, 1867.
Cohn: "Beitr. zur Losung der Subsellenfrage." Berlin, 1885.
Lorenz: "Ueber die Skolios." Wien.
Schulthess: Zeitschr. f. orth. Chir., 1892, i, 1.
Scholder: Archiv f. Orth., i, 2.
Boston Schoolhouse Commission Reports for 1901–05.
Feiss: Cleveland Med. J., August, 1905.
Gould, G. M.: Amer. Med., ix, 14, 562, 1905.
Smith: "Lateral Curvature of the Spine and Flat-foot." N. Y., 1911, p. 28.
Combe, Scholder, and Weith: "Jahrb. d. Schu. Gesel. f. Schul-Gesundheits pflege." ii, Jahrg., 1901, i, Teil, 38.
Spitzy: Verhandl. d. deutsch. Gesell f. orth. Chir., 1910, p. 462.
Hippius: "Der Kinderarztals Erzieher." Berk, München.
Kirsch: Verhandl. d. deutsch. Ges. f. orth. Chir., 1910, 94.

Treatment

Lovett, R. W.: "Lateral Curvature of the Spine and Round Shoulders." Phila., P. Blakiston's Son & Co., 1916.
Teschner: N. Y. Med. Rec., Dec. 6, 1903.
Erich: N. Y. Med. J., Oct. 7, 1899.

Schulthess: Joachimsthal's Handb. d. orth. Chir., Bd. iii, iv, v, pl. 35.
Lange and Spitzy: Handb. f. Khde., Leipzig, 1910, Bd. v, p. 140.
Schanz: Zeitsch. f. orth. Chir., 1908, Bd. xxii, p. 57.
Wullstein: Ibid., 1902, Bd. x, Teil ii.
Sever: Surg., Gyn. & Obst., September, 1912.
Lovett, R. W.: Boston M. & S. J., Oct. 31, 1901 and Mar. 17, 1904, Jour. Am. M. Ass'n, June 23, 1906.
Lovett, R. W. and Sever, J. W.: Jour. Am. M. Ass'n, Sept. 2, 1911.
Chlumsky: Verhandl. d. deut. Gesel f. orth. Chir., 1908, 317.
Bade: Zeitsch. f. orth. Chir., xii, 4, 799.

FORCIBLE CORRECTION BY PLASTER JACKETS

Calôt: France Med., 1896, 52; 12th Int. Med. Congress, Moscow, 1897.
Schanz: Münch. med. Woch., 1900, Bd. xlvi.
Lovett, R. W.: Trans. Am. Orth. Ass'n, 1901, vol. xiv; Boston M. & S. J., Oct. 31, 1901.
Wullstein: Zeitsch. f. orth. Chir., 1902, Bd. x.
Forbes: N. Y. Med. Jour., July 6, 1912.
Rich: Jour. Am. M. Ass'n, Dec. 30, 1911.
Hüssey: Zeitsch. f. orth. Chir., viii, 2, 235.
Forbes: Surg., Gyn. & Obst., April, 1914.
"Report of Scoliosis Committee of American Orthopedic Association." Am. Jour. Orth. Surg., July, 1915.
Abbott, E. G.: "Simple, Rapid and Complete Reduction of Deformity in Fixed Lateral Curvature of the Spine." N. Y. Med. Jour., June 24, 1911.
Abbott, E. G.: "Forcible Correction of Lateral Curvature of the Spine, a Simple and Rapid Method of Obtaining Complete Correction." N. Y. Med. Jour., Apr. 27, 1912.
Lance: "Le Traitement des Scoliosis graves par la methode d'Abbot." Paris, 1914.
Kleinberg: Amer. Jour. Orth. Surg., June, 1914.
Cook: Ibid., July, 1913.
Lange, F.: Zentralbl. f. Chir. u. mech. Orth., Bd. v, Hft. 12.

OPERATIVE CORRECTION

Albee, F. H.: "Bone-graft Surgery." Phila., W. B. Saunders Co., 1915, pp. 126–134.
Volkmann: Beil. klin. Wochens., 1889, 50.
Casse: Bull de l'Acad. Royal de Med. de Belgique, Dec. 30, 1893; Jan. 27, 1894.
Hoffa: Zeitschr. f. orth. Chir., 1896, 401.
Shaffer: Amer. Surg. Bulletin, Jan. 1, 1894.
Hoke: Amer. J. Orth. Surg., 1, 2.
Jaboulay: Prog. Med., November, 1893.
Bade: Klin. Mittheil in Centralbl. f. Chir., 1903, 38, 1045.

AFFECTIONS OF THE SACRO-ILIAC JOINT

Andrews, C. R.: "Sacro-iliac Disease." Charlotte (N. C.) M. J., 1908, lviii, 309–313.
Andrews, C. R., and Hoke, M.: "Sacro-iliac Disease." Atlanta Jour. Rec. Med., 1908–09, x, 241–250.
Streda, A.: "Zur Symptomatologie der Tuberculose des Iliosacralgelenks." Berlin, klin. Wochenschr., 1909, xlvi, 242–244.
Genne: "Abcés froid dû à un sacro-coxalgie par traité par la méthode Calôt." Bull. et mém. Soc. de Méd. de Vaucluse, Avignon, 1909, v, 173–175.
Picque, R.: "Sacro-coxalgie guérie par la résection sacro-iliaque." Bull. et mém. Soc. de Chir. de Paris, 1909, N. S. xxxv, 915.
Delbert: "Sacro-coxalgie." Méd. mod., Paris, 1910, xxi, 250.
Bigardus, F. B.: "Tuberculosis of the Os Sacrum Treated by Bismuth Paste." Jour Am. Med. Ass'n, Chicago, 1910, liv, 701.
Picque, R.: "Le traitement de la sacro-coxalgie par la résection sacro-iliaque." Jour. de chir., Paris, 1910, v, 237–252.
Goldschwind, F.: "Ein Beiträg. an der Unfallpraxis (Tuberkulose der Iliosakralgelenkes)." Monatsschr. f. Unfallkrankh., Leipzig, 1911, xviii, 15–20.
Parechet, V.: "Sacro-coxalgie, son traitement." Clinique, Paris, 1911, vi, 30.
Haar, F.: "Beiträg. zur chirurgischen Behandlung der sacro-iliosacralen Tuberkulose." Heidelberg, 1912, J. Hornung.
Goldthwait, J. E., and Osgood, R. B.: Boston M. & S. J., May, 1905.
Goldthwait, J. E.: "The Pelvic Articulations." Jour. Am. M. Ass'n, xlix, p. 708, Aug. 31, 1907.
Goldthwait, J. E.: "The Lumbosacral Articulation. An Explanation of Many Cases of Lumbago, 'Sciatica' and Paraplegia." Boston M. & S. Jour., Mar. 10, 1911.

ALBEE, F. H.: "A Study of the Anatomy and the Clinical Importance of the Sacro-iliac Joint." Jour. Am. M. Ass'n, Oct. 16, 1909.
CHAPMAN, J. P.: "Lesions of the Sacro-iliac Joint." South. M. J., Nashville, 1914, vii, 550–553.
CONE, S. M.: "Osteomyelitis at the Sacro-iliac Joint with Gas-bacillus Infection." Am. J. Orth. Sur., Phila., 1914, xi, 389–397.
MCCLURE, C. R.: "Sacro-iliac Traumatisms." Northwest. Med., Seattle, 1914, N. S. vi, 155–159.
ROBERTS, J. B.: "Sacro-iliac Subluxation." Tr. Phila. Acad. Surg., 1914, xvi, 32–34.
ROCHER AND BOISSERIE-LACROIX: "Disjonction de l'articulation sacro-iliaque." J. de med. de Bordeaux, 1913, xliii 843.
YOUNG, J. K.: "Sacro-iliac Displacement." Inter. State M. J., St. Louis, 1914, xxi, 849–856.
CORLEY, K. C.: "Sacro-iliac Strain." Am. J. Obst., N. Y., 1915, lxxi, 595, 601.
OPPENHEIMER, L. S.: "The Sacro-iliac Articulation." Internat. J. Surg., N. Y., 1915, xxviii, 258–261.
PECKHAM, F. E.: "A Further Consideration of Sacro-iliac Conditions." J. Advanc. Therap., N. Y. 1915, xxxiii, 237–247.
ROTH, P. B.: "Relaxation of the Sacro-iliac Joint." Proc. Roy. Soc. Med., Lond., 1913–14, vii, Surg. Sect., 54–58.
DEADERICK, W. H.: "Sacro-iliac Arthritis." Lancet-clinic, Cin., 1916, cxv, 434.
YOUNG, J. K.: "Acute Septic Arthritis of the Sacro-iliac Joint." Urol. & Cutan. Rev., St. Louis, 1916, xx, 493.
HAYDEN, J. G.: "Sacro-iliac Strains and Luxations." J. Missouri M. Ass'n, St. Louis, 1916, xiii, 531–534.
CHARLES, ETTA: "Sacro-iliac Disease." J. Indiana M. Ass'n, Fort Wayne, 1912, v, 259–263.
EVANS, E.: "Sacro-iliac Disability, Two Cases." St. Paul M. J., St. Paul, Minn., 1912, xiv, 265.
HATCH, E. S.: "Strains and Dislocations of the Sacro-iliac Joints. South. M. J. Nashville, 1912, v, 153–157.
LONGO, N.: "Sulla tecnica della resezione sacro-iliaca nella sacro-coxalgia." Gior. internaz. d. sc. med., Napoli, 1912, N. S. xxxiv, 830–845.
MALLY: "Relâchement de l'articulation sacro-iliaque; diastasis sacro-iliaque." Centre méd. et pharm. Gannat., 1911, 1912, xvii, 131–133.
PAYNE, R. L.: "Injuries of the Sacro-iliac Joint." Virginia M. Semi-month., Richmond, 1912–13, xvii, 120–124.
PAYNE, R. L.: "The Sacro-iliac Joint and its Injuries; Some Recent Teachings Contravened." Am. J. Surg., N. Y., 1912, xxvi, 400–403.
WHEELER, W. I. DE C.: "Notes on a Case of Early Operation in Sacro-iliac Disease." Tr. Roy. Acad. M., Ireland, Dubl., 1911, xxix, 219–228.
WHEELER, W. I. DE C.: "Surgery of the Sacro-iliac Joint." Brit. M. J., Lond., 1912, ii, 877, 880.
WHEELER, W. I. DE C.: "The Early Diagnosis and Treatment of Sacro-iliac Disease." Med. Press and Circ., London, 1911, xci, 673–677.
WILCOX, H. W.: "The Sacro-iliac Joint." Colorado Med., Denver, 1912, lx, 262–265.
YOUNG, J. K.: "Sacro-iliac Displacement." Am. J. M. Sc., Phila. & N. Y., 1912, cxliv, 94–103.
BRAQUEHAYE J, ADDA, M., AND BRUCH A.: "Disjonction traumatique de la symphyse sacro-iliaque droite chez une fillette de vingt et un mois; guérison." Arch. de med. d. en Par., 1913, xvi, 369–372.
GALLANT, A. E.: "The Therapeutics of Sacro-iliac Relaxation after Operation, Labor, etc." Month cycl. & M. Bull., Phila., 1913, vi, 70–77; Tr. Am. Therap. Soc., Phila., 1913, xiii, 134–141.
GOLDTHWAIT, J.: "An Anatomic Explanation of many of the Cases of Weak or Painful Backs, as well as of Many of the Leg Paralyses." Boston M. & S. J., 1913, clxviii, 128–131.
HAAS, F.: "Beiträg zur chirurgischen Behandlung der sacro-iliocäcalen Tuberkulose." Heidelb., 1912, J. Hörning, 31, p. 8.
MEISEN, V.: "(A Few Cases of Acute Inflammation in Articulatio Sacro-iliaca)." Bibl. f. Laeger, Kbenh., 1913, 207–219.
ZACHARIE, C. C.: "A Case of Sprain of the Sacro-iliac Synchondrosis." Am. J. Surg., N. Y., 1913, xxvii, 391.
ZACHARIE, C. C.: "A Loose Sacro-iliac Synchondrosis and its Treatment." N. Y. Sta. J. M., N. Y., 1913, xiii, 546.

CHAPTER XIV

MISCELLANEOUS AFFECTIONS OF THE HIP-JOINT

As an indication of the relative frequency and importance of the various lesions of the hip-joint, Koenig's statistics from the Göttingen clinic are instructive (ref. Das Hüftgelenk, Berlin, 1902):

Tuberculous disease	568	= 75 per cent.
Infectious arthritis following typhoid fever, scarlatina, and the like	110	
Gonorrheal arthritis	30	
Arthritis deformans	22	
Injuries	11	= 25 per cent.
Contractions, cause unknown	6	
Coxa vara	5	
Tumors	2	
Pyemic suppuration	3	
	757	

In the present discussion, these affections of the hip-joint will be arranged for convenience of description as follows:

I. Traumatisms.
II. Dislocations and fractures.
III. Inflammatory and infectious processes.
IV. Neuropathies.
V. Neoplasms.
VI. Deformities.
VII. Extra-articular disease.

I. TRAUMATISMS

As the result of falls, direct blows, strains, or other forms of trauma applied to the hip-joint, a hyperemia may be produced about the epiphyseal cartilage at the head of the femur. Attendant symptoms are limp, limitation of motion, and dull aching in the joint, with slight swelling and localized tenderness if the traumatism was severe. These local signs may disappear in a short time or recur at intervals. In a certain percentage of cases, nutritive disturbances in the joint, with protracted pain and restricted motion, may result from the injury to the cartilage and underlying bone. In other cases, the impairment of local resistance offers ideal conditions for the development of an infective or tuberculous focus.

Treatment.—Mild cases respond quickly to rest in bed with local applications of heat or cold, supplemented in more severe cases by a bandage. If sensitiveness is marked or persistent, a hip-splint or a short plaster-of-Paris spica may be required. An *x*-ray investigation should be made as a routine procedure in every case, to avoid the danger of overlooking an incipient tuberculous process, fracture, fracture-dislocation, and dislocation.

II. DISLOCATIONS AND FRACTURE

Fracture of the neck of the femur, its treatment and repair, by the author's bone-graft peg, will be found discussed in Chapter XVIII, page 599. Dis-

locations of the hip, apart from the congenital type (Chapter XXIV.) comprise (1) *paralytic dislocation*, (2) *congenital subluxation*, (3) *snapping hip*, (4) *spontaneous dislocation*.

1. **Paralytic Dislocation.**—The dislocation may be partial or complete. In the former instance, the head of the femur slips in and out of its socket, constituting one form of "snapping hip." The underlying causes are muscular weakness and relaxation of the capsule of the joint. The position of the dislocated head is determined by contracture of these unopposed muscles and the superimposed body-weight, while marked lordosis eventually occurs in untreated cases.

There are two types of paralytic luxation of the hip: The *iliac luxation*, from paralysis of the abductors and external rotators; and the *pubic luxation*, from paralysis of the adductors and internal rotators. Dislocations of this nature are not infrequent, and are usually diagnosed by associated contractures, adduction in the case of posterior luxation, and abduction of the thigh with flexion in the pubic luxations. The iliac dislocation is believed to be the one more frequently met with. The pubic displacement is difficult to confirm by *x*-ray because of the obscurity rendered by the neighboring bony parts; whereas the iliac luxation is readily revealed by the röntgenogram. Clinical examination is rendered somewhat difficult by the atrophy of the muscles and altered direction and shape of the femoral neck, as well as by the presence of contractures.

These luxations may be due to muscle contraction or extreme paralysis of hip muscles and a stretching of the unsupported capsule in patients unable to walk, but they also occur from static causes, even where paralysis is slight and there is an otherwise perfectly useful limb. Among the important physical signs indicating luxation are adduction and abduction contractures, with or without flexion of the thigh. An iliac luxation lordosis is to be looked for, and if the luxation is unilateral a tilting of the pelvis out of proportion to the atrophy and shortening of the leg, due directly to the paralysis, is appreciable.

Treatment.—The use of external appliances in treating these cases beyond the immediate correction of deformity is unsatisfactory, and in order to control the redislocating paralytic hips the author has applied the autogenous bone wedge to deepen the overhanging rim of the acetabulum, which, in conjunction with reefing the ballooned portion of the joint capsule, furnishes a stable and satisfactory hip-joint without sacrificing any of the joint elements.

The indications for an open operation in paralytic dislocations of the hip are the inability to replace the head of the femur, owing to contracture of the soft parts; faulty development of joint structures; or such relaxation as to permit of redislocation after repeated reductions.

Contracted structures are thoroughly stretched and the dislocation reduced, if possible, by the closed method. Failing in this, or succeeding only to have a redisplacement occur subsequently, the open method devised by the author can be resorted to when it is found that the redisplacement is due to a relaxed capsule and a shallow acetabulum, as is usually the case. The difficulty in paralytic dislocations of the hip is not the reduction of the dislocation but the retention of the hip in position after the reduction. The wearing away or flattening of the rim of the acetabulum results from the head slipping in and out repeatedly. In some cases this occurs with every step the child takes.

(The technic of the author's operation for remodelling the hip-joint by an

autogenous bone-graft wedge is completely described in Chapter XXIV, on Congenital Dislocation of the Hip.)

2. **Congenital Subluxation.**—This is a very mild grade of the ordinary complete congenital luxation. Its characteristic clinical features are slight limp and slight shortening of the affected limb. *X*-ray examination shows the acetabulum to be apparently normal but situated somewhat above the plane of the opposite side. The femoral head undergoes partial dislocation upward and forward at each step. These cases are most satisfactorily treated by abduction of the limb and retention of this position by a long plaster-of-Paris spica for a period of months. If this treatment does not succeed after one or more attempts, operative interference should be undertaken and the author's bone-graft wedge inserted and the capsule reefed, as described in the Chapter on Congenital Dislocation of the Hip.

3. **Snapping Hip.**—(*a*) *Intra-articular Type.*—In children, this term is applied to slight displacement of the head of the femur over the superior or upper border of the acetabulum when the thighs are sharply flexed and adducted. (This intra-articular type is much less common than the extra-articular type.) Ease of displacement is increased by habit, and is best prevented by a bandage about the hip to prevent flexion.

(*b*) *Extra-articular Type.*—Both in adults and children it is encountered in cases of arthritis or of effusion into the bursa between the gluteus maximus and the femur; or, again, it is due to friction between the anterior margin of the gluteus maximus and the trochanter, or between some other tendon or fascial band and some bony prominence. The *x*-ray should always be employed to exclude such conditions as osteoma or osteochondritis. With the leg flexed at the knee, internal rotation causes a tendency for the attachment of the gluteus maximus to spring backward on the trochanter. These cases are rarely of any clinical importance, and usually require no treatment. Where the affection is especially annoying or is produced by an osteoma, the latter should be chiselled away and a free or pedicled fascial fat graft interposed between its site and the "snapping" tendon or muscle.

4. **Spontaneous Dislocation.**—Effusion into the hip-joint causes capsular distention and, when the limb is in a position of adduction, promotes spontaneous dislocation, with or without rupture of the capsule. This untoward event occasionally complicates the acute infectious processes, particularly typhoid fever, but is also encountered in the course of acute articular rheumatism, scarlet fever, small-pox, gonorrheal arthritis, influenza, and erysipelas. More common still is the spontaneous dislocation following acute epiphysitis of the hip in infants (see following pages).

Distention of the joint, together with the debility commonly encountered in these infectious conditions, permits flexion and adduction or extreme rotation to occur and thus facilitates spontaneous dislocation of the hip.

Treatment.—The slightest indication of inflammation of the hip-joint in the course of an infectious disease calls for abduction and slight internal rotation of the limb in the extended position, with the evacuation of fluid if it be present in large amount. Reduction should be performed as early as possible. If the period of dislocation has been long, preliminary traction may be indicated, to be followed by the usual methods of reduction prescribed for the treatment of congenital dislocation (see Chapter XXIV, on Congenital Dislocation of the Hip).

III. INFLAMMATORY AND INFECTIOUS PROCESSES

Inflammatory processes, both infectious and non-infectious, affecting the hip-joint, are as follows:

1. Arthritis:
   (*a*) Acute osteomyelitis.
   (*b*) Subacute arthritis.
   (*c*) Gonorrheal arthritis.
   (*d*) Arthritis deformans.
2. Chronic synovitis.
3. Osteochondritis deformans juvenilis.

I. Arthritis

(*a*) **Acute Osteomyelitis** (Acute Epiphysitis).—This is not an uncommon event in infants, in whom it is manifested as an acute epiphysitis. Separation



Fig. 219.—Old suppurative arthritis of the left hip with destruction of the femoral head and neck.

of the epiphysis of the femoral head may follow, with disintegration of that structure and dislocation (Figs. 219 and 220). A contributing cause is usually trauma, with or without metastatic infection from a pyogenic focus elsewhere, or as a sequel to pneumonia or one of the exanthemata. The symptoms are fulminating, sudden onset with hyperpyrexia and prostration. The hip-joint is tender on movement and to pressure, swollen, and its surface temperature may be elevated. Syphilis with secondary infection is also a cause of this condition.

Treatment.—Prompt incision is imperative for evacuation of the pus and for drainage. This should be followed by immobilization on the Bradford

frame or fracture mattress with weight extension. Neglected cases are followed by fistulæ and sinus formation, destruction of the epiphysis, and the production of a loose, flail-like pseudo-arthrosis, the "pseudo-arthrose flottante" of the French.

This condition is frequently difficult of differentiation from congenital dislocation of the hip by means of physical examination alone; the *x*-ray is final in such cases.

Remodelling the Hip-joint.—If the pathological dislocation is loose and it is possible to pull the femur down, or if the case has been followed from the beginning and the length of the limb has been maintained, the riding up of the trochanter on the side of the pelvis has been prevented by the author in several instances by approaching the hip through the Smith-Peterson incision and turning down over the top of the trochanter a large area of the outer table of the ilium just above the location of the acetabulum, and fixing it



FIG. 220.—Suppurative arthritis of 4½ years' duration. Total destruction of head and neck of right femur. Femoral shaft dislocated onto dorsum ilii with 3½ inches of shortening.

there by means of brace-grafts, also obtained from the outer table of the wing of the ilium, as shown in Figs. 221 and 222.

Grafting of the Astragalus to Secure an Absent Head and Neck of the Femur.—In cases of loss of bone substance of the upper end of the femur, as in instances of destruction of the head and neck following septic arthritis or of deformity of the head following injury, it has been found that the astragalus furnishes an excellent substitute for such deficiency or deformity. This operation was first suggested by Roberts, who reported five cases that underwent such treatment.

In one instance, the author modified Roberts' procedure and grafted the astragalus to the upper end of the femur of a child four and a half years old, where the head and neck of the femur had been destroyed by septic arthritis eight months before the operation.

The hip-joint is exposed through an anterolateral incision extending from a point just internal to and below the anterior-superior spine of the ilium to just below the great trochanter, and then curved backward toward the tuber ischii for 1 to 2 inches. The skin and subcutaneous structures are dissected

up, exposing the great trochanter, the tip of which with its muscle attachments is cut through with the motor saw or a sharp osteotome and mallet and lifted up, exposing the joint capsule. The latter is split longitudinally and the interior of the joint is examined to determine the condition of the acetabular cavity and of the remaining portion of the neck of the femur. The remnant of the femoral neck is trimmed up with a sharp osteotome, preparatory to fitting the adapted portion of the astragalus which has been obtained for the graft and shaped to fill the space resulting from the absent femoral head.



FIG. 221.

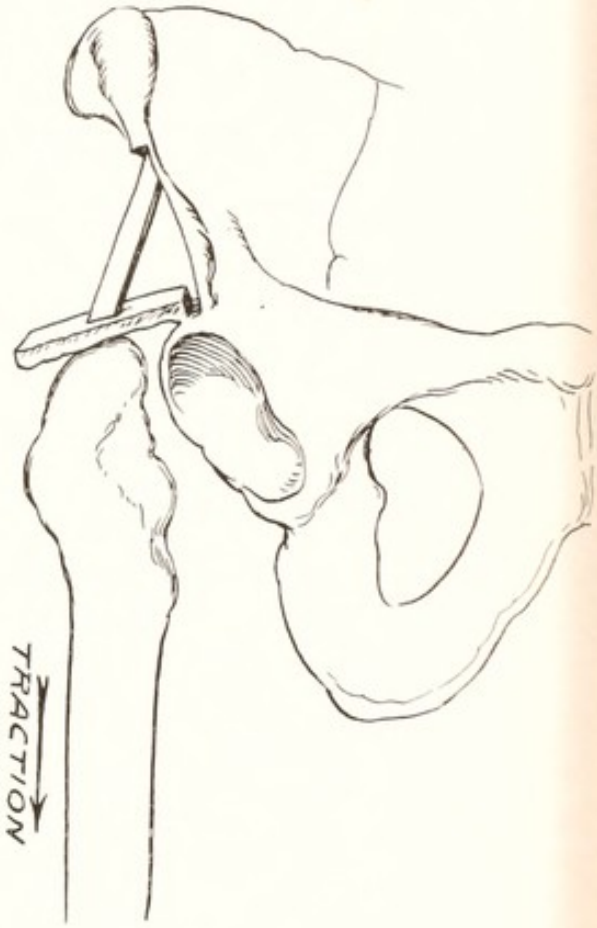


FIG. 222.

FIG. 221.—Drawing to illustrate displacement upward of upper end of femur following an old suppurative arthritis of the hip with loss of the head and neck. Dotted lines indicate shelf of bone which is turned down over tip of trochanter after the femur has been drawn down. Smith-Peterson approach to hip.

FIG. 222.—Shelf of bone turned downward over the tip of the great trochanter and held by bone-graft braces obtained from side of the ilium or the tibia. (Author's technic.)

The astragalus is secured in position, having been fitted accurately so that its head rests in the acetabulum tightly, its body end cut with the motor-saw to contact well with the freshened stump of the neck of the femur and at a proper angle in its relation to the shaft.

The large motor drill is now driven from without inward through the great trochanter, remnant of the femoral neck, and well into the new astragalus graft head, and the drill, being disengaged from the motor, is left in position while the live-bone dowel is being prepared from a segment of cortical bone removed from the crest of the tibia along its middle and lower thirds. This segment of the tibia is passed through the author's motor lathe, which turns out a dowel to fit exactly the hole drilled through the

trochanter into the grafted astragalus. When the dowel is prepared, the drill is withdrawn from its position in the trochanter and astragalus graft and the dowel pin is driven into position, thus securely fixing the astragalus graft to the upper end of the femur.

The author believes that the substitution of the live-bone spike in place of the metal screw is very essential to the uniform success of this procedure. A large portion of the astragalus graft being in the acetabular cavity, it is at best in a poor environment for the establishment of a nourishing blood supply, which must largely come through its contacted end. The metal screw not only diminishes the diameter of this contacting surface but, as is well known, produces bone absorption and destruction; while in the case of the bone-graft, not only is efficacious mechanical fixation furnished but also a stimulative influence to the callus formation of the contacting bone surfaces is supplied, and an osteogenetic force is provided, at the same time that it serves as an osteoconductive scaffold well into the astragalus graft. This feature is well illustrated also in the author's method of treating fracture of the neck of the femur by bone-graft spike, either in old ununited fractures or in fresh unimpacted fractures with malposition of the fragments, requiring an operation for reduction and fixation.

The capsule, if distinguishable, is closed with small kangaroo-tendon sutures; the tip of the great trochanter is replaced and held by strong kangaroo sutures; the soft parts are closed in, and the skin wound is closed by a continuous catgut suture, without drainage.

The leg being held in a position of slight abduction and flexion and dressings applied, a long plaster-of-Paris spica is made, reaching from the toes to the axilla. This remains on for six to eight weeks, after which time a short spica is substituted and worn for four to six weeks longer.

(*b*) **Subacute Arthritis.**—A subacute polyarthritis frequently complicates the infectious diseases. To such an involvement of the hip, the misnomer "rheumatism" is frequently applied. The clinical features of subacute arthritis of the hip-joint are infiltration of the peri-articular tissues, flexion deformity, restricted motion, and local pain or discomfort.

Fixation of the joint by a short plaster-of-Paris spica or by traction in bed or on a Bradford frame is indicated.

Aside from the infectious processes, toxemia from intestinal putrefaction sometimes excites a subacute arthritis of the hip which in some cases may be favorably affected by thorough evacuation of the bowels, a proteid-free diet, and antitoxic treatment of the large intestine. The thymol treatment successfully employed by W. L. Thompson (Boston Med. and Surg. Jour., Nov. 26, 1914, vol. clxxi, p. 819) in the treatment of other manifestations of intestinal toxemia, may be found of value in this connection.

(*c*) **Gonorrheal Arthritis.**—Gonorrheal infection invades the hip with far less frequency than the knee-joint, although it is not uncommon in adults. Clinically, gonorrheal arthritis bears some resemblance to tuberculous coxitis or to arthritis deformans of the hypertrophic type. The treatment of gonorrheal arthritis is described elsewhere in this book (see Chapter X, page 304). Immobilization with weight traction and protection of the hip are special measures indicated in the case of the hip-joint; this is best obtained by a short plaster-of-Paris spica. Vaccines are of debatable value. Their use is discussed in the chapter on Focal Infection (see Chapter IX).

(*d*) **Arthritis Deformans, Osteo-arthritis** (Degenerative).—Osteo-arthritis is quite commonly a monarticular affection, limited to the hip-joint. In this monarticular form, the affection is practically confined to adults. The much used synonym "malum coxæ senilis" is really a misnomer, inasmuch as a

large percentage of cases begin in middle life or earlier. Males are much more frequently affected than females.

Pathology.—The affection is characterized by destruction and absorption of the articular cartilage of the femoral head, which becomes eburnated, polished, and worm-eaten in appearance, due to disintegration of the underlying bone with the formation of chondrophytes, which later become converted into osteophytes, with marked lipping of the acetabular margins. These osteophytes may eventually fill and obliterate the acetabular cavity and permit the head of the femur to become dislocated (Fig. 223). This lesion is never suppurative, but is a degenerative process. There is never any indication of satisfactory self-repair, and fixation and immobilization



FIG. 223.—Advanced arthritis deformans (osteo-arthritis) of the hip in which the acetabulum has become filled with new bone and the head of the femur dislocated. (From specimen in the College of Physicians and Surgeons.)

for years would be of no avail in advanced cases. The femoral head becomes markedly flattened (Fig. 224) or cylindrical-shaped at its upper aspect, and the motions of the joint become altered from a ball-and-socket action to that of a hinge or cylindrical-shaped joint. This change of shape of the femoral head from that of a sphere to that of a cylinder, practically limits motion to flexion and extension; rotation, abduction, and adduction become limited in varying degrees up to almost complete absence. This limitation of motion is due to a change of conformation of the joint and not so much to muscle spasm, although in the more acute cases muscle spasm may also be a factor in causing limitation of motion. This condition of osteo-arthritis often becomes engrafted upon an old healed arthritis (tuberculous, infectious, etc.).

The *etiology*, more minute pathology, clinical course, etc., of the affection

are discussed in the chapter on Arthritis Deformans (see page 320). A large percentage of these cases of arthritis deformans follows trauma.

Symptoms.—The clinical manifestations are usually subacute, and consist of neuralgic pains simulating sciatica, most acute during locomotion, and stiffness on resuming movements of the joint after a period of rest. The onset of the symptoms is very insidious, as has been implied. Stiffness in the joint is followed by a slight amount of pain which gradually increases but is experienced on locomotion only. The pain is more likely to be referred to the knee than elsewhere. It may simulate sciatica in other cases, or be referred down the anterior surface of the thigh to the knee. Pain in the knee may be of such severity that many cases are treated for long periods as

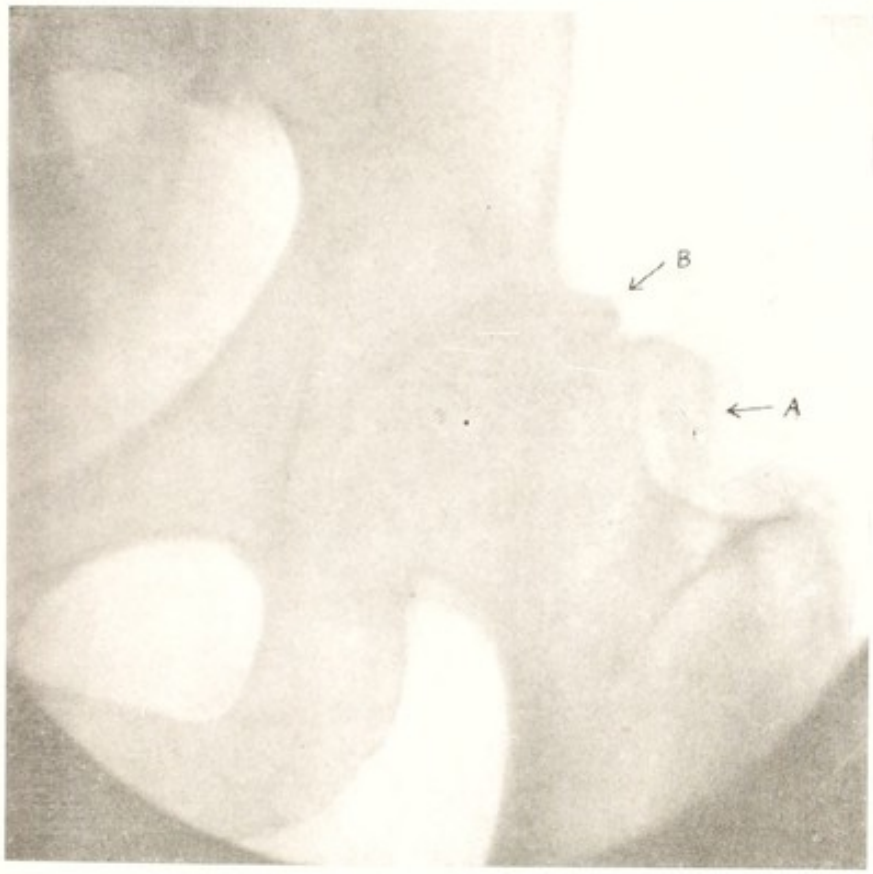


FIG. 224.—Case of advanced osteo-arthritis with flattening of the femoral head and osteophytes at *AB*.

affections of the knee-joint. In other cases, the pain may be referred backward to the sciatic region.

Limitation of motion progressively increases, and movement is often accompanied by creaking or grating within the joint which is perceptible to the patient. Late in the disease, thickening about the trochanter occurs and the latter is usually displaced upward, owing to the intrinsic alteration of the joint. Aside from the shortening, distortion of the affected limb always takes place in flexion and adduction, with eversion of the feet (Fig. 225) and is almost invariably accompanied by muscular atrophy. In the majority of cases the flexion is possible only obliquely outward, the degree of rotation and obliquity of flexion being in accordance with the axis of the newly shaped cylindrical head. The limp, pain, and restricted movement in the earlier stages, together with the later manifestation of *muscular atrophy* may cause confusion of this condition with tuberculous coxitis of subacute

type. The clinical course varies with the strain and the amount of irritation from use put upon the affected joint, the greater the strain and irritation from function the more rapid is the progress of the joint lesion. As has been stated, the motions of the hip are associated with little or no muscle spasm except when joint symptoms become acute.



FIG. 225.—Untreated case of osteo-arthritis of left hip-joint. Patient refused treatment. The hip is dislocated. Note the shortening (overcome to a certain extent by building up the shoe), and the flexion deformity of the hip with compensatory lordosis.

Differential Diagnosis.—Careful scrutiny of the history, proper interpretation of the symptoms, and physical signs, together with the *x*-ray picture, should make differentiation from tuberculous coxitis comparatively easy. The symptom-complex of this condition is so sharply differentiated from all other arthritides of the hip that an absolute diagnosis is not difficult.

X-ray appearances of osteo-arthritis differ greatly from the pictures of tuberculous or other types of arthritis. Contrasted with the rarefaction and disintegration of tuberculous arthritis, this condition shows marked increase of the density of the elements of the joint from eburnation and the accumulation of osteophytes around the superior, and usually also the inferior, margin of the joint, associated with varying degrees of flattening of the head.

Summary of Clinical Features.—Briefly, the clinical manifestations of osteo-arthritis (arthritis deformans) of the hip are:

(*a*) Insidious onset.

(*b*) Symptoms manifested only during locomotion.

(*c*) Motions of the hip change from those of a ball-and-socket joint to those of a hinge-joint.

(*d*) The axis on movement of this hinge-joint in flexion is always obliquely outward, and varies in its obliquity to the anteroposterior plane of the pelvis in different cases.

(*e*) Muscle spasm, on passive motion, may be entirely absent.

(*f*) Marked contrast of the *x*-ray appearance to other conditions which simulate it clinically.

(*g*) The frequency of trauma as an etiological factor.

Prognosis.—As to recovery with a functional joint, the prognosis is unfavorable. Cases that become advanced do not tend toward recovery. Maltreated cases develop severe flexion-adduction deformity, with increasing obstructive ankylosis from the deposit of bone within the joint and around its margins, but unfortunately actual bony ankylosis never occurs. The hip, therefore, is always subject to joint-strain and pain of varying intensity. As to prognosis after operation, bony fixation by the author's arthrodesis operation relieves the patient from all pain and gives him a limb in favorable relationship to the pelvis (15 degrees flexion, 5–10 degrees abduction) and furnishes a very satisfactory limb, even in the case of the laboring man. Arthroplasty offers a chance for mobility, but the dangers of associated pain and

the long convalescence in old subjects should be borne in mind in considering this procedure.

Treatment.—Occasionally some relief may be experienced by regulation of the patient's habits and occupation, or by local massage, friction, and manipulation of the joint in abduction and extension in order to prevent contraction. In the very early cases, a focus of infection should be carefully sought (see Chapter IX, on Focal Infection) and if found, an autogenous vaccine made therefrom and systematically administered. A prolonged course of treatment with thymus and pituitary extracts is also indicated (see Chapter XI, on Arthritis Deformans). Occasionally deformity may be counteracted by traction, rest, or reduction under anesthesia followed by a

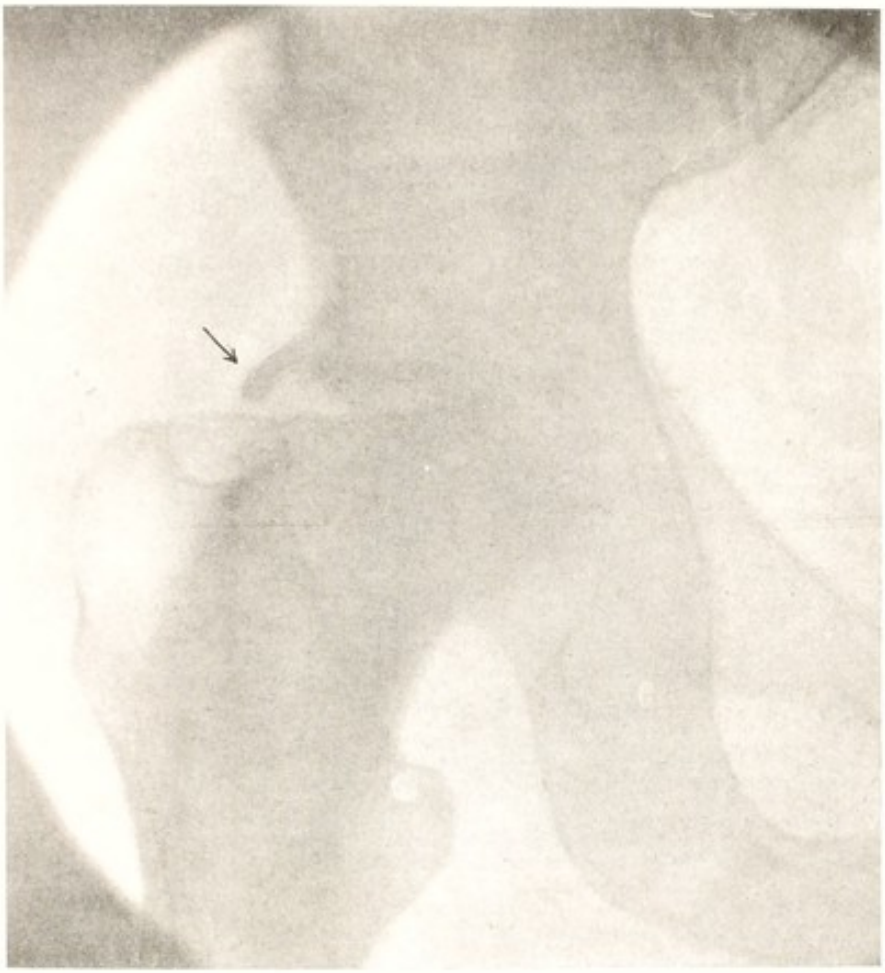


FIG. 226.—Bony union after author's arthrodesis for osteo-arthritis of the hip with relief of all symptoms. The arrow indicates small bone grafts placed about rim of joint.

hip splint to take pressure or friction from motion off the joint, or by a short plaster-of-Paris spica.

However, it has long been well-known that a large number of progressive and advanced cases of osteo-arthritis of the hip, with the accompanying deformity and disability, fail to respond to the conventional methods of systematic hygienic rest or brace treatment, and progress toward complete invalidism. This class of cases is met in adult life, and the length of time required by the treatment heretofore employed cannot be satisfactorily undertaken by the working man with a family dependent upon him, the chances for an ultimate recovery being extremely remote.

With marked anatomical and pathological changes present, such as the

wearing away of the femoral head and acetabulum, eburnation, osteophytes, and the associated flexion and adduction deformity, satisfactory results can rarely be anticipated from expectant treatment (see Fig. 223 of specimen of osteo-arthritic hip).

Resection of the upper extremity of the femur (an operation which the author believes has outlived its usefulness) was practised by Hoffa and others with very unsatisfactory results. Hoffa was one of the last to discard complete excision. Forcible manipulation under ether has produced disastrous results in both the hypertrophic and the atrophic types. In the hypertrophic type, forcible manipulation of the parts produces further hypertrophy in many instances, more pain and ultimate deformity by the traumatization of the joint structures, and, in the atrophic condition, on account of osseous rarefaction, further damage is likely to occur from the crushing of this



FIG. 227.—*X*-ray following arthrodesis for osteo-arthritis of the hip supplemented by a tibial bone graft mortised into the side of the ilium and the great trochanter. Solid union at both ends of the graft and at the hip caused all pain to subside.

rarefied bone. When this disorganizing condition of the hip-joint exists, with its accompanying adduction and flexion, with firm muscular contractures and a progressive bony obstructive ankylosis associated with pain, with the thigh in this faulty position, it has seemed best to aim for an immediate firm ankylosis by means of an operation (see Albee: The Journal of the A. M. A., June, 1908) at which time the limb is placed in a position of slight overcorrection to compensate for the existing practical shortening, there being but little further actual bone shortening produced by the operation.

The author's operation of arthrodesis of the hip-joint, which consists of the removal of portions of the femoral head and the acetabulum and the retention of the limb in slight abduction and flexion until firm bony union occurs, is fully described in Chapter VI, on Tuberculosis of the Hip-joint (see page 190) to which condition the operation is equally applicable. In

osteo-arthritis, the operation is applicable only to the advanced cases (Fig. 224).

The author has operated by this method in more than 75 cases, the patients ranging from twenty-two to sixty-seven years of age, and the time elapsing since the first cases were so treated has been more than ten years. Furthermore, to the author's knowledge, the operation has been performed by a number of other surgeons, with successful results.

W. S. Baer, in 1913 (ref. Int. Med., 1913, Subsection vii (*a*) Orthopedic, pt. 2, 141–179), in discussing the treatment of ankylosis, advocated the performance of arthroplasty in certain cases of arthritis deformans of the hip, using for this purpose a special preparation of the submucosa of the pig's bladder. Baer uses the anterior incision for exposure of the hip-joint. With a curved chisel, a small portion of the femoral head is resected and the remainder of the head dislocated forward in the wound. The head is then rounded off, but its anatomical shape is preserved as much as possible. After replacing the newly shaped head, the capsule is closed and the muscles are sewed tightly over the joint. A plaster spica is applied from toes to waist and absolute rest enjoined until the end of the third week, when passive motion is begun, and as soon thereafter as is possible the patient is encouraged to use the leg. Baer advises against arthroplastic operations in cases of arthritis deformans until several years have elapsed since any activity of the disease has been manifested.

Although the author believes that this arthroplasty of Baer's has its limited field of usefulness, especially where both hips are involved, he still favors his own arthrodesis operation, feeling that the important consideration is the relief of pain. The dangers of a recurrence of the arthritis with accompanying pain or pain immediately following the arthroplasty are real and are illustrated by the following case:

In one of the author's series of 75 cases, operated upon prior to the use of fragmented grafts to hasten bony union, he erred in removing too much of the head of the femur and failed to get bony union, and, incidentally it may be stated that this was the only case of the series in which he failed to get bony union. From the patient's standpoint, the operation was a most unsatisfactory one because of the severe pain associated with motion, and an immobilization brace was applied which he wore for a year and then discarded. His pain continued to be so annoying that during the author's absence in Europe, he sought surgical relief, and was again operated upon, still without relief.

II. Chronic Synovitis

Its occurrence in childhood arouses the suspicion that one is dealing with an incipient tuberculous process. Differentiation can be made only by minute examination into the history (both personal and antecedent), by noting the response to treatment, by careful and prolonged observation of the clinical course of the affection, and by röntgenology.

The cause of synovitis of the hip in children is to be found in trauma, rheumatism, or as a sequel to a mild form of infectious arthritis contracted in the course of such ailments as tonsillitis, diphtheria, and other throat involvements, or following osteomyelitis or epiphysitis of relatively benign type.

The course of the usual non-tuberculous synovitis of the hip in children is ordinarily short, rarely more than two or three weeks. Its clinical manifestations are limp, restricted motion, and transitory muscular atrophy. The

adult type is associated with or follows rheumatism, gonorrhea, syphilis, and arthritis deformans.

Treatment.—Synovitis of the hip in children should be managed precisely as a case of incipient tuberculosis of that joint, but the child should be carefully watched after its apparent recovery, to note the permanency of the cure. In the case of adults, rest and weight-extension (with plaster-of-Paris spica, if necessary), are in order. Caution should be exercised in using the joint too early.

III. Osteochondritis Deformans Juvenilis

A. T. Legg of Boston, in 1909, in a paper (ref. Bost. Med. and Surg. Jour., Feb. 17, 1910) read before the American Orthopedic Association, first described this obscure affection of the hip, and to him belongs the credit for its discovery. However, with a perversity not uncommon in medical annals, this affection is most commonly denominated "Perthés' disease," although Perthés' original publication on the subject was not made until 1913, four years after that of Legg. H. L. Taylor, in a recent publication has designated this condition as "quiet hip disease."

Definition.—Osteochondritis deformans juvenilis is a deforming affection of the femoral head resulting from a disturbance of growth of the epiphyseal cartilage.

Etiology.—A definite history of trauma of greater or less severity precedes a majority of the cases. The importance of this factor is in doubt, Allison in a recent series of experiments failing to reproduce the condition by trauma in the case of animals. The *familial* character of the affection has been noted by Schwarz, Calvé, and Eden.

By far the greater number of cases occurs in *males*. The commonest age of incidence is the *second quinquennium*. The disease is almost invariably *unilateral*. It makes its appearance without special warning in an individual in apparently good health and in those free from tuberculous, syphilitic, or other infections.

Pathology.—The essential lesion is a peculiar atrophy of the upper epiphysis of the femur, consequent upon destruction of the subchondral bony substance of the femoral head. There are practically no data existing as to the gross or microscopic appearance of the diseased portion of the femur. Perthés, in his original communication (ref. Archiv f. klin. chirurg., 1913, 779) described the pathological change as an overgrowth of abnormal cartilage extending down into fairly normal bone. Legg (*loc. cit.*) in his original observation on the condition, concluded that the pathological changes in the epiphysis and femoral neck were due to *interference with the blood supply* as a result of trauma of the epiphyseal line. Delitala (ref. Am. Jour. Orth. Surg., vol. xii, No. 4, 1915) believes the underlying cause of the pathological process to be *congenital alteration of the epiphyseal cartilage* of the upper end of the femur or of the epiphyseal nucleus, which gives way to processes of ossification which are insufficient and irregular.

X-ray Appearances (Fig. 228).—There is an irregular deficiency of lime-salts in the epiphysis, causing a laminated appearance. Irregular atrophy of the neck just below the epiphysis is apparent. This atrophy, with absorption, reduces the epiphysis eventually to a few segments of bone which become compressed as a result of pressure by the superimposed body-weight. Shortening of the atrophied neck takes place from the strain put upon it by the body-weight. During recovery from this pathological condition, calcium salts are again deposited in the head, which becomes flattened out against the

acetabulum as the "mushroom" type of head, while the neck is thick and short.

Clinical Features.—Claudication in a previously healthy child is the first symptom. There is hesitancy in standing on the affected limb, and the child walks with a slight lurch (in a manner somewhat like the gait of unilateral congenital dislocation) and tires easily. This phenomenon depends upon one or all of several factors, viz.: inefficiency of the pelvi-trochanteric muscle group, elevation of the great trochanter, limitation of abduction, or shortening of the leg. The limp varies in amount, and, whether or not treatment is accorded, it continues a variable number of months or years, when it disappears and recovery occurs with very slight derangement of the joint function.



FIG. 228.—Perthés' disease (Osteochondritis deformans juvenilis) of left hip.

Shortening of the leg occurs as the result of atrophy of the femoral neck and epiphysis. Pain is slight or entirely absent. No evidence of infection can be obtained, although some authors believe the condition to be dependent upon a low-grade localized hematogenous infection; while others, as Legg, believe the local infection to be merely an accidental factor. *Slight muscular atrophy* accompanies the condition. *Abduction* and *external rotation* are greatly limited. Flexion at the hip is normal. The *trochanter major* is *prominent*. Exaggerated movements at the hip-joint are accompanied by pain of slight degree.

Differential Diagnosis.—According to Delitala (*loc. cit.*) osteochondritis deformans juvenilis must be distinguished from epiphyseal and acetabular tuberculosis, coxa vara, polyarticular rheumatism, juvenile deforming arthritis of the hip, and osteomyelitis of the hip.

(*a*) From *tuberculous coxitis*, differentiation is easy except in the very early cases of Perthés' disease.

(*b*) *Extra-articular Tuberculosis* (Tuberculous Coxa Vara).—Lameness occurring in the morning after a night's rest, is one of the first symptoms, with limitation of flexion, rotation, and abduction; pain is definitely localized in the joint; swelling is usually absent. Differentiation is made by the presence of muscle spasm and the other classical signs of tubercular hip disease, and the diagnosis can always be confirmed by *x*-ray examination.

(*c*) *Infantile Coxa Vara.*—Both this and Perthés' disease are accompanied by limp, elevation of the great trochanter, limitation of abduction and internal rotation, and absence of pain; but shortening of the limb and elevation of the great trochanter are always more marked in coxa vara. An *x*-ray examination is conclusive. In congenital coxa vara the signs are positive. In rachitic coxa vara, other rachitic stigmata will aid in establishing the diagnosis.

(*d*) *Acute or Chronic Articular "Rheumatism."*—The onset with fever is different from that of Perthés' disease; likewise the accompanying emaciation and the relief afforded by salicylates and other anti-rheumatic drugs may be characteristic of "rheumatism."

(*e*) *Osteomyelitis of the Hip.*—If the infection is acute, no confusion is likely. If the osteomyelitis is extra-articular or chronic, the absence of the clinical signs of Perthés' disease and the *x*-ray appearances will permit differentiation to be readily made.

(*f*) *Juvenile Deforming Arthritis.*—The difficulty in diagnosis arises from the fact that a great many cases of this affection are encountered in children under twelve years of age having all the features of Perthés' disease. Points of differentiation are crepitus, stiffness on movement, acute pain, such lameness as to prohibit walking (on account of stiffness and pain), and the *x*-ray appearances. The latter show the head to be thickened, flattened on its upper surface, irregular, and almost plate-like, and with the presence of osteophytes.

Treatment.—The disease is practically self-limited and tends to undergo spontaneous cure; therefore, from experience, treatment appears to have very little effect on its course. However, immobilization in plaster-of-Paris or rest in bed with traction by weight and pulley seem to give relief in the early stages with muscle-spasm and pain. Inasmuch as the crushing and deformity of the femoral head are apparently due more to intrinsic and obscure pathological changes in the epiphyseal nucleus than to weight-bearing, the rationale of the use of apparatus is questionable. Massage appears to have a favorable effect, possibly because of trophic influences.

IV. NEUROPATHIES

Hysterical Hip.—Mention must be made of this neuropathic affection of the hip inasmuch as it is frequently mistaken for tuberculous coxitis, the symptoms and signs of which can be closely simulated by the hysterical patient. The signs most perfectly mimicked are lameness, flexion of the joint, lateral deviation of the spine, lordosis, flattening of the hip, and adduction and apparent shortening of the leg. Detection of the subterfuge may best be accomplished by flexing the normal leg forcibly at the hip; if the knee can then be brought down on the abdomen without raising the suspected limb from the examining table, tuberculous coxitis can be eliminated. Other evidence of hysteria can usually be obtained from the personal history and by careful examination and scrutiny of the subject. Röntgenography and examination under anesthesia will remove all further doubt.

V NEOPLASMS

(*a*) Malignant Disease

Malignant growths are very rare in the upper end of the femur. Carcinoma, when it occurs here, is almost always secondary to a primary growth elsewhere. *Sarcoma* of the round-cell variety is the usual form of malignant neoplasm in this locality. It originates in the periosteum, is very rapid in its growth, and highly malignant. The tumor is very vascular, alveolated, and often pulsating. Local extension of the growth takes place early. Spontaneous fracture of the hip is often the first sign of the disease.

Clinical Features.—Adolescents are the usual victims. There is frequently a definite history of trauma. Early swelling of the hip-joint occurs with rapid increase of its size and later elimination of motion in the joint. The size of the joint is often enormous, with consequent stretching of the overlying skin. Pain is often absent or very slight in amount, except in the case of pressure or stretching of nerve trunks. Elasticity occasionally occurs in the tumor. Fluctuation, when present, is an indication of disorganization of the growth at its center and the pressure of free blood in its interstices, in which event pulsation of the tumor becomes more marked.

Diagnosis.—The diagnosis is based on the history of the growth, its outlines and physical properties. The most reliable evidence, however, is offered by the *x*-ray. If there is still doubt of the nature of the lesion, an exploratory incision is justifiable for removal of a small piece of the suspected tissue and its microscopical examination. A pulsating sarcoma is sometimes mistaken for an aneurism.

Treatment.—Unless a positive diagnosis is made and a radical operation performed before extension of the process occurs, no treatment is of any avail. In cases detected early, while the growth is limited to the head of the femur, amputation or resection of the hip-joint offers the only hope of cure.

(*b*) Cysts of the Upper End of the Femur

Elmslie (Brit. Jour. Surg., vol. ii, No. 5, 1914) states that a larger number of cases of cysts or of osteitis fibrosa in the femur have been recorded than in any other bone. There is a considerable proportion of young children among those affected. Cysts of the *upper end* of the femur are usually of the nature of a solid mass of tissue in which the cysts are embedded. Cysts of that portion of the femur entering into the formation of the hip-joint (the head and neck) have been from time to time recorded in the literature.

Etiology.—In the chapter on neoplasms of bone, in this book, the etiological factors governing bone cysts will be found discussed.

Clinical History.—Fracture is a very common symptom, often the initial sign of the malady. Fracture is sometimes incomplete. There is frequently good union after fracture through a cyst, though bending and swelling of the bone at its site may occur, possibly on account of the increased formation of fibrous or fibrocartilaginous tissue. Simple cysts are usually encountered in young children, while the cystic formation in solid masses of fibrous or other tissue may occur at *any age*.

In some instances the clinical course resembles that of an *osteo-arthritis* of the hip, beginning with vague *discomfort* in the joint which gradually becomes worse and is followed by *limitation of motion*.

X-ray Appearances.—If the cyst has caused considerable expansion of bone, the *x*-ray picture is characteristic. A shell of cortical bone is seen surrounding the tumor except where fracture occurs. If this cortical shell of bone is absent at any point, it should make one suspicious of sarcoma. The

cyst is centrally placed, and there is absence of periosteal thickening and of sclerosis of the surrounding bone. In other cases there is practically no expansion of bone, the only abnormality in the *x*-ray picture being the uniform density of the bone, the cortical portion not being sharply delineated as in normal bone. Trabeculæ subdividing the translucent area are of common occurrence.

Differentiai Diagnosis.—(*a*) *Simple traumatic fracture* can be eliminated by the *x*-ray findings.

(*b*) *Sarcoma of the Femur.*—The clinical history is shorter in sarcoma, and the central position of the cysts, the integrity of the cortical shell, and the absence of periosteal changes in the *x*-ray appearance of cystic disease will permit of ready differentiation.

Pathology.—Elmslie (*loc. cit.*) divides these cystic conditions of the upper end of the femur into two types, viz.:

1. *Single cyst*, found almost exclusively in young children, and resembling cysts of the upper end of the femur both clinically and pathologically. Its walls consist of fibrous tissue in various stages of organization, cartilage, bone (undergoing both deposit and absorption), and blood clots.

2. *Mass of newgrowth* containing *one* or *more* cysts, and occurring at all ages. The solid mass contains cartilage (hyaline or fibrous), spiculæ of bone (in various stages of deposit and absorption), fibrous tissue of all sorts and in all stages of development, including myxomatous degeneration, the entire pathological picture being very complex.

One of the varieties of multiple cyst of rare occurrence is the *echinococcus* cyst. Very few echinococcus cysts of bone are recorded in the literature, although they are relatively common in the viscera, particularly the liver. The author recently encountered one of these echinococcus cysts of the head of the femur in a patient from New Zealand upon whom he operated and obtained the specimens illustrated by Fig. 649.

Treatment.—A cyst of the upper end of the femur with degeneration and destruction of the head, or head and neck, of the femur, presents a more formidable problem than when the disease is extra-articular. In the latter instance, a tibial bone-graft has been successfully employed to span the defect remaining after the removal of the cyst. The graft is inlaid with one end into the lower fragment and the other end contacted into the acetabular cavity. If destruction of the acetabulum is sufficient to warrant immobilization, then the graft is mortised into the pelvis at a point above the acetabulum as well as inlaid into the upper end of the femur. The limb should be fixed in a long plaster spica in slight abduction for ten or twelve weeks. In instances where the shaft of the femur has become markedly bowed because of the yielding of the weakened portion of the femur, the author has corrected the deformity by a cuneiform osteotomy (by means of his motor-saw and an osteotome) and has then inlaid a strong tibial graft through the cystic area. If the bow-deformity is not too great to leave, further progression of the bending can be prevented by inlaying a tibial graft (same technic as when bone is broken) through the weakened area.

VI. DEFORMITIES

ANKYLOSIS OF THE HIP

The ankylosis may be *bony* or *fibrous*. The commonest variety of fibrous *ankylosis* is that following a tuberculous process of the hip-joint (see Chapter VI). The best treatment for fibrous ankylosis is continuous massage, manipulation, and active and passive exercise, following splinting to

counteract the malposition, or weight-extension. The best position for weight traction is extension and abduction of the hip over long periods for corrective purposes.

Bony Ankylosis.—If the hip is ankylosed and in good position (slight flexion and abduction) it is better to leave it alone unless the ankylosis is bilateral or the patient demands an arthroplasty for mobility. If the hip is ankylosed in flexion, circular osteotomy (see chapter on Tuberculosis of Hip-joint) should be performed, following division of the contracted flexor muscles.

Arthroplasty of the Hip.—Arthroplasty of the hip is performed for ankylosis from any cause (tuberculosis, infectious arthritis, osteomyelitis, etc.). The author believes that a single hip-joint affected with firm bony ankylosis, where the femur is in proper relationship to the pelvis, is better left alone, inasmuch as a firmly ankylosed hip in good position offers a very satisfactory functional limb. In case the limb is ankylosed in flexion and adduction, it is, as a rule, deemed preferable to correct the deformity by osteotomy rather than to risk the painful movements resulting from arthroplasty. These remarks apply, however, only to monarticular conditions. When both hips are ankylosed or involved, the advantages of arthroplasty for mobilization are very much increased.

The approach to the hip-joint and the technic of arthroplasty will be found in Chapter XXVIII on Ankylosis and Arthroplasty.

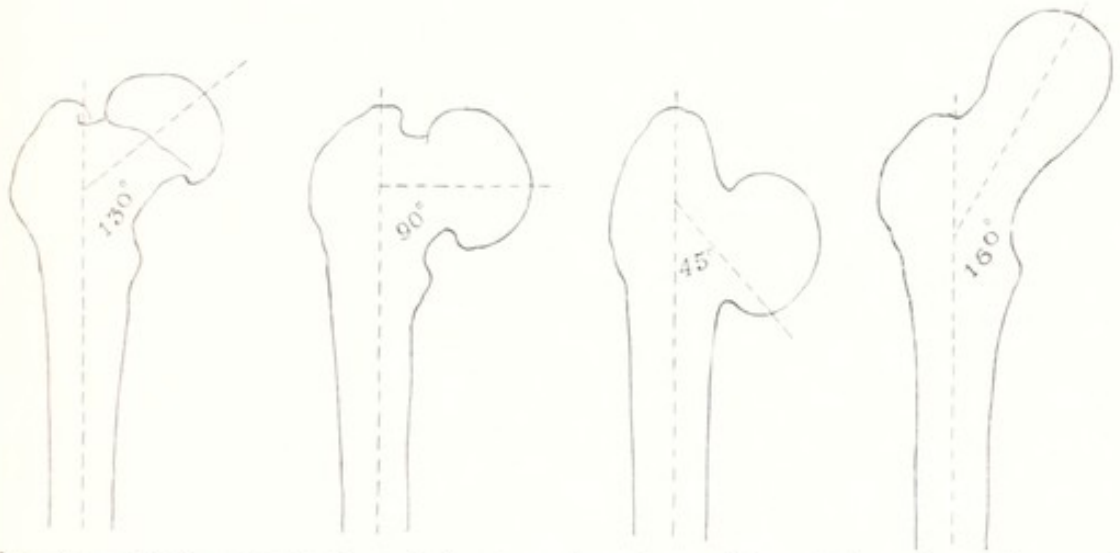


FIG. 229.—Angle of inclination of the femoral neck. *a*, Normal; *b*, moderate degree of coxa vara; *c*, extreme degree of coxa vara; *d*, coxa valga.

COXA VARA

General Considerations.—In the normal adult, the angle between the long axis of the neck and that of the shaft of the femur is 130 degrees, but in a certain proportion of people it is slightly less or slightly more, the variation depending upon the height, sex, width of the pelvis, muscularity, and racial characteristics. This angle, therefore, varies from 128 to 132 degrees; in children it is a few degrees more, in the aged a few degrees less than in adults. *X*-ray findings in this condition are final in diagnosis (see Chapter IV).

A considerable *increase* in this angle of inclination of the femoral neck is called *coxa valga;* a considerable *diminution* is called coxa vara, which results, in the case of extreme decrease in the angle, in limitation of abduction or in actual adduction (Fig. 229). In general, alteration of form in a part,

leading to *adduction of* that portion of the limb beyond the deformity, is called a "*varus*" condition; its opposite is a "*valgus*" condition. It must be borne in mind, however, that the terms "varus" and "valgus" merely denote *position*, and do not explain the fundamental pathological lesions underlying the deformity. Except in congenital cases, the factors influencing the shape of the femoral neck are the superimposed body-weight plus yielding of the neck at its most malleable point, from a variety of causes.

Definition.—Coxa vara is the clinical term signifying downward bending of the neck of the femur sufficiently to cause clinical manifestation, the condition being unilateral or bilateral.

Anatomical Types.—Bending of the femoral neck may occur at any one of three portions. Thus, the following anatomical types are recognized:



FIG. 230.—Case of cervical coxa vara in a child eight years old. Note the general bending of the femoral neck with a very little giving away at the epiphyseal line.

1. *Cervical Coxa Vara.*—This is the type encountered in most instances. Bending affects the neck as a whole, its axis being a curved line (Fig. 230).

2. *Epiphyseal Coxa Vara.*—The deformity is most marked at the epiphyseal junction. This is the type most frequently encountered in adolescents.

3. *Coxa Vara Trochanterica.*—In this type, bending occurs at the junction of the neck and shaft. This is a rare form, inasmuch as the neck is broadest and strongest at this point, and is frequently due to rickets (Fig. 229).

Beside the angle of inclination (between neck and shaft), the femoral neck also points forward in an angle of declination (appreciable by viewing the upper end of the femur from above) made by the long axis of the neck with the transverse axis of the knee-joint. This angle of declination is normally about 12 degrees. In coxa vara, the head is usually displaced backward and the neck may undergo torsion on its long axis. (Mikulicz states

that in 10–15 per cent. of normal individuals the head points backward.) Thus we may have the following:

Varieties.—(*a*) Neck bent *downward* and *backward*, the convexity looking forward and upward (Fig. 229). This is the commonest distortion. Result: *decreased abduction* with *external rotation* and *eversion of* the foot. The trochanter is elevated and *flexion limited*. Adduction external rotation, and extension are in some cases increased. The head is twisted backward, probably under the influence of the body-weight.

(*b*) *Downward bending* of the neck. Slight limitation of flexion, but increasing limitation of abduction. Next in frequency.

These two are the only varieties of bending of any clinical importance. Other uncommon varieties are:

(*c*) Depression of the femoral head with posterior convexity of the neck. Limitation of external rotation with inversion of the foot and leg.

(*d*) Torsion of the neck on its long axis.

(*e*) Forward convexity of the neck *without* downward bending.

(*f*) "False coxa vara," due to bending of the upper extremity of the shaft.



FIG. 231.—Coxa vara of extreme type.

Etiology.—Coxa vara is not an uncommon affection. Many cases probably go unrecognized in clinics where the *x*-ray is little used. The unilateral is much more frequent than the bilateral form. Males are much more frequently affected than females, on account of the influence of strain or injury in causing or increasing the distortion. In unilateral cases the left leg is more often involved than the right because it is more often used in "resting."

Coxa vara is an affection of growing bone, hence it is encountered mainly in adolescents, in whom the added factors of instability of the epiphyseal line, the greater delicacy of structure and relatively greater length of the femoral neck predispose them to the deformity. The assumption that the predisposition of the femoral neck to deformity is the result of local disease, such as local rickets or local osteomalacia, cannot be substantiated and, as Whitman states, is simply a convenient hypothesis. That the affection is symptomatic of late rickets, is affirmed by some, although signs of general rachitis are wanting in the ordinary type of coxa vara in adolescents. The essential physical cause of coxa vara is increased strain upon a diminished resistance of the neck of the femur (inherited delicacy, or weakening by injury or disease), or disproportion between these two elements.

In many instances, coxa vara is due to *lessened inclination of the femoral neck* from early *rickets*, which becomes exaggerated until it becomes a deformity during later childhood or adolescence.

General weakness, incident to rapid growth; *direct injury*, such as fracture or the strain of a laborious occupation, are contributory factors. If we could

exclude the traumatic factor (cases of fracture of the neck of the femur and separation and fracture of the epiphysis), coxa vara could be attributed in most instances to the immediate or remote effects of rickets.

A very considerable proportion of the epiphyseal coxa vara is of doubtful origin; we refer to the border line cases of gradual "sliding" of the capital epiphysis (to which more extended reference will be made later) where the influence of trauma is absent or negligible.

Classification.—For convenience of description, the following classification (modified from Tubby) may be employed:



FIG. 232.—Marked coxa vara due to rickets.

A. *Acquired Coxa Vara.*
1. *Cervical* and *trochanteric* coxa vara.
2. *Epiphyseal* coxa vara (adolescent).
3. *Symptomatic* coxa vara.
   (*a*) Due to non-inflammatory processes.
      (α) Rickets.
      (β) Osteomalacia.
      (γ) Senile osteoporosis.
   (*b*) Due to inflammatory processes.
      (α) Osteomyelitis.
      (β) Tuberculosis.
      (γ) Arthritis deformans.
   (*c*) Traumatic coxa vara.
      (α) Separation of the epiphysis of the neck in children and adolescents.
      (β) Fracture of the neck of the femur in children and adolescents.
      (γ) Fracture of the neck of the femur in adults.

B. *Congenital Coxa Vara.*

1. With no other deformity present.
2. Associated with congenital dislocation of the hip or other deformity.

CLINICAL FEATURES

1. **Cervical and Trochanteric Coxa Vara.**—(*a*) *Mechanical Deformity.*—The great trochanter is elevated above Nélaton's line, the amount of elevation depending upon the degree of depression of the femoral head or neck. The trochanter forms a marked prominence at the hip which is increased on flexing and adducting the hip. The displacement of the neck downward and backward, which occurs in the majority of cases, following the lines of least resistance, causes the trochanter to be thrown forward and the limb to undergo external rotation. Normal abduction of the thigh depends on the length of the femoral neck, consequently diminution of this angle of inclination lessens the range of abduction. This limitation of abduction is due partly to increased tension on the inferior portion of the capsule and partly to the fact that the femoral neck and trochanter impinge on the rim of the acetabulum, the disability being further aggravated by contracture of the pelvitrochanteric muscles. Also backward and downward distortion of the neck alters the relationship of the head and acetabulum, favoring luxation of the head when the femur is flexed or abducted.

To sum up: the derangements of motion are limitation of abduction, internal rotation, and flexion; increase of adduction, external rotation, and extension.

There is apparent and actual shortening of the limb. Actual shortening is due to the upward displacement of the shaft of the femur and is rarely more than 1 inch in the adolescent type of the deformity, although the apparent shortening (the result of adduction and compensatory uplifting of the pelvis) may amount to from 2 to 3 inches, and oftentimes more in extreme cases.

(*b*) *Symptoms and Signs.*—As a result of these mechanical alterations, the ordinary (cervical and trochanteric) form of coxa vara presents the following signs and symptoms: *discomfort*, *awkwardness*, *limp*, *shortening*, *atrophy*, *restriction of motion*, and *deformity*.

The more disabling features of coxa vara, as compared with analogous conditions at the knee-joint (genu varum and genu valgum), and the greater distress ensuing from the hip-distortion, are due to the subluxation of the femoral head in coxa vara; while in the distortions of the knee-joint there is practically normal opposition of the two joint surfaces.

Unilateral Coxa Vara.—Here the symptoms and signs are influenced by the degree of distortion and its duration. The commonest complaints are *stiffness* and *weakness*, accentuated by resuming activity after a period of rest. These sensations are referred to the thigh and may amount to acute pain, especially after overactivity. *Limp* is the chief disabling feature for which relief is usually sought; it is accompanied by external rotation of the hip and, according to Whitman (ref. Orth. Surg., 1903, p. 541) it resembles the limp caused by a healed fracture of the neck of the femur. Differentiation from the latter condition is made by the actual shortening in coxa vara (due very plainly to the elevated bulging trochanter and the unequal limitation of motion at the hip-joint). Moderate degrees of *muscle spasm* and atrophy of the thigh muscles are often present.

Bilateral Coxa Vara.—The *gait* and *attitude* are striking phenomena of bilateral coxa vara. The gait is characterized by swaying of the body to

overcome the abduction and prevent the knees from "interfering." In extreme cases, the legs may cross one another and make walking extremely difficult. The normal lumbar lordosis disappears in the ordinary form of bilateral coxa vara on account of the lessened pelvic inclination caused by backward displacement of the femoral neck with consequent thrusting forward of the shaft of the femur. Whitman (*loc. cit.*) calls attention to the involuntary crossing of the legs during flexion when the patient is recumbent, in cases of bilateral coxa vara of advanced degree.

2. **Epiphyseal Coxa Vara** (Adolescent).—Although this form of coxa vara is classified by many authorities as distinctly *traumatic*, the author believes that, inasmuch as a considerable proportion of the cases of this type present no trauma whatsoever while in other cases this factor is negligible, they should be regarded as border-line cases. The process *always* starts in *adolescence;* there may or may not be a history of slight trauma or slight strain; quiescent periods alternate with recurrences of the disturbance; the epiphysis slips a little at a time, the gait becomes altered and the symptoms increase accordingly until flexion can be accomplished only in an obliquely outward direction, similar to the flexion in cases of osteo-arthritis of the hip (see section on Arthritis Deformans of the Hip, in this chapter). The clinical course of the affection conforms very closely to that observed in juxta-epiphyseal fracture of the upper end of the femur (*quod vide*) and is exemplified by the case of R. B. cited in the section on Traumatic Coxa Vara in this chapter.

3. **Other Varieties of Coxa Vara.**—A rare distortion is downward or downward and forward depression of the neck. In the latter event, the mechanical disturbance differs from that of the ordinary type in that, although abduction is limited as in the ordinary form, internal instead of external rotation occurs and there is limitation of extension instead of flexion. Bilateral involvement is the rule in this type of deformity. Clinical manifestations are slight permanent flexion at the hips, with consequent increase of the lumbar lordosis (the opposite of the condition in the ordinary type).

This variety occurs in early life, but the condition is usually obscured by associated distortions of other parts. The symptoms may be slight and consist only of more or less discomfort extending over a period of years. Many of these cases are caused by rickets. The symptoms usually begin insidiously. Discomfort often ceases after induration of the affected bony parts insures their stability.

4. **Congenital Coxa Vara.**—This was first described in 1896 by Kredel (Centralb. f. Chir., No. xlii, 1896). Numerous instances have been recorded by various observers who have noted the condition many times as the only anomaly present; while in other cases it has been observed in association with congenital dislocation of the hip, defective development of the upper end of the femur, and with various congenital anomalies.

The clinical features of congenital coxa vara are a *waddling gait, lumbar lordosis, elevation of the trochanter above Nélaton's line, adduction*, and *slight external rotation*. Crossing of the legs has been observed on kneeling. Sitting is accomplished Turkish fashion, and during recumbency the limbs are oftentimes rotated completely outward.

X-ray examination shows a neck depressed to a right angle or less, and the head not completely filling the upper part of the acetabulum. The epiphyseal line is vertical and not oblique, as in rickets, and is broad and irregular.

Congenital coxa vara is very frequently confused with congenital dislocation of the hip, which it very much resembles.

Nothing is known of the *etiology* of congenital coxa vara. It occasionally

occurs in several members of one family. It is often associated with congenital dislocation of the hip and may constitute one of the causes of failure of reduction of the latter because of inability to obtain full abduction.

Differential Diagnosis.—In most instances the diagnosis is made without difficulty, particularly if the *x*-ray is employed.

(*a*) *Congenital dislocation of the hip* (anterior variety) can be excluded by the age of the patient and the history of the case, while confirmatory evidence is offered by the physical signs, which alone are usually sufficient for a diagnosis. In congenital dislocation, if flexion and adduction of the thigh are practised to an extreme degree, the femoral head and neck are felt in the buttocks. In coxa vara, on the other hand, only the prominent trochanter is palpable. Abnormal mobility of the hip-joint, present in congenital dislocation, is absent in coxa vara. In rotating the limb in coxa vara the upper end of the femur rotates around an axis through the head; in congenital dislocation, it rotates on an axis midway between the trochanter and the head. This point can be determined by palpation except in the case of very thick superimposed tissues. Finally, the *x*-ray will furnish indisputable evidence.

(*b*) *Tuberculous Coxitis.*—Tuberculous hip disease may be confused with coxa vara if the latter is in an acute state clinically and without *x*-ray (*i.e.*, spasm, fixation, and pain, see case of R. B., page 478, Traumatic Coxa Vara). But in a tuberculous hip, motion at the joint is limited in every direction by muscle spasm, while other signs of the disease are present. In the case of coxa vara, there is *deformity only* and no sign of attendant disease, while reflex muscle spasm is absent (except in very acute cases where it is incident to trauma or strain), restriction of movement occurs only in abduction, flexion (rarely) and internal rotation. Measured shortening is a late phenomenon in tuberculous hip disease, while it is the initial sign in coxa vara; furthermore it depends, in the case of coxa vara, on elevation of the trochanter above Nélaton's line from *distortion*, while such elevation in tuberculous hip disease is due to *destruction* of the femoral head or the acetabulum.

TREATMENT

I. **Cervical and Trochanteric Coxa Vara.**—(1) *Forcible Abduction and Fixation in Plaster-of-Paris.*—On the assumption that the affected neck is malleable in the instance of coxa vara in young children with acute rickets where the symptoms have rapidly increased in extent and severity, forcible abduction of the thigh (see Treatment of Traumatic Coxa Vara) may be effective in restoring the angle of inclination of the femoral neck. In this manœuvre, the head being fixed by the inferior portion of the capsule, the trochanter impinges on the rim of the acetabulum as a fulcrum, while the leg in abduction acts as the long arm of a lever. After wide abduction has been obtained, a long plaster-of-Paris spica is applied and allowed to remain for two months or more. On removal of the spica, an *x*-ray examination should be made to be assured of correction. After final removal of the spica, a support should be used in walking for some time (a Thomas hip splint or crutches) and massage should be systematically employed during convalescence. Inasmuch as the orthopedic surgeon usually encounters these cases only after the acute stage has subsided and there is little plasticity of bone present, the field for this form of treatment is very limited. Osteotomy at the lesser trochanter is, as a rule, the only efficient treatment.

2. *Osteotomy.*—Section of the femur should be performed only after thorough dietetic and medicinal antirachitic treatment has been given a

prolonged trial if there is evidence of acute rickets. As a rule, however, the surgeon first sees the case long after the acute stage has disappeared.

There are two methods of performing osteotomy which have the sanction of good surgery, viz.: (*a*) *circular* osteotomy and (*b*) the *cuneiform* osteotomy of Whitman.

(*a*) *Circular Osteotomy.*—Circular osteotomy is almost invariably employed by the author in preference to linear osteotomy, not only because the latter is an unmechanical procedure, but also because circular osteotomy avoids the corner-on-corner effect and the dead space left to be filled in as well as the overriding of fragments (Fig. 233). It is also preferable to cuneiform osteotomy because it avoids the shortening resulting from the removal of a wedge of bone from the shaft and also precludes the possible sliding and overriding of the fragments, even though the cut ends are in apposition (Fig. 234).

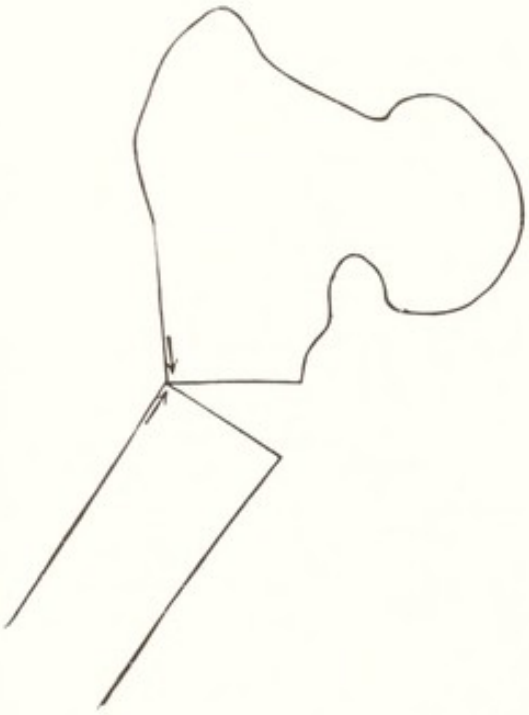


FIG. 233.—Old transverse osteotomy for the correction of a deformity of the hip associated with ankylosis. The danger of slipping and postoperative displacement of the femoral fragments is emphasized by the corner to corner contact of the fragments. The author has given up this type of osteotomy entirely in favor of the circular osteotomy of Brackett.

From a mechanical standpoint, then, circular osteotomy is preferable to all others in that there is no loss of substance and no displacement of fragments when the limb is abducted, on account of the mechanical factor of a circle within a circle.

Great credit is due to Colonel E. G. Brackett of Boston for perfecting the technic of circular osteotomy (ref. Boston Med. and Surg. Jour., clxvi, No. 7, pp. 235–242). Brackett's operation resembles that of Sir Robert Jones. It is mechanically excellent and produces no shortening. Brackett designates his osteotomy as "a curved Gant by the open method." Anterior incision over the hip-joint exposes the bone from the outer side of the great trochanter to the inner side of the neck and its junction with the femoral shaft. The iliacus muscle is lifted and retracted inward as far as the lesser trochanter. A blunt dissector is then placed vertically downward on the inner side of the bone at the junction of the lesser trochanter and the neck, and is left in position. A very narrow osteotome is used to make a curved incision with its convexity upward and inward, beginning on the outer side of the trochanter and ending at the point of junction of the neck and lesser trochanter where the blunt dissector is in place. Section is made vertically downward (the patient in the dorsal position) from the anterior to and through the posterior surface of the bone. When the leg is abducted to correct the adduction deformity, the convex end of the lower fragment turns in the hollow of the upper fragment.

The point at which the curved incision begins on the outer side of the trochanter varies with the amount of adduction to be overcome. The greater the degree of adduction deformity, relatively higher on the femur is the point of origin of the incision. If flexion deformity is marked, the vertical (antero-

posterior) line of osteotomy is deflected slightly backward to produce a slight overhanging of the anterior edge of the upper fragment.

Author's Modification of Brackett's Technic.—Brackett's technic has been modified by the author by prolonging the inner portion of the

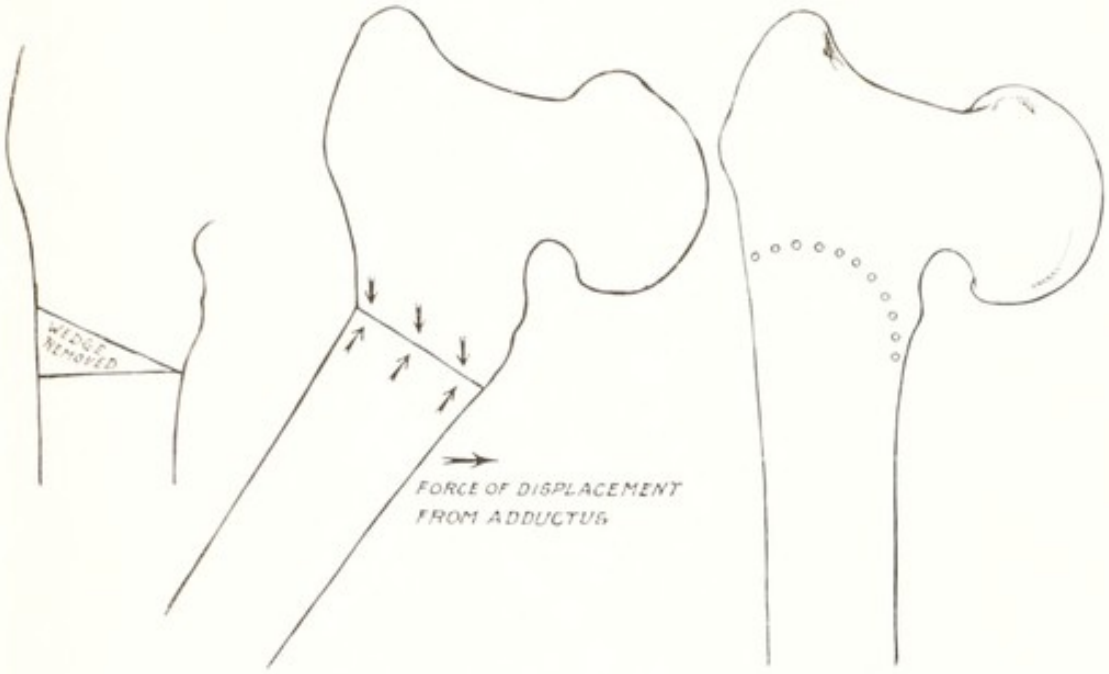


FIG. 234. FIG. 235.

FIG. 234.—Cuneiform osteotomy of the femur. Left-hand figure shows size and shape of wedge removed with base of wedge outward. The right-hand figure illustrates the danger of displacement by the muscular pull of the adductors in the direction indicated by the arrow. (The author formerly employed this procedure for the relief of adduction-deformity in coxa vara, but has abandoned its use in favor of circular osteotomy.)

FIG. 235.—Brackett's circular osteotomy, author's technic. The motor drill holes shown in the drawing are later connected by means of a thin narrow osteotome, thus severing the shaft of the femur. By this technic a long lip is left on the internal portion of the upper fragment, which, upon abduction of the long lower fragment of the femur, effectually prevents inward displacement of the latter, during the process of healing.

curved incision downward to make a long lip on the internal aspect of the upper fragment, just below the trochanter minor, so that the central point of the convex surface of the lower fragment is exactly opposite the central point of the concave surface of the upper fragment, thus providing an addi-



FIG. 236.—Special retractor for use in osteotomy. By its use the reflected periosteum can be held out of the way while the bone is being drilled or cut.

tional safeguard against sliding-by and possible displacement of the two fragments and a broader surface of contact (see Figs. 235 and 238). The author used his motor-drill in making the circular osteotomy, connecting the holes with Jones' saw.

Circular osteotomy possesses advantages over other methods:

1. It blocks any tendency of the fragments to slip by one another.
2. The line of weight-bearing is so nicely adjusted to that of the shaft,

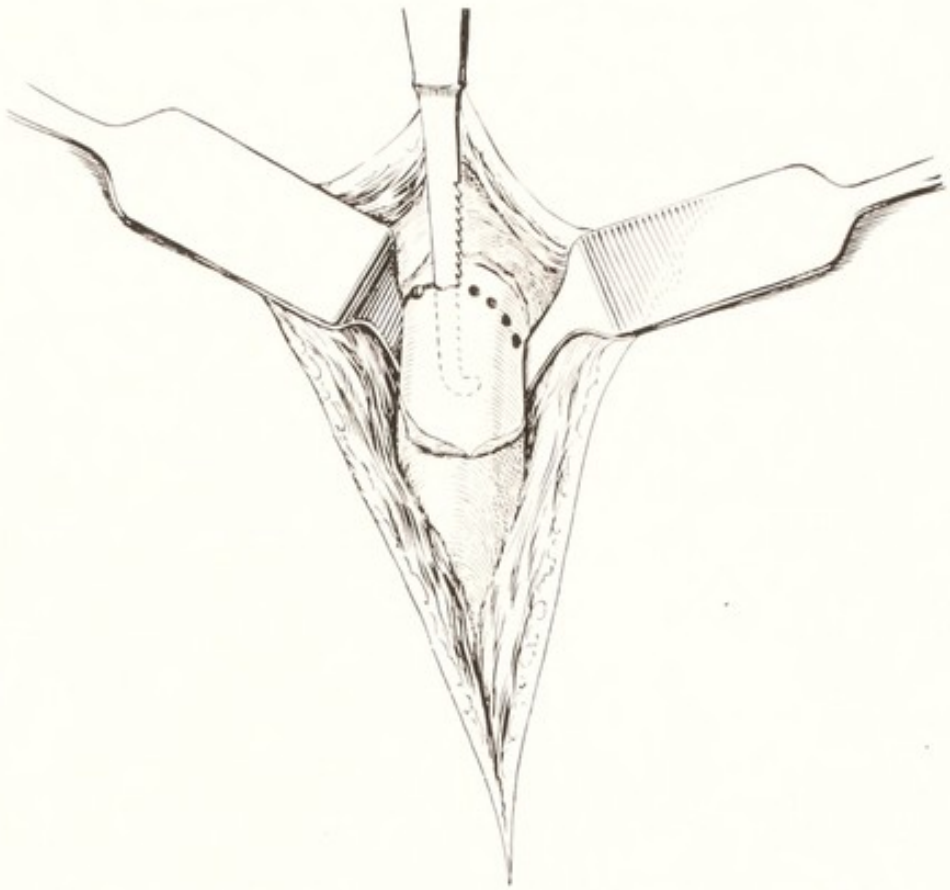


FIG. 237.—Circular osteotomy of the femur. Completing circular section of the bone between the drill holes with Jones' saw or narrow osteotome.

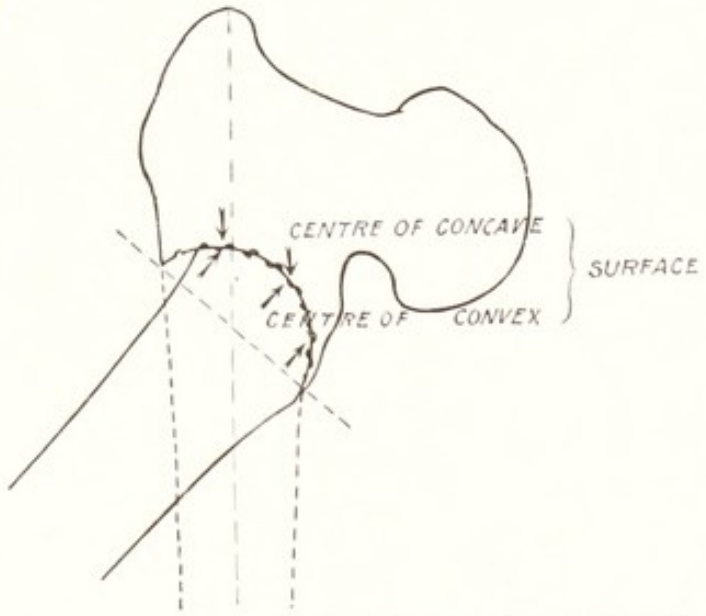


FIG. 238.—Indicates correction of coxa vara after circular osteotomy. Note that the lip on the inner side of the upper fragment causes the center of the concave surface on this fragment to come opposite the center of the convex surface on the lower fragment. The correction causes a convex surface to rotate within a concave surface hence no shortening is thereby produced and the danger of postoperative displacement is obviated.

the center of the convex surface of the lower fragment coming exactly opposite the center of the concave surface of the upper fragment, that they exactly coincide.

3. Free dissection of overlying structures affords the operator an unobstructed view of the exact field of operation and allows inspection of anatomical conditions before and after operation, so that the most exact mechanical coaptation is secured in every instance.

(*b*) *Linear Osteotomy.*—The femur is divided just below the trochanter minor at right angles with the shaft, by either the open or the subcutaneous method. After division of the femur, its shaft is rotated inward until the foot is in normal position, and is then abducted to the fullest extent and immobilized in this position in a long plaster-of-Paris spica, which may or may not be changed at the end of five or six weeks and left on for ten to twelve weeks. When firm bony union has occurred, a matter of ten or twelve weeks, massage, exercise, and manipulation should be systematically employed.

The author believes that this operation is unmechanical. Its only claim to attention is the fact that when subcutaneous osteotomy was in vogue it was the only procedure available. It should be employed only when subcutaneous osteotomy is to be performed, a circular or cuneiform section of the femur being impossible by the subcutaneous route.

(*c*) *Cuneiform Osteotomy* (Whitman).—Whitman (ref. Orth. Surg., 1903, p. 547) prefers, in younger patients, a cuneiform section of bone taken from the shaft of the femur on a level with the lesser trochanter. He directs attention to several points of importance in the technic, as follows:

Vigorous preliminary stretching and massage of contractured muscular and ligamentous structures which limit abduction should be practised. The operative incision begins at a point 1 inch below the apex of the trochanter and is carried directly downward about 3 inches. The periosteum is incised and elevated to expose the femur.

Prior to the performance of every cuneiform osteotomy, an *x*-ray examination should be made and with the exact anatomical condition of the femoral head and neck before him, the surgeon should plan his work with as great nicety as any artisan confronted by a mechanical problem. Operation, in every case, presents an individual problem and should not be performed by any fixed formula. Tracing paper (or ordinary tissue paper) is laid over the *x*-ray plate and the outlines of the upper extremity of the femur are obtained and transferred to heavy cardboard. The exact size, shape, and inclination of the femoral neck are thus secured. The surgeon now experiments until the wedge removed from the infratrochanteric region of the cardboard model is sufficient to produce an angle of inclination of 160 degrees when the shaft is fully abducted to close the cuneiform opening. It will be found that the size and shape of the wedge will vary with the size of the femur and the degree of coxa vara, and that no two cases are exactly alike By this accurate and simple method of experimentation the surgeon, on approaching the operating table, will know exactly what size and shape of wedge it is best to remove. In any event, the resulting shortening of the femur will measure approximately one-half the width of the base of the wedge.

In making the wedge, the upper section is cut at right angles to the shaft of the femur, while the lower section is made more oblique. After removing the wedge, the limb is strongly abducted, which almost invariably fractures the cortical bone on the inner aspect of the shaft opposite the trochanter minor, even though this was not severed at the beginning of osteotomy.

After the upper fragment impinges on the rim of the acetabulum, the lower fragment is swung still further outward in abduction until the cuneiform opening between the fragments of the shaft is closed by apposition of the cut surfaces, thus restoring the normal angle between the neck and the shaft. A long plaster-of-Paris spica, including the foot, is applied with the limb in wide abduction, and is retained in position for eight weeks or until there is firm union. After solid bony union is assured, adduction of the limb to the midline of the body restores, to a degree, the loss in length of the femur from the previous coxa vara. A short plaster-of-Paris spica worn for four to six weeks after removal of the long spica is the only after-treatment required.

Another method of wedge osteotomy has been devised by Leo Mayer. In this operation the wedge of bone is removed from the area directly below the linea intertrochanterica. The size of the wedge depends upon the degree of deformity to be corrected. It is evident that this operation, despite the removal of bone, increases the length of the femur, since it converts the right angle of the coxa vara into an obtuse angle. In one case of an eight-year-old child, this increase measured 3 cm.

The operation is particularly applicable to children and adolescents. After preliminary tenotomy of the adductors a longitudinal incision is made directly over the great trochanter, and the bone freed until the operator has determined the location of the trochanter minor. With this as a guide, the bone incision is made from the tip of the great trochanter to a point slightly above the trochanter minor and a suitable wedge excised below this primary bone incision. The cortex on the mesial side is not chiselled through but is allowed to remain intact to keep the fragments from slipping. The deformity is reduced by abducting until the two cut areas are brought into contact.

II. **Epiphyseal (Adolescent) Coxa Vara.**—Here the scheme of treatment is a *restoration* of the *displaced* femoral *head* on the neck. This is necessary because of the fact that, the displacement being within the hip-joint, serious interference with the function of the joint would result if the displacement was not corrected. The procedure here differs from that in cervical coxa vara in that reposition has to be made *at the site of deformity*.

On account of the slowness of development, these cases of epiphyseal coxa vara are not, as a rule, recognized soon enough after sliding of the capital epiphysis has occurred to allow of reposition of the head by manipulative methods without open operation. Treatment necessitates cutting down on the site of displacement, a separation of whatever union has occurred (usually of the fibrous type), and a prying back into position of the femoral head by means of an osteotome or some other instrument. The mechanics of the position of internal rotation and abduction locks and fixes the fragments so securely that there is no necessity of locally securing them by means of a bone-graft peg, metal spike, or other fixation material. This will be readily appreciated by a glance at Figs. 243 and 244. Further details of the treatment of epiphyseal coxa vara will be found in the next section on Juxta-epiphyseal Fracture of the Upper End of the Femur.

TRAUMATIC COXA VARA

I. **Juxta-epiphyseal Fracture of the Upper End of the Femur.**—Under this caption the author stated in a previous publication, in 1910 (ref. Am. Jour. Orth. Surg., 1910–11, viii, p. 602), that separation of the epiphysis of the upper end of the femur contributes, to a great degree, to many of the so-called epiphyseal coxa varas which are found so frequently during adolescence.

The dividing line between epiphyseal fracture or separation and epiphyseal coxa vara is very indefinite, depending wholly on the degree of trauma which caused the disjunction or deformity. Spontaneous recovery from a partially displaced epiphysis at the hip is responsible for a class of cases presenting in adults rather indefinite symptoms of some long-standing trouble in this region which have been attributed to other causes. The history of the case may or may not disclose active symptoms at some time in the adolescent period, which subsided gradually with freedom for possibly many years, when, from some cause (trauma or osteo-arthritis), the symptoms again recurred. If no intercurrent disease is in evidence, the only signs on physical examination are as follows:



FIG. 239.—Epiphyseal separation (fracture) at upper end of femur. Note the giving away of the bone in region of the epiphyseal line. This is a case of adolescent coxa vara (epiphyseal type) in a young man of eighteen years. (See also Figs. 240 and 241.)

Very slight shortening of the limb. Slight limitation of abduction and rotation. *X*-ray examination shows a flattened and somewhat "mushroomed" head, especially its superior and inner aspects, with giving away of the head at the epiphyseal line (Fig. 239).

The cause of such frequent disjunction at the femoral head is, in the first place, due largely to the fact that this is one of the last epiphyseal cartilages to ossify and disappear; and, in the second place, to the fact of its mechanical disadvantage in sustaining trauma, muscle-pull, and weight-bearing. The preponderance of adolescents over children under ten, with respect to epiphyseal separation, is due in part to the increased severity of injury in older children but in greater measure to the anatomical development of these parts. The epiphysis and the epiphyseal cartilage are proportionately larger and thicker in young children than the shaft of the femur. The head and neck are both laid down in one large mass of cartilage, and there is

no distinct line until ossification extends along the neck from the shaft toward the head. On account of its thickness, the cartilage during this period acts like rubber as a "shock absorber" and is less liable to disruption.

Contributory causes of epiphyseal separation are rickets, scurvy, inanition, septicemia, pyemia, syphilis, and prolonged mercurial treatment. The dyspituitary type of individual is peculiarly susceptible to this accident (Figs. 240 and 241).

Cases of epiphyseal separation have been seen by the author with such diagnoses as "tuberculosis," "hernia," "ruptured muscle fibers," "fracture of the neck or upper end of the femur," "sprain," and even such an absurdity as "sprained intestine."

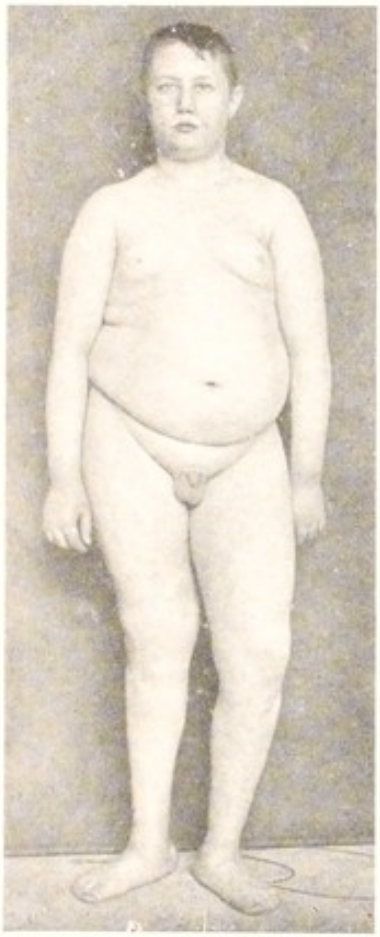


FIG. 240.—Dyspituitary type of individual particularly prone to separation of the capital epiphysis of the femur. This patient had suffered slipping of the capital epiphysis of both femora prior to the time of this photograph. The eversion of the feet is characteristic.

The symptoms or physical signs of this condition are those of fracture of the neck of the femur, with the following additions and exceptions, viz.:

Trauma may be very slight. Crepitus, which, however, is rarely obtained, is soft. There is marked fulness at the front of the joint, due to the invariable displacement of the upper end of the lower fragment forward in front of the head. If the case is recent, muscular spasm is pronounced, due to the fact that there is solution of the continuity of the bony parts *within* the joint capsule. The foot is strongly everted on account of overriding or displacement of the fractured end of the neck anterior to the head. And, it may be added, the rarefied posterior portion of the femoral neck cannot be blamed here for this displacement.

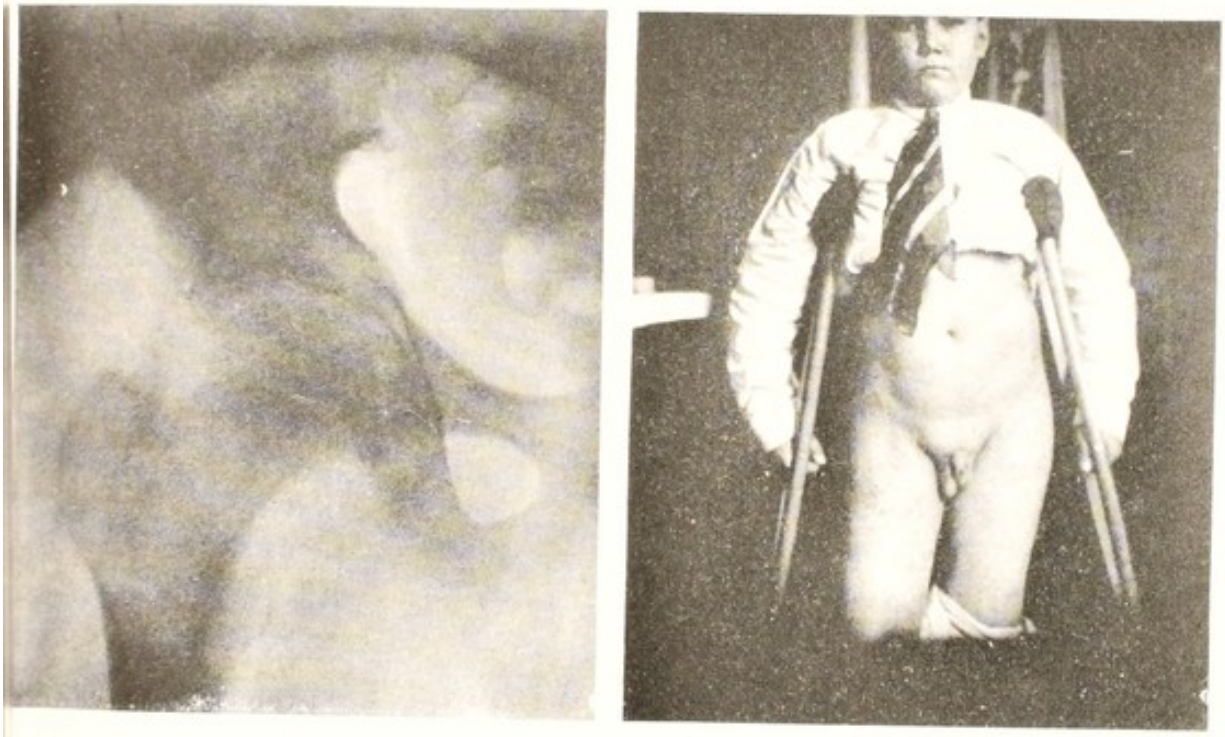
The surgeon does not often see many of these cases until sometime after disjunction and faulty union have taken place.

A correct diagnosis and proper treatment of this class of epiphyseal coxa vara are obviously of the greatest importance, in the first place, because of the necessity of integrity of the epiphyseal cartilage in the growth of bone, and hence the importance of as perfect a reposition of the sliding epiphysis as is possible; in the second place, on account of the added difficulty of obtaining and holding the capital epiphysis in consequence of its spherical shape, shortness, and inaccessibility to traction and splinting. In the third place, proper diagnosis and treatment are of paramount importance because of the danger of impaired function on account of the proximity of the lesion to the hip-joint.

As a typical instance of the almost negligible traumatic factor in these cases, the frequent gross errors in diagnosis, the characteristic symptom-complex, the usual history, and the satisfactory results of treatment in these cases of sliding of the capital epiphysis of the femur, the following case is worthy of close study:

R. B., male, seventeen years of age, referred to the writer by Dr. Leo Halpin, April 12, 1909. The following most interesting history was obtained:

Three months before, while playing and running with his schoolmates, he stopped suddenly to evade one of them and was suddenly taken with severe pain in his thigh. He stopped playing and walked home, with moderate pain and a limp. The next day he went to the dispensary of a near-by large hospital, where they told him that he had ruptured a muscle fiber in his thigh. A liniment and massage was prescribed. He slowly convalesced. Three months later, while alighting from a street car, a premature start of the car was made and he came down on the pavement with his right foot, with a great deal of force. He was immediately seized with severe pain in the region of the right thigh and was taken home. The next day he was transferred to a well-known hospital where a diagnosis of tuberculous osteitis of the hip was made. The mother, who was much opposed to the idea of having tuberculosis in her family, would not accept the diagnosis although their



a *b*

FIG. 241.—Epiphyseal separation (fracture) at upper end of femur.
a, Perfect reposition of parts by the maneuvers shown in Figs. 243, 244.
b, The type of individual particularly prone to this injury—an adolescent of muscular and obese physique—the dyspituitary type.

family physician concurred in that diagnosis. The family physician was dismissed and the boy was taken to another very well-known hospital, where the same diagnosis was again made. The mother left him there a few days and then took him home. Another physician was then called and a consultation with a well-known orthopedic surgeon was held. A diagnosis of tuberculosis was again made; terms were even agreed upon for brace treatment. The mother, still believing that it was not tuberculosis, asked for another opinion, and the writer was called. A very muscular, well nourished, rather pale boy, was found lying on the bed. He could not step on the foot on account of severe pain. There was half an inch of shortening. All motions were prevented by muscular spasm and severe pain. The trochanter was about half an inch above Nélaton's line and prominent. There was 1° rise of temperature. There was marked fulness anterior to the hip-joint. A diagnosis of epiphyseal fracture was made and a skia-

graph to confirm it was taken the next day. The case was admitted to the Post-Graduate Hospital and operated upon April 26, 1909. The hip-joint was reached by an anterior incision, starting from just inside of the anterior-superior spine of the ilium and carried downward for 5 inches. Blunt dissection was then employed to reach the point of fracture. The fractured end of the femoral neck (lower fragment) presented in the wound as it usually does. This may be very puzzling on account of the head lying far behind and being entirely obscured by the neck. As it was five weeks after the fracture, there was quite firm union. The neck was separated from the head by means of a chisel, which was then used to pry the fragments into position, at the same time that strong traction and inward rotation were applied to the limb. Good apposition was secured, and the parts were put up in a long spica in abduction and marked rotation inward. In order to hold the forced inward rotation, the leg was flexed on the thigh to a right angle. In this way the strong inward rotation forced the anteriorly displaced neck back into apposition with the head and caused the posterior part of the capsule and the unruptured soft parts to become tense, thus acting, in a way, as a splint.

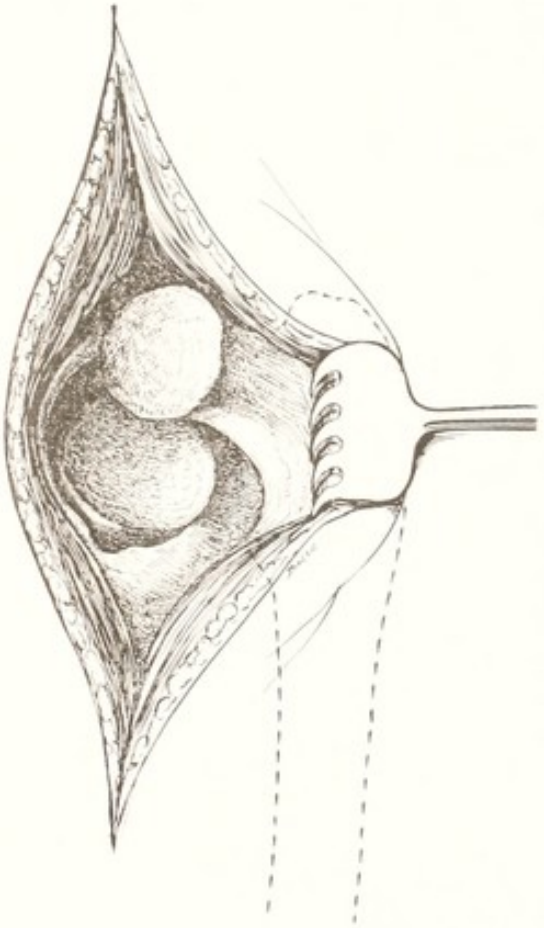


FIG. 242.—Epiphyseal separation (fracture) at upper end of femur. The head lies free in the acetabulum, behind and below the neck, its epiphyseal (cervical) surface looking directly forward. The neck is dislodged from the acetabulum, everted and dislocated upward.

The 20 and 30 degrees of abduction rotated the upper edge of the fracture end of the neck under the lip of the acetabulum, as shown in the diagram, thus preventing any possibility of an upward displacement from muscular spasm or otherwise. At the end of three weeks, the part of the plaster which was over the leg was removed and the leg extended. At the same time, an extension of plaster was applied from the knee over the foot. This was changed to a short spica at the end of six weeks. The short spica was continued until five months after the operation. The convalescence was extremely satisfactory. The motion of the hip is only slightly limited in all directions. He has no pain even when he walks long distances. A skiagraphic examination shows perfect position of fragments and perfect union. There is hardly $\frac{1}{8}$ inch of shortening.

Treatment.—If the sliding of the capital epiphysis is of recent origin, then manipulation under an anesthetic, and consisting of strong traction, abduction, and marked inward rotation (to be obtained by means of a traction table), should be tried and the limb fixed in this position in a long plaster-of-Paris spica, and the part radiographed to see if good reposition has been obtained. However, on account of the uncontrollable head, the possibility of securing good reposition is remote and open operation is usually necessary.

In either event, if the fragments are replaced they can be held in perfect apposition without metal spike, bone-graft peg, or suture by employing the above-mentioned position of abduction and internal rotation, as pointed out by Whitman (see Figs. 243 and 244). By this position, the separated end of the neck, which is always displaced forward in front of the head, is thrown backward into apposition with the separated surface of the capital epiphysis and the unruptured posterior portion of the capsule is put on the stretch and serves as a splint. The element of abduction carries the upper end of the lower fragment of the neck under the rim of the acetabulum and obviates the danger of displacement of the lower fragment upward. The internal

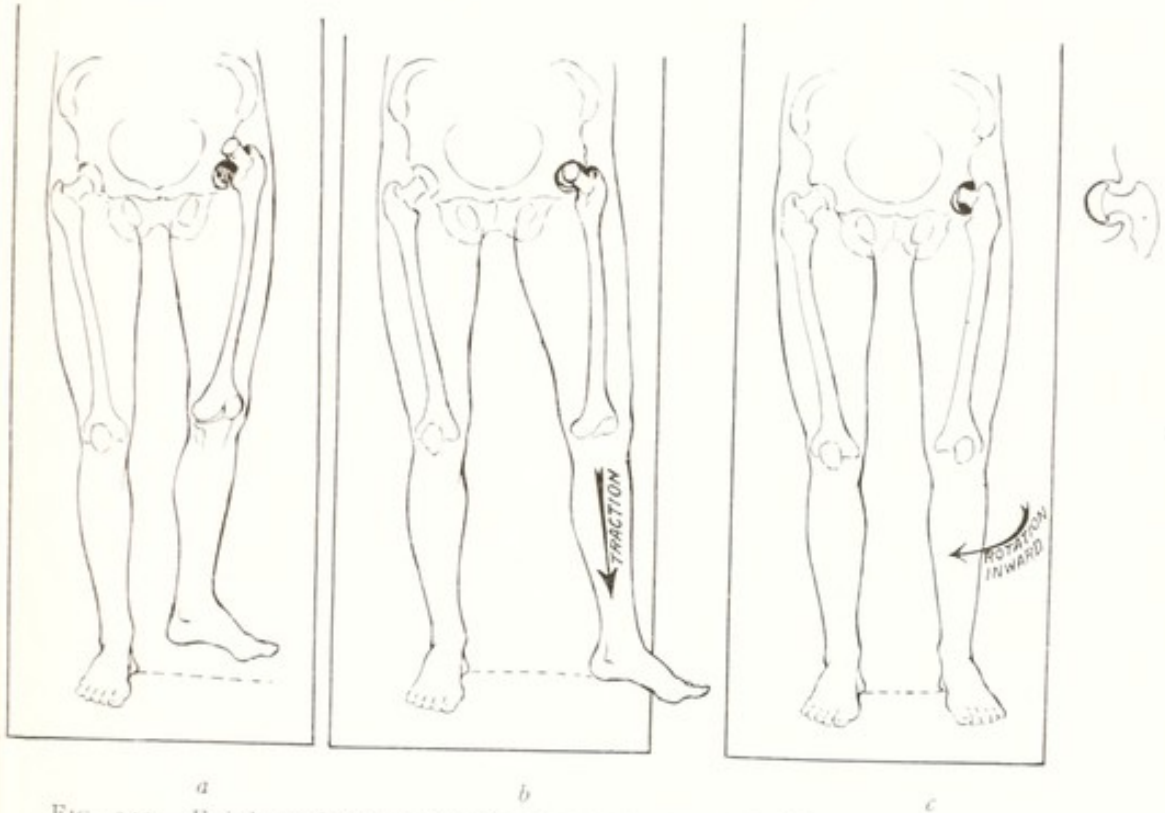


FIG. 243.—Epiphyseal separation (fracture), at upper end of femur. The maneuvers of reduction:

a. The head is free in the acetabulum and lies behind and below the neck, its epiphyseal (cervical) surface looking directly forward. The neck is dislodged from the acetabulum, everted and dislocated upward. The shortening of the lines and the eversion of the foot are marked.

b. First maneuver of reduction. *Traction* to pull the neck down below the rim of the acetabulum. Eversion (external rotation) still persists.

c. Second maneuver of reduction. *Inward rotation* of the femur to throw the neck back into the acetabulum (correcting the eversion) and into contact with the head.

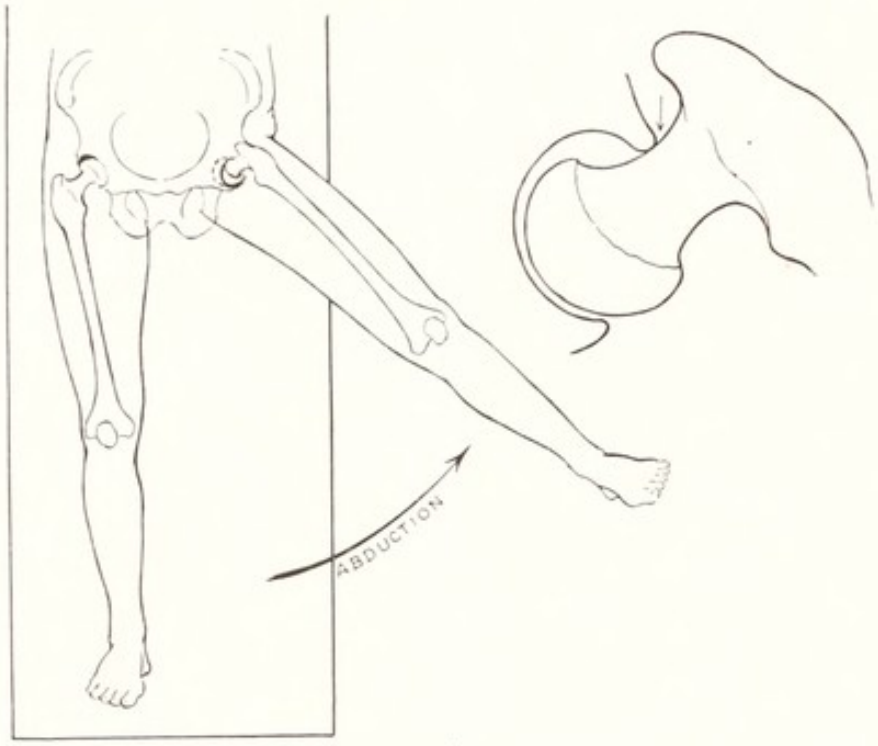
rotation is the difficult part of this position to hold, and, to obviate this difficulty, the author (Amer. Jour. Orth. Surg., vol. viii, 1910–11, pp. 602–616) flexes the knee to the right angle and is thus able in a more secure manner to maintain internal rotation perfectly by means of the long plaster-of-Paris spica, the first plaster to be retained for six weeks, after which a short spica is applied, to remain in position for ten weeks more (Fig. 245).

II. **Fracture of the Neck of the Femur in Children** (see Chapter XVIII).—This condition was for years unrecognized until its importance and not infrequent occurrence were emphasized by the writings of Whitman, who states (Orth. Surg., 1910, p. 562) that 35 cases had come under his observation

in the sixteen years prior to 1910. The fracture may be of the "greenstick" variety, complete or impacted.

Whitman states that fracture of the neck of the femur in childhood differs markedly in its symptoms and effects from a similar condition in adults, notably in the relatively slight disabling effects of the injury and in the ability to walk within a few days after the accident, which, he states, indicates bending and breaking of the neck without actual separation of the fragments. During the period of repair, he further states, the limp and attendant discomfort are usually mistaken for symptoms of hip disease.

The *diagnosis* is based upon the *history*, which usually relates a fall from a height with subsequent confinement to bed for a longer or shorter period; slight *measured shortening* (usually half an inch to an inch), with elevation of



d

FIG. 244.—Continuation of Fig. 243.

d. Third maneuver of reduction. *Abduction*, to cause the femoral neck to impinge upon the rim of the acetabulum, thus fixing the fragments and preventing the powerful thigh muscles from pulling the femur upward.

the trochanter above Nélaton's line; *restriction of motion* incident to voluntary and involuntary muscle spasm; limitation of flexion, abduction, and internal rotation are the most marked and are dependent upon displacement of the distal fragment of the neck downward and backward.

Although the immediate after-effects are less serious than in adults, Whitman states (*loc cit.*) that deformity often increases as time goes on because the strain on the neck is greater in its right-angled relation to the shaft. He furthermore has found from actual experience that, in several patients examined years after the injury, there was increase of measured shortening together with permanent adduction, at which time he states that "the deformity could not have been distinguished, except for the history, from the ordinary coxa vara of a rather extreme degree."

Treatment.—(*a*) If the case is seen soon after the accident and a diagnosis is made (for which the *x*-ray is indispensable) before firm bony union has oc-

curred, extreme abduction should be secured with retention of this position in a long plaster-of-Paris spica extending from the axilla to the toes.

(*b*) If the fragments are too firmly united to warrant abduction treatment, and yet the union not sufficiently firm to justify osteotomy, the hip-joint should be supported by a plaster-of-Paris spica or a Phelps' hip splint, to prevent further deformity.



1



2



3



4

FIG. 245.—1. Author's method of applying plaster-of-Paris spica to hold the strong inward rotation, also abduction.

2. Side view, showing application of spica over the flexed knee.

3. Epiphyseal separation from jumping off a street car while in motion. The patient did not fall, but landed on his right foot with great force.

4. Skiagram taken six weeks after the open reduction of the fracture, showing position of united fragments.

(*c*) If the case is not seen until consolidation of the neck is complete, circular osteotomy should be performed after the manner described in the treatment of cervical coxa vara (see page 473).

III. **Fracture of the Neck of the Femur in Adults.**—Inasmuch as malposition of a fractured femoral neck in adults results in coxa vara, the condition must be mentioned here, although a discussion of the subject with complete details of its treatment is to be found in Chapter XVIII, on Fractures of the Hip, etc.

Coxa Valga

Most writers dismiss the subject of coxa valga with the briefest possible mention. The condition is undoubtedly rare but it nevertheless demands some consideration.

Coxa valga is a condition diametrically opposite to coxa vara and consists of *upward* displacement of the femoral head with abduction of the femur. The symptom-complex consists chiefly of *abduction*, *external rotation*, and *limitation of adduction*, together with other less distinctive symptoms and signs. An increased angle of inclination of the femoral neck is generally considered a coxa valga.

ETIOLOGY

A. **Congenital Coxa Valga.**—1. *Associated with Congenital Dislocation of the Hip.*—It is a question whether the valgus condition of the neck is primary or secondary to the dislocation and due to the constant pressure of the pelvis against the dislocated head in walking, thus exerting strain on the epiphyseal line and causing upward bending of the head. This condition of coxa valga in congenital dislocation accounts for the difficulty in some cases, not only of reducing but of retaining such a deformed head in the acetabular cavity.

2. *Coxa Valga not Associated with Other Abnormalities.*—Young has reported several instances of coxa valga in which no other deformity was present.

B. **Acquired Coxa Valga.**—1. *Traction by a pendant limb plus absence of the body-weight above plus abeyance of action of the pelvifemoral muscle group.*

(*a*) *Infantile paralysis* of all varieties affecting the lower limbs, and even loss of activity of the lower limbs from other causes, may be followed by coxa valga.

(*b*) *Amputation through the thigh* in early childhood, with the inevitable loss of function and removal of the body-weight from above and the upward thrust of the femora from below, is followed in some instances by coxa valga.

2. Deviations of the femora from their normal relationship to the pelvis, as in the case of (*a*) tuberculosis of the hip with abduction of the femur; (*b*), scoliosis, with its unequal loading of the hips; (*c*) genu valgum; and (*d*) in rare instances in case of fracture of the shaft of the femur.

3. Traumatism, as exemplified in very rare instances by (*a*) impaction and malunion of fragments in fracture of the femoral neck; (*b*) separation of the capital epiphysis of the femur; (*c*) a direct blow applied to the great trochanter; and (*d*) a fracture of the lower end of the femur.

4. Excessive malleability of the bones, in very rare cases, in the course of or following (*a*) rickets, (*b*) osteomalacia, etc.

SYMPTOMS AND SIGNS

The condition is relatively unimportant and very rarely encountered as a clinical entity. One or more of the following signs and symptoms may be present:

(1) Pain and discomfort in the region of the hip-joint. (2) Limping in unilateral cases, and a waddling gait in bilateral cases. (3) Lengthening of a fraction of an inch. (4) Abduction and external rotation, with limitation of adduction and internal rotation. (5) Flattening of the trochanteric region and depression of the great trochanter below Nélaton's line.

DIAGNOSIS

It may be mistaken for tuberculosis of the hip, but in coxa valga pelvic inclination does not compensate for lengthening of the limb.

TREATMENT

Extreme adduction with inward rotation and fixation in a plaster-of-Paris spica may afford correction.

Equalizing the length of the limbs by a high sole on the boot of the sound side may improve the gait.

In cases with great discomfort and disability, a circular osteotomy (see treatment of coxa vara in this chapter) will effectually restore the mechanical relationship of the bony parts.

VII. EXTRA-ARTICULAR AFFECTIONS

1. Gluteal Bursitis

Inflammation with enlargement of the bursa beneath the gluteal muscles occasionally occurs, producing a rounded fluctuating swelling in the buttock. The symptoms are tenderness to pressure, limp, distress on movement, varying with the grade of inflammation. The cause is usually trauma or tuberculous infection, and the condition may be either primary or secondary to tuberculous disease of the hip.

2. Iliopsoas Bursitis

The iliopsoas bursa lies anterior to the capsule of the hip-joint and extends from the trochanter minor to the brim of the pelvis. It sometimes communicates with the joint. Enlargement of this bursa produces a quadrilateral swelling in Scarpa's triangle. The position of the iliopsoas tendon is sometimes indicated by central umbilication of this swelling. Iliopsoas bursitis is usually attended by slight flexion, abduction, and external rotation for the relief of tension.

Bursitis can be distinguished from disease of the joint by the absence of muscle spasm and of any limitation of all joint movements.

Treatment.—As tentative measures in the treatment of gluteal or iliopsoas bursitis, aspiration and the injection of carbolic acid or iodoform emulsion into the sac may be tried. Radical treatment, however, is the most satisfactory, and consists of incision and enucleation of the sac whenever possible. The iliopsoas bursa is most accessible through a vertical incision between the femoral artery and crural nerve, according to Lund (ref. Boston M. and S. Jour., vol. clvii, No. 13, p. 345), and by inward retraction or blunt dissection of the iliopsoas muscle.

MISCELLANEOUS OPERATIVE PROCEDURES OF THE HIP

1. **To Expose the Ilium for Fracture or Disease.**—Sprengel's incision.—The incision is made along the iliac crest from the posterior-superior spine to the anterior-superior spine. The muscles are reflected sub-periosteally from the crest. The incision is bisected by a vertical one down to the top of the great trochanter. The skin, fat, muscle, fascia, and periosteum are retracted *en masse* downward and also anteriorly and posteriorly from the bone, thus exposing the ilium.

2. **To Expose the Sacro-iliac Joint.**—An incision is made from a point 2 to 4 inches anterior to the posterior-superior iliac spine, extending backward along the iliac crest and curving downward along the lateral border of the sacrum. If preferred, a curved incision may be made from a point 1 inch external to the third or fourth lumbar spinous processes, curving outward beyond the posterior spine of the ilium on the affected side and downward to the top of the coccyx. By dissection of the flap the fascia is exposed, and by continuation of the dissection the sacrum is readily bared.

3. **Arthrotomy.**—The anterior and lateral incisions are described in Chapter XVIII, and the Sprengel or Smith-Peterson method, page 216.

(*a*) *Posterior Incision.*—The incision begins 2 inches below the top of the great trochanter and extends upward to a point on the crest about 3 inches anterior to the posterior-superior spine. The primary incision extends through the skin and fat, exposing the muscle layer. For the purpose of drainage, the fibers of the gluteus maximus may be separated by blunt dissection, or some of the fibers cut. If preferred, the aponeurosis of the gluteus maximus, as well as some of the fibers of the gluteus minimus, may be separated from the great trochanter and retracted, exposing the capsule of the joint. The latter is open in the line of its fibers.

(*b*) *Murphy's* U-*shaped Incision.*—The sides of this incision are about 5 inches long and 3 inches apart. The incision begins above and about 1 inch behind the trochanter and extends 2 inches below the top of the latter, which should be in the center of the U. The anterior portion of the U starts 2 inches below and 1 inch anterior to the trochanter and extends upward in a straight line for 5 inches to the anterior-superior iliac spine. By retracting skin, fat, and fascia upward, the trochanter is exposed.

(*c*) *Anterior* U-*incision* (Brackett).—An inner incision extends downward from a point just below the anterior-superior spine a distance of 5 inches (just external to the artery), thence 3 to 4 inches in a curved direction anteriorly, and 5 inches upward anterior to the trochanter. The sartorius is retracted inward, together with the rectus, and the tensor fasciæ femoris outward.

4. **Exposure of the Sciatic Nerve.**—The incision is made in the posterior aspect of the thigh, 3 inches in length, in the middle line and begins at the gluteal fold dividing the lower fibers of the gluteus maximus. The tissues below this muscle are separated by blunt dissection. The sciatic nerve is now palpable and is brought into full view by retraction of the muscle.

5. **Exposure of the Gluteal Bursa.**—An incision 3 inches long is made over the great trochanter, its long diameter parallel with the femoral shaft. Upon elevating the fascial portion of the gluteus maximus, the bursa is thoroughly exposed and can be readily dissected out, incised, or drained.

6. **Aspiration or Injection of the Hip-joint.**—The trocar may be entered from the front or the side of the hip. It may be thrust into the joint just above the great trochanter, passing directly inward. If the anterior approach is desired, the joint may be reached from a point on the same level but in the front of the thigh (Fig. 246). Upon reaching the femoral head or neck, the sharp point of the trocar may be withdrawn and the dull end used as a probe to locate the exact point of entry.

In this maneuver, the skin should be drawn to the side so that the puncture holes in skin and muscle will be out of alignment upon withdrawal of the trocar. For infectious synovitis, Murphy recommended that a formalin-glycerin solution be injected. Its composition is: Liquor formaldehyd, 2 per cent. in glycerin (about 10 drops of formaldehyd to 1 ounce of glycerin).

Murphy advised that the solution be prepared twenty-four hours in advance of its use.

7. **Operation for Separation of the Capital Epiphysis.**—The anterolateral incision described in Chapter XVIII is the easiest method of approach when operating for this condition.

8. **Drainage for Suppuration.**—(*a*) *Acute Arthritis of Infancy.*—In addition to what has already been said with regard to the treatment of this condition (page 486), the incision for drainage is preferably the anterolateral incision, omitting its second part. The joint should be opened as soon as the diagnosis has been made, the incision extending down to the capsule, the latter opened by a minute incision, and a tube inserted. This is usually all that is required. Evacuation of the pus relieves the tension in the capsule and obviates the danger of spontaneous dislocation. This procedure is applicable also to suppuration of the hip from any condition, such as following middle-ear disease, scarlet fever, or other acute infections. After drainage, the hip should be immobilized with sand-bags, and the patient placed upon a Bradford frame.

(*b*) *Osteomyelitis of the Hip.*—Thorough drainage is the desideratum. If the disease is not so extensive as to warrant wide exposure of the joint, particularly if it is confined to the head and neck of the femur, prompt evacuation of the pus is of paramount importance, otherwise the invasion of the synovial cavity along the line of least resistance through the thin layer of cartilage of the head, is likely to occur. If the capsule, with its wide expanse of synovial surface, were once infected with pus from the original focus through a communicating sinus, it would preclude the possibility of radical cure by any method. Huntington has said, "If an attempt at relief can be instituted through a channel which will avoid interference with the joint capsule, afford relief of tension, and admit of more or less complete removal of infected tissue, such a procedure would seem to be based upon sound surgical doctrine. This would mean operative interference at a time when rest, traction, and fixation are the acknowledged reliance." Actuated by a suggestion of Macnamara of Dublin, Huntington (Surg., Gyn. and Obst., vol. ii, No. 4, pp. 406–10, April, 1906) described an operation for trephining the subtrochanteric region of the femur and tunnelling through this opening with a small bone curet into the neck of the femur. If there is any evidence of focal lesion, external to the epiphyseal cartilage, further efforts may be suspended. If it is necessary to enter the head of the bone, this should be accomplished by some instrument, establishing a channel of communication between the head and neck, through which, as a line of least resistance, a liquefied focus may find exit. Such a channel may be employed not only for drainage, but for the removal of sequestra.

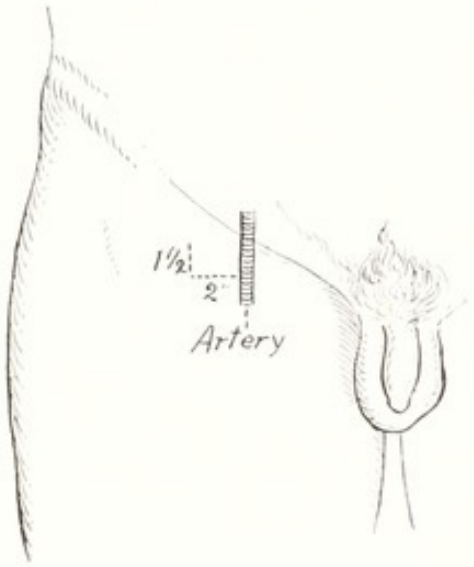


FIG. 246.—Landmarks for aspiration or injection of the hip-joint. In an adult, the needle is introduced at a point 1½ cm. below the horizontal plane of the pubic spine and 2 cm. external to the femoral artery.

The author suggests that the large drill attachment of his motor outfit be used (following the technic employed for inserting the bone-graft peg, see Chapter XVIII), and a hole bored from the great trochanter into the neck

until the focus is reached, any sequestra found removed, and the channel either packed with iodoform gauze or left open for drainage.

REFERENCES

COXA VARA

FIORANI: "Sopra una forma speciale do zoppicamento." Gazz. degli ospedali., 1881.
MÜLLER: Centralbl. f. Chir., Nov. 27, 1897.
MÜLLER: Beiträge z. klin. Chir., 1889, iv, Sec. 137.
RICHARDSON: "Deformity of the Neck of the Thigh Bone Simulating Fracture, with Ossific Union." Trans. Philadelphia Pathol. Society, 1857.
MONKS: "Case of Unusual Deformity of Both Hips." Bost. Med. & Surg. Jour., Nov. 18, 1886.
KEETLEY, C. B.: "A Case of Rhachitis Adolescentium." Illustr., Med. News, September, 1888.
KÖCHER: "Über Coxa Vara, eine Berufskrankheit des Wachstumsperiode." Zeitschr. f. Chir., xxxviii.
HOFMEISTER: "Coxa Vara eine typische Form der Schenkelhalsverbiegung." Beiträge z. klin. Chir., Bd. xii.
HELBING, CARL: Zeitschr. f. Orthop. Chir., Bd. xv, Hefte 2, bis. 4, 1906.
WHITMAN, ROYAL: New York Med. Rec., July 25, 1893.
WHITMAN, ROYAL: Annals of Surg., June, 1897; February, 1899; November, 1902.
WHITMAN, ROYAL: Med. News, September 24, 1904.
KÖCHER: Joachimstal's Handb. f. orth. Chir.
KIRMISSON: "Deformités acquises." Paris, 1902.
KREDEL: Centralbl. f. Chir., No. xlii, 1896.
JOACHIMSTAL: Arch. f. Gynäcol., lxv.
JOACHIMSTAL: Zeitschr. f. orth. Chir., xii, Hefte 1 and 20.
REINER: Zeitschr. f. orth. Chir., ix.
DREHMANN: Verhandl. d. deutschen Gesells. f. orth. Chir., I. Kong., 1902.
HELKING: Zeitschr. f' orth. Chir., 1906, xv.
FRANCKE: Verhandl. d. deutschen Gesells. f. orth. Chir., II. Kongress, 1903.
ELMSLIE: Lancet, February, 1907.
HOHMANN: Münch. med. Wochenschr., June 7, 1910, lvii, No. 23.
DREHMANN: Zeitschr. f. orth. Chir., 1906.
JOACHIMSTAL: Handb. d. orth. Chir., 6 u. 7, Lieferungen.
FREIBERG: Amer. Jour. Orth. Surg., July, 1905.
NASSE: Beitr. z. Centralbl. f. Chir., 1897, xxviii.
MAYDL: Wiener klin. Rundschau., 1897, Nos. x, xi, xv.
VON BRUNN: "Über die juvenile Osteo-arthritis Deformans des Hüftgelenkes." Beitr. z. klin. Chir., xl, Heft. 3.
KIRMISSON: Rev. d'orthop., November, 1898.
SPRENGEL: Arch. f. klin. Chir., lvi, 1898.
HESSE: Zeitschr. f. orthop. Chir., xv.
BROCA, A.: Presse méd., March 4, 1905.
GAUDIER: Rev. d'orth., March, 1905.

TRAUMATIC COXA VARA

WHITMAN, Royal: "Further Observations on Fractures of the Neck of the Femur, etc." Annals of Surg., 1897. New York Med. Jour., Jan. 21, 1899.
WHITMAN, ROYAL: Annals of Surg., 1900.
WHITMAN, ROYAL: Annals of Surg., 1902.
WHITMAN, ROYAL: Trans. Am. Orthop. Ass'n, 1902.
CHARPENTIER: Thèse de Doct. Paris, 1897.
DE QUERVAIN: "De la Coxa Vara." Sem. mèd., No. 6, 1898.
SPRENGEL: "Über die traumatische Lösung der Kopfepiphyse, etc. Verhandl. d. deutsch. Gesells. f. Chir., 1898.
SPRENGEL: Arch. f. klin. Chir., lix.
KIRMISSON: Rev. d'orthop., 1898, p. 459.
JOACHIMSTAL: Sammlung. klin. Vorträge, No. 215, 1898.
JOACHIMSTAL: "Über Coxa Vara Traumatic Infantum." Arch. f. klin. Chir., lx, 1899.
FROELICH: Rev. d'orthop., 1900.
STIEDA: Arch. f. klin. Chir., Heft. 3, 1901.

GLUTEAL AND ILIOPSOAS BURSITIS

Brackett, E. G.: "Gluteal Bursitis." Trans. Am. Orth. Ass'n, x.
Wieting: Deutsch. Zeitschr. f. Chir., September, 1904.
Zuelzer: Deutsche Zeitschr. f. Chir. i, Heft. 1 and 2.
Lippfert: Beitr. z. klin. Chir., xl, 503.

OSTEO-ARTHRITIS OF HIP

Albee, F. H.: "A New Method for Osteo-arthritis of the Hip." Jour. Am. Med. Ass'n, June, 1908.
Albee, F. H.: "A Further Report of a New Operation for Arthritis Deformans and Certain Other Deforming Affections of the Hip." Surg., Gyn. and Obst., March, 1910.

MALIGNANT DISEASES OF THE HIP

Wyeth: Ann. of Surg., 1901, xxxiv.
Jenckel: Deutsch. Zeitschr. f. Chir., 1902, liv.

PARALYTIC DISLOCATIONS AND SUBLUXATIONS OF HIP

Dislocations of Hip-joint

Sever, J. W.: "The Causes and Treatment of Paralytic Dislocations and Subluxations of the Hip-joint." Bost. M. and S. Jour., clxv, No. 9, 313–323, Aug. 31, 1911.
Reclus: Rev. de. Méd. et Chir., 1878, p. 170.
Karewski: Ann. Surg., x, 1889, p. 226.
Stimson: "Fractures and Dislocations," vol. ii, 1899.
v. Nicoletti: Zentralbl. f. Chir. Mech. Orthop., January, 1910, p. 44.
Vulpius: Münch. Med. Wochenschr., 1908, s. 7.
Böcker: Verhandl. Deutsch. Gesellsch. f. Orthop. Chir., Bd. xxiv, April, 1909.
Cramer, K.: Arch. f. Orthop. Mech. u. Unfallchir., Bd. ix, Heft. 1, 1910.
Reidinger: Ibid., Bd. viii, Heft. 3, 1910.
Lovett and Lucas: Jour. Am. Med. Ass'n, vol. li, Nov. 14, 1908.
Verneuil: Bull. de la Soc. de Chir., Gaz. de Hôp., No. 70, 1866.
Tubby: Orthopedic Surgery, 1896.
Bradford and Lovett: Ibid., 2d Ed., 1899.
Keen: "Keen's Surgery," vol. ii, 1907.
Taylor, H. L.: Orthopedic Surgery, 1909.
Sayre: Orthop. Surg., 1883.
Hoffa: Orthop. Surg., 1905.
Holtzmann: Virchow's Archiv f. Path. Anat. u. Phys. F. K. Med., Bd. 140, 1895.
Rich, E. A.: Northwest. Med. Jour., Seattle, vi, 335, 1908.
Martin: Zeitschr. f. Orthop. Chir., x, 4, 1902.
International Text-book of Surgery, 1900.
Gray: "Gray's Anatomy" (Pick's Edition), 1897.
Lombard and Abbott: Am. Jour. Physiology, xx, No. 1, October, 1907.
Mercière: "Contribution en Traitement de la Hanche Paralytique, etc." Extrait du Congrès Français de Chirurgie, 23d Session, Paris, 1910.

PERTHES' DISEASE

Allison and Moody: "Osteochondritis Deformans Juvenilis (Perthés' Disease)." Am. Jour. Orth. Surg., October, 1915.
Legg: "An Obscure Affection of the Hip-joint." Boston Med. and Surg. Jour., Feb. 17, 1910.
Perthes: "Osteochondritis Deformans Juvenilis." Verhandl. Deutsch. Gesell. f. Chir., 1913.
Sonderlund, G.: "Non-tuberculous Hip-joint Disease in the Young." Upsala Lab. for Hand, Jan. 10, 1915.
Moller, P. F.: "Deforming Osteochondritis in the Young." Ugeskrift for Laeger, Feb. 5, 1915, lxxxi, No. 6.
Wilkee, D. P. D.: "Osteochondritis." Edinburgh Royal Inquiry Report, 1915.
Michelson, K.: "Probable Non-tuberculous and Non-rahachitic Hip-joint Trouble in Boys." Deutsch. Med. Woch., Berlin, Feb. 18, xli, No. 8.
Delitala, F.: Perthés' Disease." Am. Jour. Orth. Surg., xii, No. 4, 1195.

CHAPTER XV

MISCELLANEOUS AFFECTIONS OF THE KNEE AND OTHER JOINTS

KNEE-JOINT

Traumatic Affections and Internal Derangements

1. DISPLACEMENT OF THE SEMILUNAR CARTILAGE

As the result of a twist or wrench, usually a lateral strain on the joint in partial flexion, a dislocation of one or both semilunar cartilages may be produced. The internal is displaced about ten times as frequently as the external cartilage.

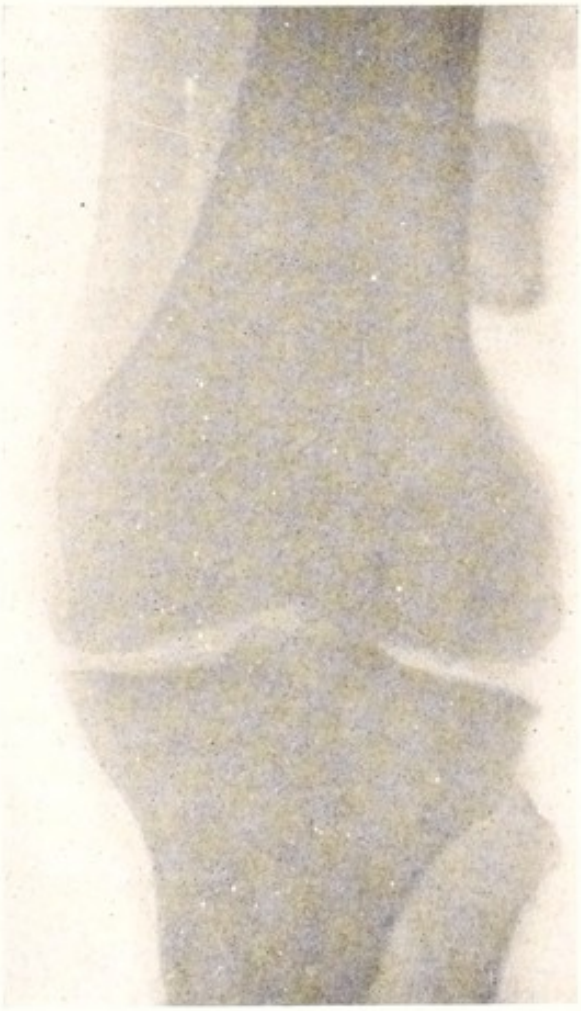


Fig. 247.—Joint-mouse in knee-joint. Probably due to trauma years before resulting in fracture and dislodgment of piece of joint cartilage into knee-joint.

Anatomical Data.—The external and internal semilunar fibrocartilages are two crescentic plates of dense compact structure, attached by their thick, convex, outer surface to the inside of the capsule. They rest upon the circumferential portions of the upper articular facets of the tibia, covering a little less than two-thirds of these surfaces. They increase the concavity of these surfaces for articulation with the femur by a gradual thinning to their concave, free, inner borders. Their upper, concave, femoral, and lower, flattened tibial surfaces are free and covered by synovial membrane. They taper to their attached ends or *cornua*, which are purely fibrous and are fastened in front of and behind the tibial spine, the cornua of the external cartilage being within those of the internal. The external semilunar cartilage is therefore more circular, the internal is more oval and longer from before backward. The external is also more movable, from the close approximation of its cornua and from the greater laxity of the part of the capsule to which it is attached. Its outer surface is grooved behind and separated from the capsule by the popliteus tendon, the bursa surrounding which connects with the joint above and below the cartilage (Gerrish).

Clinical Anatomy.—The fact that the knee is not a true hinge-joint is frequently forgotten, yet it must be borne in mind that rotation of the tibia on the femur occurs during flexion and extension of the knee. Lateral movement of the joint is prevented by the lateral and crucial ligaments, but when these are stretched and relaxed the joint can undergo lateral movement with consequent separation of the contiguous surfaces of the femur and tibia. The external semilunar cartilage is attached very slightly, if at all, while the internal cartilage has a strong attachment to the internal lateral ligament, is less movable than the external, and more intimately adherent to the capsule. This explains the effect of strain on the internal lateral ligament in dislodging the internal cartilage. The cartilages are both attached to the tibia by fibrous bands. The internal cartilage moves with the femur during its inward rotation in the act of flexion of the knee. As has been stated, synovial membrane exists on both the upper and lower surfaces of the cartilages, and this fact explains the occurrence of effusion into the joint after dislocation of these cartilages. The internal cartilage is further attached at its circumference by bands of fibrous tissue extending to the internal lateral ligament, thus assuring its movement with the femur on rotation of the latter.

Etiology.—The mechanical factors producing dislocation of the internal semilunar cartilage are *flexion of the knee, inward rotation of the femur, and the application of force through the inner side of the knee-joint.* This position is always attained in *abduction of the foot* which also puts the greatest strain on the internal lateral ligament. The cartilage is sometimes displaced toward the center of the joint; in other cases it rotates on a central pivot, its anterior cornu swinging forward and outward, its posterior cornu inward, in which position the classical sign of "locking" of the joint occurs.

The degree of force necessary to dislocate a semilunar cartilage varies widely. Dislocation occasionally results from so slight an accident as catching the toes in the bedclothes. Other causes are: dancing, golf, football, baseball, and other sports, or wrenching the leg by entanglement in the spokes of a wheel. The etiological bearing of very acute flexion of the knee (practised in the course of plumber's work) and such acts as crawling under a table, is very apt to be overlooked.

Clinical Features.—The immediate after-effect of dislodgment of a semilunar cartilage is acute pain, with inability fully to extend the leg. These phenomena are soon followed by effusion into the joint, which remains for several days or even longer. Full extension of the leg is frequently impossible without recourse to the manipulative or operative methods about to be described.

Recurrences of the dislocation are common and are characterized by a locking of the joint so sudden in onset that the patient frequently falls to the ground; this is followed by effusion, as in the primary accident, and increased relaxation of the lateral ligaments and consequently increased range of lateral motion, with increasing predisposition to recurrent dislocations. The edge of the dislodged cartilage may, in some instances, be palpable through the surface of the joint.

The severity of the symptoms varies with the degree of mutilation or floating of the displaced cartilage. The following are some of the accidents which may befall a dislocated semilunar cartilage:

Torn from its anterior attachment; torn transversely near the lateral ligament; longitudinal splitting; dislocation into intercondyloid notch; loose, cystic, and ossified cartilage.

In the event of recurring dislocations, the edges of the cartilage become

thin and frayed. From the clinical manifestations, it is occasionally impossible to tell which cartilage is affected.

Diagnosis.—Absolute diagnosis is founded on a history of trauma to the knee, followed immediately by locking of the joint during function, tenderness most marked on the inner or outer aspects of the joint, according to which cartilage is deranged, and by lateral movement at the knee.

Differential Diagnosis.—(*a*) *Loose Bodies.*—Locking of the knee occurs, but it is transient and is usually easily remediable by manipulation or may disappear spontaneously.

(*b*) *Hypertrophied Synovial Fringes.*—There is pain over the affected portion of the membrane, absence of tenderness in the region of the internal lateral ligament, and the hypertrophied mass is frequently palpable.



FIG. 248.—Method of examining the knee in determining the presence of fluid in the joint. The fluid is milked under the patella from the joint pouches above and below, in the upper drawing and the surgeon is testing for ballottement of the patella by pressing with the forefinger of the right hand.

(*c*) *Lipoma Arborescens.*—The symptoms are mild, and there is present a chronic swelling which is slightly tender, appreciable on either side of the ligamentum patellæ. Furthermore, no effusion exists.

(*d*) *Rupture of the Internal Lateral Ligament.*—If below the attachment of the semilunar cartilage, the latter is not displaced; if above, the cartilage may be displaced toward the center of the joint. In the case of a ruptured lateral ligament, an extreme degree of lateral movement is obtainable on extension of the leg, with tenderness over the ruptured ligament.

(*e*) *Ruptured Crucial Ligaments.*—The tibia can be freely dislocated backward or forward, or in both directions, on the femur; and on flexion, lateral motion is abnormally free.

Treatment.—Manipulation should first be attempted, and for its successful execution an anesthetic may be necessary. The following movements should be practised in the order prescribed, viz.: (*a*) acute flexion; (*b*) lateral deviation and internal rotation of tibia; and (*c*) complete extension.

The effusion is best treated by local applications of heat or cold and counterirritants with the leg in full extension and immobilized by a posterior splint of plaster-of-Paris or other material, to prevent any lateral movement. Walking must be strictly forbidden until all tenderness has disappeared from the site of dislocation or over the internal lateral ligament; this may cover a period of two to six weeks.

An ambulatory support is indispensable when the patient begins to walk. The essential requirement of such an apparatus is that it prevents any lateral motion in the joint, and to fulfill this object most supports for this purpose are constructed somewhat as follows (Fig. 250): A ring above and one below the joint are connected by two vertical steel rods hinged at the knee-joint behind; a pad is so placed as to make pressure on the anterior aspect of the dislocated cartilage; the apparatus is made to embrace varying extents of the limb, according to the severity of the disability, reaching from the middle of the thigh to the middle of the calf in cases of extreme laxity of the lateral ligaments. Further insurance against lateral motion at the knee may be secured by re-inforcing the inner edge of the sole and heel of the boot. Flexion in the apparatus should be limited at first to 30 degrees, then 60, then 90. The patient should be instructed to walk with the feet parallel, and in running, to toe in. Massage should be systematically administered while the apparatus is being worn, not only to maintain the tone of the joint but also to preclude wasting of the tissues.

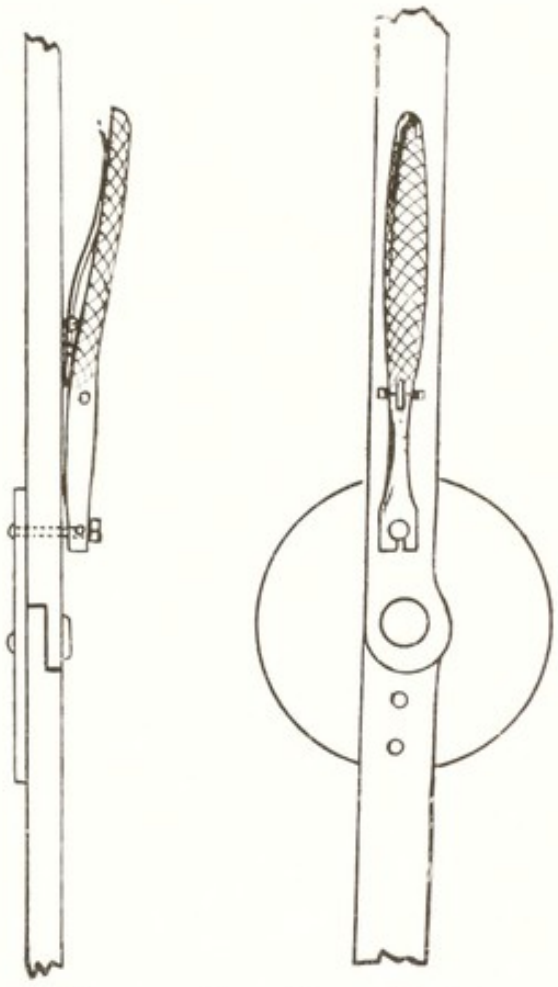


FIG. 249.—Snap joint. (Taylor.)

Another method of mechanical support is offered by a knee-lacing of canvas or light leather, with a pad over the cartilage involved. The use of apparatus, however, is far less reliable and satisfactory than removal of the offending cartilage. If the cartilage does not immediately become fixed in position by conservative methods, time is wasted by prolonged delay.

Operative Treatment.—It is, as a rule, unwise to operate in a case of primary dislocation of a semilunar cartilage, but when the patient is unable to afford the time or the means to use a mechanical support, or would be hindered in the pursuit of his occupation by such a contrivance, and in the case of artisans whose work takes them to superstructures where a fall would be fatal, and those cases in which external supports have been tried and found wanting, operative interference is clearly indicated.

The dread of surgery of the knee-joint has now been largely dispelled by the elaboration of modern aseptic technic, so that in these days the

surgeon can open the knee-joint as safely as any other cavity of the body without the danger of infection or other surgical accident.

Technic.—After the usual iodin preparation of the patient, following the method described elsewhere in this book, and the application of a tourniquet above the knee, the joint is entered by the lateral incision of Sir Robert Jones (Fig. 252). If both cartilages are deranged, or if uncertainty exists as to which one is affected, median bisection of the patella should be performed.

A case in point illustrates the limitations of a unilateral incision where any doubt exists as to the location of the offending cartilage. A patient had been operated upon by the lateral approach for suspected derangement of one semilunar cartilage and subsequently wore an apparatus for ten years without relief. At the end of this period, the author exposed the joint a second time, but in this case by median bisection of the patella and

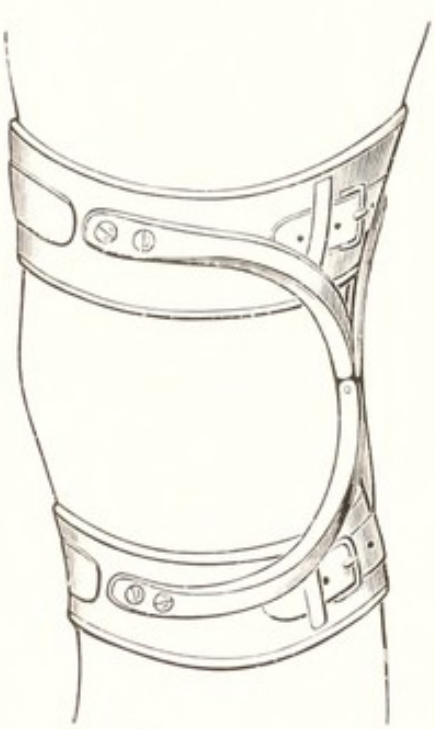


FIG. 250.



FIG. 251.

FIGS. 250 and 251.—The Griffiths brace. (Jones.)

found the inner edge of the internal cartilage splint longitudinally and whipping back and forth in the joint like a jumping rope, at each movement of the knee. Removal of the cartilage at once relieved all symptoms.

The author's modification of Jones' method may be employed (see Figs. 254 and 255) in the case of dislocation of only one cartilage. If the cartilage is at all mutilated, or even in the event of a typical history of dislocation, it is best to remove it, inasmuch as it is not always possible to determine whether or not it is abnormally loose. The author believes that it is never advisable to suture a movable cartilage back into position; its removal does no harm, and at the same time it completely relieves the patient of all symptoms. Removal is best accomplished by curved scissors. If it is deemed advisable to retain the cartilage, it should be fastened to the cartilaginous margin of the tibia with two or three sutures of fine silk. After removal of the tourniquet and the obliteration of all bleeding points, the synovial membrane and the capsule are closed with a continuous suture of

No. 0 chromicized catgut, and the skin with a continuous suture of No. 0 plain catgut. After the proper dressings have been applied, the joint is immobilized in a plaster-of-Paris cast from toes to groin, for a period of seven to ten days. Massage is instituted about the tenth day after operation. At the end of the second postoperative week, gentle manipulation and flexion are in order, and at the end of the third week mild exercise may be allowed.

Other Loose Bodies in the Knee-joint.—Besides the dislocated semilunar cartilage, other loose bodies are sometimes found in the knee-joint, their commonest location. These bodies may be composed of masses of fibrin, fragments of synovial membrane, or particles of cartilage or bone. They are occasionally encountered in large numbers in some types of synovial tuberculosis and arthritis deformans, and are sometimes seen in cases of otherwise normal joints, in which event the patient can appreciate the presence of a smooth, movable body at one side of the patella. Frequently the initial sign of their presence is a disturbance of the joint function. Severe pain and locking of the knee in flexion occasionally occur, as in the case of dislocation of the semilunar cartilage. The offending foreign body may often be dislodged from its position between the joint surfaces by massage, manipulation, or spontaneously, but as a rule distress and effusion into the joint follow and are persistent. The treatment of obstinate cases is removal of the loose body by median bisection of the patella, as described on page 498.

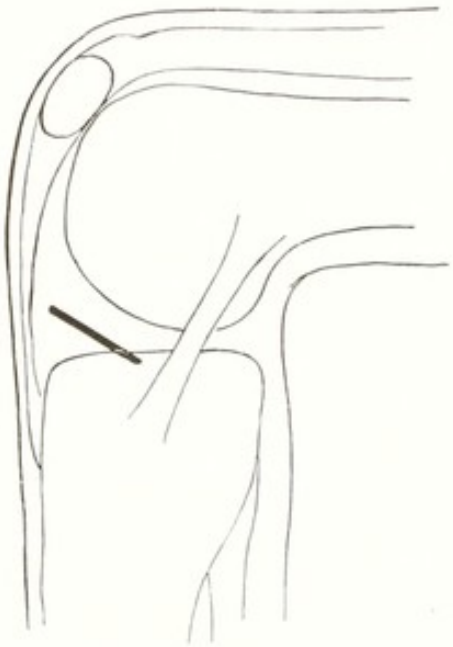


FIG. 252.—Indicates location and direction of incision for approach to the internal semilunar cartilage with the knee flexed.

2. RUPTURE OF THE CRUCIAL LIGAMENTS AND FRACTURE OF THE SPINE OF THE TIBIA
(Fig. 253)

Fracture of the spine of the tibia is often associated with rupture of one or both crucial ligaments, but either accident may occur without the other. Rupture of one or both crucial ligaments undoubtedly occurs frequently in dislocations of the knee-joint. Sir Robert Jones (Brit. Jour. Surg., 1915, i, p. 70) states that the first recorded operation for ruptured anterior crucial ligament with avulsion of the spine of the tibia, was done by Hogarth Pringle in 1907. Fracture of the tibial spine is, in some cases, the result of extreme traction on the anterior crucial ligament, while in other cases some other force is operative.

Jones (*loc. cit.*) thus enumerates the important points in the mechanism of the crucial ligaments:

(*a*) The anterior crucial ligament is tense when the knee is fully extended, and prevents the tibia from being displaced forward on the femur.

(*b*) The posterior crucial ligament is tense in complete flexion and prevents the tibia from being displaced backward on the femur.

(*c*) Both ligaments check inward rotation of the tibia.

Therefore, if, following an injury to the knee, manipulation allows forward displacement of the tibia or its inward rotation in the position of

extension, disturbance of one or both crucial ligaments may be safely inferred.

If the tibia cannot be displaced forward, with the leg extended, the anterior crucial ligament is intact. If it cannot be displaced backward, with the leg flexed, integrity of the posterior crucial ligament may be assumed.

The history of injury will exclude abnormal mobility due to derangement of the ligaments consequent upon chronic effusion into the joint, Charcot's arthropathy, etc.

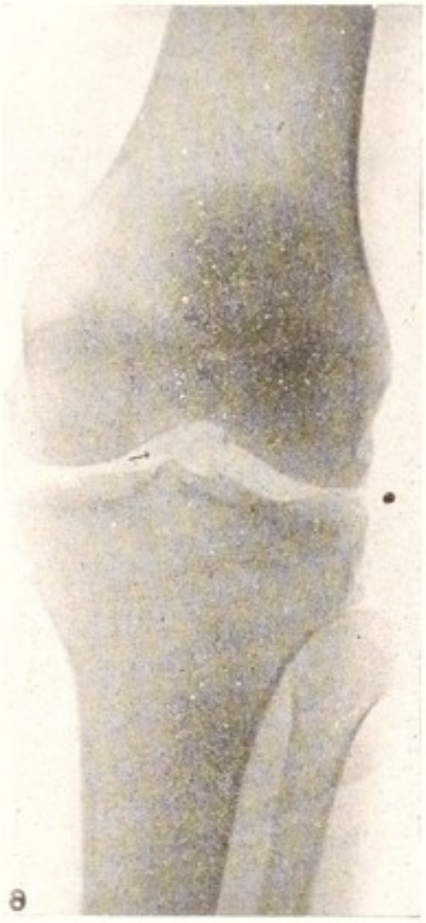


FIG. 253.—Fracture of tibial spine. Fragments indicated by arrow. This accident detaches the crucial ligaments from their moorings and relaxes the knee-joint. The tibia can be passively moved to and fro (antero-posteriorly) on the femur when the knee is flexed—a clinical feature of great diagnostic value. The diagnosis was confirmed by radiograph in this case.

Jones states further (*loc. cit.*) that the most constant sign of fracture of the spine of the tibia is inability fully to extend the leg. The obstruction feels bony on manipulation and is markedly different from the locking due to a dislocated semilunar cartilage.

Jones classifies these injuries as follows:

(*a*) Avulsion of the tibial spine or its internal tubercle.

(*b*) Fracture of the external tubercle of the spine.

(*c*) Injury to the spine, combined with fracture of a tuberosity of the tibia.

(*a*) **Avulsion of the Tibial Spine or its Internal Tubercle.**—This is due to extreme tension on the crucial ligaments by the mechanism which produces rupture of those structures. Extreme violence is necessary to produce this accident, such as a land-slide, coal-slide, wrenching the leg in the spokes of a revolving wheel. A flail-like knee is produced by the severer injuries.

The ruptured ligaments unite firmly as a rule, if the joint is immobilized for a long period, so that cases seen late exhibit no great amount of abnormal mobility.

In rupture of the anterior crucial ligaments, internal rotation of the leg is the most important mechanical factor. After the ligamentous fibers have begun to tear, abduction of the leg stretches the ligament across the sharp internal margin of the external condyle.

A characteristic method of fracture of the internal tubercle of the tibial spine is as follows, according to Jones (*loc. cit.*):

An individual is thrown forward on his flexed knees, with the feet turned inward and with the knees and feet forced against the ground. The body goes forward by its own momentum until the individual measures his length on the ground. The knees are thus forcibly extended while the foot is still pressed on the ground and the leg rotated inward, the toes being also fixed in inversion. Instead of the condyle circling around the tibial spine at the end of extension, it impinges on the back of the internal tubercle of the spine and fractures it.

(*b*) **Fracture of the External Tubercle of the Spine.**—This accident is not associated with injury of the crucial ligaments. The fragment of detached bone is very small and is not in the region of attachment of either

crucial ligament. The tip of the external tubercle is broken off, probably from behind, by the sharp internal border of the external condyle by impact of the femur forward or the tibia backward. An unusually high tibial spine is particularly liable to this accident. The mechanism of the injury is similar to that which produces dislocation of the internal semilunar cartilage (*q.v.*).

(*c*) **Injury to the Spine with Fracture of One of the Tuberosities of the Tibia.**—This injury is more serious than in the preceding instances, and the line of force producing it is more direct.

Treatment.—(1) *Ruptured Crucial Ligaments.*—Excellent recovery is the rule in cases of dislocation of the knee and of ruptured crucial ligaments, by prolonged immobilization in plaster-of-Paris for many weeks. This statement is true even for total dislocation of the tibia. A ruptured crucial ligament combined with dislocation of the knee is a much more serious affair than when either accident

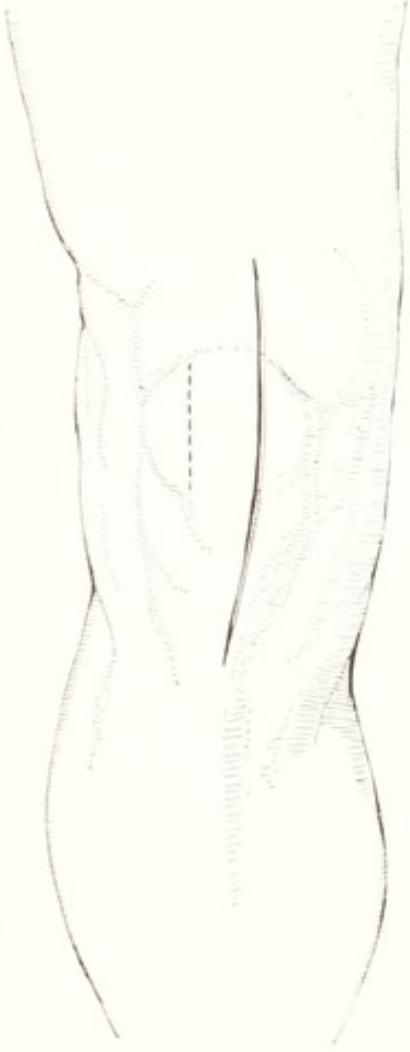


FIG. 254.

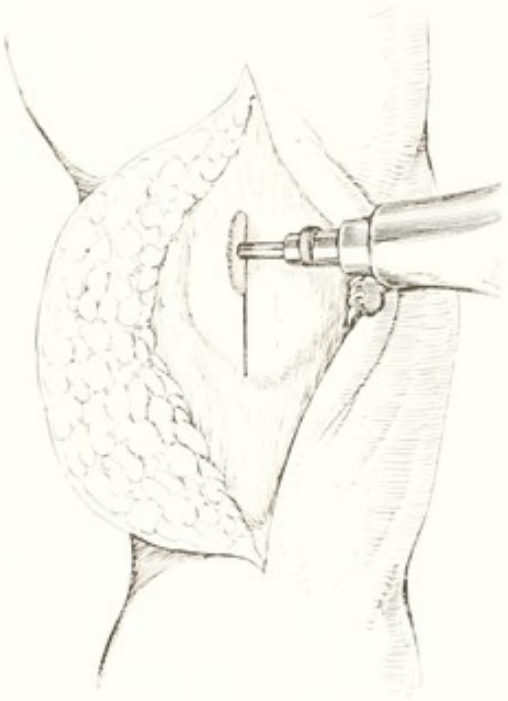


FIG. 255.

FIG. 254.—Exposure of knee-joint, by bisection of the patella. Drawing shows long curved skin incision. The dotted line indicates the location of the incision to be made in the patella (to the right or left of the median line as the case may be) when the lesion can be definitely localized, prior to operation, in the right or left sides of the joint. In case such definite localization cannot be made, it is best to bisect the patella in the median line.

FIG. 255.—Exposure of the knee-joint by bisection of the patella. The skin and subcutaneous flap has been reflected. The motor-saw is making the incision in the patella. (Method of Sir Robert Jones.)

occurs alone, but good functional results invariably follow proper mechanical treatment. According to Sir Robert Jones (*loc. cit.*), this comprises absolute rest of the part, with prohibition of all active and passive motion for three to six months, and even then the latter must be practised with the greatest caution. For some time after the expiration of this period, the splint should be worn during the day but may be removed at night. After the flail-like character of the joint has disappeared, a short jointed splint should

be worn (see Treatment of Dislocated Semilunar Cartilages and Fig. 250), and flexion to 20 degrees allowed at first, its range to be gradually increased. Jones emphatically advises against operation in a recent case of ruptured crucial ligaments.

In long-standing cases of rupture of the crucials, with pain, disability, and recurring effusions into the joint, several methods of procedure are available, viz.: (*a*) suture of the ruptured ligaments, (*b*) mechanical support permitting flexion, (*c*) arthrodesis.

The surgery of the knee-joint has been radically changed by the introduction of median bisection of the patella, devised by Jones. Surgical procedures on the interior of the joint (*e.g.*, repair of the crucial ligaments, of fractures of the tibial spine, etc.) were practised with the greatest rarity prior to this revolutionary procedure.

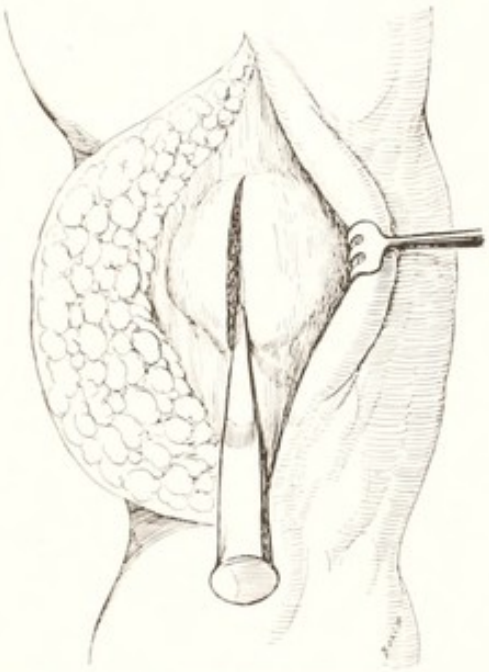


FIG. 256.—Bisection of the patella completed with osteotome.

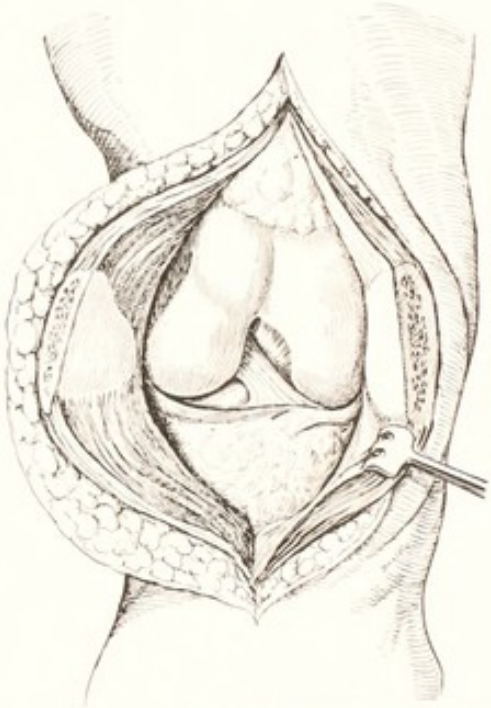


FIG. 257.—Demonstrates the splendid exposure of the interior of the knee-joint obtained by bisecting the patella.

(*a*) *Median Bisection of Patella (Jones).*—Jones advises that to obtain the best exposure of the knee-joint the knee be flexed over the table at nearly a right angle, and that a vertical incision be made through the patella. The incision begins 1 inch above the patella and is carried down almost to the tubercle of the tibia (Fig. 254). The patella is sawed through vertically and its ligament correspondingly split (Figs. 255 and 256). The two halves of the patella are separated to the borders of the condyles (Fig. 257). Removal of the fat from behind the patella affords an excellent view of the interior of the joint. After completion of the desired operation, the leg is extended and the ligamentum patellæ, aponeurosis, and quadriceps extensor are sutured. No internal fixation of the cleft patella is necessary.

In unilateral disturbances of the knee-joint, the author practises lateral incision of the patella, except in cases of doubtful diagnosis or where there are symptoms referable to both sides of the joint. When the symptoms point to derangement of one side of the knee only, the patella and quadriceps tendon are split laterally at some distance from the center (whether to right

or left depends upon the location of the suspected lesion in the right or left side of the joint). The approach appears to the author to give readier access to a unilateral lesion than does median section of the patella.

Repair of the Ruptured Crucial Ligament.—Having exposed the knee-joint by one of the above methods, the torn ligaments may be repaired with fine catgut sutures, uniting the *anterior* ligament to the synovial membrane and tissues on the *inner side* of the *external condyle*, the *posterior* ligament to the synovial membrane and cartilage on the *outer side* of the *inner condyle*. If the ligament is torn across and not merely detached, the ends may be linked with plaited sutures of fine kangaroo tendon. If, on account of loss of substance or other cause, additional tissue is needed, the author recommends that a fascial graft be obtained from the fascia lata for this purpose (for Technic, see Chapter XXVIII).

As a highly important adjunct to suture of the crucials, Sir Robert Jones emphasizes the importance of rendering the joint capsule and ligaments tense by reefing and stretching them.

(*b*) *Mechanical support allowing flexion* (see Treatment of Dislocation of the Semilunar Cartilages).

(*c*) *Arthrodesis of the knee* (see Chapter VII).

2. *Fracture of the Tibial Spine.*—Treatment immediately after the injury is sustained consists of manipulation of the leg to full extension. In the absence of evidence of laxity of the joint (from injury of the crucial or other ligaments), fixation is necessary for only two months or less, and the outlook is good for the recovery of full extension.

If full extension cannot be obtained, and disability exists from pain, stiffness, or effusion, operation is then indicated. The joint is approached by median bisection of the patella, the offending fragments of bone are removed, and the joint is closed as described above, or, if the fracture is extensive and has resulted in detachment of the moorings of the crucial ligaments, the fragments may be fixed in place by small bone-graft pegs or by sutures of kangaroo tendon.

3. SCHLATTER'S DISEASE

Synonym.—Enlargement of the tibial tubercle (Figs. 258 and 259).

Description.—An affection of the tongue-shaped lower portion of the upper epiphysis of the tibia, which is frequently developed from a separate center. The tubercle becomes enlarged and painful in adolescents, particularly those engaged in athletic sports. The patient is unable to kneel, as the result of a direct blow or from indirect causes, especially sudden strain on the partially extended knee. In very rare instances, rickets, tuberculosis, or syphilis affect this epiphysis.

The affection is one of puberty, and of boys more often than girls. There are elevation of surface temperature, pain, and tenderness on use of the affected part. The *x*-ray discloses an enlarged tongue-shape process, projecting and separated from the tibia by a space which is irregular and fluffy in appearance. In some cases the condition is due to local hyperemia of the epiphysis.

Symptoms.—In the traumatic cases, there are sudden pain and swelling, and occasionally ecchymosis. In other cases, the enlargement of the tubercle is gradual and accompanied by bulging of the ligamentum patellæ at its lower part; in these cases the onset of pain is gradual rather than sudden. The symptoms occasionally subside spontaneously.

Diagnosis.—The condition may be confused with inflammation of the bursa which lies behind the ligamentum patellæ; in fact, bursitis may be

secondary to Schlatter's disease. If during normal ossification at puberty, the tubercle appears loose, and if the *x*-ray shows a normal tubercle on one side and upward displacement of the tubercle on the other, a positive diagnosis of Schlatter's disease can be made.

Treatment.—If the condition is due to rickets, syphilis, or tuberculosis, appropriate treatment should be instituted. If the affection is due to trauma, the leg should be put in extension until the acute stage has subsided, in hopes of getting union. If no union occurs, the tubercle can be quickly and effectively secured to the tibia by means of a small bone-graft peg, as advocated by Soule.

4. SNAPPING KNEE

This is a recurrent subluxation of very moderate grade, quite common in infants, and is produced by a slipping forward of the tibia or its external



FIG. 258.—Disease of tubercle. Schlatter's disease.

rotation on the femur upon sudden extension of the leg. Contributory causes are laxity of the ligaments and, possibly, irregular movements of one of the semilunar cartilages. Some discomfort may be caused by this recurrent slipping. This ability to displace the tibia forward on the femur is sometimes encountered in adults. Another cause of the "snapping" may be the slipping of the biceps tendon.

Treatment consists of firm bandaging or immobilization for a variable length of time by a brace or plaster-of-Paris bandage in conjunction with massage of the knee-joint.

5. ACUTE SYNOVITIS

This is usually the result of trauma. The symptoms are local elevation of temperature, limitation of motion, and swelling. The latter is due to the effusion in the synovial cavity, which obliterates the normal outline of the knee and causes floating of the patella, an important diagnostic feature.

Treatment consists of rest of the parts by elevation on a posterior splint, and the application of an ice-bag. As soon as the most urgent symptoms have subsided, compression should be employed by means of a firm bandage of muslin, flannel, or adhesive plaster. The latter is applied in overlapping strips from a point several inches below the joint to an equal distance above it, and a flannel bandage firmly applied over it. This not only allows sufficient motion of the joint to maintain an equable circulation and thus promote absorption of the effusion, but it also affords an extremely satisfactory support for the joint. In cases in which there is much swelling of the leg, an elastic stockinet bandage may be applied from toes to groin as an additional support.



FIG. 259.—Schlatter's disease resulting from repeated traumata to the tubercle of the upper epiphysis of the tibia.

Counterirritants, such as tincture of iodin, may be tried to hasten absorption, and for the same purpose light friction and massage are of undoubted benefit.

Aspiration may be practised if there is great discomfort from the tension. One should not hesitate to incise a joint if chronic proliferative inflammation of the synovial membrane has rendered the latter too thick to permit absorption of the fluid. After the joint has been opened, it is advisable to irrigate the cavity with hot normal salt solution, after which the joint is swabbed out with a weak solution of tincture of iodin.

6. SPRAINS

Sprains of the knee are produced by twists, wrenches, or blows. Although the term is rather loosely applied, it consists of sudden, partial displacement of the articular surfaces with injury to the joint structures and surrounding tissues, *i.e.*, the joint is moved beyond its physiological limits, with consequent overstretching of its component parts. (The severer types of sprain, complicated by fracture, are not considered here.) The synovial membrane and the subsynovial tissues suffer most. The capsule may be overstretched or some of its fibers torn, and the tendons and ligaments

surrounding the joint stretched, displaced or ruptured, with resulting teno-synovitis.

Pathology.—The morbid anatomical changes are those of trauma, viz.: extravasation of more or less blood into and around the joint, followed by acute inflammation of the intra- and peri-articular tissues. In a few days after the acute symptoms subside, the parts are weak, swollen, and edematous. The extra-articular structures may be matted together, and points of tenderness, particularly on the bones where the ligaments have been torn away or along the course of the tendon sheaths, may be noted. There is gradually a resumption of normal function.

Symptoms.—Sharp, sickening pain is experienced at the time of injury, accompanied by a tearing sensation and inability to move the joint. This is soon followed by swelling (blood and effusion), increasing for two to three days on account of inflammatory reaction and exudate. Ecchymoses appear under the skin. Swelling and disability gradually subside, and in well treated cases normal function is progressively restored.

Diagnosis.—It is imperative to exclude serious internal derangement of the joint, which is conclusively done by means of radiography. Fracture very commonly complicates what at first appears to be a simple sprain.

Treatment.—The fundamental principle of treatment is rest. Applications of cold (douches or ice-bag) should be made for a half hour after the injury, and then cotton wool and a tight, evenly applied bandage of muslin or flannel should be used.

In other cases, plaster-of-Paris support is preferable, because the plaster can be moulded so well, and the even compression thus afforded limits the extent of the effusion. The plaster-of-Paris dressings are removed in two or three days, and hot soaks or baking, followed by massage are instituted and repeated daily, to promote absorption of blood and exudate. In the intervals of massage, a tight flannel or muslin bandage, or adhesive strapping, is applied and the part kept absolutely at rest. At the end of seven to ten days, in the average case, gentle passive motion may be begun, avoiding any strain upon the ligaments which have been stretched or torn. Prolonged fixation of a joint is to be avoided, as such immobilization often results in stiffness and disability.

7. CHRONIC SYNOVITIS

Causes: loose bodies, hypertrophied synovial fringes, lipoma arborescens, displaced semilunar cartilage, the proliferative form of arthritis deformans, repeated strains of the knee (flatfoot and genu valgum), and possibly also an attenuated type of septic arthritis.

Effusions have a more profound effect upon the knee than upon any other joint. They establish a vicious circle in the following order: loose body, effusion, laxity of ligaments (allowing too great mobility), loose body again between the joint surfaces, another effusion, and increased weakness of the ligaments.

Hypertrophic Synovial Villi.—An overgrowth of subsynovial tissue results from chronic synovitis; the fringes are reduplicated and covered with pedunculated, vascular, sensitive masses which are frequently palpable on either side of the patella. These masses may become detached and form loose bodies. The joint is always the seat of discomfort, the cause of constant dull pain with acute exacerbations, is tender, and its movements are limited. *Treatment* consists of rest and counterirritation, followed by compression and strapping. After the acute stage has subsided, douches, massage, and regulated motion are of benefit. If the condition remains obstinate,

the joint should be opened by a lateral incision or by section of the patella (see elsewhere in this chapter), and the growths removed. After the operation, immobilization should be practised for ten days to two weeks, after which passive movements may be instituted.

Lipoma Arborescens.—This growth is of fatty origin and is commonly found in the knee. It assumes a regular, more or less rounded shape, or may be "arborescent." Its origin is either (*a*) a hernia of the subsynovial fatty tissue into the joint, or (*b*) due to overgrowth of the fatty tissue beneath the synovial membrane, or (*c*) fatty hypertrophy of the synovial villi. The symptoms are the same as those of hypertrophic synovial villi. If the lipoma is troublesome to the patient, it should be removed by arthrotomy.

8. CONGENITAL DISLOCATION OF THE KNEE

The usual variety is forward dislocation, partial or complete. Pure lateral displacement is rare.

Forward dislocation of the tibia, the usual form, presents the following:

Symptoms.—Hyperextension of the knee is the leading abnormality: the skin lies in transverse rugæ over the patella, the popliteal region is full, and in it the posterior aspect of the condyles and the intercondyloid notch are palpable. The patella is small and high up. On attempted flexion at the knee, an elastic resistance is felt.

As the child grows, the hyperextension decreases, partly from gravity and the weight of the limb, and partly from the active and passive movements incidental to flexion. When active movements (running and jumping) are begun, the forward dislocation may become complete, as in traumatic cases. Talipes calcaneovalgus, occasionally varus, and not infrequently congenital dislocation of the hip may co-exist.

Treatment.—The deformity may yield to gradual reduction of hyperextension by a malleable iron splint at the back of the limb, its angle being intermittently reduced until the knee is straight or flexed; after this it is important to apply massage to the muscles and furnish a support with a check at the knee to prevent extension.

Surgical interference has been practised by various men as follows: (1) Tibial surface gouged out to fit the condyles (Reiner); (2) simple removal of the patella (Fowler); (3) hypertrophy of the condyle produced by repeated blows of a mallet (Ridlon and Thomas); (4) plastic operations on the capsule (Wright, Le Dentu, and Chevrier); (5) osteotomy, with folding of the inner part of the capsule and enlargement of the trochlear surface by chiselling (Aldebert); (6) chiselling of the trochlea and excision of the inner part of the capsule (Pollard); (7) cutting away the insertion of the vastus externus from the patella and transplantation of the insertion of the ligamentum patellæ farther inward on the tibia (Roux); (8) pegging the patella to the inner portion of the tibia (Casati); (9) aperture made with the chisel under the external condyle and the insertion of a bone-graft wedge, (10) opening the joint, gouging out a space on the inner condyle to receive the patella, and suturing it in place (Championnière).

Hübscher's Operation.—Binnie (Manual of Operative Surgery, P. Blakiston's Son & Co., 1912, p. 920) thus describes Hübscher's operation (Fig. 260):

"Hübscher (von Salis: Deutsche Zeitschrift f. Chir. cxiv, 148) operated on a case of anterior dislocation of the tibia on the femur in a girl fourteen months of age. The patella was absent. Manual reduction was impossible. The skin was reflected in a flap from in front of the knee (Fig. 260). The tendo patellæ was found to be short and to constitute an impediment to re-

duction. The tendon was incised longitudinally down to its insertion into the tibia (Fig. 260). A portion of the tibia corresponding to the insertion of one-half of the tendo patellæ was separated from the rest of the bone. The other half of the tendon was divided transversely high up. Only after division of the anterior capsule of the knee was complete reduction possible. The two halves of the patellar ligament were united in such a manner that the fragment of tibia attached to one of them lay in the normal position of a patella (Fig. 260). The wound was closed. The knee was immobilized in a position of slight flexion. The result was good."

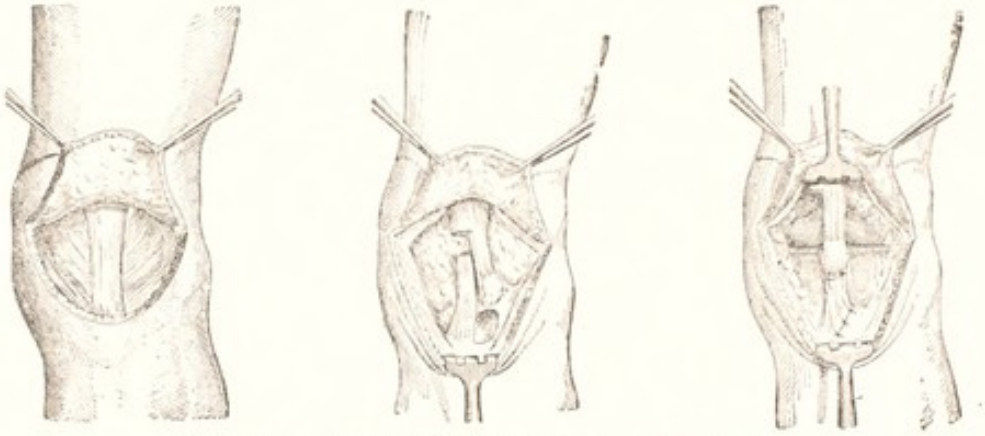


FIG. 260.—Hubscher's operation. (Hubscher.)

9. ACQUIRED GENU RECURVATUM

This condition is seen in rickets and as the result of infantile paralysis (posterior thigh muscles or gastrocnemius, or both), or from rupture of the crucial ligaments. It is also observed in equinus as the result of continuous effort to get the heel on the ground; in hip disease, if the brace does not properly support the knee, and even in cases where no brace has been employed; also on the sound side as a compensation for shortening of a tuberculous hip. It occasionally follows disease of the knee-joint in which the leg is held by a brace for a long time in hyperextension. It is due rarely directly to traumatic sudden overextension, with rupture of the crucial ligaments. It is a common phenomenon in the so-called "loose joints" of childhood. It is frequently combined with more or less knock-knee, and there is often abnormal mobility.

Symptoms.—Aside from habitual overextension of the knee, there are weakness and insecurity in weight-bearing, increased by strain on the displaced structures. Impairment of flexion results from the altered relationships of the joint surfaces and the accommodative shortening of muscles and ligaments.

Treatment.—If due to deformity of the bones, osteotomy of either tibia or femur, as seems best, may correct the distortion. If due to other abnormalities, it is essential to correct the primary cause. If due to infantile paralysis, treatment should follow the lines laid down in Chapter XXI, *q.v.* If due to trauma, the leg should be immobilized in flexion until healing occurs, then massaged and properly supported by a brace with a stop-joint to prevent hyperextension.

10. PREPATELLAR BURSITIS (HOUSEMAID'S KNEE)

A chronic enlargement of the small bursa overlying the patella and its ligament is commonly due to excess of kneeling (housemaids, scrubwomen,

etc.). It is occasionally due to acute inflammation, in which case it may be mistaken for synovitis of the knee.

Treatment.—In acute cases, adhesive strapping must be immediately applied for immobilization and compression. If there is much effusion, the bursa may be aspirated. In a persistent chronic case, operative removal gives quick and certain relief.

11. PRETIBIAL BURSITIS

The bursa between the ligamentum patellæ and the tibia may become enlarged from traumatism, and also in the course of infectious diseases, etc. The symptoms are: stiffness at the knee, with pain on sudden movement and on strong activity in flexion or extension. There may be sensitiveness to pressure and swelling on either side of the ligamentum patellæ.

Treatment consists of fixation to relieve pressure from the tendon and, at a later period, adhesive strapping. Counterirritation (iodin, the actual cautery, etc.) tends to hasten absorption of fluid. In some cases it may be advisable to aspirate, incise, or by dissection to remove the sac.

The superficial pretibial bursa, lying upon the insertion of the ligamentum patellæ, may become enlarged and simulate overgrowth of the tubercle (Schlatter's disease). Adhesive strapping and protection of the bursa by an annular corn plaster is usually sufficient to cause the inflammation to subside.

12. CYSTS OF THE KNEE-JOINT

These are usually found in the popliteal space, but may be located as remotely as the middle of the leg. They are simple serous cysts, and communicate with the knee-joint. Fluid cannot be forced from one cyst to the other. They are probably due to extension of the synovial membrane. They may cause confusion in diagnosis.

Treatment is by extirpation.

13. Inflammation of the bursa between the inner head of the gastrocnemius and the semimembranosus muscles may produce a fluctuating swelling on the inner side of the popliteal space.

Treatment consists of compression or excision.

Miscellaneous Operative Procedures at the Knee

1. **Manipulation under Anesthesia.**—The patient should lie on the face with a sand-bag under the lower end of the femur. In the case of slight flexion at the knee from contracture of the hamstrings, the surgeon should grasp the thigh near the tibia with the left hand and the leg just above the ankle with the right. Assistants should fix the lower end of the femur and the buttock. The joint should be alternately stretched and relaxed, force being employed with caution, gradually increasing its vigor to a maximum, and then declining to total relaxation. Rhythmic extension and flexion should be the rule, avoiding forcible extension without an equal degree of relaxation.

2. **Rupture of the Quadriceps Extensor.**—To repair a ruptured quadriceps, a long median incision is employed. The upper and lower ends of the muscle and its sheath should be sutured with quilted sutures of silk or whatever material the surgeon prefers. Strong interrupted sutures should be used for the relief of tension, while interrupted sutures of chromicized catgut of small size are used for the edges of the muscle. The sheath should be repaired with interrupted sutures of small-sized catgut, the fat with in-

terrupted sutures of chromicized catgut, and the skin with a continuous suture of No. 1 plain catgut. The knee should be immobilized in full extension in plaster-of-Paris dressings. The patient should have a low bed rest and the leg should be elevated. The plaster may safely be removed after the sixth week.

3. **Transplantation of two Hamstrings Forward to Replace a Paralyzed or Weakened Quadriceps Extensor.**—The technic of transplanting one hamstring is described in Chapter XXI, page 752. When an outer as well as an inner hamstring is to be transplanted, an incision over the posterior lateral aspect of each side of the knee-joint is required for the release of these muscles. They are both passed down through the same tunnel and fastened to the superior-anterior border of the patella, as indicated in Chapter XXI, and the remainder of the technic carried out as therein indicated.

4. **Transplantation of the Sartorius for the Quadriceps.**—This muscle can easily be made to reach the patella, is an easy muscle to transplant, and may be very successfully employed, particularly if caused to hypertrophy by appropriate postoperative muscle training. The author prefers the insertion of the tendon into the patella, as already indicated, although some surgeons suture it to the quadriceps tendon, quilting silk into the muscle and carrying the silk downward and inserting it into the patella and also into the tibia in the middle line.

5. **Bartow Silk Ligaments at the Knee in Paralytic Conditions.**—Bartow employs his special drill with a handle which allows the drill to protrude slightly as it enters the bone. The drill handle slides back on the drill and is held by a thumbscrew. The drills are made with different curves, all fitting into the drill handle.

The drill is passed into the tibia an inch or an inch and a half from the middle of the tubercle and is pushed through the skin and the bone at this point, extending through the tuberosity of the tibia and upward. It emerges at the top of the tibia into the joint, and is then passed into the lower surface of the femur, emerging anteriorly at the side of the patella. The two ends of a piece of heavy braided silk, 10 to 12 inches in length, are threaded through the drill, which is then withdrawn. This silk is used as a leader, through which a loop of finer silk is drawn through the bone double. The drill is next introduced subcutaneously at the lower incision and made to protrude through the upper incision. The silk is threaded through it, and brought down subcutaneously and out through the lower skin incision. The silk now extends through the tuberosity of the tibia, emerges at the top of the tibia into the joint, into the lower end of the femur, out through the anterior surface of the femur, and down subcutaneously in front of both bones, ready to be tied in front of the tibia; in the same manner, a second ligament is placed on the other side of the knee-joint, making one silk ligament on the outer and another one on the inner side of the patella. If there is unusually great relaxation of the joint, Bartow places additional ligaments at the inner and outer sides of the knee-joint behind. It is best to slightly hyper-extend the knee before tying the ligaments, and to tie them 3 times, double strands having been employed for each ligament. The ends are left about a sixteenth of an inch long, and the knot is then pushed back through the puncture hole and allowed to retract through the skin and below the fat. The puncture holes as a rule do not require suture. By proper splinting, tension should be taken off the ligaments, while any lateral or flexion deformity should be corrected before the ligaments are inserted. Plaster-of-Paris splints should be applied for a period of eight to ten weeks and followed by a caliper splint or other form of brace as long as required. This operation is satisfactory in

some cases inwhich there remain some joint stability and muscular power, but in heavy patients, with extensive paralysis, arthrodesis of the joint is the operation of election for stabilizing purposes.

6. **Posterior Incision of the Knee.**—Access to the posterior part of the knee-joint for the removal of loose bodies from that part of the joint, for exostoses in that locality, or for drainage when anterior and lateral incisions are insufficient, is obtained by a long vertical incision, 5 to 6 inches in length, beginning about 3 inches above the tibia-femoral interspace. By blunt dissection, the tissues are separated between the outer side of the vessels and the outer head of the gastrocnemius and the biceps. Retraction of the tissues exposes the synovial membrane which is then opened.

7. **Lateral Incisions at the Knee.**—These incisions are useful in certain operations and fractures of the tibia and femur. Also in certain suppurative conditions, for the purpose of drainage when an anterior median incision has been used for exploration. These lateral incisions are made about 1 inch from the patella, their central points being at the middle of the patella, and are usually 4 to 6 inches in length. The incision is carried down to the bone, all tissues are lifted subperiosteally from femur and tibia, and on retraction forward and backward free exposure of the joint is obtained.

8. **Aspiration of the Knee-joint.**—The joint may be entered with the trocar under the vastus internus or the vastus externus, or posterior to the outer border of the patella or at its superior-internal angle (Fig. 261). Counter pressure should be used from the opposite side of the joint. The skin should be drawn to one side so that the punctures in skin and muscle will not be superimposed upon the withdrawal of the needle.

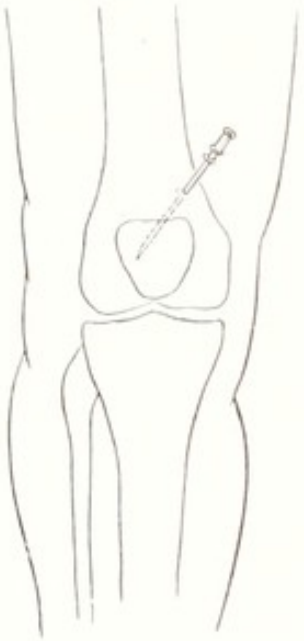


FIG. 261.—Aspiration and injection of the knee-joint. The trocar is entered at the superior-internal angle of the patella and plunged in a direction obliquely downward and outward so that it will enter the intercondyloid notch between the femur and the under surface of the patella and penetrate the joint cavity.

SHOULDER

1. SUBACROMIAL BURSITIS

This common cause of "stiff and painful shoulder" was first described by Codman (Bost. Med. and Surg. Jour., 1906, cliv, 613). To gain a better conception of the size and extent of this bursa, and more fully to realize the disabling features resulting from its inflammation, it is important to review its:

Anatomy (Fig. 262).—The subacromial is one of the largest bursæ in the body. Above, it is adherent to the under surface of the acromion process and coraco-acromial ligament, and thence it is reflected on to the joint capsule. Below, it is adherent to the inner surface of the deltoid, extending fully 1½ inches distal to the greater tuberosity. Anteriorly and posteriorly, it encircles almost half the circumference of the humerus, and is attached by its under surface to the bone, joint capsule, biceps sheath, and the tendons of the subscapularis and spinati.

Pathogenesis.—The essential pathological lesions, found singly or combined, are inflammation of the bursa with or without swelling and with or without calcareous deposits, and with more or less laceration of the spinati

tendons, associated with swelling, hemorrhage, granulation tissue, and necrosis of these tendons. A thickened bursa may exist without calcareous deposits, and in such a case casts no shadow in the radiogram.

When present, the calcareous deposit occurs not in but *beneath* the bursa, in or in and upon the supraspinatus tendon, or occasionally in the infraspinatus near its insertion. Brickner (Am. J. Med. Sci., vol. cxlix, No. 3, March, 1915, pp. 351 to 364), as the result of a study of over 100 cases

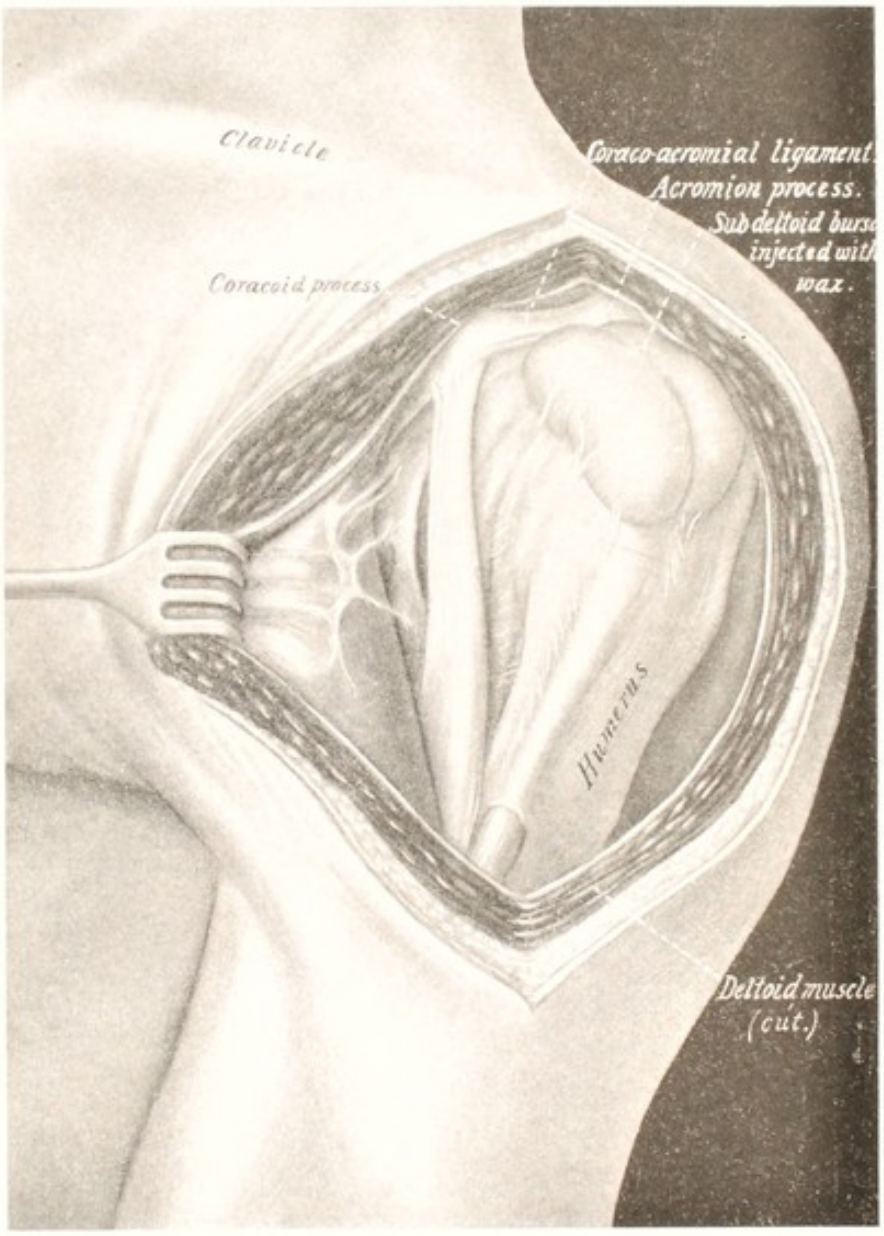


FIG. 262.—The subdeltoid bursa. (Baer.)

of shoulder disability, including 19 that showed this calcareous deposit, radiographically, and upon 7 of which he operated, found the deposit in 3 cases on the supraspinatus tendon and underneath the bursal floor; in 1 case, completely embedded in the infraspinatus tendon. He describes this calcareous material as "dry, gritty, and composed of rough, sand-like granules, in color and appearance much resembling shad-roe or yellow tartar when scraped from the teeth." Larger smooth masses may be present in this material, and are composed of varying amounts of calcium and other

salts. In other cases, the deposits may be semifluid and "wen-like" (Codman), not cysts, in that no limiting membrane exists, although their contents are chiefly broken down cellular material.

Radiographic Appearance.—Shadows (present only when there is accumulation of lime-salts) are usually close to or even in contact with that of the greater tuberosity of the humerus, but may be away from the tuberosity and in line with the supraspinatus or widely separated from the bone margin. The size of the shadow varies, is usually single, though it may be multiple, and corresponds with the amount of salts present.

The deposit of lime-salts occurs *early* after trauma (Brickner found it on the fifth, the tenth, and the eleventh days). The deposit is discrete, without infiltration or ossification of tendons, and can be removed with a blunt spoon.

Laceration of Tendons (in Association with Subacromial Bursitis).—There is frequently a transverse tear in the supraspinatus near its insertion, without calcareous deposit, and this tear may extend through the tendon, exposing the joint capsule. The tendons may be swollen and hemorrhagic. As the result of contusion or laceration, there are often noted granulation tissue, necrosis of the tendon substance, and the deposit of lime. The frequent, early, sometimes multiple appearance of lime in the spinatus tendons after mild traumatisms, Brickner believes has no parallel in the human body.

Etiology.—Subacromial bursitis is an affection of adults. There is no substantiated evidence of bacterial or toxic origin. The tuberculous form is rare. The affection is occasionally incidental to septic processes elsewhere in the body.

The preponderating cause is trauma producing contusion of the structures between the acromion and the greater tuberosity. The traumatism is usually mild but often repeated (*e.g.*, "straphanging," swinging on flying rings, scrubbing floors, throwing a baseball, etc.), in other words *repeated abduction of the arm with compression of the bursa between the greater tuberosity and the acromion.* In other cases, rupture of the supraspinatus tendon and laceration of the bursal floor have been caused by such procedures as cinching a saddle, and throwing a heavy blanket over a clothes line (Codman), "something snapped in the shoulder and the arm fell limp." Occupational movements (cello playing, hammering, machine operating) have also been noted as the etiological factors, as also a fall upon the outstretched arm or a fall or blow upon the deltoid region.

Clinical Features.—*Swelling.*—In the early stages an effusion of serum takes place in the bursa, occasionally of sufficient amount to produce appreciable swelling in the deltoid region, but later this swelling entirely disappears, and in most instances is replaced by adhesions. There may even be atrophy of the deltoid and spinati. *Tenderness* may be localized externally just below the acromion, but may be absent as often as present and is not pathognomonic. The most constant point of tenderness is anteriorly over the lesser tuberosity or just above it. In other cases, the point of greatest tenderness is posteriorly over the infraspinatus. Dawbarn's sign (disappearance of the point of tenderness when the bursa is carried under the acromion by abducting the arm) may or may not be present. Brickner's sign (pain referred to the anterior deltoid region on gently pressing the circumflex nerve against the inner aspect of the humerus) is likewise variable. More or less *limitation* of *abduction* and *internal rotation* is a striking feature of typical cases, although there may be normal movements in the presence of dense adhesions and large calcareous deposits.

The following motions between the head of the humerus and the scapula are free; (*a*) 45 degrees or more of abduction; (*b*) moderate flexion and exten-

sion; (*c*) external rotation; (*d*) adduction. The presence of free motion in the above directions absolutely excludes arthritis of the shoulder-joint.

Diagnosis.—The diagnosis rests upon (*a*) careful history of the onset and development; (*b*) traumata (such as have just been described); (*c*) the incidence, location, and radiation of the pain, its behavior at night and on resting the arm; (*d*) careful inspection and palpation of both shoulder girdles; (*e*) tests of all shoulder movements, active and passive; (*f*) exclusion of arthritis, cervical rib, inflammations of bone, true brachial neuritis, and other forms of shoulder disability not due to bursitis; (*g*) *x*-ray examination, not only to detect calcareous deposits but also to exclude localized periosteitis, tuberculosis, or syphilis of the humeral head, fractures, or other lesions. It should be borne in mind that a normal radiographic appearance does not exclude bursitis in the absence of lime deposits.

Treatment.—I. *Non-operative.*—In the acute stage, rest and fixation are indicated. A sling and a bandage will serve to keep the arm at the side and relieve pressure of the humeral head against the acromion. Compression should be applied if there are swelling and effusion. Immobilization should not be unduly prolonged, and after its completion active and passive movements and massage are indicated. If adhesions are present, manipulations under anesthesia may be advisable, to be followed by massage. Usually, however, gentle graduated passive exercise is sufficient for the purpose.

II. *Operative Treatment.*—If in acute cases there are severe, increasing pain and loss of function, and radiography demonstrates a deposit of lime, open operation gives the quickest relief and often aborts a prolonged disability. None of Brickner's cases in which there were calcareous deposits was relieved of pain without operation. Indications for operation are: pain and loss of function serious enough to interfere with sleep and work, muscular atrophy of the deltoid and the spinati, and radiographic evidence of calcareous deposits.

Brickner's Operation.—"The patient is turned partly on his side and a cushion is placed under the affected shoulder conveniently to expose its outer surface. The forearm and hand, which may be laid across the body, are wrapped in sterile towels or pillow case so that, if necessary, an assistant can manipulate the extremity.

"A 2½- to 3-inch vertical incision is made from the outer border of the acromion process downward over the greater tuberosity, *i.e.*, toward the external condyle. The exposed deltoid muscle is split in the same line, largely by blunt, partly by sharp dissection. Retraction of the muscle exposes the roof of the bursa. This is drawn up, away from the bone, with two forceps, and freely divided between them, in the line of the muscle incision. With retractors in the bursa its interior is thus freely exposed where it is usually most affected, viz., over the greater tuberosity. Adhesive strands or bands are divided with scissors or excised. 'Villous' or 'papilloma-like' masses, as described by Painter and Codman, if found, are cut away. With curved scissors, concavity toward the humerus, the sac is then explored below (toward the deltoid insertion), anteriorly, posteriorly, and above (under the acromion), and any further adhesions are divided. The bursa is then explored with the finger, the arm being rotated backward, then forward, and pulled down upon, to facilitate this palpation, if necessary. At the site of maximum injury the bursal wall may be more or less thickened. I have not seen it thick enough to suggest the necessity of excising even small areas.

"The floor of the bursa is now incised, in the same dissection line, over the greater tuberosity and the supraspinatus insertion, and dissected up

from the tendon. If a deposit, fluid or solid, is thus found, it is removed with a blunt spoon. The tendon thus exposed will reveal a superficial injury or a distinct small transverse tear, within which is more of the solid or cheesy material. The edges of the rent are trimmed with a scalpel to remove adhering granules and frayed fibers. The tendon wound is then closed with a couple of vertically placed chromicized catgut stitches. If no extratendinous deposit is found, the supraspinatus tendon is opened axially at the point suggested by the röntgenogram, if necessary enlarging upward the incision in the floor of the bursa. The tendon wound is retracted and the deposit is spooned out. The tissue immediately surrounding the deposit is trimmed away with the granules adhering to it. The tendon is sutured with transverse stitches of chromicized catgut. If no deposit is found in the supraspinatus the infraspinatus is opened, axially, and the material removed therefrom in the same way.

"The above paragraph refers to those cases in which the röntgenogram shows a shadow or shadows. In all cases, however, I think it worth while to examine the tendons for a possible tear, through a small incision in the floor of the bursa.

"The incision in the bursal floor is closed with fine catgut sutures. In some cases of very adherent extratendinous deposit, these cut edges of the bursa are so frayed at this site, after it has been dissected up, that it cannot be entirely approximated over the tuberosity.

"A thin layer of vaselin is spread over the lining of the sac with the gloved finger or a smooth instrument. No small lump of the lubricant is left in, lest, by encystment, it might cause adhesions. In spite of this theoretical objection to the vaselin, I have found that it behaves well in these cases, and I believe that it probably prevents the immediate reformation of the adhesions. The roof of the bursa is sutured completely with catgut. Codman thinks it advisable to leave both layers of the sac unsutured so that fluids may drain through. I see no advantage in this practice; it has the perhaps theoretical objection that through gaps in the bursa adjacent structures may become adherent to the opposite wall.

"The deltoid muscle is allowed to fall together. I usually insert a few catgut stitches. The skin wound is closed without drainage. The arm is dressed in abduction of about 120 degrees, in a light plaster-of-Paris spica.

"The abduction is continued until the first dressing—eight to ten days. Painter sees no advantage in the primary abduction and Codman abandoned it. I think it quite important. It relaxes the sutured supraspinatus; it relaxes the bursal walls and puts them in the position of maximum separation; it stretches the contracted peri-articular structures (muscles chiefly), and assures at once a certain amount of abduction capacity, thus, I believe, reducing the period of after-treatment. It is a position by no means insupportable, and though some patients find it irksome, their discomfort is a small price to pay for the service it renders.

"After the cast is removed the healed wound needs but a bit of gauze and adhesive plaster or collodion; and the patient is free to move his arm about. He is instructed to move it but little and gently at first to rest it in a sling when sore or fatigued, and at night to abduct it as much as he comfortably can on pillows, or with a bandage carried from the wrist to the head of the bed. In the third week after the operation more active movements are instituted if necessary. The length of time needed for full restoration of shoulder function depends upon how much and how long it had been previously interfered with. In cases of moderate disability, cure

may be complete, or nearly so, within a month. In more severe cases, it will take two or three months to effect restoration of full mobility, by means of light Indian-club exercises, etc. Long after abduction is fully restored, there is apt to persist some limitation of internal rotation (inability to quite touch the opposite scapula across the back.)"

2. Congenital Dislocation of the Shoulder

This condition is rare. The dislocation is usually posterior, the head resting just below the junction of the acromion process and the spine of the scapula. Attention is first arrested by limitation of motion of the upper arm, the humerus being abducted and rotated. The *x*-ray is valuable in diagnosis. No paralysis is evident to electrical tests. The condition has to be differentiated from obstetrical paralysis and separation of the upper epiphysis of the humerus.

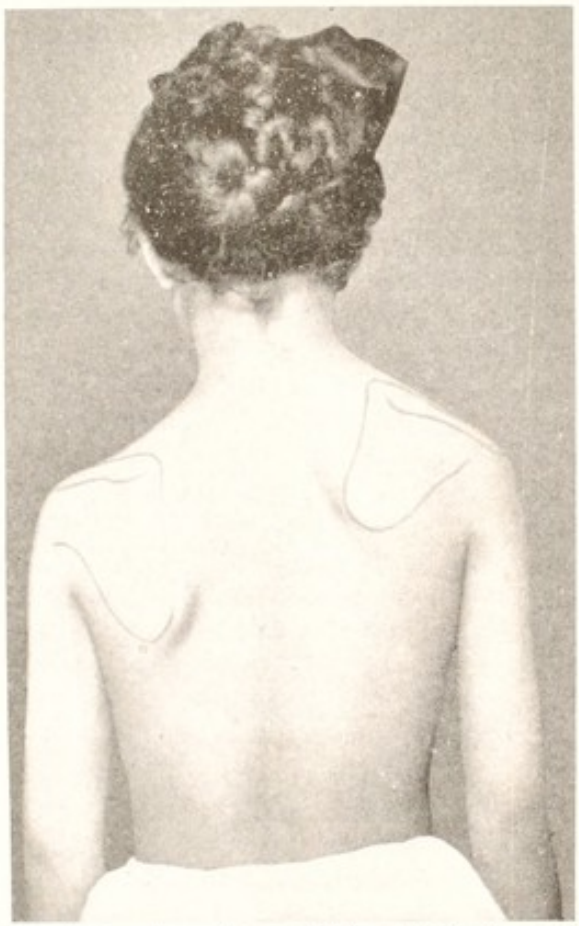


Fig. 263.—Congenital elevation of the scapula of a moderate degree in adolescence. (Whitman.)

Treatment.—An attempt should be made at reduction, and, if successful, immobilization is enforced for a sufficient length of time to insure its retention during manipulation without redislocation. If not at first successful, a prolonged forcible manual stretching should be applied to the contracted muscles and ligaments, or even continuous traction should be employed to that end as a preliminary to a second attempt.

3. Congenital Elevation of the Scapula (Sprengel's Deformity) (Fig. 263)

The scapula is elevated above the level of the normal one, with rotation. Shortening and altered direction of the scapular muscles partially fix the scapula and limit elevation of the arm. It is a frequent complication of scoliosis and is occasionally accompanied by other deformities. The condition may be bilateral.

Etiology.—The cause is doubtful. The deformity may be the result of protracted malpositions in utero, which prevented descent of the arm at the normal time.

Symptoms.—In addition to being elevated, the scapula is rotated about its anteroposterior axis, so that its vertebral border instead of being parallel to the spinous processes is rotated so that the upper angle is nearer the middle line than the lower angle, but the reverse may occur. The clavicle is frequently shortened, bringing the scapula and shoulder nearer the spine. The upper angle of the scapula forms a prominent projection at the back of the neck. There is limitation of motion, particularly on elevation of the

arm. Although disability is at first slight, it is pronounced about puberty, when increased activity is attempted. The chest is poorly developed, being narrow from side to side. In bilateral cases, the dorsal and lower cervical vertebræ are prominent. In unilateral cases, the spines are frequently deviated, usually away from, though occasionally toward, the affected side. Torticollis and facial asymmetry complicate some of the cases. The asymmetry in unilateral cases is striking: one shoulder elevated and the head drawn to the side of the deformity. The condition occurs in both sexes.

Pathology.—The chief points of difference between a normal scapula and one concerned in Sprengel's deformity are: disturbed ratio between the scapular diameters (diminished vertical and increased horizontal); upper border curved or supraspinatous portion bent forward; superior median angle prolonged or rounded; exostoses and articulations in the vertebral column often present (the abnormal articulation is usually by means of a triangular shaped piece of bone, its base on the scapula and its apex on the transverse process of a vertebra), union being either cartilaginous or bony. Associated abnormalities have been discussed in Chapter XII.

Treatment.—Conservative treatment has already been discussed in Chapter XII.

Operation.—Soutter (Technic of Operations on the Bones, Joints, Muscles, and Tendons. The Macmillan Company, 1917, p. 189) suggests the following procedure:

"An incision is made along the vertebral border of the scapula down to the bone; as the edge of the scapula is reached, an osteotome is used to lift the muscles subperiosteally from its inner border upward, and the muscles from the upper border. That part of the border above the spine which is often folded over should be chiselled away and removed. When the muscles are detached subperiosteally from the under side and upper end of the scapula by a subperiosteal dissection, using a long-handled osteotome, the scapula will be released and may be depressed, and if necessary held in position to the rib by a long chromic catgut suture No. 1. Plaster-of-Paris bandage is used to hold the arm and thorax."

We believe that the use of slowly absorbable chromicized catgut would eventually demobilize the scapula and permit recurrence of the deformity. For the purpose of permanent anchorage, the use of a fascial transplant would appear more rational.

4. Habitual Dislocation of the Shoulder

The commonest indirect cause is traumatic dislocation; the immediate cause is laxity of the capsule of the joint, with more or less weakness of the peri-articular muscles, which in some cases is the result of injudicious treatment of the original dislocation. Deltoid paralysis is another common cause of the condition. The dislocation may be partial or complete. In any case, the disability is great.

Treatment.—If treatment is begun soon, before the capsule and muscles have become too greatly stretched as the result of a long series of dislocations, it may be possible to restore these structures to normal by immobilization of the shoulder, followed by massage and appropriate exercises of the overstretched muscles. Immobilization can be secured by a shoulder-cap applied to the shoulder and upper arm and attached by straps under the opposite axilla, to prevent abduction and elevation of the arm, which seem to be the movements most commonly causing the displacement. In other cases, when a forward-drooped position of the shoulders appears

to be the cause, straps or an apparatus to hold the shoulders back may be tried. But a great number of cases refuse to yield to these conservative measures and operation is demanded. The most effective consists of excision of a portion of the capsule, combined with reefing.

Operative Treatment.—In 1908, the author published (Am. Jour. of Surg., July, 1908) a modification of Burrell and Lovett's technic for reefing the capsule of the shoulder-joint, viz.: An incision was made over the coracoid process and extended downward, following the lines of the cephalic vein to the insertion of the deltoid muscle. The cephalic vein was drawn inward and the intermuscular septum between the deltoid and the pectoralis major was recognized, and those muscles were separated by blunt dissection. The coracobrachialis and the short head of the biceps came into view in the upper end of the wound, and the insertion of the pectoralis major in the lower angle. The head and neck of the bone were then exposed by thorough blunt dissection.

In order to accomplish this, it was necessary to carry the incision in its whole depth up to the coracobrachialis and short head of the biceps origin on the coracoid process. The anterior and interior aspect of the capsule were then exposed by developing the pectoralis major and latissimus dorsi, and by retracting them inward; by dividing a portion of the subscapularis muscle and retracting it upward. The arm was then abducted anteriorly (Albee's position) about 25 to 30 degrees. This allowed the best exposure as well as the best relaxation of the capsule. The loose part of the front and inferior aspect of the capsule was then grasped with three hemostats.

The sutures of small kangaroo tendon were inserted with a curved needle beneath this fold of capsule, from which an elliptical piece 1 inch long and ½ inch wide was excised between the sutures already placed. When these sutures were tied, it was found that the capsule was distinctly shortened. A broad retractor, without sharp points, to retract the coracobrachialis muscle and the vessels inward, is a great help. When the arm was brought to the side, all the muscles fell into place, and it was necessary to suture only the superficial fascia and the skin. The arm was held to the side with a plaster shoulder-cap. A tight sling was applied to the elbow and forearm, to remove the weight of the arm from the deep sutures. The arm was retained in this way for two weeks, when the plaster was removed. The sling was allowed to remain one week longer, with passive exercises twice a day. At the end of three weeks, all apparatus was removed, and the patients were encouraged to execute both passive and active exercises. The patients were back at work in five weeks after operation and have continued working ever since, presenting practically normal functioning shoulders. Some of the patients furthermore have stated that they have sustained injuries which would have caused dislocation prior to the operation.

Miscellaneous Operative Procedures on the Shoulder

(*a*) **Manipulations to Relieve Contractures.**—Manipulation is to be sedulously avoided in the presence of disease or severe injury. Manipulation under anesthesia should be practised only in the case of limited motion where there is no evidence of acute inflammation and where the limitation is due to extra-articular adhesions, muscular contractures, or to very slight adhesions within the joint.

Manipulations should follow the normal arcs of motion. Stretching of the structures should be gradual, followed by a period of relaxation,

then an increase, and then a decrease to complete relaxation. Before an operation on the shoulder (*e.g.*, muscle transplantation), as good motion as possible should be secured by this method as a preliminary procedure. The following signs constitute the criterion: (1) If the fingers will reach the opposite scapula, the forearm passing in front of the face and the hand over the shoulder to the scapula; (2) the arm behind the waist and upward to the scapula; (3) the arm behind the head and neck to the scapula; outward rotation is very important; it should reach 60 degrees at least, using the flexed forearm as a guide, while inward rotation (including scapular motion) should equal 110–120 degrees. With a normal arm, extended full length perpendicularly, it can be moved backward 15 degrees or more. Abduction is equal to about 45 degrees from the side (beyond that, abduction is executed by scapular motion), but with more outward rotation the arm can be raised to the perpendicular. Adduction varies, but averages about 30 degrees. Extension backward equals 30 to 45 degrees.

In executing these manipulations, the surgeon should grasp the arm just below the flexed elbow, but should remember the great leverage which it is easily possible to obtain in that position, also that disuse atrophy in the bone renders it brittle. Manipulative movements should be gradual, not forcible or sudden, and rhythmic in character.

The desired position for immobilization after manipulation is with arm straight above the head or in Albee's position (anterior elevation). The position should be maintained by means of a splint or plaster-of-Paris dressing for a period of two to four weeks, depending upon the amount of swelling. Before fixing the arm in a splint, an ice-bag should be applied for some minutes after the operation. Repeated gradual reductions of the elevated position can be secured by means of a wire splint (shelf) on which the exercises can be performed, and this splint should be worn in some cases for as long a period as six to ten months.

(*b*) **To Correct Permanent Inward Rotation of the Upper Arm.**—Aside from intra-articular lesions, permanent inward rotation of the upper arm is caused either by relaxation and insufficiency of the posterior outward rotators of the shoulder or contracture of the inward rotators, spastic conditions (Erb's palsy) or infantile paralysis with occasionally adhesions, and contractures and depression of the acromion. Radiography will reveal any bony change.

In moderate cases, the posterior capsule may be reefed to tighten the infraspinatus. In extreme cases, the attachment of the pectoralis may be slit and overlapped and thus lengthened; or an osteotomy may be performed on the upper or lower thirds of the humerus, rotating the lower fragment outward and immobilizing the arm in this position until healing occurs. In spastic cases, myotomy of the pectoral and subscapulars may be performed (Sever), supplemented in some cases by osteotomy of the acromion.

(*c*) **To Correct Inward Rotation of the Humerus.**—*Osteotomy.*—The patient should be in the dorsal position close to the edge of the table. The arm is held by an assistant, with the forearm flexed at the elbow. An incision 1 inch in length is made at the junction of the upper and middle thirds of the outer aspect of the arm, or in the upper part of the lower third. The bone is exposed by blunt dissection. With the arm very firmly held, the bone is severed with a sharp osteotome. The wounds are sutured and dressed in the usual manner. Coaptation splints should be applied *tightly* over the site of operation. The arm is gently rotated outward about 30 degrees (*i. e.*, the flat of the forearm to the front). Plaster-of-Paris dressings are applied to hold the forearm flexed at right angles and to maintain the external rotation.

The patient is kept in bed for ten days, using the head rest constantly. Outward rotation is maintained for six to eight weeks, but the hand can be used at the end of the third week. After removal of the plaster-of-Paris splint, the case may require supplementary apparatus for several months to maintain external rotation; the style of apparatus and the method of its use are individual problems.

(*d*) **Depressed Acromion.**—This condition accompanies paralytic conditions and long-standing dislocation of the shoulder in children. The depressed acromion limits the motion of the arm. It can be detected by radiography and by palpation.

Subcutaneous Osteotomy.—At a point 1½ inches from the tip of the acromion, an incision is made with the osteotome and the acromion is severed, correcting the depression and permitting reduction of the humeral head. The wound is sutured and dressed, and the shoulder held by means of plaster-of-Paris dressings in abduction of 90 degrees, and internal rotation of 90 degrees, for six weeks.

(*e*) **Arthrotomy of the Shoulder.**—*Indications.*—Exploration, removal of foreign bodies, to repair traumata, for the reduction of dislocations, for the performance of arthroplasty, arthrodesis, drainage, subacromial bursitis, rupture of the supraspinatus, joint disease, etc.

General Rules.—Incision is made down to the synovial membrane, is made ample before the latter is opened, and absolute hemostasis is secured. Unnecessary traumatization of the joint structures is to be avoided. After the desired procedure has been executed, the synovial membrane is carefully sutured and the overlying tissues closed in layers. Blunt dissection is used whenever possible, and unnecessary separation of the tissue layers is avoided. The tendons are left in their sheaths. Overlapping incisions should always be used. To reef the capsule, the anterior incision is best; for drainage, the anterior, posterior, or both incisions may be necessary. Motion is begun early, executed gently, and gradually increased.

Technic.—(*a*) *Anterior Incision* (for procedures on the Capsule, Excision, Arthrodesis, and Fracture).—The incision is made from a point ½ inch below the acromion downward parallel to the deltoid and just external to its inner border for a distance of 3 to 4 inches. (The subacromial bursa lies under the deltoid and acromion). More room can be obtained by prolonging this incision downward, or a second incision made from the primary inward just below and parallel with the clavicle.

The synovial cavity is opened in line with the bicipital groove (palpable by finger) by inserting a grooved director and opening the capsule on it. By displacing the biceps tendon inward, a better view is obtained. First by internal and then by external rotation, the restricting portions of the capsule are exposed and severed subperiosteally, thus allowing avulsion of the head by adducting the arm. After the operation has been completed, the head is replaced in the glenoid cavity, the biceps tendon in its groove, and the overlying structures sutured in layers with interrupted sutures of chromicized catgut Nos. 00, or 0.

(*b*) *Posterior Incision.*—This is made 3 inches long from a point ½ inch posterior to the tip of the acromion downward, parallel to and 1½ inches from the posterior border of the deltoid through the skin and fat. The deltoid is separated by blunt dissection, exposing the capsule which is lifted with forceps and incised. The rest of the technic is as described for the anterior incision.

(*c*) *Kocher Incision.* (Fig. 264).—The incision is made from the acromioclavicular joint, following the upper border of the acromion and spine of the

scapula to its root, thence downward and forward to the posterior fold of the axilla. The acromion ligament is detached subperiosteally from the acromion; the deltoid is separated from the underlying tissue by blunt dissection or by the fingers. The muscles at the spine of the scapula are separated subperiosteally. The acromion is severed with an osteotome and retracted forward with the deltoid. The surgeon should avoid injury to the suprascapular nerve, passing under the muscle from above to a point below the spine into the infraspinatus fossa. Ease of displacement and reposition of the acromion and spine are facilitated if drill holes are made and sutures passed through the structures before they are severed. The head and the glenoid are now fully exposed by dislocating the bicipital tendon inward.

Drainage of the Shoulder Joint for Suppuration.—In the case of a small focus, drain by an appropriate incision (see page 516), cleanse the cavity with gauze, place a wick to the deepest recesses, and pack the wound rather full.

If there is much constitutional disturbance, drainage and counter-drainage should be established. If osteomyelitis is present, multiple drill holes should be made to the marrow cavity. All pus and débris should be wiped out, and gauze wicks or cigarette drains placed to the remotest recesses of the pus pockets. If the sequestra are easily removable, they should be taken out, but the patient's condition should not be jeopardized otherwise. The question of instituting the Carrel-Dakin treatment should always be decided by the merits of the individual case.

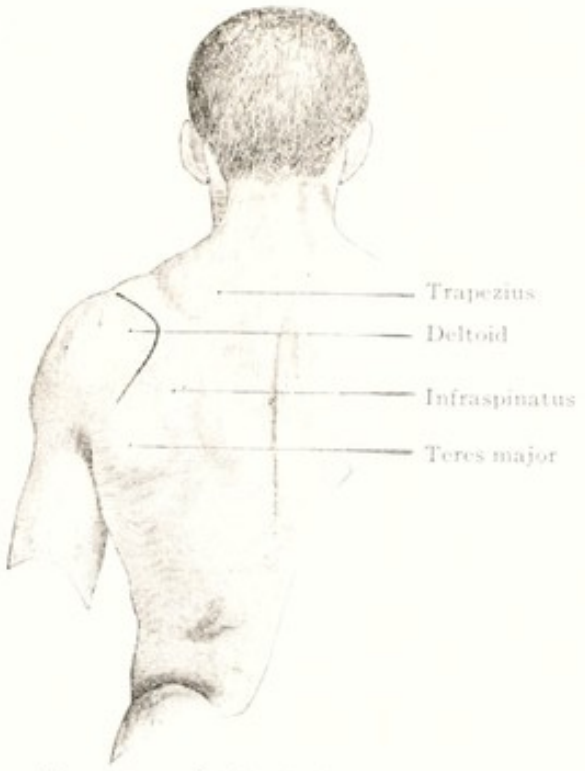


FIG. 264.—Kocher's incision for resection of the shoulder. The incision begins at the acromioclavicular joint, carried along the upper margin of the spine of the scapula to about the middle of that bone and thence continued to curve downward and outward to about two fingers' breadth from the posterior axillary fold. (Binnie.)

ELBOW

1. Chronic Synovitis

Aspiration or Injection (see Fig. 265).—In "tennis elbow," chronic synovitis is often present from strain on the internal lateral ligament and the common tendon of the flexor and pronator muscles. Chronic synovitis may be associated with tenderness of the pronator radii teres, with tenderness and swelling of its insertion into the radius, probably from inflammation of the small bursa at that point. The treatment consists of rest, counterirritation, and later, massage.

2. Flail-elbow

Partial or complete paralysis of all its muscles is the usual cause. Arthrodesis should be performed only as a last resort.

Operative Treatment.—The forearm may be supported in several ways, viz., by silk ligaments, fascial transplantation, or a plastic operation on the skin. If all are ineffective, arthrodesis is the procedure of choice.

(*a*) *Silk Ligaments* (Soutter).—An incision is made through the internal surface of the lower third of the humerus, the periosteum incised and elevated, and a hole drilled through the humerus; the drill is left in position, a leader of silkworm gut is placed in the drill eye and into the leader a strand of heavy silk is passed; withdrawal of the drill pulls the silk through the hole. A second incision on the internal aspect of the upper third of the forearm is made down to the ulna (by means of the drill the silk is drawn down subcutaneously from its humeral insertion); the ulnar periosteum is incised and elevated, the ulna is drilled as above, silk is threaded through the carrier and drawn through the ulna. Both ends of the silk are now protruding from the second incision (one from the humerus the other from the ulna, their ends are tied subcutaneously and the incision is closed.

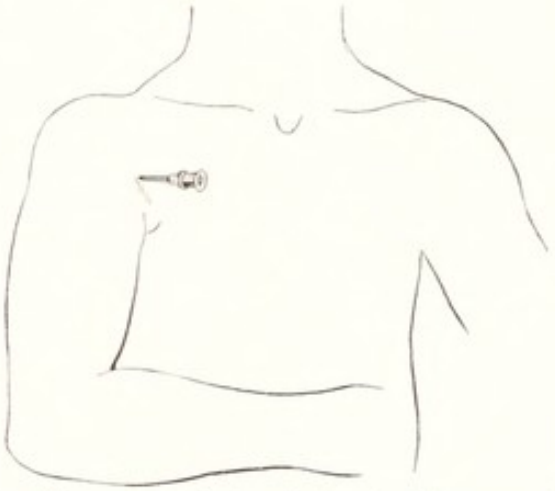


FIG. 265.—Aspiration and injection of the shoulder-joint. The trocar is entered at a point 1 cm. outside the coracoid process, in the adult (0.5 cm. in the child), and pushed from before backward and a little (15°) upward.

(*b*) *Fascial Transplantation.*—On the anterior surface of the lower third of the humerus, an incision 3 to 4 inches long is made, the fibers of the biceps and brachialis anticus are separated to the bone and held apart with retractors. A drill hole is made from side to side through the anterior third of the humerus, and a carrier placed in the drill eye. A second incision is made over the upper third of the ulna, 3 inches in length, the bone is drilled, and the carrier attached to the drill eye.

Fascia is obtained from the outer surface of the upper thigh, a piece broader and longer than the distance between the two incisions above mentioned, its measurements made with a probe, two extra inches being allowed, the fascia is slit at each end, and the two sections at each end rolled in tubular form.

A subcutaneous tunnel is made connecting the humero-ulnar incisions, the fascial flap is passed into the tunnel and its tubular ends are drawn through holes in the humerus and ulna respectively (two to the former and two to the latter), overlapped and lashed down over the anterior surfaces of these bones with No. 0 or No. 1 chromicized catgut sutures.

The elbow is flexed 15 degrees more than ultimately desired (remembering that the fascia will stretch 25 degrees or more in time), fixed, with plaster-of-Paris dressings without tension, and immobilized in this position for eight weeks; or else the plaster-of-Paris dressing is cut down after it has hardened, into anterior and posterior halves to allow inspection of wounds. At the end of six weeks, the weight of the forearm is allowed to come on the fascial band for five to fifteen minutes twice each day, gradually increasing the play of the arm.

(*c*) *Sir Robert Jones' Plastic Procedure on the Skin* (see Chapter XXI).

Miscellaneous Operative Procedures on the Elbow

1. **Arthrotomy.**—The general rules for arthrotomy (see Arthrotomy of the Shoulder) should be observed. For exploration, erasion, excision, arthrodesis, dislocation, and drainage, either a posterior or combined externo-lateral incision should be employed.

(*a*) *Posterior Incision.*—The outer or inner side of the olecranon is selected. The outer is preferable for excision, arthroplasty, fracture of the olecranon and of the external condyles, and for exploration. The inner and external incisions are preferable for dislocations.

Incision is begun 2 inches above the olecranon and carried vertically downward for 4 inches on the outer side of the olecranon. The dissection is carried down to the bone, the periosteum incised and lifted with a sharp periosteal elevator from above downward, first on one side and then on the other. The outer condyle is cleared first, then the inner.

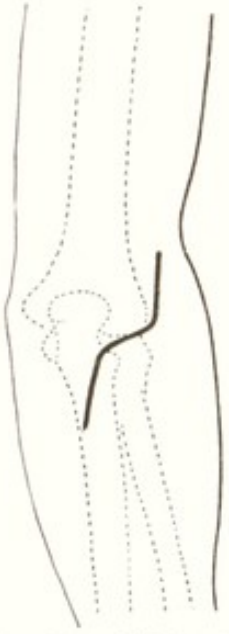


Fig. 266.—Ollier's incision for resection or excision of elbow. (Binnie.)



Fig. 267.—Rutherford-Morison's incision for resection or excision of elbow. (Binnie.)

(*b*) *Externo-lateral Incision.*—The incision is made from a point just below the head of the radius upward for 5 inches, immediately anterior to the condyle and parallel with the bone. Careful dissection is made down to the bone, the radial joint being opened if necessary. The periosteum is incised and elevated, beginning over the head of the radius and working up and forward to the upper angle of the incision, then gradually downward and upward subperiosteally. The periosteum may also be lifted posteriorly if necessary.

(*c*) *Interno-lateral Incision.*—The incision is made from a point 2 inches above to a point 2 inches below and just posterior to the condyle. Care should be taken to avoid the ulnar nerve by lifting the periosteum under it. The periosteum is cleared to the required extent anteriorly and then posteriorly.

2. **Drainage** (For General Rules, see Shoulder).—For non-tuberculous suppuration, if at all extensive, employ a posterior and an anterolateral external incision, or both, with the addition of an interno-lateral one. If osteomyelitis is suspected, the bone should be drilled to the marrow in

several places; rapidity and good drainage are more important elements than the removal of sequestra at this time.



FIG. 268.

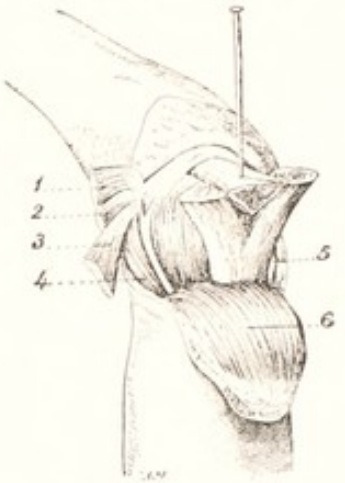


FIG. 269.

FIGS. 268 and 269.—Extracapsular arthrectomy—Bardenheuer's operation. (Lossen.)

FIG. 268.—1, Anconeus; 2, ext. digitorum; 3, division musculospiral nerve; 4, ext. carpi radialis longior; 5, supinator longus; 6, musculospiral nerve; 7, pronator radii teres; 8, brachialis anticus; 9, flexor muscles divided; 10, ulnar nerve; 11, tendon of triceps.

FIG. 269.—1, Anconeus; 2, extensor com. digitorum; 3, division musculospiral nerve; 4, ext. carpi radialis longior; 5, supinator longus; 6, musculospiral nerve.

3. **Extracapsular Arthrectomy.**—Bardenheuer's operation (modified) (see Figs. 268 and 269). Bardenheuer exposes the joint by a U-shaped incision on the posterior aspect of the elbow-joint with the pedicle of the flap above. The triceps tendon is divided above the olecranon. By sharp and blunt dissection, the posterior and lateral surfaces of the joint capsule are exposed but the joint *is not* entered. The humerus is divided, and its articular end retracted downward, thereby exposing the anterior surface of the joint. The overlying soft structures are now separated from the anterior surface of the capsule. The ulna is divided, and next the radius (but at a lower level than the section of the ulna, in order to preserve pronation and supination). A V-shaped notch is now cut in the lower extremity of the humerus by means of osteotome, bone forceps, or motor-saw; the ulnar extremity is shaped to fit into this and held with a bone-graft peg at a little less than a right angle with the humerus. The wound is closed and dressed, and the position maintained with a plaster-of-Paris splint.



FIG. 270.—Aspiration and injection of the elbow-joint, a few millimeters above the point of the olecranon, and outside the middle of the triceps tendon.

4. **Aspiration and injection** (see Fig. 270).

WRIST

1. **Chronic Synovitis.**—This is very common, particularly in those using the hands to excess (*e.g.*, pianists). The treatment is the same as for chronic synovitis of other joints. If the effusion is slow in undergoing ab-

sorption, massage (manual and vibratory), electric light baths, hot soaks, followed by counterirritants and some form of support to the wrist, Bier's hyperemia, etc., may be tried.

2. **Chronic Tenosynovitis.**—This affection causes progressive enlargement of the tendon sheath and the symptoms of weakness and distress. In the case of these aggravating symptoms, the underlying cause is usually tuberculosis, and operative removal is indicated. If the tuberculous process is old and extends into the palm, the débris is evacuated by incision, the wound then closed, and pressure applied to promote the formation of interadhesion of the involved structures.

Operative Procedures upon the Wrist

1. **Arthrotomy of the Wrist.**—*Indications.*—Deformity (congenital or acquired), compound fracture, ankylosis from injury or disease, and suppuration.

It is best to use anterior and posterior incisions at the same time rather than a single incision. Long incisions are desirable, in order to avoid injury, adhesions, or sloughing of tendons, and also to allow good retraction and to avoid disturbing the tendon sheaths by working subperiosteally. It is necessary to incise the posterior annular ligament, and by passing one finger through the anterior and one through the posterior incision, the surgeon can work without unnecessary trauma and without producing postoperative swelling, pain, and injury from operation.

For exploration, an anterior or a posterior incision, or both, are employed; the posterior incision is best, however, and extends from a point between the styloids to the second or third metacarpal. For drainage, an anterior and a posterior, and sometimes a radial or a lateral incision are used; radiography will aid in deciding which incision to employ. When the removal of one or more bones is necessary, a better functional result is obtained in some cases by complete excision of the carpus, performed subperiosteally, than by removal of the individually affected bones, and, moreover, it is unusual to get abnormal mobility from this radical procedure.

Ollier's Incisions.—For suppuration, it is advisable to employ three incisions: an anterolateral, a posterior, and one small external incision for drainage. After the usual surgical toilet, a tourniquet is applied, the arm placed on a table at the side of the operating table, pronated, and rested on a sand-bag.

(*a*) *Posterior Incision.*—From a point midway between the styloids, and 1 inch above the wrist-joint the incision is carried downward through the posterior annular ligament, to the middle of the second metacarpal, along the outer side of the extensor indicis, and down to the periosteum. The extensor indicis is retracted inward, and the extensor secundi internodii outward. The extensor carpi radialis longus and brevis are detached subperiosteally.

(*b*) *Anterior Incision.*—Over the radial border of the ulna from a point 1 inch above the styloid process, the incision extends to the base of the fifth metacarpal, leaving the flexor carpi ulnaris to the inner side. The incision is carried downward to the periosteum.

(*c*) *Radial Incision.*—This is a short incision, 1 inch in length, over the styloid of the radius and carried to the bone for the purpose of drainage.

2. **Excision of the Wrist.**—If removal of one or more carpal bones is necessary, a better functional result is obtained, as has been said, if all the carpal bones are removed, with the possible exception of the pisiform and

trapezius, and the unciform process of the unciform. There is less danger of stiffness by this procedure and no danger of abnormal mobility, if the subperiosteal method is used; motion will amount to one-third to two-thirds or more of the normal flexion and extension at the wrist. Gentle handling and the use of long incisions will enhance the result in operating for ankylosis from deformity, old fracture, or inflammation. Interadhesion of tendons should be relieved by manipulation prior to operation. There should be no attempt at the time of operation to break up adhesions, which will largely be effected by removal of the carpus; but immediately after operation the fingers should be manipulated, to be sure that their tendons are not obstructed.

Ollier's three incisions, which have just been described, are employed. Having incised, widely elevated, and retracted the periosteum, the bones are laid bare without disturbing the tendon sheaths. The next step is removal of the carpal bones one after another. The tourniquet is not removed from the arm until the final fixation dressings have been applied. The deep structures and the periosteum are closed with interrupted sutures of small-sized chromicized catgut, and the skin with a continuous suture of plain catgut No. 1.

If this operation has been performed for suppuration, the cavity should be swabbed out, irrigated with normal salt solution, and if the ends of the ulna and radius, or the metacarpus, are necrotic, the diseased portions should be removed.

In children, while clearing away the diseased bone, the epiphyses should be spared, even if diseased, reliance being placed upon good drainage for the alleviation of the condition. If the tendons, or their sheaths, and the ligaments have been invaded, all diseased tissue possible should be cleared away. The wounds are packed wide open at their corners, and if the incisions have been long the intervening portions may be temporarily or permanently united by sutures.

In septic cases, the wicks should be left in position for eight to ten days, not removed unless clearly indicated. The plaster-of-Paris dressing, with a window cut out over the site of operation, is applied from the axilla to the metacarpo-phalangeal joints, with the forearm flexed, the fingers being left free for active or passive manipulation. The plaster dressing should be gradually cut down, beginning at the end of the eighth week, or, in clean cases, at the fifth week.

3. **Disease of the Metacarpal and Phalangeal Bones and Joints.**—The incision is made on the dorsal surface of the finger, between the artery and tendon, and carried through the periosteum, which is elevated and retracted without disturbing the structures between it and the skin. In the case of children, the epiphyses must be avoided, as has already been stated, even if they are diseased. With motor saw outfit or the osteotome, a section of bone of appropriate diameters is removed from the cortex and the diseased marrow cleaned out with a curet, sharp spoon, and swab. A gauze wick or a cigarette drain is inserted down to the focus, and the wound packed wide open. The wicks are removed on the tenth day. The wound is dressed on the third or fourth day, and as often thereafter as necessary, without disturbing the wicks, which, however, may be shortened at intervals until the date of their removal, but are not renewed.

Immobilization from the fingers to the elbow is secured by a palmar splint and maintained for seven to ten days, after which the fingers are liberated and their use encouraged.

However, if infection is still active at the end of that time, immobilization should be continued until it has subsided. A palmar abscess frequently develops, and is indicated by swelling at the palmar aspect of the wrist and on the dorsum of the hand. Incision and drainage should be performed to whatever extent indicated (including the forearm, if necessary), by the presence of pus and the degree of local and general disturbance. Frequent daily prolonged soaks in hot, mildly antiseptic solutions increase the comfort of the patient and alleviate the local conditions, and may be supplemented by the use of hot poultices. The foregoing directions apply equally to diseased metacarpal bones. The surgeon should be on the watch for axillary lymphadenitis.

4. **Drainage for Suppuration at the Wrist and Hand.**—The general rules previously outlined for drainage should here be observed. In cases with much prostration, the operation should be performed with as much speed as is consistent with thorough drainage. During immobilization, the fingers should be left free in every case, when this is possible. If the disease is at all extensive in the wrist and hand, anterior and posterior incisions should be made at the wrist and on the back of the hand and fingers. The use of the Carrel-Dakin technic should be decided on the merits of the individual case.

5. **Aspiration or injection** (see Fig. 271).

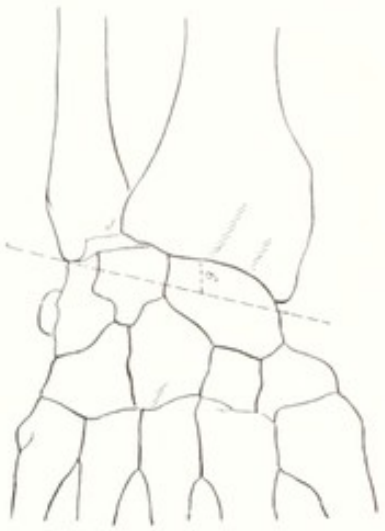


FIG. 271.—Aspiration and injection of wrist-joint. The point of election is located 6 mm. above the center of a line connecting the extremities of the styloid processes of the ulna and radius.

FOOT AND ANKLE

(1) SPRAIN

Sudden forcible inversion or eversion of the relaxed foot produces traumatization of the synovial membrane with effusion, more or less rupture of muscle fibers, strain on the tendons and their sheaths, and, in extreme cases, rupture of the peri-articular ligaments with more or less hemorrhage, and constitutes the so-called "sprain."

Symptoms.—The clinical features immediately following the accident consist of sudden, intense, throbbing pain, swelling, local heat, and ecchymosis of varying degree, which may include the whole foot and lower leg.

Treatment.—Immediate immobilization and compression of the part are the desiderata. Either cotton sheet wadding and a bandage firmly and evenly applied (the "semi-elastic" bandage is excellent for this purpose) or simply an unsupported flannel bandage is adequate. In more severe cases, a plaster-of-Paris splint, applied from the toes to the tibial tubercle, is required; this may be cut down over the anterior aspect of the ankle and foot, for the purpose of administering massage, hot air, hot and cold douches, electricity, etc.

After subsidence of the acute stage, Gibney's method of strapping the ankle with adhesive plaster is the most satisfactory form of support: strips of adhesive plaster ¾ inch in width and 9 to 18 inches in length are used, and placed as follows: (*a*) one is applied to the center under the heel and its ends are carried up each side of the leg parallel to the tibia and fibula, and extending to the junction of the middle and lower thirds; (*b*) the other is applied with its center behind the heel and its extremities carried forward, to and beyond the tarsometatarsal junction on each side. A duplicate of (*a*) is placed in the same manner overlapping it, and a duplicate of (*b*) is similarly

placed. This covers and compresses the ankle except for a small space directly in front of its dorsal surface. It is best to place re-inforcing strips of plaster at the points of greatest tenderness.

Another method of applying adhesive strapping is as follows: One end of a long strip of plaster, about 2 inches in width, is fixed just above the malleolus of the sound side of the ankle, and the strip is then carried down under the sole up the sprained side of the joint (which is thereby relaxed by increasing its eversion or inversion, as the case may be) and further up the leg to the junction of the upper and middle thirds, where it is fixed by an encircling band of adhesive. A second such bracelet is placed just above the malleoli. Overlapping narrow strips of adhesive, applied in a figure-of-8 manner, are then used to encase the foot from the metatarsophalangeal joints to the malleoli and a firm bandage is applied. The patient is then encouraged to walk. This adhesive support is renewed as swelling subsides (indicated by wrinkling of the plaster); its re-application may be necessary two or three times. Vigorous massage should be administered between the several applications of the adhesive.

Chronic Sprain.—*Causes.*—A poorly treated acute case, prolonged fixation of the joint (with muscular and osseous atrophy and failure of absorption of exudate on account of impaired circulation), also long disuse or subluxation of the astragalus incidental to the primary sprain. Many cases diagnosed as "chronic sprain" represent traumatized weak foot.

Treatment.—The basis of treatment is the restoration of the normal attitude of the foot by fixing it in a position opposite to that which it has acquired. To do this, anesthesia may be necessary because of the adhesions present. The foot is fixed in the correct position in plaster-of-Paris, and the patient is encouraged to walk with the foot thus held in its proper relationship to the leg; after he can do this without distress and is accustomed to the new position, the plaster-of-Paris dressings are removed and a light brace temporarily applied, to restrain lateral movement of the foot, or he is furnished with a foot-plate. Exercises, massage, baking, manipulation, etc., are to be prescribed.

(2) Tenosynovitis

Inflammation of the tendon-sheaths about the ankle-joint may be incidental to sprain, or the tendons may be subjected to independent strain. Chronic tenosynovitis may result from injury or follow gonorrhea or other infectious disease. The **symptoms** of acute tenosynovitis are: distress on gliding of the inflamed tendon, accompanied by "creaking" (appreciable to touch), localized swelling, and tenderness to pressure.

The tendon sheaths liable to inflammation about the ankle-joint, are: (*a*) in front, the sheaths of the tibialis anticus, extensor longus hallucis, and extensor communis digitorum; (*b*) behind the internal malleolus, the common sheath of tibialis posticus and flexor longus digitorum, and that of the flexor longus hallucis; (*c*) behind the external malleolus, the common sheath of the two peronei.

Treatment.—Rest and compression are essential, and for this purpose adhesive strapping may be employed in moderately severe cases, or a plaster-of-Paris compression splint in obstinate cases. Local counterirritation (*e.g.*, the actual cautery) is beneficial. If the case is intractable, operative removal of the sheath must be performed.

(3) Congenital Dislocation and Subluxation of the Ankle

Although these deformities are very rare, they are encountered in various forms, viz.: (*a*) in conjunction with congenital deficiency of the fibula, the

foot being in a position of equinovalgus; (*b*) the fibula is rudimentary, and the foot complete but luxated more or less outward; (*c*) the external malleolus is present but situated above, or above and behind, its normal location, the foot being luxated out and in valgus; (*d*) the tibia is defective and the foot displaced inward in varus or equinovarus; (*e*) forward dislocation of the foot, the result of sharp backward curvature of the lower end of tibia and fibula.

Treatment.—In infants, tenotomy and fasciotomy, with maintenance of the correction by splints, may afford some relief. In older children, osteoplastic repair of the defect in the tibia or the fibula may correct the deformity. If these measures fail, arthrodesis of the ankle will effectually stabilize the foot.

(4) Traumatic Dislocation of the Forefoot (see Fig. 272)

Miscellaneous Surgical Procedures at the Ankle

1. **Arthrotomy.**—The general rules prescribed for arthrotomy of other joints should here be carefully observed.



a *b*

Fig. 272.—Dislocation outward of the forefoot at the metatarso-tarsal joints from a severe fall in a very heavy individual. Longitudinal incisions were made over the joints of the second and third metatarsal bones and the joints lowered into position by a long periosteal elevator as seen in *b*. The foot was then held in extreme varus and dorsal flexion by a plaster splint from toes to tubercle of tibia.

(*a*) *Anterior External Incision.*—A curved incision is begun at a point $2\frac{1}{2}$ inches above the external malleolus, carried along the anterior border of the fibula downward and forward just above the peronei tendons, to end at the cuboid. The tibiotarsal joint is about 1 inch above the tip of the fibula.

(*b*) *Posterior External Incision.*—The incision is made midway between the external malleolus and the outer edge of the tendo Achillis, beginning $2\frac{1}{2}$ inches above the malleolus, carried along and parallel to the posterior

border of the fibula, downward and forward to a point ¾ inch below the tip of the external malleolus.

(*c*) *Anterior Internal Incision.*—From a point 2 inches above the internal malleolus, an incision is carried along the anterior border of the tibia, downward and forward, to end at the tubercle of the scaphoid.

(To gain access to the tarsus, all three of the above incisions may be prolonged forward).

(*d*) *Posterior Internal Incision.*—The incision is located midway between the tendo Achillis and the internal malleolus, begins at a point 2 inches above the latter, is carried downward and forward, and ends 1 inch below the internal malleolus. This incision is particularly designed for exposure of the os calcis and the posterior portion of the ankle-joint; in combination with the posterior external, this gives ample access to the os calcis, unless the disease extends far forward into the astragalus, in which case it is advisable to use the anterior median incision in addition to the two posterior.

(*e*) *Anterior Median Incision.*—From a point 2 inches above the anterior transverse line of the ankle-joint, the incision is carried vertically downward over the midtarsus, just outside the extensor longus hallucis to the base of the third metatarsal.

Incisions into the sole should be avoided; it is preferable to gain exposure in this region by incisions at one or both sides of the foot.

(*f*) *Circular Incision.*—For approaching the astragalus or for complete exposure of the ankle, begin the incision at a point 1 inch above the external malleolus, midway between the fibula and tendo Achillis, carry it forward and slightly downward until the front and middle of the tarsus are reached, and then directly downward to the base or center of the third metatarsal. The periosteum and overlying tissues are elevated *en masse*, thus allowing retraction of the tendons in the tissues. The ligaments attached to the external malleolus are separated subperiosteally from the anterior, external and posterior surfaces of the fibula, permitting inward dislocation of the foot. This gives wide exposure of the tibiotarsal joint, astragalus, and upper portion of the tarsus. After completion of the desired operation, the foot is replaced and the deep structures and skin approximated by sutures. The external ligaments usually require no suture, since their separation from the fibula was accomplished subperiosteally. The foot is immobilized in a plaster-of-Paris splint with dorsal flexion of 30 degrees.

2. **Aspiration of the Ankle-joint.**[1]—For performing aspiration, local anesthesia may be necessary, for which purpose ethyl chlorid or 1 per cent. of novocain-adrenalin solution may be employed. Observing the most thorough aseptic precautions, the joint is reached by introducing the trocar immediately anterior to either the external or the internal malleolus and just posterior to the tendon sheaths in either locality. To prevent the puncture wound of the skin overlying that of the subcutaneous tissue, the skin may be drawn to one side after puncture, before entering the joint. It is best to insert the trocar independently of the syringe, which can be attached later. A connecting piece of rubber tubing, tied to the trocar and subsequently to the syringe, tends to prevent accidents from sudden movement on the part of the patient. The trocar should be of large caliber to permit the passage of sediment or débris without becoming clogged (Fig. 273).

[1] The tibiotarsal joint is, as has been stated, about 1 to 1¼ inches above the tip of the external malleolus.

3. **For Suppuration at the Ankle.**—The number and location of the incisions and counterincisions vary with the circumstances of the individual case.

(*a*) *Os Calcis and Tarsus.*—Diseased foci in these bones should be drained on both sides and anteriorly, if necessary. The focus (which should be localized by the *x*-ray beforehand) is removed with osteotome and gouge as far as healthy bone. The cavity is irrigated with hot normal saline solution, swabbed out with gauze, and wicks or cigarette drains are inserted to its depths, and the wound packed wide open. A plaster-of-Paris dressing is applied, with windows at the site of operation. The wicks are shortened after the tenth day, removed soon thereafter, and not renewed.

The entire os calcis or individual bones of the tarsus may be removed, providing their periosteum and a thin shell of bone remain, and be followed by almost complete restoration. The plaster may be finally removed when weight can comfortably be borne on the foot.



FIG. 273.—Aspiration and injection of the ankle-joint. One point of election for penetrating the joint.

(*b*) *Metatarsal and Phalangeal Bones and Joints.*—The location of the incision varies with the particular bone to be reached, but in every case the incisions are made on the dorsal surface, between the artery and tendon, carried down to the bone, and the overlying structures lifted *en masse* by incising and elevating the periosteum with a small, thin, sharp osteotome, followed by wide retraction.

REFERENCES

KNEE-JOINT

DISPLACEMENT OF THE SEMILUNAR CARTILAGES

HEY: "Practical Observations in Surgery," 1803.

TENNEY: Annals of Surg., July, 1904 (with bibliography).

ALLINGHAM, H. W.: "Internal Derangements of the Knee-joint." London.

JONES ROBERT: "Certain Derangements of the Knee-joint." Clin. Jour., May 9, 1906.

JONES, ROBERT: Annals of Surg., 1909, l, 074.

BARKER, A. E., AND GOFFÉ, E. G. L.: Ency. Med., vi, 127.

POWER, D'ARCY: "The Results of the Surgical Treatment of Displaced Semilunar Cartilages of the Knee." Brit. Med. Jour., Jan. 14, 1911, p. 61.

LANE, W. ARBUTHNOT: "A Clinical Lecture on Some of the Common Injuries of the Knee-joint and Their Consequences." Brit. Med. Jour., March 11, 1911.

RUPTURE OF CRUCIAL LIGAMENTS

JONES, ROBERT: Brit. Jour. Surg., 1915, i, 70.

SCHLATTER'S DISEASE

OSGOOD, C. F.: Boston Med. and Surg. Jour., Jan. 29, 1903.

THOMSON, ALEXIS: Edinburgh Med. Jour., March, 1908.

ELMSLIE, R. C.: "Enlargement of the Tubercle of the Tibia." Brit. Jour. Childr. Dis., January, 1911.

LOVETT: Phila. Med. Jour., Jan. 6, 1900.

LIPOMA ARBORESCENS

PAINTER AND ERVING: Boston Med. and Surg. Jour., March 19, 1903 (with literature).

STIEDA: Beitr. z. klin. Chir., 1896, xvi, 285.

MEISENBACH, R. O.: Buffalo Med. Jour., February, 1908.

Cysts

Baker, Morrant: St. Bartholomew's Hospital Reports, xiii, 245, xxi, 177.
Baker, Morrant: Centralbl. f. Chir., 1898, p. 585.

SHOULDER-JOINT

Recurrent Dislocation

Albee, F. H.: "A Report of Two Cases of Recurrent Dislocation of the Shoulder Successfully Operated upon, with Description of the Technique." Am. Jour. Surg., July, 1908.

Epiphyseal Fracture of the Upper End of Humerus

Albee, F. H.: "Epiphyseal Fracture of the Upper End of the Humerus. Two Cases Successfully Treated by a New Method." N. Y. Post-Graduate, June, 1908.
Albee, F. H.: "Juxta-Epiphyseal Fracture of the Upper End of the Humerus, a New Postural Treatment." N. Y. Med. Record, May 4, 1912.

Gumma of the Shoulder

Albee, F. H.: "A Case of Gumma of the Shoulder." Post-Graduate, N. Y., March, 1912.

Congenital Dislocation of the Shoulder

Eve: Clin. Soc. Trans., 1895, p. 299.
Robinson: Lancet, 1893, vol. i, 475.
Lewis: Phila. Med. News, 1895, p. 183.
Stimson: "Fractures and Dislocations."
Scudder: Arch. of Pediat., April, 1890.
Scudder: Am. Jour. Med. Sci., February, 1898.

Stiff and Painful Shoulder

Brickner, W. M.: "Shoulder Disability (Stiff and Painful Shoulder)." Am. Jour. Surg., June, 1912.
Jarjavay: "Sur la luxation du tendon de la langue portion du muscle biceps huméral." Gaz. Heb. de Méd., 1867, iv, 325.
Duplay, Simon: "Periarthrite scapulo-humérale." Arch. gén. de méd., November, 1872. Also Cliniques Chirurgicales de l'Hotel Dieu, 1897, 265.
Küster: "Ueber Bursitis Subacromialis (Peri-arthritis Humero-Scapularis)." Archiv. f. klin. Chir., Bd. 67, 1902, s. 1013.
Codman, Ernest A.: "On Stiff and Painful Shoulders; the Anatomy of the Sub-deltoid or Sub-acromial Bursa and Its Clinical Importance; Subdeltoid Bursitis." Boston Med. and Surg. Jour., May 31, 1906, vol. 154, p. 613.
Codman, Ernest A.: "Bursitis Subacromialis or Peri-arthritis of the Shoulder-joint (Subdeltoid Bursitis)." Read before the Mass. Med. Soc., June 9, 1908, and published serially in Boston Med. and Surg. Jour., beginning Oct. 22, 1908 (vol. 159).
Finney, J. M. T.: Johns Hopkins Hosp. Bull., June, 1894, p. 83.
Painter, C. F.: Boston Med. and Surg. Jour., March 21, 1907.
Goldthwait, Painter, and Osgood: "Diseases of the Bones and Joints." D. C. Heath and Co., 1909, pp. 615–627.
Bilhaut: "Observation de kyste à grains riziformes de la bourse séreuse sous-deltoidienne." Ann. d'orthop. et de Chirurg. prat., 1892, v, 193, p. 6.
Codman: "On Stiff and Painful Shoulders, as Explained by Sub-acromial Bursitis and Partial Rupture of the Tendon of the Supra spinatus." Boston Med. and Surg. Jour., July 27, 1911, 115–120.
Codman: "Complete Rupture of the Supra-spinatus Tendon, Operative Treatment with Report of Two Successful Cases." Boston Med. and Surg. Jour., May 18, 1911, 708–711.
Velut, F.: "La peri-arthrite scapulo-humérale traumatique et les fractures des tuberosités humérales." Thésis, Paris, 1904.
Turner, T. T.: "Stiff and Painful Shoulders, with Loss of Power in the Upper Extremity." Am. Jour. Med. Sci., April, 1911, 515.

GOLDTHWAIT, J. E.: Am. Jour. Orthop. Surg., 1908, vi, 579.
ALLEN, A. R.: Penn. Med. Jour., August, 1911.
RUGH, J. T.: Penn. Med. Jour., August, 1911.
STEVENS: Am. J. Med. Sci., December, 1909, p. 870.
TURNER, T. T.: Therapeutic Gazette, Feb. 15, 1912.

CONGENITAL DISLOCATION OF ANKLE

FREIBURG, A. H.: Am. Jour. Orth. Surg., May, 1904.
DREIFUSS, A.: Zeitschr. f. orth. Chir., xvi, 422, 1906.
BURCKHARDT, L.: Jahrb. f. Kinderheilkunde, 1890, xxxi, S. 375.
VOLKMANN, R.: Deutsch. Zeitschr. f. Chir., 1873, ii, S. 538.
KRASKE: Verhandl. d. deutsch. Gesells. f. Chir., 1882, S. 126.
BIDDER: Verhandl. d. deutsch. Gesellsch. f. Chir., 1888, S. 92.
FALER: Inaug. Dissert., Halle, 1884.

CHAPTER XVI

INFECTIOUS OSTEOMYELITIS

Definition.—Infectious osteomyelitis is an acute suppurative inflammation of bone always due to infection of the bone-marrow by pyogenic micro-organisms. It has been graphically called "bone furunculosis," the process being analogous to the pathology of furunculosis of soft parts.

The following remarks on the pathology, clinical features, and etiology are founded largely on the exhaustive studies of E. H. Nichols of Boston from the Surgical Laboratory of Harvard University (ref. Acute, Subacute, and Chronic Infectious Osteomyelitis; Nichols, E. H., Jour. A. M. A., vol. xlii, pp. 439–466).

ETIOLOGY

(*a*) **Direct Causes.**—Some *pyogenic micro-organism* is the constant direct etiologic factor.

1. *Staphylococcus pyogenes aureus* is the commonest cause and produces the most typical and extensive bone destruction.

2. *Staphylococcus pyogenes albus* or *citreus* is occasionally isolated in pure culture. The bone lesions of the staphylococci are often secondary to suppurative lesions elsewhere in the body (*e. g.*, carbuncles or furuncles).

3. *Streptococcus* is the infectious agent in a few cases, having a selective affinity for the joints and tending to produce separation of an epiphysis or to attack the superficial portion of a bone and excite periosteitis rather than to invade the marrow. It is frequently the causative factor in infants whose mothers are suffering with breast disease or septicemia, raising the question of infection during delivery or through milk. Again, the streptococcus may be derived from a phlegmon or from erysipelas.

4. *Pneumococcus.*—This diplococcus tends to produce a superficial lesion or a joint infection. It may be that the process follows or is incident to pneumonia, or it may be independent of any other demonstrable lesion.

5. *Bacillus typhosus* may be present in pure culture. The lesions are small in extent, superficial, involve the marrow alone, cause slight destruction, and usually occur late in the course of typhoid fever (Figs. 274 and 275).

Whatever the nature of the infectious agent, it can usually be isolated in pure culture, but is occasionally associated with other organisms. Chronic cases are often associated with a great variety of invaders (*e.g.*, B. fetidus, B. coli communis, B. pyocyaneus, B. anthracis).

(*b*) **Predisposing Causes.** 1. *Adolescence.*—The incomplete development of the bones is probably a contributing cause of the incidence of 50 per cent. of the cases between thirteen and seventeen years of age, usually boys.

2. *Exhaustion and exposure.*

3. *Trauma*, with or without demonstrable injury to the overlying skin.

4. *Antecedent infectious diseases*, particularly measles, scarlet fever, pneumonia, typhoid fever, and small-pox. In these cases (with the exception of typhoid fever and pneumonia) the lesion is due to secondary infection with

pyogenic organisms. In typhoid fever and small-pox, areas of necrosis in the bone offer a nidus for secondary infection by the pyogenic cocci.

5. *Compound fracture.*

METHOD OF INFECTION

1. **Secondary to other pyogenic lesions,** *e.g.*, furuncle, paronychia, chronic ulcer, etc.
2. **Respiratory tract,** pneumonia, pleurisy, or empyema.
3. **Intestinal tract,** *e.g.*, typhoid.

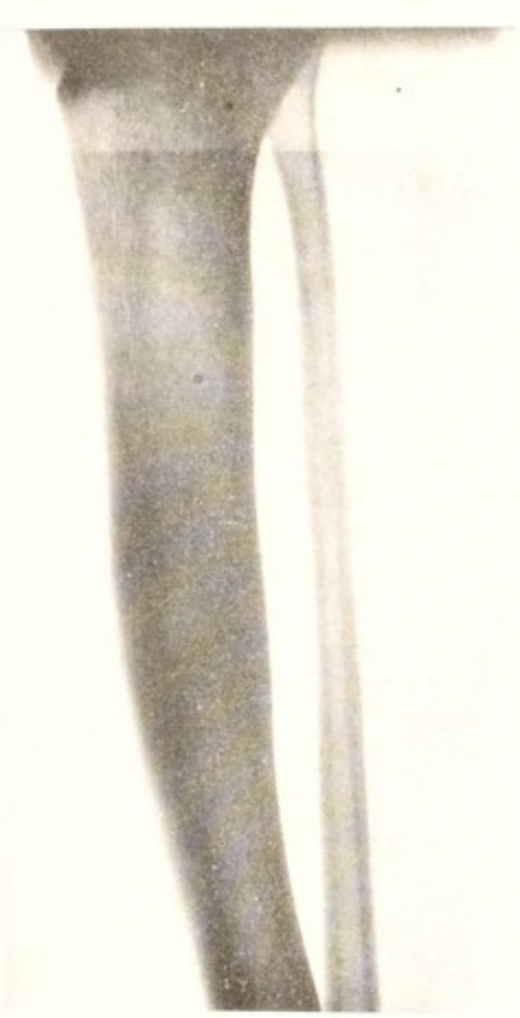


FIG. 274.



FIG. 275.

FIG. 274.—Osteomyelitis complicating typhoid fever demonstrating the extreme amount of bone density found in this condition.

FIG. 275.—Osteomyelitis complicating typhoid fever. The four light spots in the dark area of tumefaction represent foci of rarefaction. The circular conformation of these foci is quite characteristic of typhoidal osteomyelitis.

4. **Primary infection,** when it is impossible to demonstrate the portal of entry of the infectious agent.

Location.—The site of election is the diaphysis near the epiphyseal line. This is in contradistinction to tuberculous bone lesions which very frequently originate in the epiphysis.

Chronic focal osteomyelitis of the upper or lower ends of the tibia is known as "Brodie's abscess," and was first described by Sir Benjamin Brodie, in 1832, before the Medical and Chirurgical Society of London. The

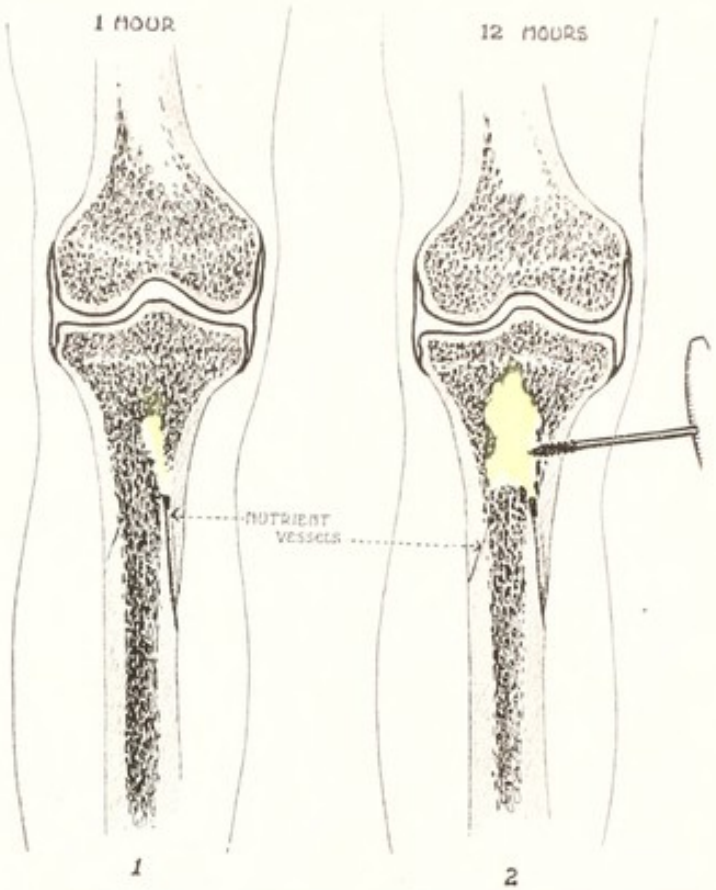


FIG. 276.—1, The metastatic infective focus in its incipiency, close to the medullary orifice of the nutrient canal; 2, the focus has spread, but is given early and timely vent by the gimlet. A chronic focus at this site, or one at the lower end of the tibia, constitutes Brodie's abscess. (Murphy.)

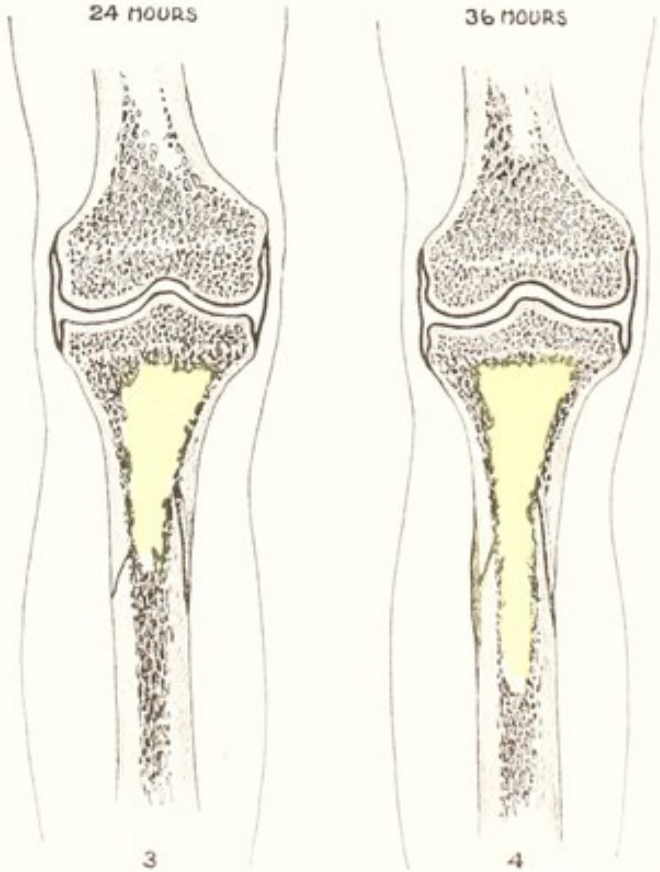


FIG. 277.—3, 4, The march of pus in the untreated case, sweeping through the medulla like wild-fire. (Murphy.)

femur and tibia are the commonest locations of chronic focal osteomyelitis, and the humerus next. But any bone may be invaded, including the phalanges and flat bones. The lesion is usually single, multiple osteomyelitis being uncommon.

PATHOLOGY

The primary focus is in the bone-marrow, the cortex and trabeculæ being involved secondarily. The portion of the diaphysis near the epiphyseal line (the metaphysis) is the point of election. The epiphysis is rarely attacked but, when invaded, extension to the neighboring joint occurs early (Figs. 276 to 279).

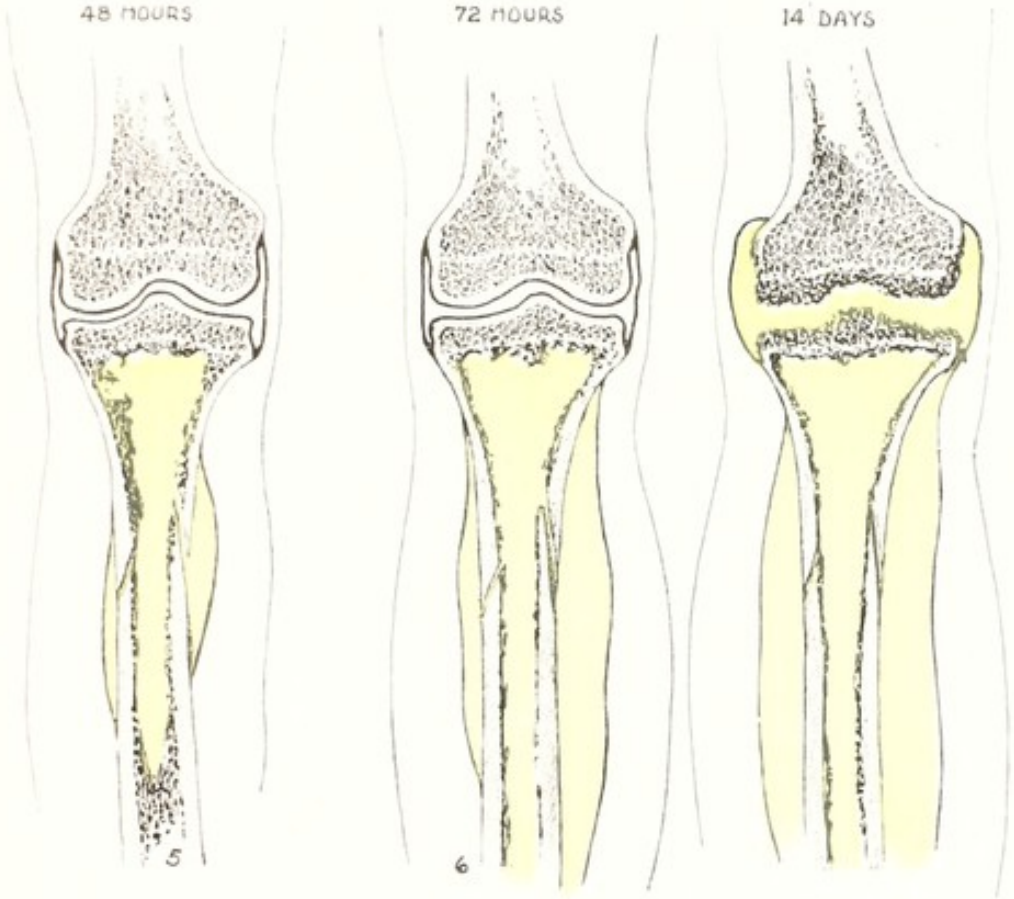


FIG. 278. FIG. 279.

FIG. 278.—5, Escaping through the nutrient canals the pus encounters and elevates the periosteum and, still without vent, continues its march through the medullary cavity (6). Edema of soft tissues appears. (Murphy.)

FIG. 279.—Extending upward beneath the periosteum, the pus circumvents the epiphyseal barrier and attacks and enters the knee-joint. (Murphy.)

Soluble toxins produced by bacterial growth cause necrosis of marrow cells, which may be an extensive process before there is marked purulent infiltration. The marrow is gelatinous and hyperemic. On section, it appears mottled, with yellow or greenish foci of suppuration alternating with reddened areas of injection or hemorrhages. There is great solution of the soft tissue. "Bone abscesses" are present, but are small in size. Their necrotic, injected, and purulent areas are interspersed with areas of normal marrow.

Subperiosteal abscesses form early by extension of the process through the

Haversian canals of the cortex. They may elevate the periosteum over a wide area. Further extension of the purulent process produces myositis, subcutaneous inflammation, or superficial abscess. The latter may be extensive and communicates directly with the marrow. The abscess may break through the skin at one or more points but such spontaneous rupture is rare, because, as a rule, in such severe cases a fatal septicemia or toxemia supervenes. When spontaneous eruption does occur, intractable sinuses communicating with dead bone persist indefinitely.

If perforation of the epiphyseal line occurs (an unusual event), more or less complete disorganization of the joint, or separation of the shaft and epiphysis, results. (It should be noted that the epiphyseal cartilage is a formidable barrier to the extension of any infectious process from diaphysis to epiphysis, as is frequently observed clinically.) Necrosis of cortical bone usually covers a considerable area. It depends upon the extent of destruction of the endosteum and the amount of separation of periosteum from the shaft. If these processes encircle the shaft, they cause necrosis of the entire circumference in the latter case, and of the entire inner circumference in the former case. The amount of necrosis varies from the formation of a sequestrum of the outer layer of the cortex without opening into the marrow to destruction of the entire shaft of cortical bone.

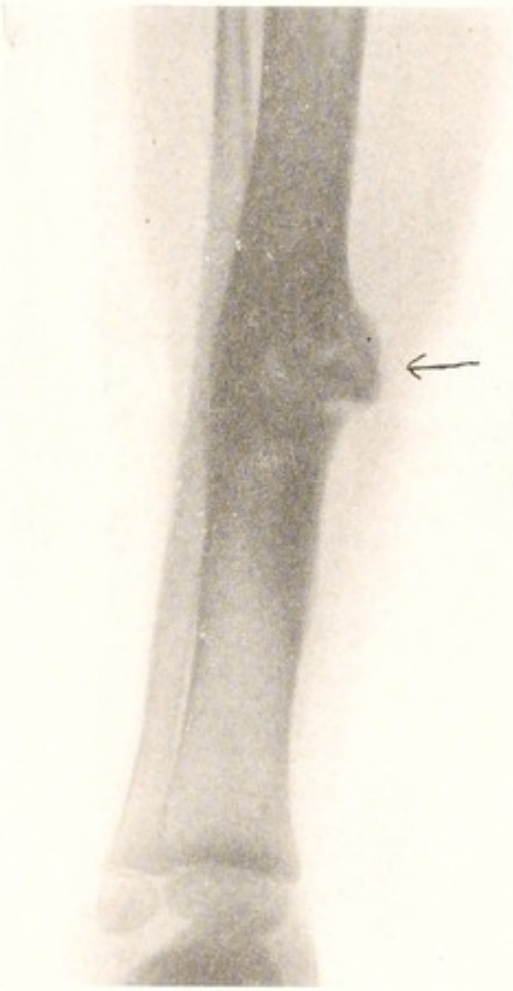


FIG. 280.—Localized osteomyelitis of tibia. Bone furuncle with sequestration, indicated by arrow.

Because of the impermeability of the cortex and the rapid extension of the process throughout a large extent of marrow, areas of suppuration from which absorption is great are not spontaneously evacuated and consequently symptoms of toxemia and septicemia appear early and are extreme.

REPAIR

Repair takes place by natural process in the event of spontaneous evacuation of the abscess or as the result of operation. Granulation tissue is formed from the reticulum of the marrow, and new bone from the endosteum; while externally a shell of new bone, "involucrum," is deposited by the periosteum.

Histological Changes in Process of Repair.—It should be noted that the endosteum covers all the calcified trabeculæ as well as the internal surface of the cortex.

Marrow.—The connective-tissue reticulum of the fat marrow forms a zone of granulation tissue around the purulent area, or the granulation tissue may fill the entire marrow space. It later becomes scar tissue and separates the diseased from the healthy portion. The granulation tissue is

irregularly distributed throughout the shaft. It is edematous prior to its conversion into scar tissue.

The endosteum proliferates from the inner wall of the cortex and from the surfaces of the trabeculæ to form a deposit of new bone in these localities. It thickens old trabeculæ, forms new ones, and fortifies the inner wall of the cortex, besides erecting an osseous barrier between the necrotic and the healthy portions of the shaft. It may surround an abscess and may obliterate the marrow canal at a given point.

Cortex.—Dense cortical bone has no power of direct repair. Its regeneration depends on the integrity of the periosteum externally, the osteogenetic cells of the Haversian canals and the endosteum internally. If the endosteum is intact, the inner layer of the cortex may remain viable. Even when elevated by pus, the periosteum resumes its adherence to the cortex if the pus is removed and renews the vitality of the underlying cortex, even though the latter may have appeared necrotic. This renewed adhesion of the periosteum may take place over the entire shaft or only in detached points, thus explaining the patchy character of the necrosis in some sequestra. (Precisely the same thing occurs in the case of a bone-graft, whose nourishment has been established from the endosteal side; the periosteum may be separated by interposed pus and may again become adherent to the graft at the end of the infection, and not a sliver of the graft be lost.)

Necrosis of the cortex is the chief cause of the persistence of sinuses in chronic osteomyelitis, the sequestra persisting and remaining indefinitely until discharged piecemeal or removed by operation. On the other hand, the regenerative powers of the marrow are considerable.

Periosteum.—After the purulent inflammation has subsided and the pus has been evacuated, the periosteum proliferates to preserve the vitality of the external layer of the cortex and to produce new bone. In some instances the periosteum adheres to the cortex after the pus has been evacuated and the corresponding part of the cortex then retains its vitality. But, on the other hand, if the stripping of the periosteum has been extensive, this reunion does not take place but proliferation of the periosteum occurs in a manner analogous to the process of formation of the external callus in fracture. Polygonal bone-forming cells exist in the periosteum next to the cortex. A homogeneous intercellular substance between these cells (early "osteoid" tissue) fuses to form early osteoid trabeculæ. Some of these polygonal cells become included in the trabeculæ as bone corpuscles, others remain on the outer surface of the trabeculæ as "osteoblasts." Thus a thin layer of new periosteal bone is formed from the deep layer of periosteum and is usually separated from the cortical sequestrum. Further osteogenesis of the periosteum occurs peripherally, the deep layer of the membrane forming bone, the intermediate layer producing the polygonal osteoblastic periosteal cells, and the peripheral layer consisting of spindle cells as in the normal periosteum.

In the early stages, the intertrabecular spaces are filled with a myxomatous mass of cells, polygonal or stellate, with delicate intercellular fibrillæ, and very edematous. Intermingled with these cells are numerous lymphoid and plasma cells, and a few leukocytes, while new blood-vessels are numerous.

Thus the old necrotic shaft is surrounded by a shell of newly formed periosteal bone, perforated by numerous sinuses discharging pus from the necrotic shaft. This bony shell is the *involucrum* surrounding the "sequestrum." The latter may be entirely detached from the involucrum or adherent only in spots. Any free space between the sequestrum and the

involucrum is filled with edematous granulations which may continue to discharge pus indefinitely.

This new periosteal shell of bone is at first soft, very vascular, and its alveolar space is filled with myxomatous tissue. The formation of new periosteal bone continues only until sufficient bone has been formed to permit weight-bearing. At first, the diameter of the new bone-shell is greater than that of the old necrotic shaft; this is due to the fact that the new bone is softer than normal bone and more of it is necessary to sustain a given weight. As its density increases, the diameter diminishes to approximate the normal.

In time, the entire involucrum is transformed to practically normal dense cortical bone or to spongy bone (like the epiphysis) but its regenerative power, like that of ordinary cortical bone, is very limited, so that if a sequestrum is removed at this late stage a cavity remains, with walls of dense bone, which persists indefinitely. Persistence of the cavity is also enhanced in case of coincident obliteration of the marrow canal by a dense bone plug.

GROSS APPEARANCE OF OSTEOMYELITIC BONE

Marrow.—*Acute Stage.*—As a rule, if the process is very acute no suppuration is seen. The marrow appears injected and gelatinous, and at operation, on account of hemorrhage, it may be impossible to state that any gross lesion is present. In most cases operated upon in the suppurative stage, there is a copious discharge of pus on opening the marrow canal; the pus may be yellow, greenish, red (from hemorrhage) or brown (from altered blood-pigments), and usually contains oil droplets from disintegrated fat marrow, which are very characteristic. A cross-section of bone at this stage has a mottled appearance, partly red (hyperemia or hemorrhage) partly red or yellow (normal marrow), partly yellow or greenish (suppuration).

Later Stage.—Yellow areas of suppuration persist, with other red and injected portions, but the red color of this stage is due to granulation tissue. One end of the shaft may look normal, while the other end has this mottled appearance; and between the two a pink or red zone of granulation tissue appears, entirely blocking the marrow canal and delimiting the diseased from the healthy marrow. If the infected marrow and the cortical bone are both entirely necrotic, the shaft may exist as a mere bony tube filled with granular detritus and pus.

Cortex.—The appearance of the cortical bone varies with the stage of the infection.

Early Acute Stage.—The periosteum is thickened, hyperemic, edematous, and loosened from the bone. The cortex is white and shiny, with small, red, vascular foci.

Subacute Stage.—A fusiform, fluctuating sac of pus of large dimensions lies between the periosteum and the bone. The underlying cortex is smooth, white, and lustreless.

Chronic Stage.—Necrosis of the cortex is complete; the latter is dirty white, brownish, or black, bare and dull. It is fragile, perforated by sinuses, worm-eaten, and may be readily broken into splinters of varying size. It is partially adherent to the periosteum or entirely free, or is united by scattered areas of bony adhesion.

Periosteum.—*Early Stage.*—The periosteum is thickened, indurated, and is usually elevated by a large subperiosteal abscess.

Later Stage (Involucrum).—The thickness increases, the deep layers

becoming rigid from the formation of new trabeculæ, giving to the touch a crackling sensation like parchment. This crackling offers a good guide to operation, as it is demonstrable by means of a probe passed into a sinus. Progressive increase in the thickness of this bone-shell takes place until it equals or exceeds the total thickness of the original shaft. This shell is perforated by sinuses discharging pus. It may ultimately be adherent to the sequestrum or entirely separated, at the same time being intimately adherent to the living shaft or to the epiphysis at either side of the sequestrum. Transverse bands of dense scar tissue or bone in the periosteal bone-shell (frequently occluding the marrow space) separate the necrotic from the healthy portions of the shaft. A wall of dense eburnated bone limits the sequestrum-chamber and is lined with unhealthy granulation tissue. This wall of dense bone remains after removal of the sequestrum and shows no tendency to undergo spontaneous resolution.

Soft Tissues.—Early changes are edema, redness and induration of the neighboring muscles, subcutaneous tissues, and skin. After perforation of the periosteum by an abscess, sinuses persist in the soft parts, lined with unhealthy granulations, and often of great size. Dense cicatrization of the soft tissues supervenes, and edema and infection continue. Enormous ncrease in the size of the affected limb may persist for years.

SYMPTOMS AND PHYSICAL SIGNS

1. **Pain.**—This is the usual symptom of onset, sudden local pain. It is severe, throbbing, and referred to the shaft of the bone, usually near the epiphyseal line. It is increased by even faint percussion of the bone or by continued pressure.

2. **Swelling.**—This may come on very early and is then incidental to involvement of the adjacent soft parts, whose skin is thereby reddened and pits on pressure; or swelling may be entirely absent if the infection has not broken through from the marrow cavity.

3. **Joint Tenderness.**—Heat, swelling, and tenderness of the joint are due to the edema of inflammation rather than to direct infection. Cultures of the joint fluid are frequently sterile.

4. **Fever.**—Elevation of temperature to 103° or 104° usually accompanies the pain of onset.

5. **Pulse.**—Acceleration of the pulse to 120–140 is usual.

6. **Toxemia.**—As a result of the absorption of local toxins, the tongue is dry, furred, and tremulous, the face is flushed, and delirium is common. The latter, though often mild, frequently continues for weeks after drainage of the lesion has been established. In the more acute types, the toxemia may be extreme because the infection is confined within a rigid bony chamber.

7. **Abscess** (of soft parts or a subperiosteal abscess) is the rule.

8. **Sinuses** lead directly to necrotic bone and are usually actively discharging pus.

9. **Hyperleukocytosis** is incidental to suppuration, and is usually very high.

DIFFERENTIAL DIAGNOSIS

The above train of symptoms, denoting a fulminating lesion with profound local and systemic disturbances, ought to render mistakes uncommon. The following affections may, in some cases, cause confusion:

Disease	Points of resemblance	Points of difference
1. Early acute tuberculosis of joints.	Swelling, abscess, and sinus formation about a joint.	Begins in epiphysis—(osteomyelitis in diaphysis). Insidious onset (osteomyelitis very acute). Pain and constitutional symptoms late; (early in osteomyelitis). Slight or moderate temperature in p.m. only. *X*-ray. Spontaneous separation of epiphysis uncommon; (in osteomyelitis, common).
2. Acute articular rheumatism.	Swelling, pain, redness, and local heat, fever, rapid pulse, local tenderness.	Polyarticular. Absence of tenderness over shaft of bone. Severity of affection; multiplicity of joints involved. Severity of infection less marked.
3. Gonorrheal rheumatism.	Severity of early acute symptoms.	Absence of bone tenderness. History of presence of gonorrhea. Isolation of gonococci from joint. Joint symptoms. *X*-ray.
4. Typhoid fever.	Severe "typhoid state," dulled mentality causing local pain to be unnoticed.	Local symptoms may be absent. Low leukocyte count. Insidious onset. Positive Widal reaction. *X*-ray.
5. Osseous tuberculosis. (Diaphyseal osseous tuberculosis extremely rare in this country.)	Persistent discharging sinus. Local pain with or without healing.	Insidiousness. Local heat; redness and swelling not so common. Toxemia not fulminating. *X*-ray.
6. Actinomycosis.	Persistent discharging sinus.	Absence of local signs of severe inflammation. Identification of the ray fungus, microscopically. *X*-ray.
7. Epidermoid cancer.	Persistent discharging sinuses.	Rare. Severe local inflammation and toxemia absent. Age of patient above 40. *X*-ray.

PROGNOSIS

In every case of massive infectious osteomyelitis the prognosis is serious, because of the danger of toxemia in the acute stages and of exhaustion from prolonged suppuration with possible amyloid disease in the chronic stage. In neglected cases the outlook is still more grave, *e.g.*, in Guyot's experience, quoted by Whitman (ref. Orthopedic Surgery, Lea & Febiger, 1917, p. 282), in 54 cases of acute osteomyelitis of the upper extremity of the femur, in all but 7 of which the joint was involved, the death rate was 60 per cent. If treatment is not both prompt and efficient, loss of function of the affected part may result, and in any case a prolonged period of convalescence is inevitable. On the other hand, prompt evacuation of the pus by boring into the medulla will nearly always effectually check the disease.

TREATMENT

Cases presenting themselves for treatment are of two general types, viz.: cases of massive infectious osteomyelitis in which the first considera-

tion is to establish prompt and efficient drainage; and cases in which there is a localized osteomyelitis, usually chronic in character, which requires not only drainage of the pus pocket but complete removal of the sequestrum.

Treatment will be considered under three headings, viz.: (A) abortive treatment; (B) curative treatment for (*a*) drainage and (*b*) removal of the sequestrum; (C) reparative treatment.

Abortive treatment concerns the evacuation of pus in the *very earliest* stage of the infection; curative treatment concerns the drainage of the infected bone in the acute stage, and removal of the sequestrum at a considerably later period in the subacute and chronic stages; reparative treatment comprises restoration of the bone defect by inlay graft in those cases in which regeneration by the periosteum fails to repair the hiatus. It should be understood that a bone-graft is not to be inserted until all infection has disappeared and the wounds are healed.

(A) **Abortive Treatment.**—If the case is seen early enough, one or several *large drill-holes* through the cortex into and draining the marrow cavity may serve effectually to abort the infection of the entire marrow and thereby entirely prevent necrosis of the bone or reduce it to a minimum.

Murphy ("Murphy's Clinics," vol. v, No. 1, Feb., 1916, p. 121) advocated drilling a hole in the affected bone with an ordinary gimlet and evacuating the pus on the first day the patient complains of "aching" in the affected extremity, or, to use his own words, to "vent the abscess as a dentist treats a tooth." He claimed that the process is thus averted and no sequestrum is formed.

(B) **Curative Treatment.**—(*a*) *Treatment of the Acute Stage, for Drainage.*—In this stage the surgeon is confronted with active infection, necrosis, suppuration, and more or less general intoxication. The keynote of treatment is the immediate evacuation of pus, as indicated in any other pyogenic process.

For rapid and effective entrance to the marrow canal, the author has found his motor-driven instruments far superior in every respect to any hand tools yet devised. Multiple openings can be made into the marrow in a fraction of a minute by means of the large motor-drill. If pus is revealed by this procedure, the initial opening may be rapidly enlarged by the motor-twin-saw, which can be made to cut a trough in the bone of any desired dimensions; the ends of the trough can be cut with the cross-cut saw, and the portion of the cortex between the cuts pried off with a chisel. If motor-driven instruments are not available, the surgeon can use trephine, gouge, chisel and mallet for this purpose. The opening into the marrow canal should be progressively enlarged until no more pus is evacuated; if necessary, the cortical lid should be removed from the entire length of the shaft, producing a gutter the length and width of the medullary canal.

The surgeon should avoid cureting the marrow, in order to preserve as much of the endosteum as possible for reparative osteogenesis and to prevent necrosis of the inner layer of cortical bone which is likely to follow its removal.

If the epiphysis is involved, a portion of its cortex must be removed for drainage, but the epiphyseal line should be avoided if it is possible to do so. If the joint also is involved, it should be incised, irrigated, and drained. The bacteria-resisting properties of the epiphyseal cartilage almost always prevent invasion of the epiphysis. The entire wound produced by the operation should be thoroughly packed, from the skin margins to the bottom of the medullary canal, with plain or iodoform gauze; and efficient drainage of the bone should be maintained for three or four months, or until the

periosteum has produced a sufficiently thick involucrum (as indicated by *x*-ray examination), at which time the sequestrum should be entirely removed.

(*b*) *Treatment of the Subacute and Chronic Stages, for the Removal of Sequestra.*—It is absolutely essential that all necrotic cortical bone be removed, whether it consists of a mere sliver of bone or the entire diaphysis; otherwise, a permanent sequestrum enclosed by an involucrum will be the result.

A localized osteomyelitis is usually chronic, in contradistinction to the massive infectious osteomyelitis which is diffuse in character and acute.

In a case of suspected osteomyelitis, it often happens that the surgeon makes an incision down to the periosteum and, finding no pus, packs the superficial wound and withdraws from the operation. In such cases there is frequently a deep-seated infection which is not revealed by the superficial incision. Because of these deep-seated cryptic lesions, the surgeon is advised to treat every case of suspected osteomyelitis by a routine procedure as follows:

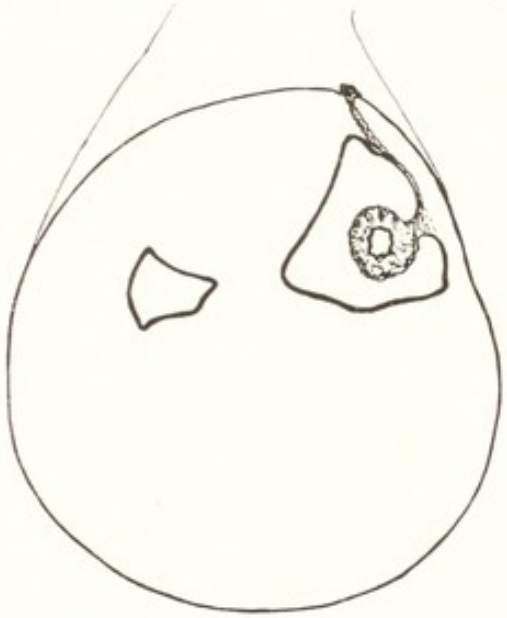


FIG. 281.—Diagram illustrating a clinical case of localized osteomyelitis of the tibia. The resulting skin sinus was located over the tibial crest whereas the bone orifice leading to the sequestrum pocket was situated in the posterior portion of the anterior internal surface. This case had been curetted twice without result before coming to the author and illustrates the unreliability of the subcutaneous curettage procedure in such cases.

1. A gutter should be chiselled or produced by motor-saw and burrs into the infected bone, the width of the medullary cavity and of sufficient length to include the *whole infected region.* The importance of applying a tourniquet to the limb above the field of operation cannot be overestimated; hemorrhage in these cases may not only endanger life, especially with children, but may obstruct the field of vision to such an extent that small sequestra are readily overlooked.

2. At the expiration of two or three months, the sequestrum is usually isolated and separated from its bed. The tourniquet having been applied, as in the first instance, the involucrum is peeled from the sequestrum by blunt dissection. If the sequestrum has extended beyond the gutter formed by the primary operation (1) the involucrum should be incised distally at either end of the gutter with a knife or osteotome and the sequestrum withdrawn as one would withdraw a banana from its skin. The granulations are gently removed from the inner surface of the involucrum, but cureting should not be practised. The involucrum is now made to collapse and either tubes for the introduction of Dakin's solution are inserted and the cavity gently packed with plain gauze, or iodoform gauze alone is used. In this second step of the operation, the tourniquet is particularly necessary. The dangers of hemorrhage and its interference with the surgeon's view are increased by the fact that it is essential that the most minute particles of sequestra be removed and none be left to continue the infection. Without a clear field, the surgeon may overlook recesses of the sequestrum pocket.

In this connection it will be well to mention the sharply localized type of osteomyelitis, which is usually chronic. This type is of hematogenous

origin. Although often due to direct traumatism there is as frequently no contributing cause known. As a rule, these cases do not come to treatment early because the lesion is not extensive, the systemic disturbance not severe, and the case exists with little or no local disturbance until a soft tissue abscess forms.

At operation (in which the importance of the tourniquet is again emphasized) the sinus may be found to be tortuous and dissecting, while its superficial opening may be located at an entirely different level from that of the sequestrum pocket, so that merely probing to the bone is a very untrustworthy means of ascertaining the true condition (Fig. 281).

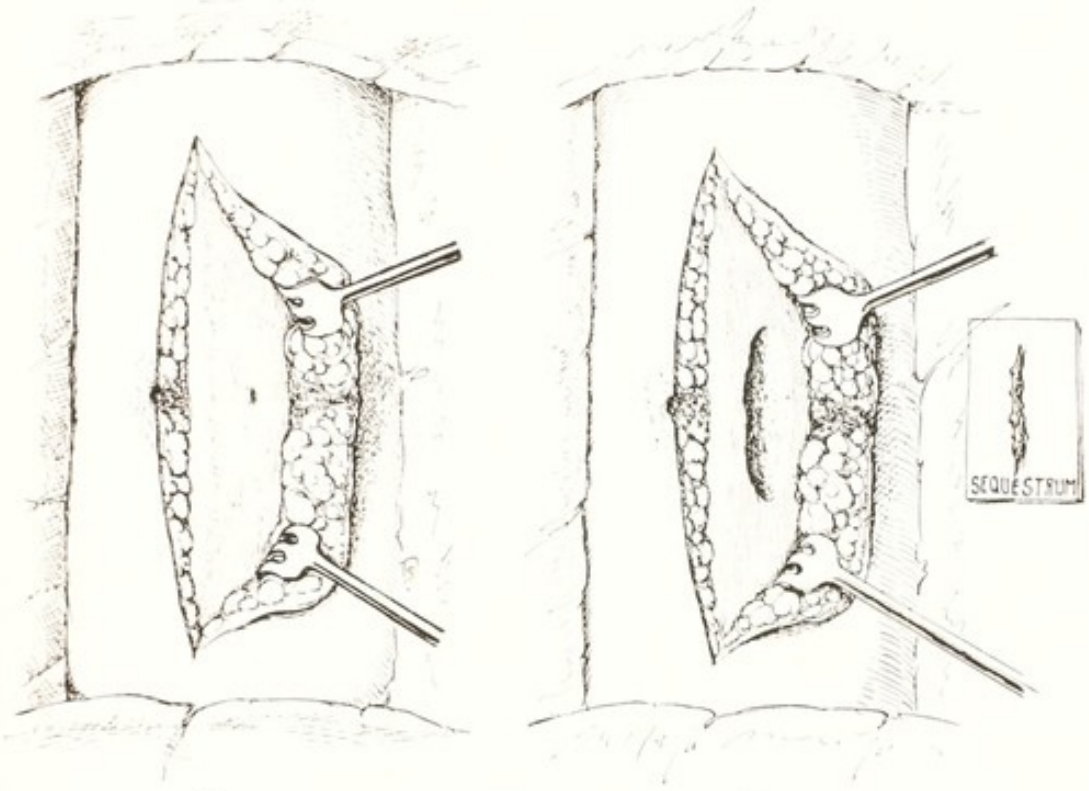


FIG. 282. FIG. 283.

FIG. 282.—(Same case as Fig. 281.) A generous incision and thorough exploration was made and the soft tissue sinus traced to the bone orifice leading to the sequestrum pocket. The overlying bone was then thoroughly removed with osteotome and gauze exposing full extent of sequestrum pocket. (See Fig. 283.)

FIG. 283.—(Same case as Fig. 282.) Shows removal of bone to expose sequestrum and the sequestrum (to right) removed in toto, as it always should be when possible in order to avoid leaving fragments.

In these cases of chronic localized osteomyelitis, a very free skin incision should be made, the sequestrum-pocket widely uncovered with the sinus as its central point, and the overhanging shelf of cortical bone removed to such an extent that an extremely shallow cavity is left. The sequestrum should be removed *en masse*, if possible, the cavity wiped out, filled with tincture of iodin (which should be allowed to remain for one or two minutes, after which the excess is removed), the soft parts pressed down firmly into the cavity, a small wick of rubber tissue inserted, and the remainder of the wound closed by sutures (Figs. 282 and 283).

In cases of osteomyelitis of any extent, owing to the weakness of the involucrum, the limb should be very carefully supported after operation by a plaster-of-Paris cast or a brace with or without traction, and this support should be continued until the newly formed bone is sufficiently strong to

withstand weight-bearing and muscle-pull. If the Carrel-Dakin method is to be applied, a fenestrum is cut in the cast and the skin edges are protected by vaselin (yellow) and oiled silk applied to prevent irritation of the skin, on the one hand, and soaking of the cast by the Dakin solution, on the other. The details of the Carrel-Dakin technic may be found elsewhere in the monographs of its authors.

It should be stated here, however, that the Carrel-Dakin method is not well adapted to the treatment of lesions requiring support in plaster-of-Paris

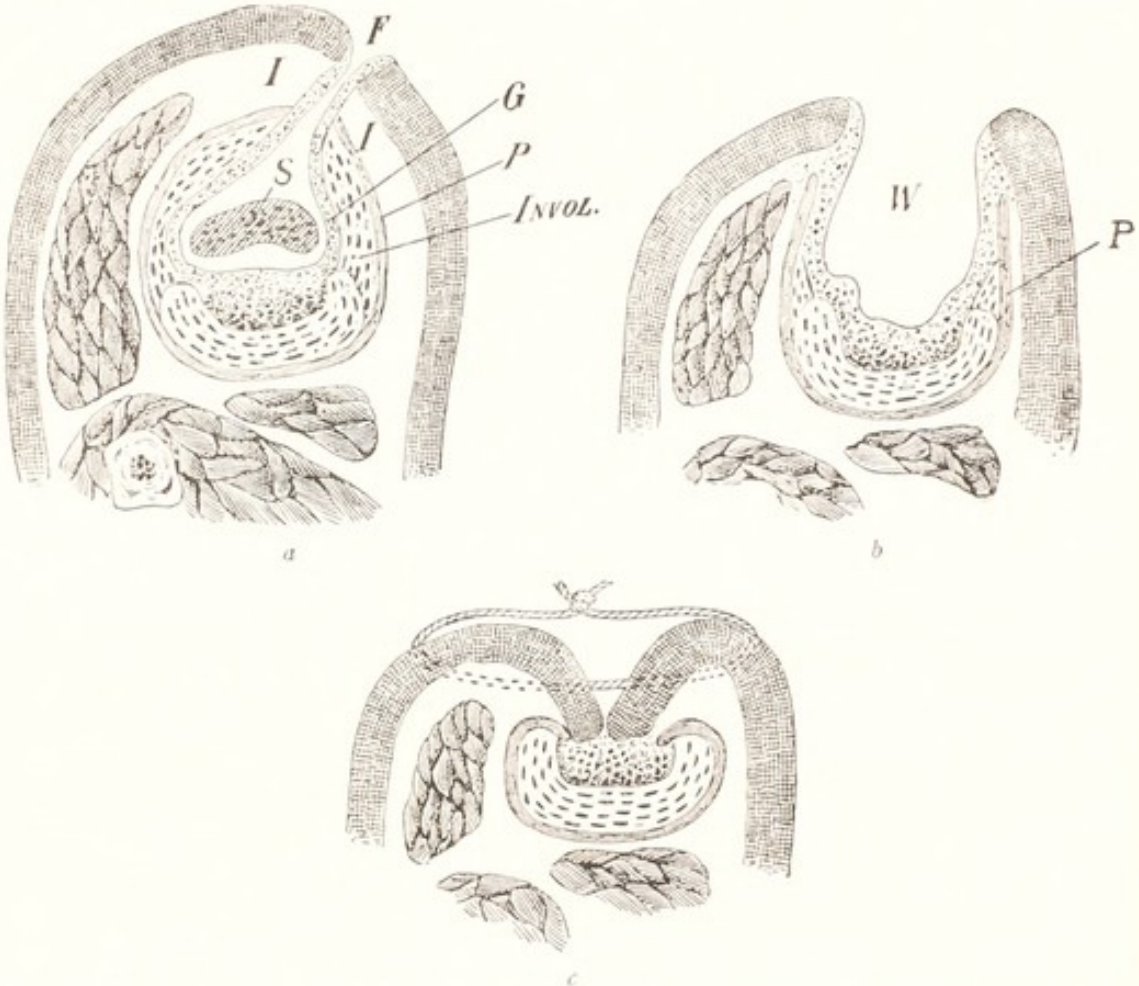


FIG. 284.—Sequestrotomy. Neuker's method of invagination. Sequestrotomy having been performed, the wound disinfected and all sclerosed connective tissue dissected away, Neuker removes with a chisel most of the lateral walls of the bone cavity, but preserves the periosteum unless it is infected. The overlying soft parts are then invaginated and fixed in position by suture, bone pegs or strapping. (Binnie.)

dressings, because saturation of the plaster by the solution softens the cast, thus impairing its support, while saturation of the gauze and cotton dressings is apt to irritate and burn the skin.

It should be indelibly impressed upon the mind of the surgeon that the secret of success is absolute fixation of the part; therefore no therapeutic measure directed toward the sterilization of the lesion should be adopted which in any way militates against this absolute immobilization. Accordingly, if it is found that the Carrel-Dakin solution saturates the cotton and softens the plaster-of-Paris splint, it should be supplanted by Dichloramin-T (see Chapter XXX for technic of use) or the surgeon should be content to employ balsam of Peru, iodoform gauze, or similar antiseptic measures.

(C) **Reparative Treatment.**—For absence of the tibia from destruction from osteomyelitis, or its partial or complete removal therefor, as in the case of failure of the involucrum to regenerate, the upper part of the fibula may be moved over to a socket cut in the upper epiphysis of the tibia. As reported by Hahn (1884) and others, the fibula underwent hypertrophy and supported the weight of the body very well. Huntington (Annals of Surgery, 1905, vol. xli, p. 249) first described his operation for substituting for the whole diaphysis of the tibia that of the fibula of the same leg. The fibula is divided with a saw at a point opposite the lower end of the upper tibial fragment and the distal portion of the fibula is firmly planted in a cup-shaped depression in the upper fragment of the tibia. In Huntington's first case, the union was very slow, and solidification did not finally occur until six months later. In this case, he did not transplant the lower end of the fibula to the lower fragment of the tibia until eight months later. The consequent faulty weight-bearing over this long period of time caused a permanent change in the conformation of the tarsus and an outward alignment of the axis of the lower end of the tibia.

Stone (Annals of Surgery, xlvi, p. 628) transfers the upper end of the fibula into the tibia by precisely the same technic as Huntington. The lower end of the diaphysis, however, he splits longitudinally with a chisel for a distance of 4 inches, care being taken to avoid separating the periosteum from either half of the bone. At the lower end of the split portion, the inner half is cut transversely at the level of the upper part of the remaining lower epiphysis of the tibia. A small pocket is then cut in the epiphyseal cartilage covering the end of the tibial epiphysis, just large enough to receive the inner half of the fibular fragment, which is then sprung into its new position in the tibia.

The second step at the lower end of the fibula was planned to maintain connection between the shaft of the fibula and the external malleolus, because if this is lost the outer side of the ankle-joint would be seriously weakened. At the same time, it is necessary to bring a portion of the fibula above and contact it with the lower epiphysis of the tibia. The promptness and the extent of new-bone formation from each of the fibular halves was very satisfactory.

Bond (Brit. Jour. Surg., April, 1914) described two cases in which he did the Huntington operation of replacing the whole shaft of the tibia by moving the fibula over into its place. "The fibula was cut across just below the head of the bone and this portion was left in its normal position. The divided end of the shaft of the fibula was then pushed to the inner side and inserted into the freshened lower surface of the tibial epiphysis, to which it was wired in position. Some difficulty was experienced in keeping the sutured bone in good position owing to the friability of the softened bony tissues and to the drag of the muscles which tended to displace the fibula outward to its old position. This necessitated a second operation and the introduction of a second silver wire." In one year and ten months the transference of the lower end of the fibula was done at a third operation. The fibula was divided just above the external malleolus and the lower end of the shaft was displaced inward and inserted into the soft cancellous tissue of the lower tibial extremity. The fibular shaft in its new location gradually hypertrophied, resulting in a firm limb. Röntgenograms taken at intervals showed that the upper end of the shaft of the fibula gradually assumed the flattened inverted-cone-shaped outline characteristic of the normal tibia, again demonstrating the efficacy of Wolff's law in causing both detached and undetached bone-grafts to take on in their new environments both the size

and shape which function demands. The actual shortening, however, was $3\frac{1}{2}$ inches. Mr. Bond's case illustrates some of the difficulties and disadvantages inherent in this technic.

A more nearly ideal procedure, and the only one that the author employs, has for its aim complete anatomical and mechanical restoration, leaving the fibula to functionate and supplying the absent portion of the tibia by a free transplant from the other tibia or some equally satisfactory source. A portion or the whole of the tibia may be absent from removal on account of the osteomyelitic process.

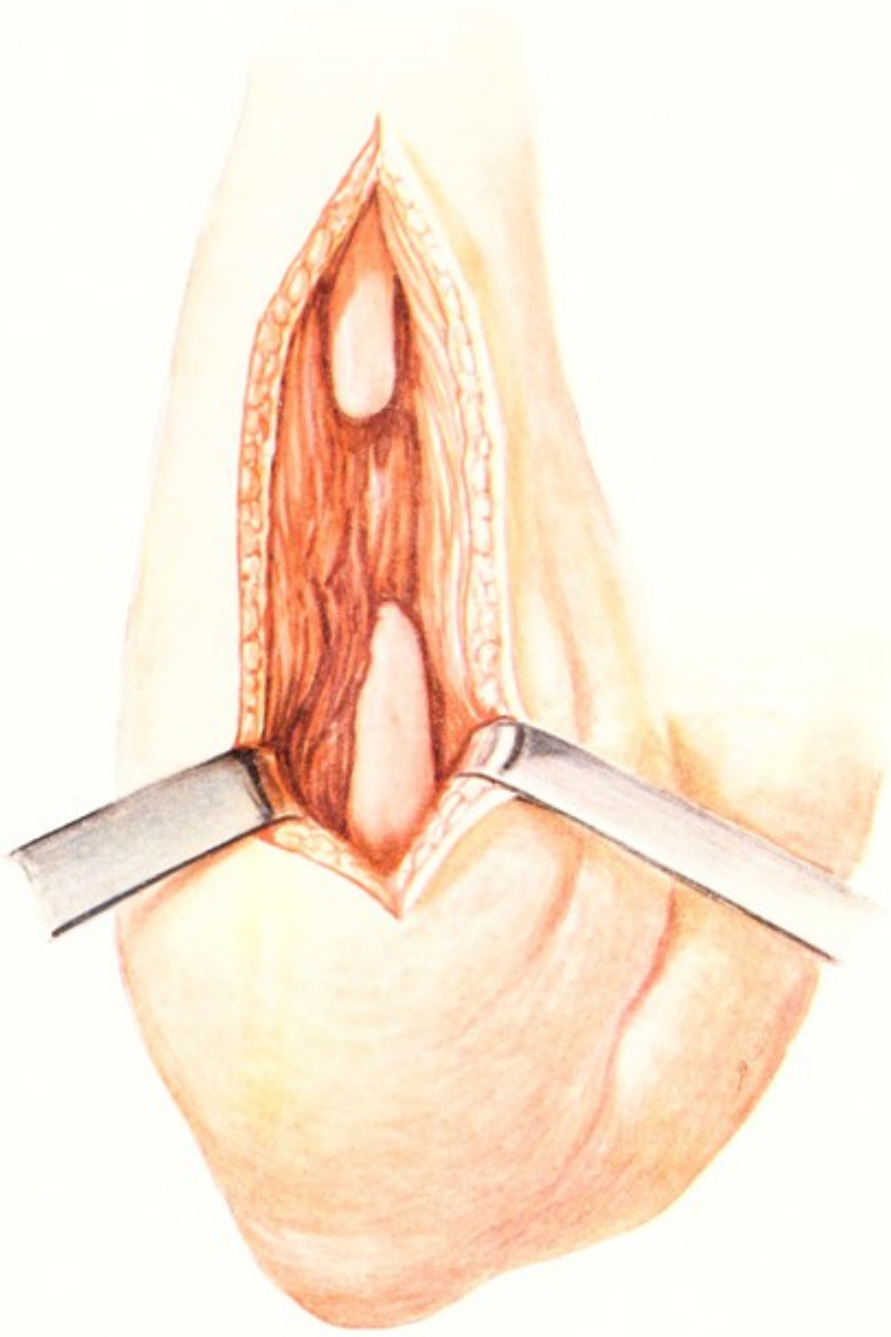
RESTORATION OF A PART OR THE WHOLE OF THE SHAFT OF A LONG BONE BY AUTHOR'S INLAY BONE-GRAFT

In every case operated upon, acute suppuration should have subsided and all infectious material and necrotic bone should have been removed and the skin completely healed for some weeks prior to operation, so that a clean field is assured.

In military cases, where the loss of bone has been the result of shell or bullet wounds, great conservatism must be observed because of the dangers of latent infection being present on account of the presence of small portions of foreign body material, such as clothing or bits of metal, and a lapse of four to six months after complete healing must be allowed, and even then every possible effort must be made to determine whether latent infection still exists. Tests, such as rough manipulation or deep massage may, by lighting up the infection, disclose its presence by the cardinal signs of inflammation. In such cases, free incision should be made, the wound cleaned, and sufficient time allowed for cessation of the infection and complete healing; then the bone-graft operation may be attempted. The author had ample experience in the operative clinics conducted by him at the invitation of the French War Office in the various military hospitals of France, in 1916, to substantiate the remarks just made. In the course of his work in France, he was able to apply these principles to every long bone in the body, as well as to the jaw (see also Chapter XXX).

The fragment ends on either side of the hiatus are laid bare and the bed for the graft is prepared, care being exercised not to place the graft in dense cicatricial tissue. The graft is inserted into the fragment ends by precisely the same technic as that employed in applying the inlay to fractures (see Chapter XVII), except that a shouldered or tongue-and-groove joint is used at the ends of the graft to prevent muscle-pull from shortening the limb by forcing the fragments together before union occurs (see Chapter XXX).

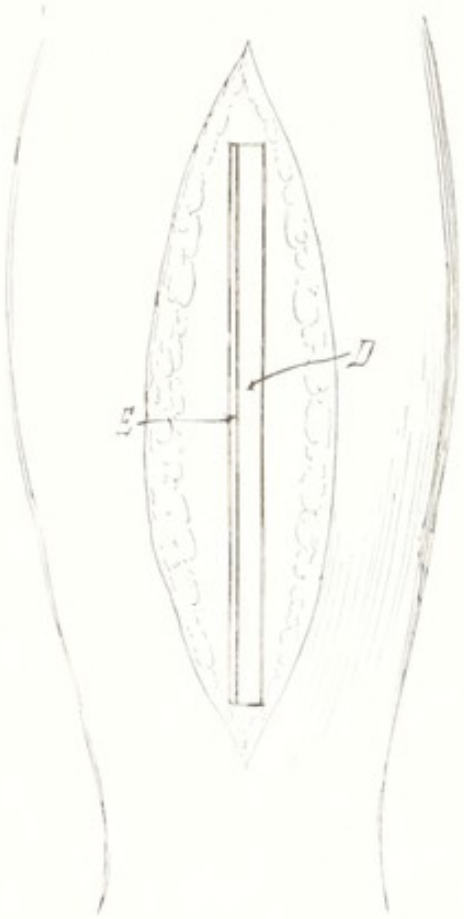
The graft should always include the complete thickness of the tibial cortex, periosteum and endosteum, and some marrow substance. The other dimensions depend upon the bone whose place is taken or the mechanical strain to which it will be subjected. The muscle ends which have been detached from the removed bone are attached to the graft in their normal anatomical position by means of encircling sutures of kangaroo tendon. If the graft is inserted to take the place of the end of a bone, such as the upper end of the humerus or the femur, the upper end should be placed in the glenoid or acetabular cavity and the capsule sutured around it. Extension is necessary at the shoulder to prevent the end of the graft from pushing through the capsule. If the ends of the fragments are small in diameter, and spindle or conical in shape, it is best to split them with the motor-saw into equal portions for a distance of 1 to 2 inches. The corresponding end of the graft is fashioned into a long and slender wedge, its dimensions vary-



Actual pathologic conditions found in an illustrative case of loss of bone from gunshot wound.

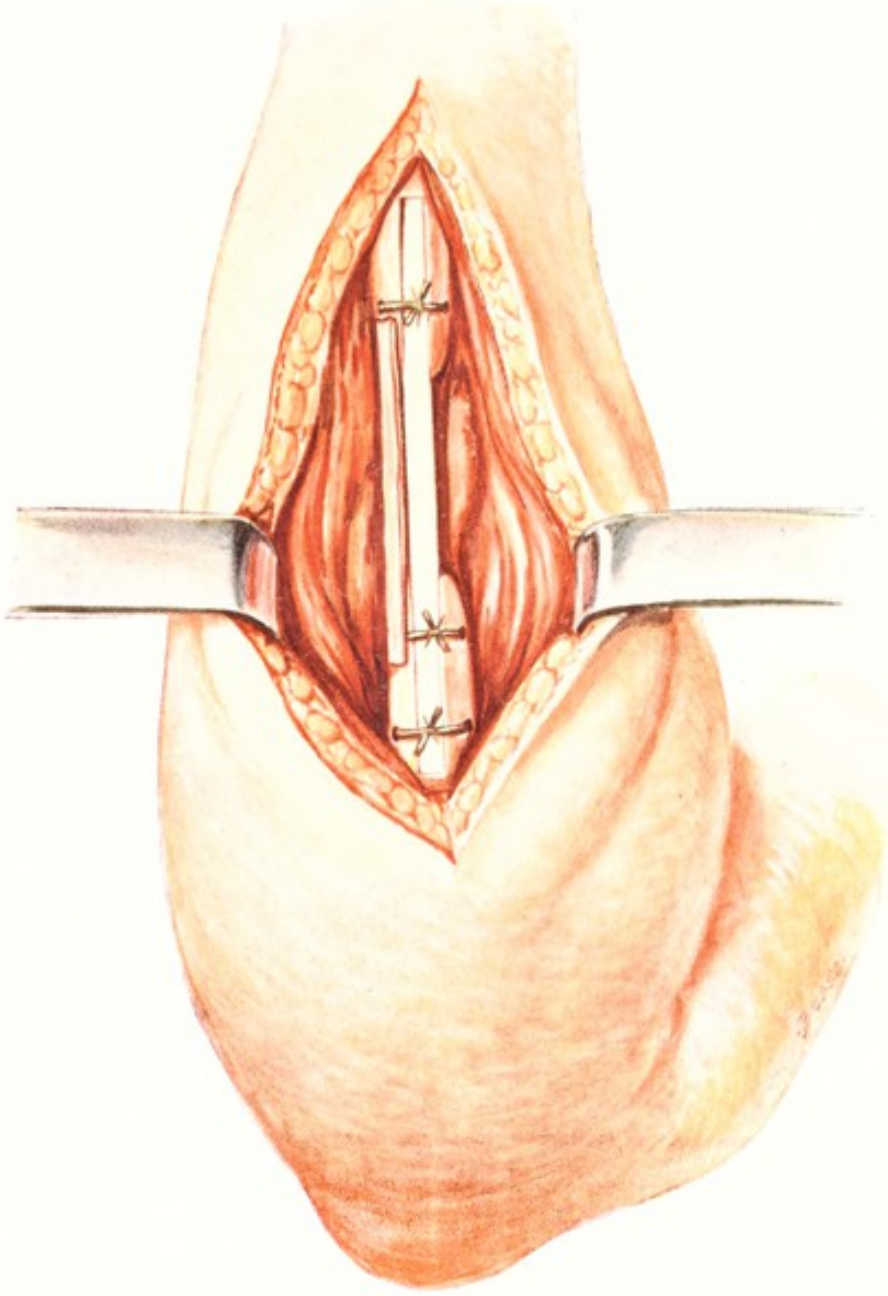
Note the absence of $2\frac{1}{2}$ inches of substance from the middle third of the shaft of the ulna, with the characteristic conical end of the proximal fragment.

This anterior view shows the arm flexed acutely. (The tip of the elbow was resting on a small table at the side of the operating table.)



Same case as Plate 2. Diagrammatic drawing to illustrate technic employed in obtaining the graft from the central portion of the anterior internal surface of the tibia.

For purposes of increased osteogenesis a sliver graft, E, is removed from the side of the gutter formed by the removal of the large graft, D. This sliver graft is placed alongside of the inlay fixation graft, as indicated in Plate 4, which follows.



Same case as Plate 2, showing the inlay fixation graft in place and held with kangaroo sutures, with the sliver graft engaging on the ends of the ulnar fragments, to the left.

ing with the mechanical conditions encountered, and it is jammed into the cleft made in the end of its recipient fragment. The graft ends are secured to the host fragments by means of kangaroo tendon, either placed in drill holes or wrapped about the ends of the recipient bones and graft (see illustrative diagrams, Figs. 315 and 320). The soft structures are drawn about the graft and the wound is closed with a continuous suture of No. 0 plain catgut.

A carefully fitted plaster-of-Paris dressing should be applied, including the joints on either side of the grafted bone. If there is no cause for its earlier removal, it should remain upon the limb for four or five weeks, at the end of which time it should be replaced by a second plaster splint for two or three months, or until the röntgenograms and physical examination show that there has been a sufficient hypertrophy of the graft to be trusted without support.

For repairing less extensive defects in the bone, and where there is not complete destruction of the shaft at any point as the result of osteomyelitis, Murphy ("Murphy's Clinics" vol. v, No. 1, Feb. 1916, p. 124) has inserted the end of a pedicled flap of muscle, fat, and fascia into the bone cavity.

Kanavel (Surg., Gyn. and Obst., 1916, xxiii, 163–176) has employed free flaps of fat to fill in these defects. The fat was generally obtained from the abdominal wall and was $\frac{1}{4}$ to 1 inch in thickness. In Kanavel's 2 cases of osteomyelitis in which he used these fat transplants, the fat was lost by droplets and seemed to have had no beneficial effect, and he abandoned the procedure in favor of muscle flaps. His results seem to show that the greatest value of fat transplantation is in plastic operations to restore mobility and remove disfigurement, as a protection to prevent contracture about vessels and nerves, and to prevent adhesions about tendons and hip-joints. Its use in osteomyelitis and in large, open, potentially infective areas, Kanavel has found to be unsatisfactory.

REFERENCES

Albee, F. H.: "Osteomyelitis." N. Y. Med. Jour., June 6, 1908.

Albertin: "Ostéomyélites et traumatisme en face de la loi de 1898 sur les accidents du travail." Lyon méd., 1912, cxviii, 608–616.

Bamberger: "Eine Fall von akuter Oberschenkelosteomyelitis bei einer Schwangeren." Münch. med. Wochenschr., 1912, lix, 1380.

Barrie, G.: "Chronic (Non-suppurative) Hemorrhagic Osteomyelitis." Post-Graduate, 1912, xxvii, 1049–1066.

Beck, C.: "The Operative Treatment of Chronic Osteomyelitis." Surg., Gyn. and Obst., Chicago, 1911, xiii, 550–565.

Baureau and Tillaye: "Ostéomyélite grave avec abcés sous-périostique multiple sans foyers intra-osseux; autopsie." Rev., d'orthop. Paris, 1912, 3 s. iii, 87–89.

Briggs, J. E.: "Acute Infectious Osteomyelitis, with Report of Case by Autoplastic Bone Transference." Jour. Am. Inst. Homoeop., Cleveland, 1911–12, iv, 1219–1229.

Broca: "A propos de l'ostéomyélite aiguë." Pédiatrie prat., Lille, 1911, 111–116.

Brockman, D. C.: "Acute Osteomyelitis." Jour. Iowa State Med. Soc., Clinton, 1911–12, i, 620–625.

Dawbarn, R. H. M.: "Osteomyelitis Treated by a New Method." Ann. Surg., Phila., lv, 106.

Debally and Guillot: "Ostéomyélite chronique hyperplasique." Bull. et mém. Soc. anat. de Paris, 1911, lxxxvi, 514–516.

Fassett, F. J.: "Osteomyelitis." Northwest. Med., Seattle, 1912, N. S. iv, 315–317.

Ferran, F.: "Traitement des cavités d'ostéomyelite chronique par les greffes graisseuses." Paris, 1911, J. Steinheil, 79, p. 80.

Goebel and Goerke: "Ein abnormer Fall chronischer Osteomyelitis." Berl. klin. Wchnschr., 1912, xlix, 42.

Guibal: "Plusiers cas d'ostéomyélitis aiguës primitives chez des adultes (Rapport de M. Mauclaire)." Bull. et mém. Soc. de Chir. de Paris, 1912, N. S., xxxviii, 77–93.

Haller: "Ostéomyelite du nourisson." Gaz. d. Hôp., Paris, 1912, lxxxv, 625–631.

Hoffmann, L.: "Osteomyelitis chronica als Unfallfolge." Monatschr. f. Unfallheilk, Leipzig, 1911, xviii, 361–366.
Homans, J.: "Osteomyelitis of the Long Bones; a Study of 94 Cases from the Children's Hospital, Boston." Ann. Surg., Phila., 1912, lv, 375–387.
Kirmisson: "L'ostéomyélite chez les nourrissons." Rev. gén. de clin. et de therap., Paris, 1912, xxvi, 451.
Klemm, P.: "Die akute osteomyelitis des Beckens und Kreuzbeins nebst 4 Fällen von Wirbelosteomyelitis." Beiträge z. klin. Chir., Tübing., 1912, lxxx, 1–53.
Klemm, P.: "Über die chronische Form der sklerosierenden Osteomyelitis und ihrer Varianten." Ibid., 54–72.
Magniaux: "Ostéomyélite des adolescents." Normandie méd., Rouen, 1912, xxviii, 19–21.
Ombrédanne: "Ostéomyélite: forme commune, forme articulaire, forme subaiguë, forme chronique, forme prolongée, douleurs de croissance." Pédiatrie, prat., Lille, 1911, ix, 380–391.
Rigollot-Simonnot: "Vaste cavité ostéomyélitique; auto-plastie cutanée." Paris Chirurg., 1911, iii, 1047.
Siegel: "Ein Fall von Osteomyelitis acuta infectiosa." München med. Wchnschr., 1912, lix, 1786.
Spasokukotskaya: N. I.: "Paratyphoid Osteomyelitis." Khirurg. Arkh. Velyaminova, St. Petersb., 1911, xxvii, 1086–1096.
Savariaud and Pont: "Ostéomyélite costale; mort par septicopyohémie." Bull. Soc. de. pédiat. de Paris, 1912, xiv, 71–75.
Towle: "Osteomyelitis; Nerve Involvement, Ulcers." Jour. Cutan. Dis. inc. Syphilis, N. Y. 1912, xxx, 289.
Allen, L. W.: "Acute Osteomyelitis and its Complications." Am. Jour. Surg., N. Y., 1913, xxvii, 50–55.
Barbarin, P.: "Des formes anatomiques et cliniques de l'ostéomyélite prolongée ou chronique." Paris Chirurg., 1912, iv, 941–943.
Barrie, G.: "Chronic (Non-suppurative) Hemorrhagic Osteomyelitis." Ann. Surg., Phila., 1913, lvii, 244–258.
Bosquette: "Sur deux cas d'ostéomyélite attenuée; ostéomyélite de la tuberosité antérieure du tibia; ostéomyélite de la deuxieme phalange du medius." Ann. de méd. et Chir. inf., Paris, 1913, xvii, 312.
Broca, A., and Philbert: "Radiographies d'ostéomyélites." Gaz. d'hôp., Paris, 1913, lxxxvi, 693–696.
Castel, L.: "État actuel du traitement immédiat. de l'ostéomyélite aiguë de croissance." Montpellier, 1912, No. 58, 73, p. 80.
Clopton, M. B.: "The Treatment of Osteomyelitis; with Special Reference to Bone Regeneration." Weekly Bull. St. Louis, M. Soc., 1913, vii, 156.
Delrez, L.: "Pathogénie de l'ostéomyélite aiguë" Scalpel, Liége, 1913–14, lxvi, 171.
Dietsche, E. K.: "Die akute Osteomyelitis Erwachsener unter Ausschluss der rezidiven Formen mit primärer Infektion im Wachsumsalter." Freiberg, i Br., 1912; H. M. Poppen, 58, p. 80.
Dumont, F. L.: "Experimentelle Beiträge zur Pathogenese der akuten Hämatogenen Osteomyelitis." Deutsche. Zeitschr. f. Chir., Leipzig, 1913, cxxii, 116–149.
Estor, E., and Etienne, E.: "La greffe graisseuse dans l'obliteration des cavités ostéomyélitiques." Rev. d'orthop., Paris, 1913, 3 s. iv, 193–220.
Etienne, E., and Aimes, A.: "Osteomyelite typique chez les nourrisson." Progrés méd., Paris, 1913, 3 s. xxix, 34–36.
Fasano, M.: "Contributo alla conoscenza di alcune rare forme di ostéomielite." Gazz. d. osp., Milano, 1913, xxxiv, 304–307.
Field, M.: "Fat Embolism from a Chronic Osteomyelitis." Jour. Am. Med. Ass'n, Chicago, 1913, lix, 2065.
Froustey, G. J.: "De l'intervention large et précoce dans les ostéomyélites aiguës des os longs." Bordeaux, 1912, No. 134, 81, p. 80.
Gatti, G.: "Osteomieliti chroniche da piogeni." Gior. internaz., d. sc. med., Napoli, 1913, N. S., xxxv, 438–450.
Gibbon, J. H.: "Acute Osteomyelitis." Penn. Med. Jour., Athens, 1912, xvi, 223–228.
Glinka, Ye: "O fermentakh Bacillus osteomyelitidis." Arch. biol. nauk., St. Petersb., 1911–12, xvii, 487–494. Also Transl. Arch. de sc. bio., St. Petersb., 1912–13, xvii, 479–486.
Hamant, A., and Pigache, R.: "Ostéomyélite à infections mixtes." Gaz. d. hôp., Paris, 1913, lxxxvi, 1158–1160.
Hamilton, F. A.: "Osteomyelitis with Bone Transplantation." Jour. Am. Med. Ass'n, Chicago, 1913, lx, 2030–2032.
Hammond, R.: "The Seashore Treatment of Osteomyelitis." Am. Jour. Orth. Surg., Phila., 1912–13, x, 569–583.

HERDBY, M.: "À propos d'un cas d'ostéomyélite à pneumocoques." Nancy, 1913, 48 pp., No. 1002, 80.
MCGUIRE, R. C.: "Aberrant and Recurrent Osteomyelitis." Brit. Med. Jour., London, 1913, i, 13.
MAYET, H.: "Considérations sur l'ostéomyélite." Paris, Chirurg., 1912, iv, 921–940.
OLDHAM, J. E.: "Acute Osteomyelitis; Report of a Case." N. Albany Med. Herald, 1913, xxxi, 1–3.
PHÉLIP, J. A.: "Étude clinique des résultats éloignés dé l'osteomyélite des os longs chez l'enfant et l'adolescent." Paris, 1912, No. 320, 171 pp. 80.
SIMMONS, C. C.: "Localized Osteomyelitis of the Long Bones." Boston Med. and Surg. Jour., 1913, clxviii, 637–645.
TENNANT, C. E.: "The Use of a Blow-torch and Large Autodermic Grafts in the Treatment of Acute and Sub-acute Osteomyelitis." Denver Med. Times (etc.), 1912–13, xxxii, 322.
AYROLLES, H.: "L'Osteomyelite du nourrisson." Montpellier, 1913, 45 pp. No. 64, 80.
BARRIE, G.: "Hæmorrhagic Osteomyelitis, with Observations on its Pathology by O. S. Hillman." Surg., Gyn. and Obst., Chicago, 1914, xix, 42–52.
BULL, P.: "Osteomyelitis as a Result of Accident." Norsk. Mag. f. Lægevidensk., Kristiania, 1914, 5R., xii, 649–658.
DAVIS, A. W.: "Osteomyelitis." Kentucky Med. Jour., Bowling-Green, 1913–14, xii, 156–158.
DENNIS, W. A.: "Treatment of Osteomyelitis." St. Paul Med. Jour., 1913, xv, 605–612.
DYAS, D. G.: "The Treatment of Acute Osteomyelitis of the Long Bones by Means of the Dental Engine and a Large Burr." Jour. Am. Med. Ass'n, Chicago, 1914, lxii, 1216.
KANNENBERG: "Ein Beiträg. zur Kentniss der primären infektiösen Osteomyelitis und Polyarthritis des Pferdes." Monatschr. f. prakt. Tierh., Stutg., 1913–14, xxv, 193–222.
KIRMISSON: "Les ostéomyélites." Progrés. méd., Paris, 1913, 3 s. xxix, 643–645.
KIRMISSON: "Ostéomyélite à foyers multiples, ostéomyélite chronique de l'emblée." Rev. gén. de clin. et de thérap., Paris, 1914, xxviii, 422.
KIRMISSON: "Ostéomyélite de l'omoplate." Ibid., 471.
MCKINLEY, W. R.: "Acute Suppurative Osteomyelitis." Internat. Jour. Surg., N. Y., 1914, xxvii, 15–17.
MOSCHOWITZ, A. V.: "Multiple Osteomyelitis of Fifteen Years' Duration, Cured by Autogenous Vaccines." Ann. Surg., Phila., 1914, lix, 451.
ORZECH, C. M.: "Beiträg. zur Kenntniss der akuten infektiösen Osteomyelitis." Zürich, 1913, J. F. Kobold-Lüdi, 36, pp. 80.
PELISSIER, G.: "Conception actuelle de l'ostéomyélite aiguë à staphylococques et déductions thérapeutiques." Bull. méd. de l'Algérie, Alger, 1914, xxv, 258–265.
PRINGLE, S.: "Radical Operation for Chronic Osteomyelitis." Brit. Jour. Surg., London, 1914, i, 625–631.
RAMET, G.: "Un cas foudroyant d'ostéomyélite suraiguë septicemique." Scalpel, Liége, 1913–14, lxvi, 319.
ROST: "Experimentelle und klinische Untersuchungen über chronische granulierende Entzündungen des Knochenmarkes." Deutsche med. Wchnschr., Leipzig., u. Berlin, 1914, xl, 207.
ROST: "Weitere experimentelle Untersuchungen über chronische, etc." Leipzig, 1914, cxxvii, 404–407.
ROST: "Über Chronische Osteomyelitis." Med. klin., Berlin, 1914, x, 1591–1596.
SLOMANN, H. C.: "Om Trauma og Osteomyelitis." Ugesk f. Laeger, Kobenh., 1914, lxxvi, 1363–1377.
TIETZE: "Osteomyelitis fibrosa (Knochencyste)." Berl. klin. Wochenschr., 1914, li, 234.
WILLIAMS, G.: "The Localization of Osteomyelitis, Especially in Adults." Brit. Jour. Surg., London, 1914, ii, 97–101.
BOLOGNESI, G.: "Su la osteomielite da bacillo piocianeo." Policlin., Roma, 1915, xxii, sez. chir., 361–367.
CAMPBELL, W. F.: "Osteomyelitis." Med. Times, N. Y., 1915, xliii, 189.
CLOPTON, M. B.: "The Diagnosis and Treatment of Osteomyelitis." Surg. Gyn. and Obst., Chicago, 1915, xx, 6–24.
HAUSS, A. P., JR.: "The Radical Treatment of Osteomyelitis of the Long Bones." Internat. Jour. Surg., N. Y., 1915, xxviii, 309–311.
KLEMM, P.: "Die Akute und chronische infectiöse Osteomyelitis des Kindesalters auf grund eigener Beobachtungen und Untersuchung." Berlin, 1914, S. Karger, 271 pp. 80.
LYON, D. M.: "Case of Osteomyelitis with Pyemia." Edinburgh Med. Jour., 1915, xv, 18–28.
MCWILLIAMS, C. A.: "Osteomyelitis with Multiple Foci." Ann. Surg., Phila., 1915, lxii, 112–114.
MARSIGLIA, G.: "Sul l'osteomielite da proteo." Riforma med., Napoli, 1914, xxx, 1349–1354.
MURPHY, J. B.: "A Diagnostic Talk on Osteomyelitis." Surg. Clin., Chicago, 1915, iv, 187–219.

Murphy, J. B.: "Recurring Multiple Osteomyelitis and Peri-ostitis; Curettement of Sinuses and Granulation Masses." Surg. Clin., Chicago, 1915, iv, 219–230.
Murphy, J. B.: "Acute Osteomyelitis of the Right Radius; Incision and Drainage." Ibid., 231–237.
Ochsner, J. F.: "Acute Suppurative Osteomyelitis." New Orleans Med. and Surg. Jour., 1914–15, lxvii, 678–686.
Oser: "Zur Frage der Dauerheilung nach Operation Wegen akuter Osteomyelitis," Verhandl. d. deutsch. Gesellsch. f. chir., Berlin, 1914, xliii, 1, Teil, 240–242.
Rodano, F.: "Postumi rari di osteomielite." Riv. ospedali, Roma, 1915, v, 77–83.
Simmons, C. C.: "The Treatment of Osteomyelitis; Observations on 97 Consecutive Cases, with End Results." Surg., Gyn. and Obst., Chicago, 1915, xx, 129–153.
Thiem: "Bei der Anerkennung der Mitwirkung eines Unfalles auf den Ausbruch einer eitrigen Knochenhaut-und Knochenmarkentzündung ist der Nachweis der Gewalteinwirkung, auf die erkrankte stelle unerlässlich?" Monatschr. f. Unfallheilk., Leipzig, 1915, xxii, 229–233.
Wallace, W. L.: "Surgical Treatment of Acute Osteomyelitis." N. Y. State Jour. Med., N. Y., 1915, xv, 70–73.
Warbasse, J. P.: "The Physician's Responsibility in Acute Osteomyelitis." Jour. Am. Med. Ass'n, Chicago, 1915, lxiv, 1293.
Bancroft, F. W.: "Osteomyelitis in Children (Two Cases); with Demonstration of Lantern Slides of X-ray Plates, Showing the Bone Repair Following This Disease." Med. Rec., New York, 1916, xc, 780.
Dial, J. J.: "Acute Infective Osteomyelitis." Jour. Oklahoma Med. Ass'n, Muskogee, 1916, ix, 245.
Jacoby, A.: "Chronic Osteomyelitis and its Operative Treatment." South. Med. Jour., Birmingham, 1916, ix, 989–991.
Murphy, J. B.: "Bone Infections Metastatic to Furuncles (Two Cases)." Case I, Pathologic Fracture of Femur from Osteomyelitis; reduction and dove-tailing of fragments. Case II, Osteomyelitis of ilium; treatment by autosensitized autogenous vaccine. Surg. Clin., Phila., 1916, v, 751–764.
Phemister, D. B.: "Subperiosteal Resection in Osteomyelitis, a Clinical and Experimenta Study." Jour. Am. Med. Ass'n, 1915, lxv, 1994–2000.

CHAPTER XVII

MALUNITED AND UNUNITED FRACTURES OF THE LONG BONES: THEIR SURGICAL TREATMENT BY BONE-GRAFT

In compiling this chapter, it has been found most difficult to keep the text within reasonable limits, because of the multiplicity of detail that requires consideration. We shall make no attempt to cover the entire subject of fractures, which would carry us too far afield and would require a separate volume for the undertaking. Our purpose therefore is to consider only malunited and ununited fractures, viz.: (1) Malunited fractures; (2) ununited fractures; (3) fractures requiring open operation as their primary treatment; and (4) all fractures requiring secondary treatment (*i.e.*, those in which primary treatment has resulted in failure). We shall also touch upon certain fundamental principles illustrated by such cases, which should influence primary treatment.

General Considerations.—In no other field of surgical practice is there a greater difference of opinion than that existing in reference to the open or operative treatment of fractures, in contradistinction to the conservative or non-operative treatment. The important questions arise: in which case is operative treatment demanded, and in which will non-operative treatment give a perfectly satisfactory result?

It is exceedingly difficult to answer this question with any degree of accuracy from clinical evidence alone. The circumstances of clinical observation have such a wide range that comparison of the results of different methods of treatment is almost impossible. Some of the more important of these varying factors are: the age and health of the patient; the site and anatomical condition of the fracture; the length of time that has elapsed before treatment was undertaken; the period between the termination of the treatment and the recording of the result; the skill and attitude of mind of the surgeon. "It is only by experiment that these variables can be replaced by constants and a true estimate made of the factors which underlie success or failure of operative methods" (Gross).

Lane operates on all cases of simple fracture of the long bones in which he is unable to obtain accurate apposition of fragments when the restoration of the bone to its normal form is of mechanical importance to the patient. With the development and perfection of aseptic surgical technic, there has been a natural coincident increase in the number of simple fresh fractures submitted to operation. Many surgeons feel that the numerous cases of badly set fractures which become useful only after one year to eighteen months, might have had better functional results in a much shorter period.

Whatever methods are adopted should be carefully selected at the start. If the surgeon is confident from his experience that a certain fracture cannot be successfully treated by conservative means, and that operation is indicated he should make his decision without delay and operate at a time best suited to the individual case, *i.e.*, at some time after the lapse of six or seven days. Too long procrastination in this department of surgery is the greatest of evils. If after a reasonable number of attempts by conservative methods, the sur-

geon is unable to bring the fragments into satisfactory alignment, he should not delay operative interference longer than five to six weeks at the outside. After the lapse of several months, the opportunity of obtaining an ideal result in cases with malposition by operative means has passed. The reparative processes which have been at work in and about the fragments have effectually prevented favorable union by bone plastic surgery. These obstacles to ideal results are: exuberant callus and connective tissue formation; shortening of ligaments, muscles and fasciæ; and disappearance of the fracture serrations and the consequent impossibility of locking the fragment ends together.

Fortunately, the day is fast disappearing when fracture cases in our large hospitals are handed over for treatment to internes or to some disinterested junior attendant. The advent of the *x*-ray, the workmen's compensation law, the insurance carrier, and, as the result of the recent war, the development of special military orthopedic hospitals where the results of expert treatment have been demonstrated as never before, have helped to awaken the profession to a recognition of the fact that in fractures we have some of the most difficult and interesting problems to be met with in the whole realm of surgery, and that there is nothing that taxes the experience, anatomical knowledge, and good judgment of a surgeon to a greater degree than a difficult fracture.

During the last few years, as the profession has been more carefully investigating the end-results after fractures, a strong feeling has developed that the results must be improved. Since the advent of the *x*-ray, both the profession and the public have become educated to higher ideals, and are demanding shorter and more efficient treatment, a shorter period of disability, and better functional results.

A plea, however, should be made for caution against the too enthusiastic adoption of the open method of treatment as a routine means of dealing with simple fractures. An inexperienced surgeon, faulty surroundings, and inadequate armamentarium, form an absolute contra-indication to an open operation for fracture. A necessary adjunct to surgical technic, moreover, is exact anatomical knowledge of the field of operation and a mechanical conception of the muscles, ligaments, fasciæ, etc., which control the position of the fragments. Thus equipped, the surgeon will not be guilty of so many glaring defects in his surgical treatment of fractures.

ARMAMENTARIUM OF THE SURGEON

Hospitals are, as a rule, poorly equipped for fracture work, and in many instances surgeons of the general staff, overstimulated by their zeal for abdominal, urological, gynecological, and general surgical operations, allow their fracture cases to take a subsidiary position. For this reason, many hospitals have devoted their finances to the most minute details of equipment for these favorite departments, and have sadly neglected to provide an adequate armamentarium for fracture and other bone work. If this discrepancy has not already been rectified, a strong impetus will soon be brought to bear in that direction by the large number of fracture and other military cases accruing from the recent war and an unusually large number of bone cases will be entering our hospitals in the course of the next twenty-five years. This remark is substantiated by the fact that surgeons are not infrequently called upon at the present day to rectify bone and joint distortions incurred in our Civil War of fifty years ago.

Every surgeon who attempts to do general surgery should have not

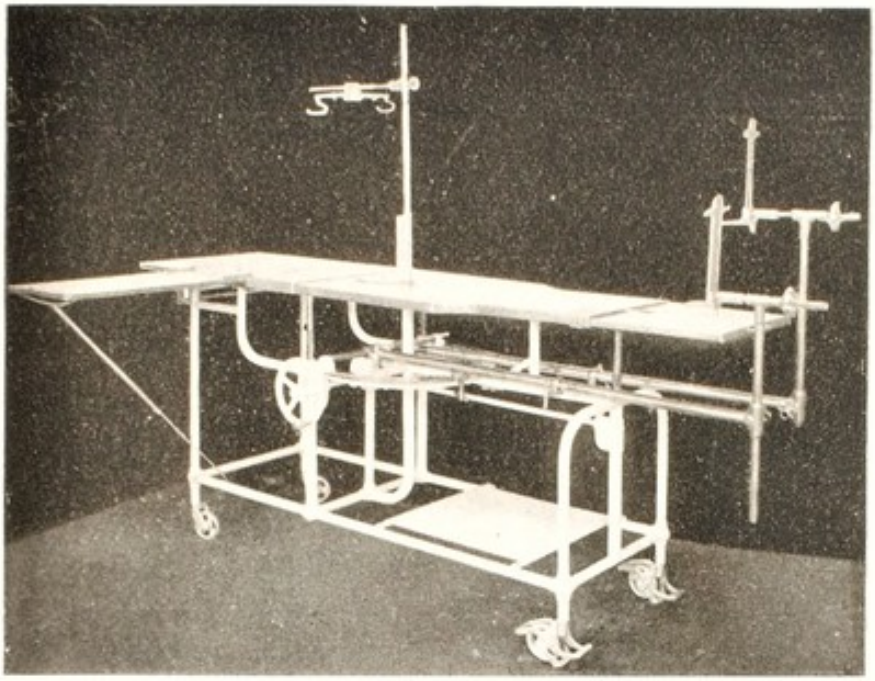


FIG. 285.—Author's fracture-orthopedic operating table. Table opened to its full extent, showing the sliding leaf at the foot, hinged leaf at the head, the removable armshelf, with rest, the long traction rods with foot bars, the arm suspension apparatus, the perineal post, the swiveled rollers with locking apparatus, etc.

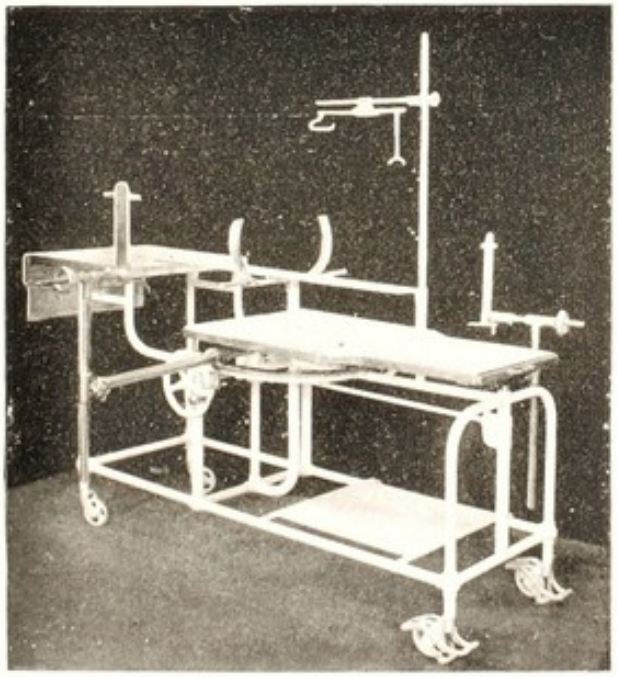
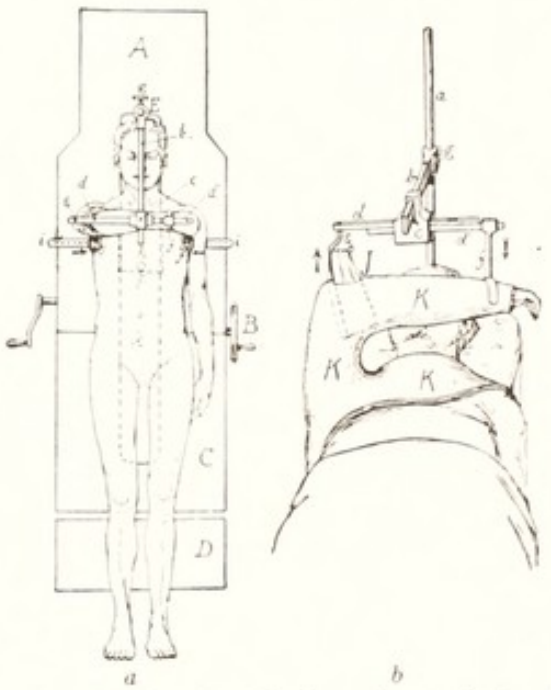


FIG. 286.—The table prepared for securing traction in the position of neutral muscle pull (anterior elevation of the arm) for controlling epiphyseal and surgical-neck fractures of the upper end of the humerus. The drop shelf at the head has been lowered, the shelf at the foot slid into the table top, the lower half of the table fully depressed, the arm suspension apparatus in place, the rest iron placed upon the hip rest post with the cross bar inserted and the axillary holds in position, and the thin metal board back rest placed on the iron. The leg traction arm in the foreground has been abducted to a right angle with the long axis of the table to secure traction and fixation if the arm is to be immobilized in the abducted lateral instead of the anterior elevated position.

only an outfit for abdominal work, but also a complete outfit for doing up-to-date and efficient bone surgery; a complete armamentarium for the latter should contain the following:

1. **Traction Operating Table** (Figs. 285 to 294).—Although the remark may appear paradoxical, nevertheless we wish to state that when used by the novice (or even by the experienced surgeon unless he practises eternal vigilance) the more efficient the traction table the greater the danger of ultimate failure of union or the production of malunion when the table is used in the application of Lane's metal plates. This is explained by the following facts (Fig. 295): during distraction of the fragments, the holes are bored, the plate



a *b*

FIG. 287.—*a*, Bird's-eye view of patient fixed on the author's table in the position of neutral muscle pull (anterior elevation of the arm) for controlling epiphyseal and surgical neck fractures of the upper end of the humerus. All the constituent parts of the arm suspension apparatus and the axillary holds can be dismounted and withdrawn from beneath plaster dressing, piece by piece, without disturbing the fixation. The axillary holds, *j* and *j'* are each furnished with an automatic catch which fits into holes in the cross bar, *i*, thus regulating the interspace between them. (The lettering in this figure corresponds with that of Fig. 289.) If these holds are pressed internally at their tips as shown by direction of arrows at *j*, they can be readily detached from cross bar.

b, Method of using author's table to produce traction and to immobilize the arm by a plaster-of-Paris shoulder spica, *K*, in the anterior elevated position (neutral muscle pull) for epiphyseal and surgical neck fractures of the upper end of the humerus. With the wrist fixed by the hand rest, *f*, as a fulcrum, traction is maintained in the direction of the arrow by a bandage *J*, passed over the hook *e* of the cross piece *d* and beneath the proximal end of the forearm. Other letters as in Fig. 289.

is applied, and the screws are set while the fragments are still distracted and thus permanently held apart by the plate; thus effectually preventing the operation of Roux's law of frictional irritation of the bone ends, which is so essential to their union. Furthermore, the lateral stress thus brought to bear upon the screws loosens them and causes them to come out, but this event occurs too late to allow coaptation of the fragment ends, because the period of their osteogenetic activity has elapsed, and the result may be non-union.

2. Electro-operative bone outfit.

3. Suitable retractors, sharp-pointed and rake, and of varying sizes and depth of tooth.

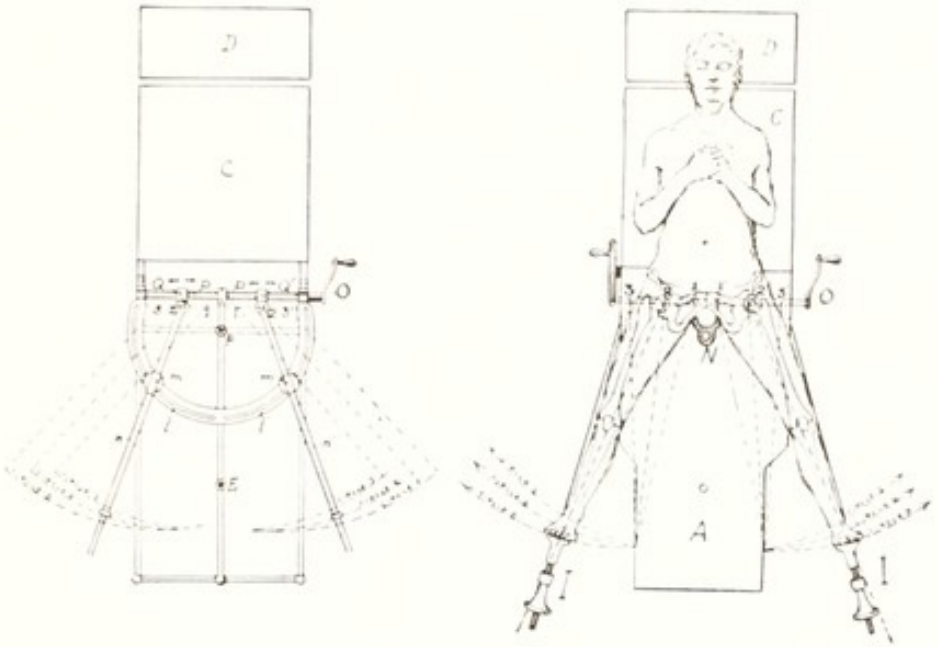
4. Bone clamps and bone-jacks.

5. Bone elevators (*e.g.*, Lane's).

6. Materials for external and internal fixation of fragments; kangaroo tendon of heavy sizes.

7. Provided the surgeon has not fully developed his technic, so as to avoid the use of metal, various metal plates and tools for their application.

We believe that the wood screw, adapted only for soft materials, should never be used in bone, and only a self-tapping screw, or a suitable screw



a *b*

FIG. 288.—*a*. Screw adjustment of proximal ends of traction arms, a mechanical device for shifting the centers of rotation of the traction arms to points corresponding with, or greater or less than, the interval between the hip-joints of the individual. The crank *O* turns the bar *P*, the halves of which have worm threads cut in opposite directions. Turning the crank moves the riders Q and Q′ simultaneously, keeping them always equidistant from the center of the table. The pivots of the arms *n* and *n′* are thus made to travel along lines from 1 to 3 and 1′ to 3′ respectively, enabling the abduction or adduction of these arms to describe the arc of a new circle with each new position. The traction arms can be fixed upon the quadrant *l*, *l′* in any given position by the set screws *m*, *m′*. Other letters as in Fig. 289.

b. Practical application of leg traction showing mechanism of the screw adjustment of the proximal ends of the traction arms illustrated in *a*. Traction is made by the arms *l*, and *l′* against counter traction exerted by the perineal post *N*. The axis of rotation of the patient's leg in abduction has its center at 2, 2′, and the foot describes the arc of circle 2. If the axis of rotation of the traction arm coincides with this, there is no change in the amount of traction from abducting or adducting the limb. If, however, the center of rotation of the traction arc is at 3, 3′, abduction causes the foot to describe the arm of circle 3 and the amount of traction is increased. If the center is at 1, 1′ abduction causes the foot to describe the arc of circle 1, and there is great diminution in the amount of traction. (In former traction tables the axes of movement of the traction rods were rigidly fixed at points 1, 1′.)

with a mechanical tap, should be used. It should be said, in this connection, that to do fracture work in these days, a man should either master the mechanical principles involved or not attempt to do the work at all.

Furthermore, the author is convinced from a very careful laboratory investigation, that silver wire should be entirely omitted from the surgeon's armamentarium, for the reason that it is a very treacherous agent because it is so likely to break at the twist, where it is fixed. It is surprising how little force large strands of silver wire will withstand when placed in an accurate machine for testing tensile strength. In many instances the wire will begin

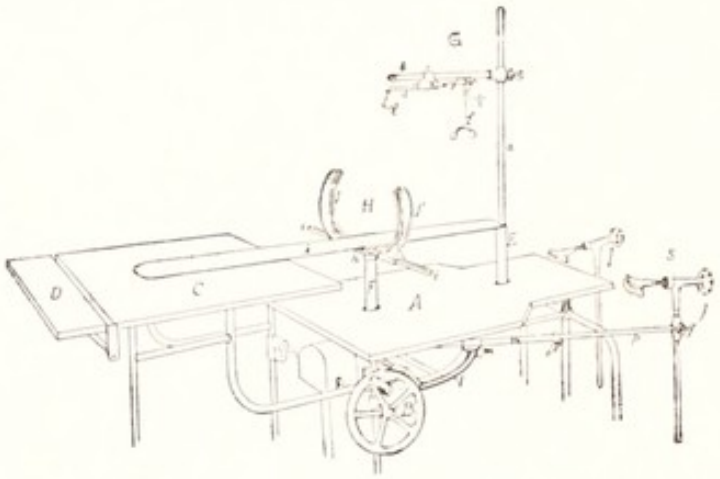


FIG. 289.—The principal attachments of the author's fracture-orthopedic operating table are: *A*, Movable part of table top; *B*, wheel to raise and lower *A*; *C*, stationary part of table top; *D*, drop shelf; *E*, post forearm suspension apparatus; *F*, hip rest post; *G*, arm suspension apparatus: *a*, bar for vertical adjustment; *b*, suspension bar; *c*, carrier; *d* and *d'* sliding cross pieces adjustable to individual forearm; *e* and *e'*, hooks for traction bandages; *f*, hand rest for counter pressure; *g*, screw for fixing height of *b*, thus allowing for graduated traction; *H*, body holder for application of shoulder spica; *h*, rest iron; *i*, cross bar; *j.j'*, axillary holds; *k*, metal board back rest easily removable after application of shoulder spica; *I*, traction and abduction apparatus: *l*, grooved quadrant for control of abduction adduction of traction arm; *m*, set screw to hold traction arm; *n*, telescoping traction rod, recipient tube; *o*, set screw; *p*, distal half of traction rod; *q*, set screw; *r*, sliding rod for foot support which allows graduated adjustment of flexion and extension; *s*, screw for "fine" adjustment of traction (for details see Fig. 288, *a*).

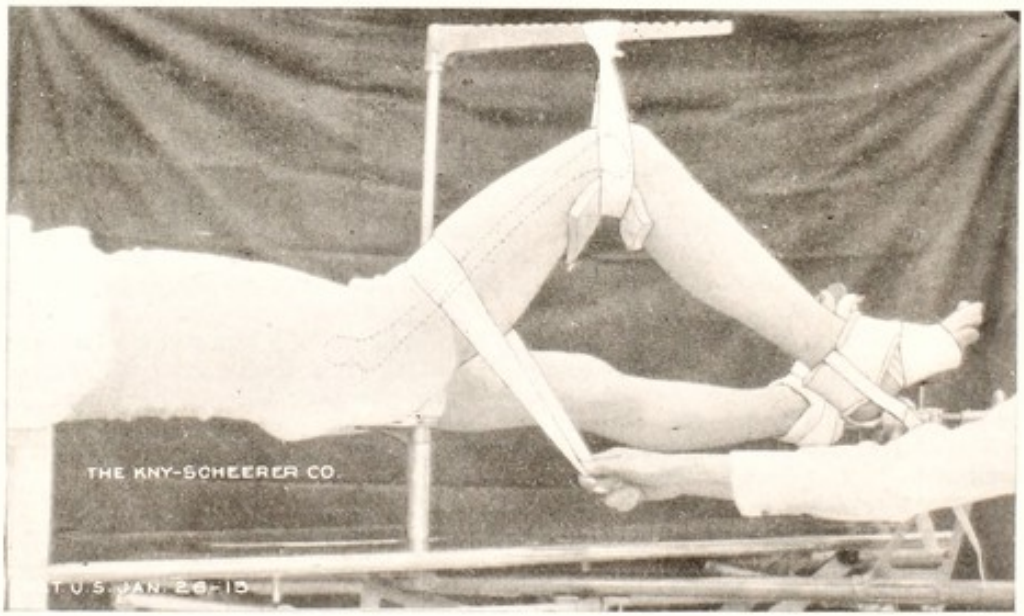
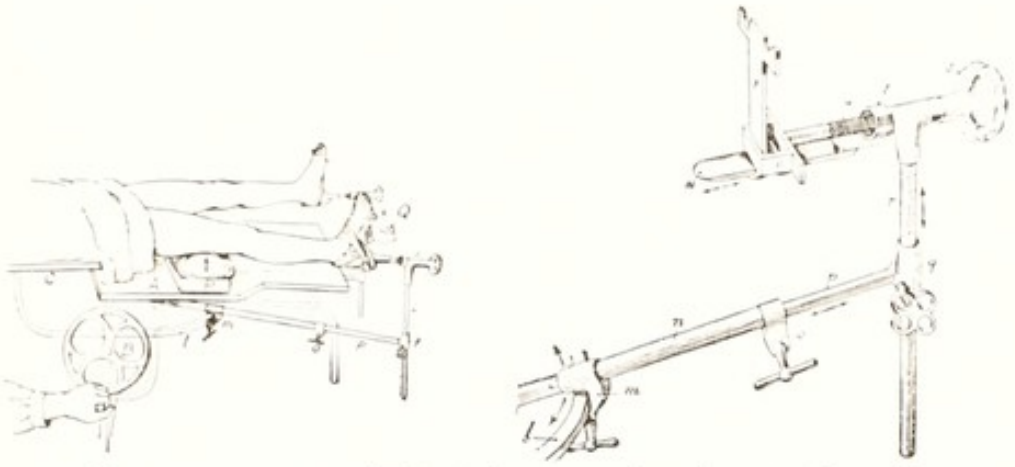


FIG. 290.—Hawley table. Flexion and abduction of the thigh in the treatment of subtrochanteric fractures of the femur with or without counter-pressure on the upper fragment. This posture can equally well be obtained in using the author's table. There is a material advantage in having the knee flexed, over the customary thigh flexion with the knee extended, in that the relaxation of the powerful hamstrings greatly aids reduction, the quadriceps also being relaxed by the hip flexion. The traction obtained with the knee flexed is quite as effective as with the knee in extension. It is often advantageous in many tibial and femoral fractures to immobilize with some flexion of the hip and knee, because flexion naturally aids relaxation, and the angles in the cast make the immobilization more secure.

to yield at the twist or knot before the dial of the testing machine has begun to register (Figs. 296, 297 and 298).

Some ten years ago, the author began using kangaroo tendon as a fixative agent in fractures, and found that when a great deal of strength was needed it was necessary to multiply the strands. Later, on consulting certain well-known producers of this material, it was suggested that heavier strands of this tendon be prepared. This was done, and the various sizes were labelled x-heavy, xx-heavy, xxx-heavy, and xxxx-heavy. It was then discovered that these heavy tendrils had hitherto been discarded by all



FIGS. 291 AND 292.—Author's fracture-orthopedic operating table.

FIG. 291.—Details of the distal portion of the traction arm and the foot hold. (*l*, *m*, *n*, *o*, *p*, *q*, and *r*, as in Fig. 289.) *s*, Grip of screw for "fine" adjustment of traction; *t*, collar to prevent draping sheets from becoming "jammed" in threads of screw; *u*, adjusting screws; *v*, box for foot bar and heel rest; *w*, sliding heel rest which slides back to release foot and plaster splint from table; *x*, broad flat steel foot bar which after cutting bandages is withdrawn from slot in traction arm, thus freeing completely patient's foot from table.

FIG. 292.—Practical application of traction. Position of body shown in Fig. 288, *b*. Foot bandaged by Q to the foot bar, the bandage passing over projection *x* of the foot bar. The leg is swung into the desired degree of abduction and fixed by turning set screw *m*. Gross traction is made by elongating *p* and fixed by tightening *o*. Flexion is secured by elongating *r* and fixed by tightening *q*. Greater traction is secured by turning grip of screw *s*. Lower half of table *A* is lowered by turning *B*. To overcome posterior displacement of a short lower fragment of the femur, a pillow or block and sandbag *P* may be placed under the offending fragment and the table again elevated, levering the fragment into place, while the internal fixation agent is applied whether it be an inlay bone graft, kangaroo suture, wire, or Lane plate. In a similar way the rotation of the patient's trunk may be controlled by placing a sandbag between the hip and the movable portion of the table. A few turns of the wheel up or down controls the situation very satisfactorily.

the prominent producers of suture materials, as it was not advisable to split them. At the author's suggestion, therefore, the leading producers in this country are now making these large sizes of kangaroo tendon.

The figures in the following table represent the breaking strain (in pounds) at the knot (or reef) of the special heavy kangaroo tendon prepared for the author by Kny-Scheerer Co., Van Horn and Sawtell, and others and labelled x, 2x, 3x and 4x heavy, and silver wire of the size generally used as a bone suture.

Kangaroo tendon	Breaking strain (in pounds)			
Heavy	16	30	15	34
x Heavy	41	34	40	42
xx Heavy	48	63	41	(not at knot)
xx Heavy	42	43	42	38
xxx Heavy	72	32	40	41
xxxx Heavy	55	41	100	41

A comparison was also made between x-heavy kangaroo tendon, Nos. 19 and 20 silk, and gauge 17 silver wire:

x-heavy kangaroo	No. 19 braided silk	No. 20 twisted silk	Silver Wire B. S. gauge 17	
			Slipped at twist	Broke
38	30	14	14	32
41	24	18	18	24
40	35	22	4	18
43	32	20	8	12

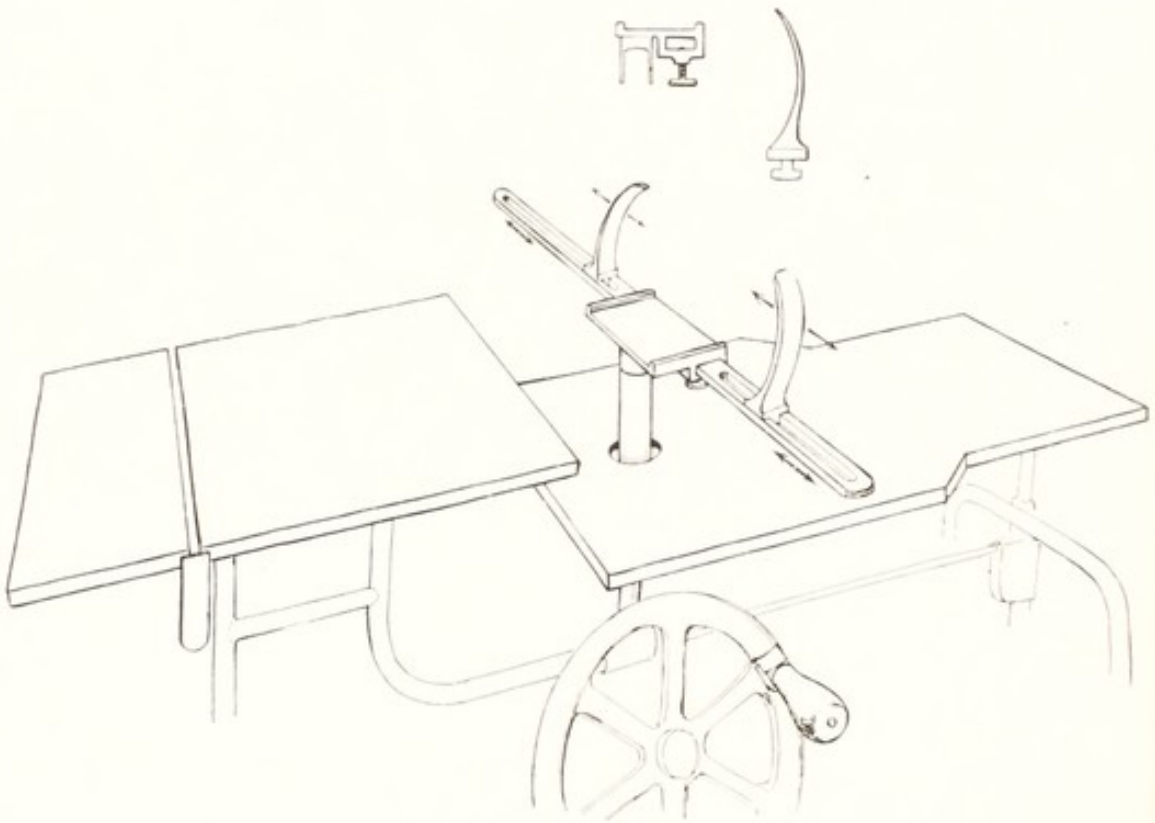


FIG. 293.—Author's fracture-orthopedic table. Attachments in place for holding the patient's shoulder while applying the shoulder spica. (See Fig. 289.) The rest for the thin metal board (for the patient to rest on) is shown in center. Thin metal board is detachable and pulls out of the plaster after it is applied. (The traction-part and arm-holder are not shown in this drawing.)

The special sizes of kangaroo tendon as a fixative agent for bone have the following advantages (Figs. 299, 300, 301, 302 and 303):

(*a*) They are much stronger than catgut, silk, or silver wire. The last-named is so treacherous that it should be entirely discarded for this purpose.

(*b*) They are absorbable, but not too rapidly so. They remain in bone for upward of forty days, and then begin to disappear.

(*c*) They can be tied in a firm, tough, non-slipping knot.

(*d*) They do not stretch, as silk-worm gut does.

(*e*) Kangaroo tendon is comparatively easy to sterilize and is not at all irritating to the tissues.

8. **Osteotomes** of various widths. The author never under any circumstances uses a blunt-edged chisel. There is so little flexibility and fiber



FIG. 294.—Author's fracture-orthopedic table. This is illustrative of the author's position for the treatment of fractures of the upper third of the humerus and the method of holding the patient on his table while operating and applying the long plaster-of-Paris shoulder spica. The position is held with any amount of traction while the plaster is applied. Co-aptation fixation is very efficient in this method in that the plaster can be moulded on every side of the arm.

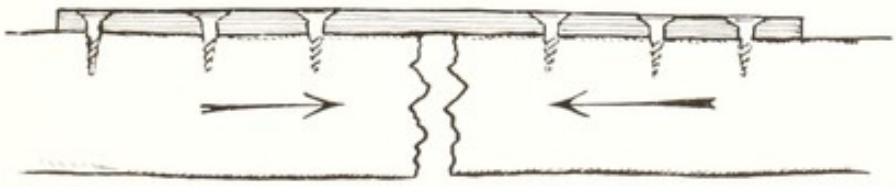


FIG. 295.—The result of the unintelligent use of an efficient traction-table or bone-jack and the Lane plate, causing separation of the fragment-ends which the surgeon is apt to inadvertently allow to remain while he applies the plate. The rigid plate and the firmly-set screws prevent the obliteration of this interval and the operation of Roux's law of frictional irritation during the important, active, bone-growing period immediately following the operation. Subsequently the screws, by their disintegrating effect on the bone, fall out, the plate becomes dislodged and non-union results.

in bone that it crushes or breaks very readily under the chisel, and for that reason a thin edged osteotome is preferable (Fig. 304).

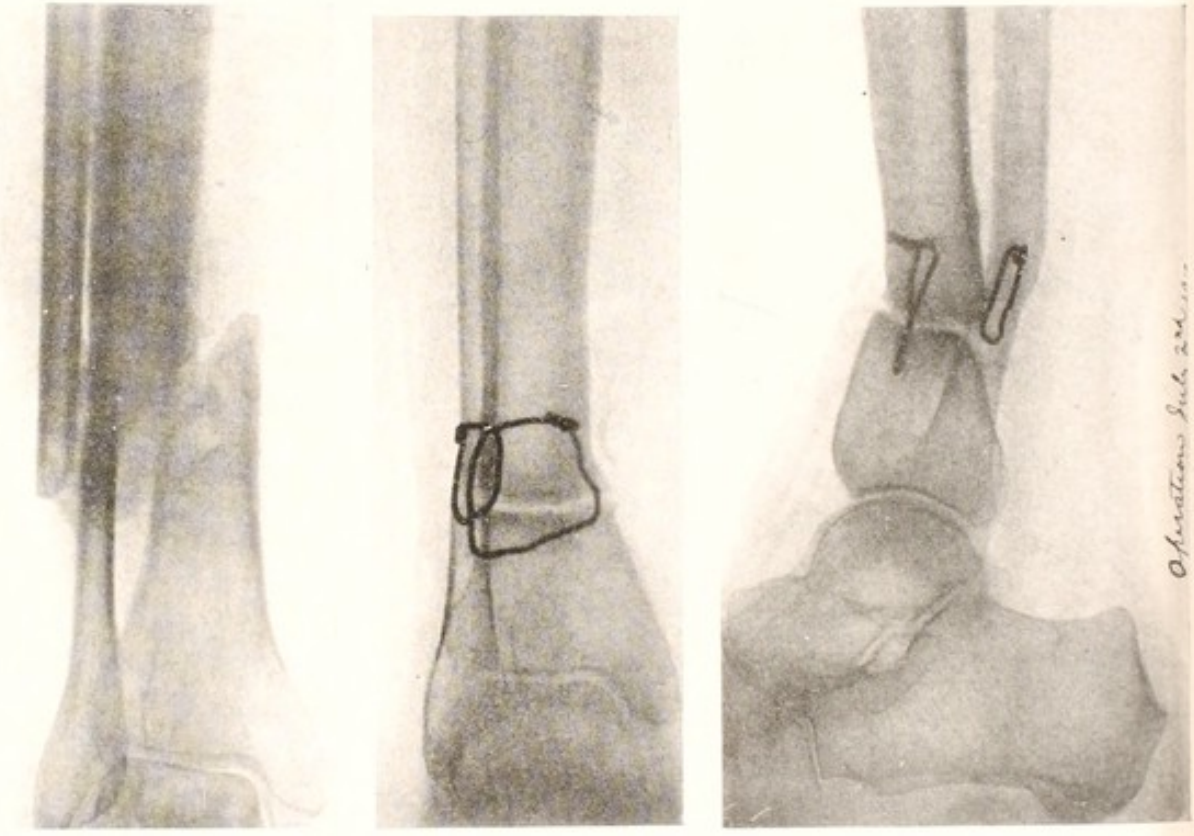
The blunt-edged chisels with which the instrument makers frequently supply us, are always more likely to crush or break bone than to cut it. The author wishes here to interject the remark that manufacturers of instruments are often prone to supply the surgeon with chisels and other cutting tools which are so thick at the edge and so clumsy that a carpenter or a mechanic would never consider using them in his work, which is far less delicate than that of the surgeon.

9. Rongeur.

10. Lion-jaw forceps.

11. Gouges with long handles and of various widths.

12. Heavy mallet; it should be large and of solid metal, although one of lignum vitæ is very good.



a *b* *c*

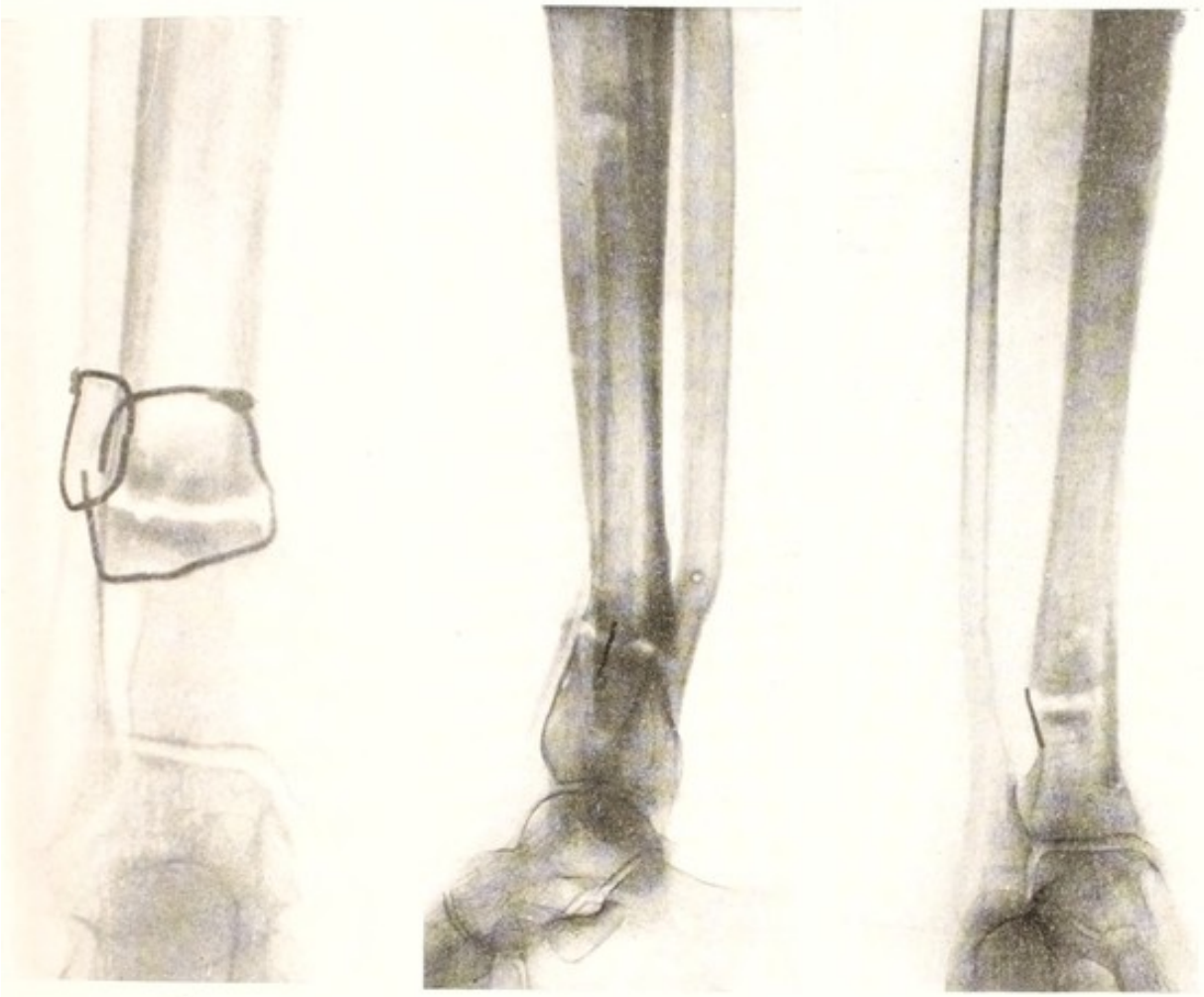
FIG. 296.—Oblique fracture of the tibia resulting in non-union. *b* and *c* show marked resection of bone and shortening of the tibia and the introduction of silver wire. It is seen that the lower fragment has been shortened by almost two-thirds of its length and the upper fragment possibly a corresponding amount. A procedure that was not only unnecessary but of very little influence toward securing a union.

13. Suitable materials for external fixation dressings. The importance of this should be emphasized, and it is furthermore believed that every surgeon having anything to do with fractures should thoroughly master plaster-of-Paris technic. Suitable materials consist of plaster-of-Paris roller bandages and "strengtheners" (the latter are of the greatest service), as well as cotton, sheet wadding, stockinet, or flannel (see also Chapter XXIX, on Plaster-of-Paris Technic).

14. The Balkan bed-frame (Figs. 305 and 306).

15. Thomas' knee-brace, and other necessary apparatus.

It should be emphasized that while operative treatment is necessary in many cases, there are numerous instances of closed fracture in which it is not needed. Excellent results can often be secured, as to both anatomical restoration and function, by non-operative treatment at the hands of a careful, experienced surgeon who has a mechanical mind, anatomical knowledge, and experience in the management of plaster-of-Paris and the various fixation splints.



a *b*

FIG. 297.—Same cases as Fig. 296. *a*, Was taken after three operations needlessly resulting in over 3 inches of shortening and at the same time contributing to non-union. This *x*-ray also illustrates the unreliability of silver wire as a fixation agent. Both of these loops have broken; the one has broken in two places. *b*, *X*-ray 6 weeks after the author inserted a sliding inlay graft from the upper fragment resulting in immediate firm union.

The great objections to operative treatment involving the use of the internal metal plate (Lane) are: danger of infection, and delayed or non-union. Both of these objections, especially the latter, can be overcome by the use of kangaroo tendon and ideal external fixation, or by the inlay bone-graft, where imperfect osteogenesis or the existing mechanical conditions demand it.

In a recent paper, W. P. Carr states: "I have never put on a Lane plate, but I have had to remove many. Of 54 that were applied by half a dozen of our best surgeons at the Emergency Hospital, 30 had to be removed for non-union, suppuration, irritation, breaking or bending of the plate. The other 24 may have trouble later" (Figs. 307 and 309).

The less non-absorbable material used the better. If one is determined to use Lane's plates, the fewer the plates the better. The methods of internal

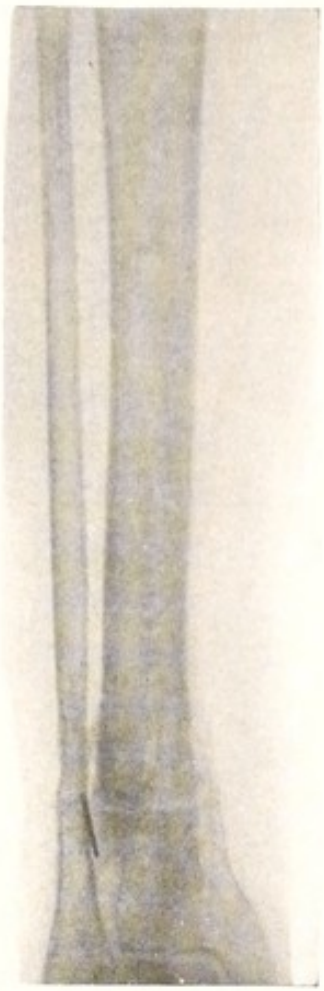


FIG. 298.

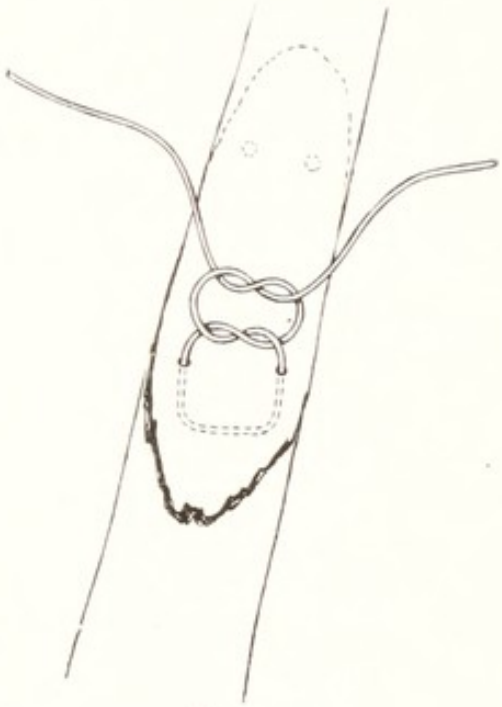


FIG. 299.

FIG. 298.—Same case as Figs. 296 and 297 after complete consolidation.

FIG. 299.—Illustrates square knot which is always essential in bone work.

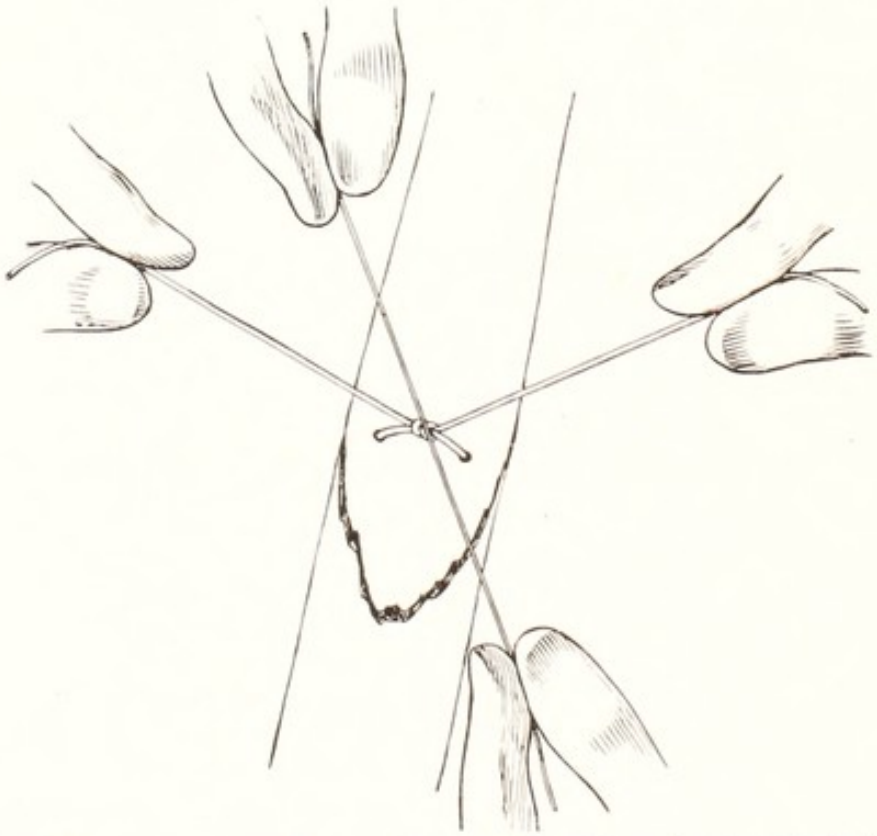


FIG. 300.—Illustrates with the succeeding drawings the author's method of preventing the untying of the knot in heavy kangaroo tendon. A strand of No. 1 chromic catgut is held at right angles to and in contact with the square knot in the kangaroo tendon while a third half knot is tied around it. (See Fig. 301.)



a *b* *c*

FIG. 301.—*a*, Third half knot in kangaroo suture with No. 1 chromic beneath it; *b*, chromic ligature being tied about the last half knot of the kangaroo tendon; *c*, the knots in kangaroo tendon and chromic completed.

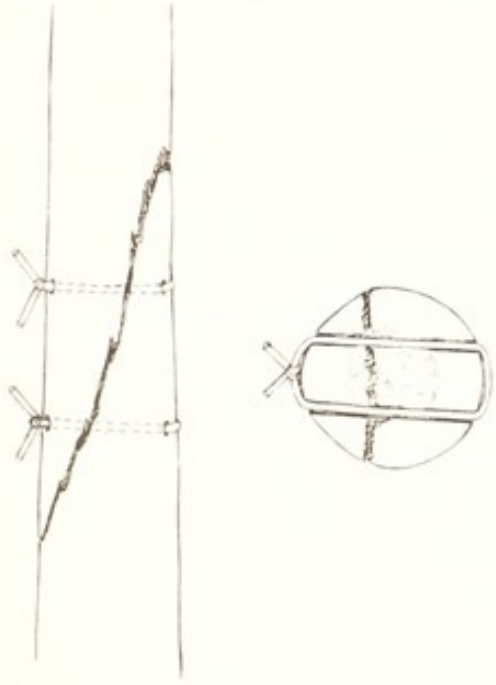


FIG. 302.

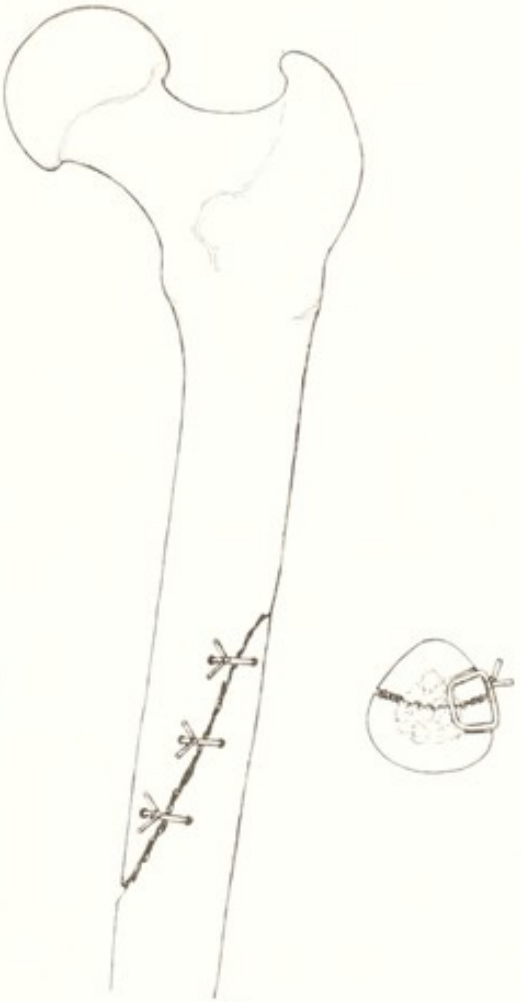


FIG. 303.

FIG. 302.—Bolting suture of heavy kangaroo tendon for oblique fresh fractures. Such sutures will answer all purposes even in the most difficult cases providing an operating-fracture table is used and the most is accomplished in securing plaster-of-Paris fixation and an adequate position of "neutral muscle-pull."

FIG. 303.—Kangaroo sutures for oblique fresh fractures of long bones. It should be noted that the drill holes are so placed that the sutures are oblique and not at right angles with the axis of the fracture. The holes in the upper fragment are placed relatively lower than those in the lower fragment, so as to prevent sliding upward of lower fragment on upper.



FIG. 304.—Various types of osteotomes and chisels. *a* and *b* represent a thin sharp osteotome which will cut bone and not break it. *c* is a chisel with blunt bevelled end which is more likely to break bone than to cut it; *d* is a particularly blunt osteotome and an instrument of this type should never be used in bone surgery.

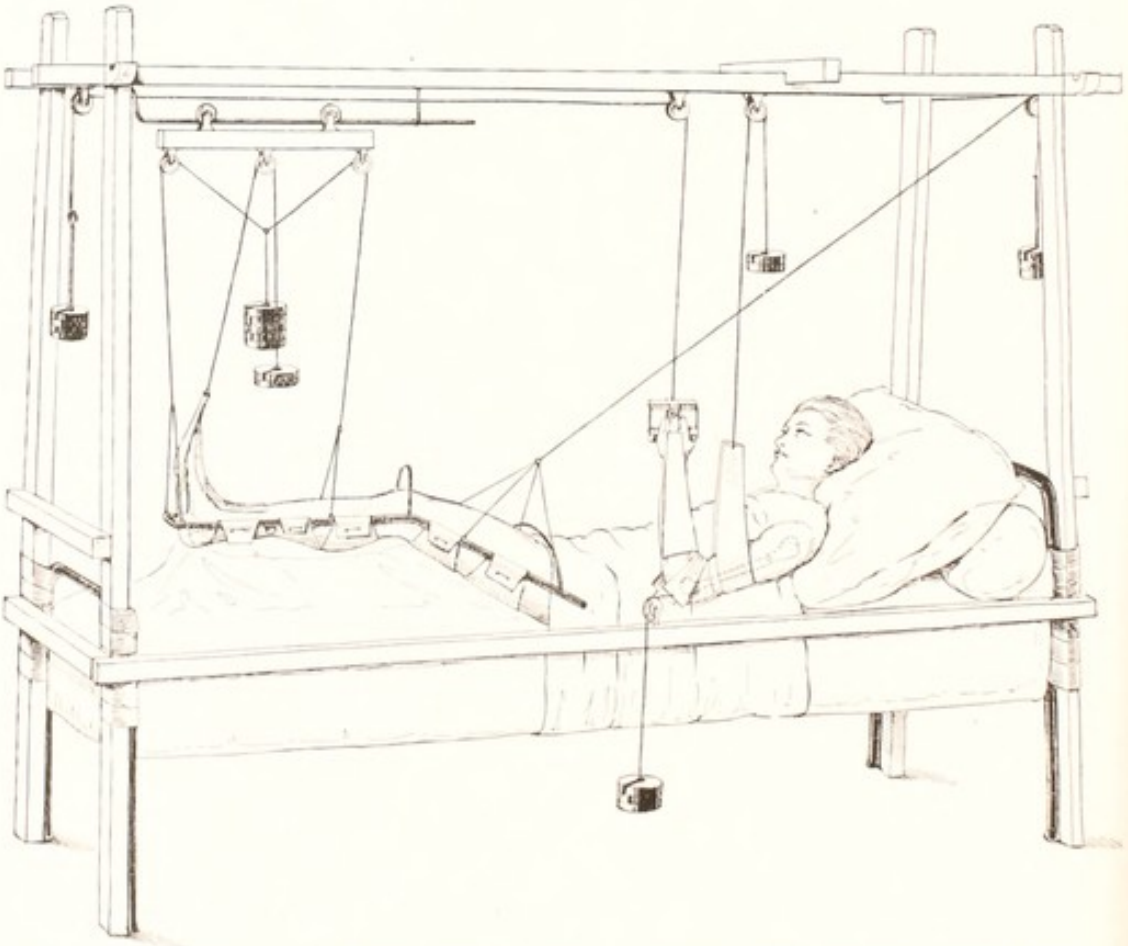


FIG. 305.—Adjustable Balkan frame—a development largely of the recent war. It allows traction to be applied to both upper and lower extremity in any direction desired. (*i.e.* in a "posture of neutral muscle-pull"). (After Blake.)

fixation vary to a certain extent. If it is merely desired to steady the fragments until the application of external fixation, the internal fixative agent need not be so strong as when used to protect the part against great strain, as in fracture of the femur. But it must be remembered that no internal fixative agent, however strong it may be, will withstand constant strain; this is particularly true of metal screws which become loosened more by lateral than by end-to-end stress. The chief function of internal fixative agents in fresh fractures is to maintain end-to-end apposition of the fragments, but the chief reliance for obviating strain from every source is the external support of the part.

Groves reports that in all his experiments (2 cats' tibiæ; 2 rabbits' tibiæ; 5 rabbits' femora) where metal plates were used to hold fractures, "the bone ends became disunited within the first week, with more or less

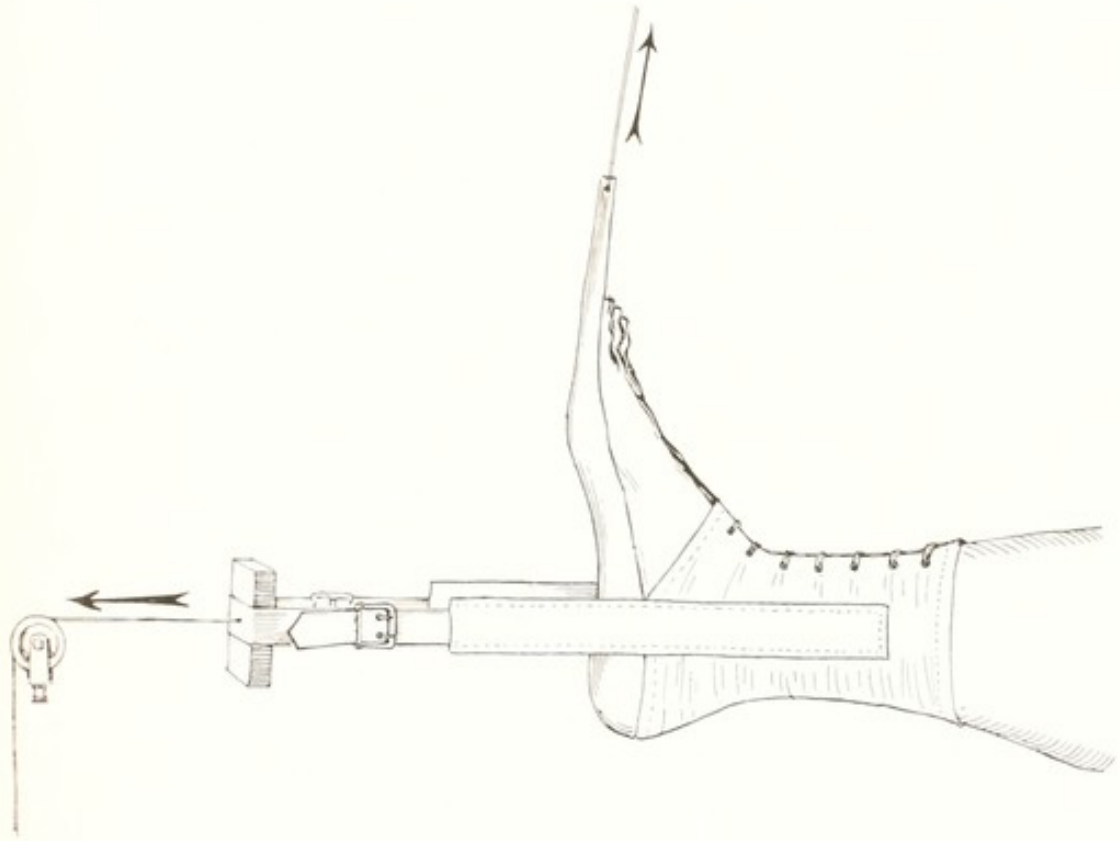


FIG. 306.—Method used with Balkan frame to prevent the development of toe drop by placing a mole skin traction strap on the plantar surface of the foot. (After Blake.)

angulation and deformity. This was due in every case to the screws coming out. Usually both screws came out from one fragment and the plate remained fixed to the other; but sometimes all the screws were out and the plate was loose among the muscles. Examination of the bone from these cases showed that the screw-holes became enlarged so that whereas the screws held tightly at the time they were inserted, later the same sized screw would drop loosely out of the hole." The screws quickly gave way from bone absorption around them. "A second undesirable feature of these series of experiments was the tendency to sepsis, with occasional extrusion of the plate. That it was not due to faulty technic, is shown by the fact that in other methods (no metal used) where the same procedure was observed, there was very little sepsis." This marked tendency to sepsis as compared with other methods, is due to the combination of the great irritation caused by free

movement of the displaced fragments, on account of loosened screws, with the presence of a foreign body. Groves believes that "many times the sepsis is the result and not the cause of the loosening of the screws," and it is evident from his series of experiments that the screws do rapidly become loose in all cases.

The presence of a metal plate, instead of stimulating osteogenesis, retards it. This is in strong contrast to the bone-graft, which not only produces bone itself but also stimulates the bone ends to more active osteogenesis. There is an immediate adhesion of the inlay graft to the gutter walls of the frag-

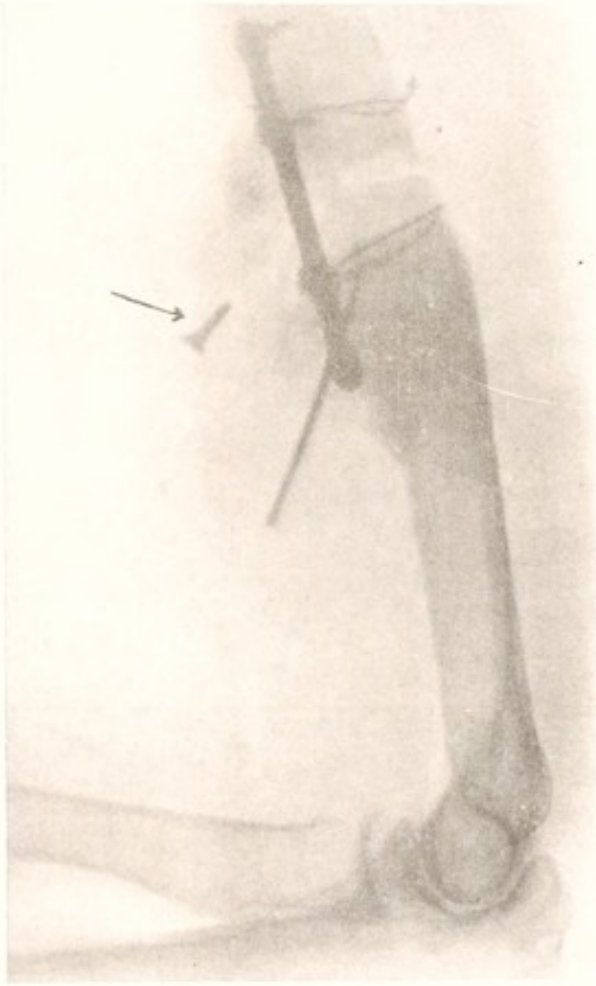


FIG. 307.—Non-union of humerus. Lane's plate, wire nails and silver wire here shown are contributing to the delay in union besides causing destruction of bone and inviting infection.

ments, and as time elapses this becomes a firmer and firmer bone union. Furthermore, the graft has certain bacteria-resisting properties.

It should, however, be emphasized that as a rule the author uses kangaroo tendon in fresh fractures, resorting to the inlay graft only when it is especially indicated, *e.g.*, where the mechanical features of the fracture demand the graft, such as loss of bone substance, extreme tendency to lateral displacement, evidences of sluggish osteogenesis in cases of delayed operation, etc. It is believed to be undesirable to produce such rigid fixation as is caused by the metal plate; the fragment ends should be held in apposition, but without interfering with end-to-end pressure and friction, and with the general alignment of the fragments maintained by coaptation splints or by traction in the position of neutral muscle-pull. It is believed that this type of

treatment furnishes ideal conditions for rapid solidification at the point of fracture.

Hitzrot enumerates the following indications for operative treatment:

"Fracture of the patella with separation of the fragments.

"Fracture of the olecranon, with separation of the fragments.

"Fracture of the head of the radius with displacement of the fragments, or where the fracture line involves the radio-ulnar joint.

"Fracture of the shaft of a long bone, in which the soft parts become interposed between the fractured ends of the bone.

"Fracture of the carpal and tarsal bones, with wide separation of the fragments (carpal scaphoid and the astragalus).



a *b*

FIG. 308.—Comminuted fracture of tibia and fibula. Non-union of tibia after application of a Lane plate. Note the eburnation of bone at the point indicated by the arrow. *b*, Same case after insertion of a bone graft obtained from the other tibia, with immediate union.

"Fracture dislocation, viz.: fracture of the surgical neck of the femur, with dislocation of the head.

"Fractures of the tuberosities and condyles of the various bones with rotation of the fractured process, for example, fracture of the external condyle of the humerus with rotation of the condyle, so that the fractured surface points outward or away from the line of fracture in the shaft.

"Furthermore, operation is indicated when there is hemorrhage due to the injury of a large vessel; when there are signs of compression of a nerve; when

the sharp point of a fragment is caught in the skin; and when infection has occurred in the region of the fracture."

Practically every type of fracture may need operation if reduction is not otherwise feasible. Necessity for open operations should be recognized within the first three weeks after the injury, and the operation should always



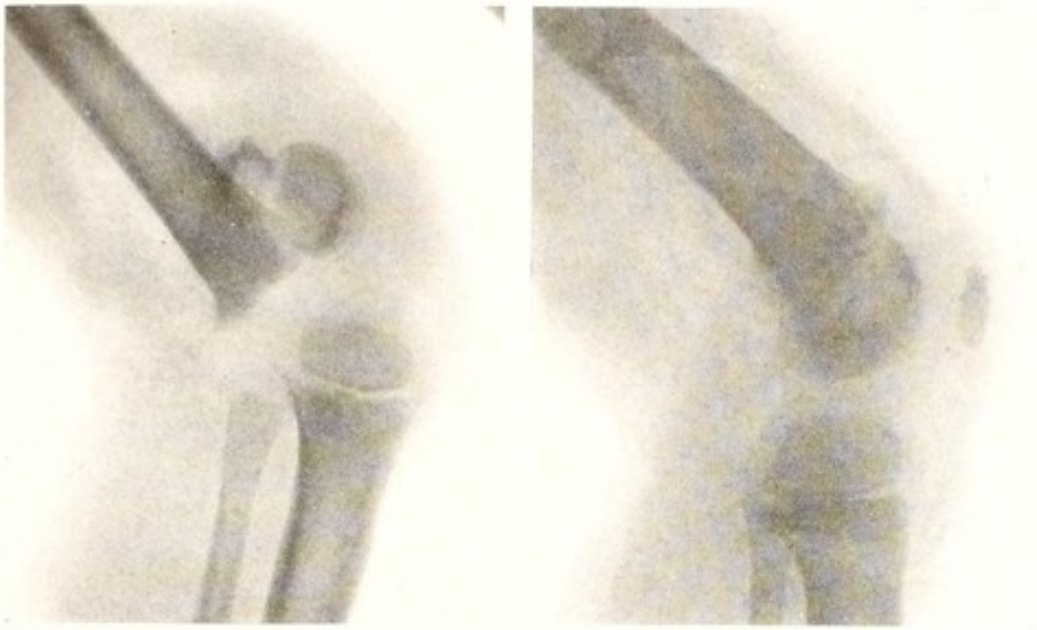
FIG. 309.—Malunited fracture of femur. The localization of the callus on the side of the femur opposite to the location of the Lane plates indicates that metal in contact with bone is an inhibitor of bone-growth. In this case, however, the location of the callus happens to be on the concave side of the fracture and this fact may explain the stimulation and contribution to bone-formation exhibited here.

This radiograph also illustrates the inefficiency of internal fixation agents of whatsoever kind in withstanding lateral stress which can only be maintained by an external fixation dressing applied in the position of neutral muscle-pull (in this case abduction). In this case, the Lane plates undoubtedly contributed to their self-destruction, in that they prevented union while at the same time, by their temporary fixation-effect, premature functioning was permitted, the result being that one of the plates broke while the screws were pulled out of the other.

be performed within the first four weeks, unless this is contra-indicated. The *x*-ray obviates any difficulty in determining this fact.

Those fractures which need operation the most frequently are those of the

femur, lower third of tibia, fractures involving joints (as fractures of the neck of the femur, lower end of humerus and femur) and fractures of the forearm.



a *b*

FIG. 310.—*a*. Fracture of the epiphysis of the lower end of the femur with dislocation forward and upward onto the femoral condyles.

b. Same case after the knee had been immobilized for a period of 7 weeks in the position of acute flexion which not only relaxed the gastrocnemius but also put the quadriceps tendon on the stretch, the latter acting as a living splint forcing the epiphysis into place.

In February, 1911, the council of the British Medical Association appointed a committee "to report on the ultimate results obtained in the treatment of simple fractures with and without operation" and the following conclusions were reached by the committee:

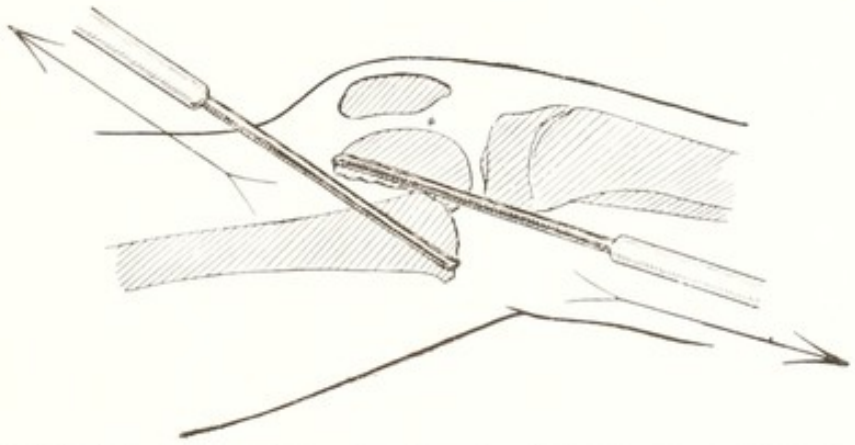


FIG. 311.—Separation of lower femoral epiphysis. Instruments and direction of forces used to secure reduction at open operation. (Scudder.)

"1. It is possible by either non-operative or operative treatment, to obtain a high percentage of good results in children. The results of non-operative treatment in children, with the exception of both bones of the forearm, are unlikely to be improved upon by any other method. Operative results expressed in percentage are approximately the same as the

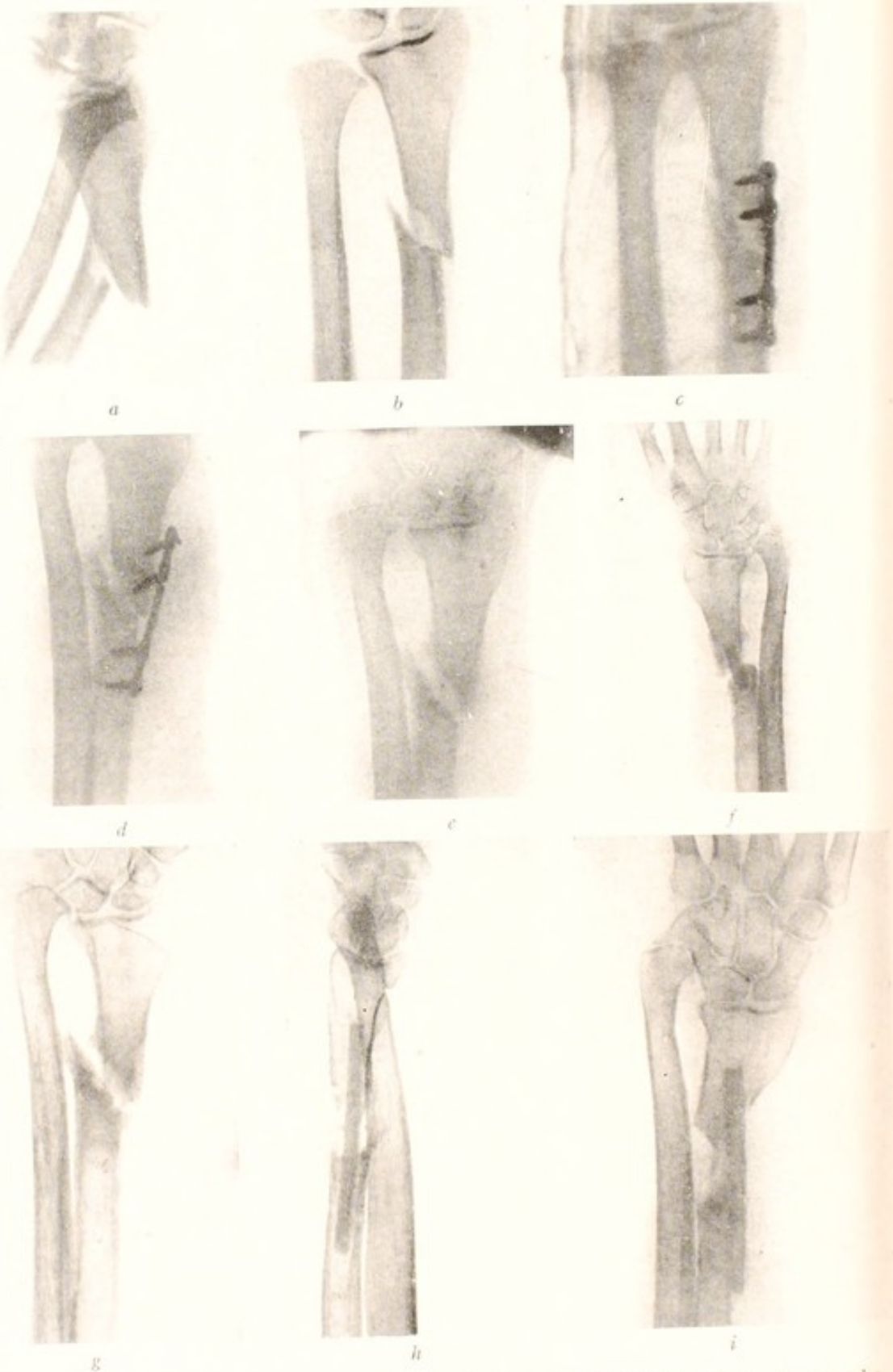


FIG. 312.—*a*, Fracture of forearm before reduction; *b*, after reduction; *c*, two weeks later after the application of a Lane's plate; *d*, two months later with no union and screws falling out and metal plate displaced; *e*, after removal of Lane's plate, non-union resulting. There was no suppuration in this and it is believed that the metal plate contributed to the non-union. *f*, Two months after the insertion of an intramedullary graft, resulting in failure to obtain union; *g*, non-union 6 months later with disappearance of intramedullary graft; *h* and *i* after the insertion by the author of an inlay tibial graft resulting in firm union. Note in (*h*) that as a result of previous operation precedures there was a loss of two-thirds of an inch of the radius.

non-operative; 1017 non-operative cases, 90.5 per cent. good functional results; 64 operative cases, 93.6 per cent. good functional results.

"2. In comparison with the results in children, the non-operative results in those past fifteen are not satisfactory, and from the analysis of the age groups it is clear that there is a progressive depreciation in the functional result as the age advances in those cases submitted to non-operative treatment, *i.e.*, the older the patient, the worse the result.

"3. Although the functional result may be good with an indifferent anatomic one, the most certain way to obtain a good functional result is to secure a good anatomic one. Of the operative methods, those which secure perfect reposition and absolute fixation of the fragments yield better results than methods which fall short of this, and imperfect fixation of the fragments by wire or other suture has been found unsatisfactory in fractures of the long bones (the olecranon excepted).

"4. In order to secure the most satisfactory results from operative treatment, it should be resorted to as soon as practicable. Operative treatment should not be regarded as a method to be employed when non-operative measures have failed, as the results of secondary operation compare very unfavorably with those of immediate operation.

"5. Operative treatment of fractures requires special skill and experience.

"6. A considerable portion of the failures is due to infection.

"7. The mortality due to operative treatment is so small that it cannot be urged as a sufficient reason against this method of treatment.

"8. In nearly all age groups, operative cases show a higher percentage of good results than non-operative cases."

The author has used the inlay graft in the treatment of more than 150 ununited fractures since 1911, and has secured most gratifying results. Many of the ununited fractures were of the most desperate character. One of the series had been operated upon 7 times, including intramedullary grafting. In 8 of the series, the intramedullary graft had been unsuccessfully employed: 2 had been operated upon unsuccessfully 4 times; 3 of the cases, 3 times; and 3 of the cases, twice. Nearly one-half of these cases were previously plated with Lane's plates.

In reference to these statistics, the author wishes to advance a further statement. A metal plate placed on a fracture seriously inhibits, as a rule, the formation of callus on that area of the fragments at the same time that osteogenesis may be active on the other areas of the fragments, and in a certain percentage of cases the inhibition of callus formation is sufficient to result in non-union, even though there may have been no infection. There are few surgeons who execute Lane's technic, therefore infection occurs in a varying percentage of cases and is a frequent cause of non-union. Apropos of this, Thomas has emphasized the unreliability of the Lane plate, as used by a number of operators, and cites statistics of 450 fracture cases gathered by him at the Cook County Hospital. It was found that it had been necessary to remove the Lane plates on account of suppuration or other causes, in 48 per cent. of the cases which had been plated.

When the author first began (1911) to employ the inlay bone-graft in the treatment of fractures and other bone conditions, hand tools were used. After doing about 50 of these operations and thoroughly realizing the inadequacy of all hand tools, he turned to the development of motor-driven tools and, in 1912, began to perfect the motor mill which he is now using so satisfactorily. It is almost like a cabinet-maker's or carpenter's mill. With it the surgeon can saw bone, drill it, turn it into nails (with attached lathe), or fashion it into any shape or form required, with accuracy and speed, so

that he can devote himself to the fixation, ligature work, and delicate tissue work that is necessary with a minimal expenditure of time and trauma. All the heavy laborious bone work is done by electrical power. The surgeon can also do many things with motor-driven tools which it would be impossible to do with hand tools.

The twin saws cut bone into inlays, or make grooves for the same, of exactly uniform width throughout, thus assuring a "cabinet-maker's fit," which in ununited fracture work is absolutely essential to success in many instances. In this respect, the callus may be compared to the glue of the cabinet-maker, and the graft to the accurately fitted wood of the glued furniture. It is essential that the wood be accurately fitted, otherwise the glue would not hold. This is a fair comparison in many respects, especially in cases of pseudarthrosis, where the callus is meager in amount because of sclerosis of the fragment ends. An accurate fit may mean success, and an inaccurate fit failure.

In cases of fresh fracture or in favorable cases of delayed union, the bone being normal, or nearly normal, the material can be taken from the fragments themselves and used as bone-grafts. This, as well as other similar inlay technic, would be difficult without the use of the motor instruments. The motor-saw has opened up a field of osteoplasty and of application of the bone-graft in various forms which it had been impossible to develop heretofore.

In place of wire, the author always uses kangaroo tendon. During the last five years, he has not used metal for any internal fixation purpose. Metal has a destructive influence upon bone, and frequently adds an inhibitory effect which may be sufficient to prevent the bone from uniting, as osteoporosis or necrosis usually develops around the metal screws or nails, causing them to become loose and to drop out in a very short time. Furthermore, metal favors infection, absorption, and disintegration of tissue.

LANE'S PLATES A CONTRIBUTORY CAUSE OF NON-UNION

The chief reasons why Lane's plates exercise a deleterious effect on fractures, delaying and often preventing their union, are as follows:

1. They prevent end-to-end stress of the fragments and also produce a too perfect fixation of these fragments (whether with or without distraction). The former defect prevents the operation of Roux's law of frictional irritation, so essential to the stimulation of bone growth.

2. They not only inhibit bone growth, but cause actual destruction of bone. These untoward effects of the plates are enhanced by traumatization of soft parts and bone and destruction of the normal blood supply of the fragment ends incidental to their application, with consequent cicatricial formation.

(The factors above enumerated are *always* present in the use of Lane's plates; the following are present in a considerable percentage of cases and are due either to faulty technic, some surgical accident, or to a false conception of the usage of metal plates.)

3. Infection.—Contact of metal with the tissues lowers their resistance, and the erosion of bone produced by the metal screws leaves interstices between their threads and the bone (in some cases even large holes), the result being the production of a locus minoris resistentiæ.

A further contributory cause of infection is the faulty manner of placing the skin incision, so that when it is closed its line of sutures lies directly over the metal plate. The effect of this is that the postoperative reaction of the

tissues causes an exudate to form about the metal and, by distention, it is forced out through the wound or suture holes, and the sinus thus established offers the best possible avenue of entrance for infection in the weeks following operation. The slightest amount of infection at any point about the plate or screws is certain to invade the entire portion of bone lying in contact with any part of the plate. On the other hand, if the incision is so placed that a semicircular skin-and-subcutaneous flap is turned up, and the line of sutures on closure of the wound is located at some distance from the plate, this accident is not so likely to occur.



FIG. 313.—Microphotograph of a section taken from the end of a fragment of an ununited fracture to demonstrate the microscopical appearance of bone which has undergone sclerotic changes. The bone is partially necrotic as manifested by the few and poorly stained nuclei. The attempt at regeneration is slight and abortive, there being few active osteoblasts.

This fate of the Lane plate is in marked contrast to the immediate primary union of the bone-graft with the structures in which it is embedded. An infection occurring at one end of a bone-graft may, and frequently does, remain entirely localized. The author has observed this several times in animal experimentation and in human beings; mild infection, causing one end of the graft to become bare, has yet remained entirely localized, granulations covering the rest of the graft which remained intact and viable.

4. Faulty Technic.—In applying the metal plate, too great distraction is often made, with the result that a hiatus is frequently established between

the fragments. The screws are set with this hiatus still maintained, the fragments are prevented from coming in contact, and Wolff's law of adaptability and Roux's law of frictional irritation both become inoperative, and frequently malunion or non-union results.

In ununited fractures it is very important that the graft be long enough to have ample contact with active bone beyond the sclerosed or eburnated area. Through the influence of Wolff's law, a tibia whose diameter has been lessened by obtaining a bone-graft from it will return to its normal size and strength in about two to three months; at the same time, the graft likewise will proliferate and become of a size and strength commensurate with the mechanical requirements of its new environment. In other words, it is a physiological hypertrophy.

In every case of non-union which has existed for any length of time, from any cause whatsoever, whether from soft tissue between the fragments, local infection, systemic disease, idiosyncrasy in lack of osteogenesis, or from any inhibitory influence to bone growth from a Lane plate or other metal appliance, there is always a distinct pathological change in the fragment ends, consisting of diminution and degeneration of bone-cells and a coincident increase of calcium salts, or, in other words, sclerosis (see Fig. 313). This eburnated area may extend as much as 1½ inches into each fragment and osteogenesis is greatly impaired, so much so that bone fragments ideally contacted and perfectly immobilized by external splints or internal metal devices do not unite (see Fig. 307). In other words, it is clear that the surgical problem which presents itself is not the securing of better fixation and a more close approximation of the fragment ends by bone removal and freshening, but the furnishing of an efficient internal splint and at the same time supplying a bone-growing and osteoconductive element which spans these sclerosed areas and is closely and favorably contacted with the healthy vascular osteogenetic bone, especially with the marrow, in each fragment beyond the eburnated area and distal to the point of fracture. The inlay bone-graft fulfills these requirements and even more, in that it acts as a strong stimulus to osteogenesis on the part of the host fragments themselves.

In many cases where there had been non-union and even loss of bone, following severe comminution or osteomyelitis with death of the complete diameter of the ends of the fragments, or after Lane plating, amputation or marked shortening was avoided by spanning these areas with long inlays.

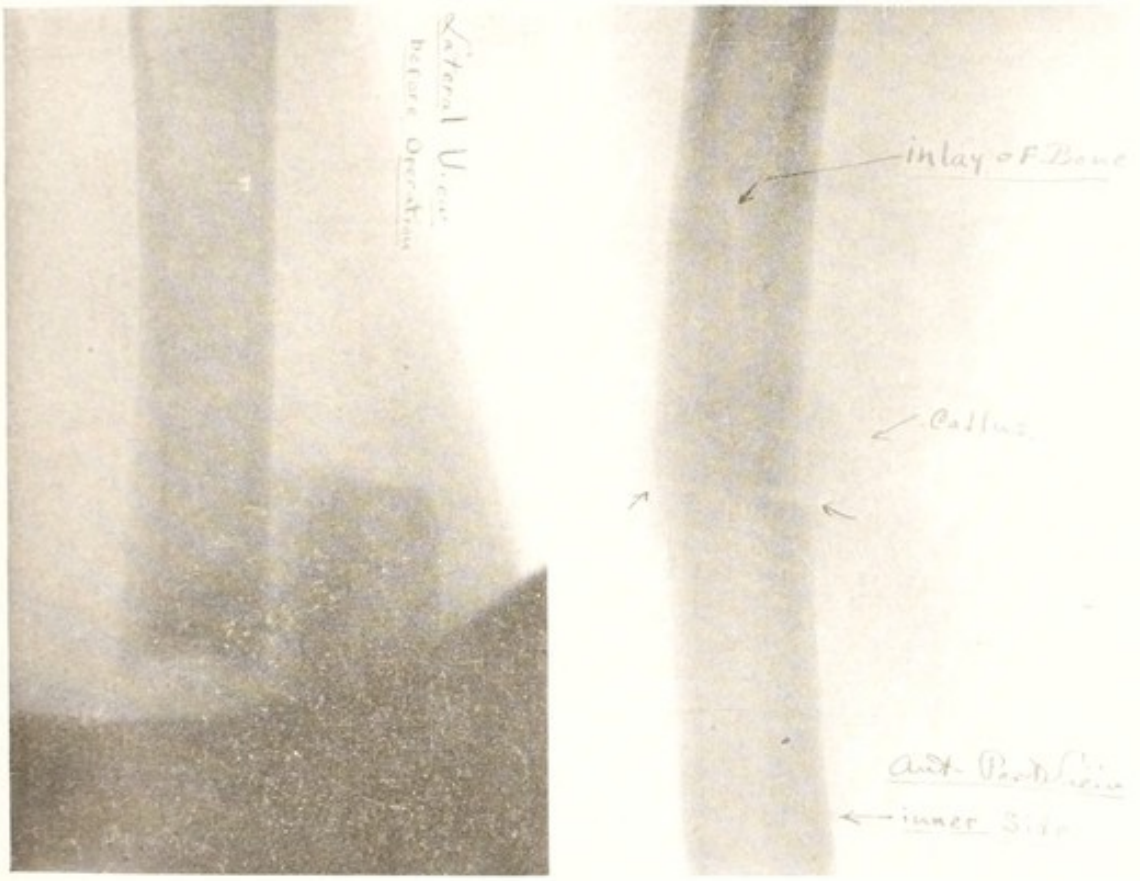
TECHNIC OF AUTHOR'S INLAY BONE-GRAFT OPERATION FOR UNUNITED AND MALUNITED FRACTURES

Preparation of Patient.—The general preparation is not different from that required for any major surgical procedure. The local preparation should be generous in its extent and by the iodin method, which should be carried out both on the night before and on the day of the operation in the most thorough manner.

The night before operation, the part is dry-shaved, scrubbed with benzin (undiluted), dried and painted with tincture of iodin (3½ per cent.), and covered with a sterile towel. At the time of operation, the application of a coat of 3½ per cent. tincture of iodin is the only preparation used; if it is feared that the skin is so delicate as to become blistered, it is advisable to wash off some of the iodin with alcohol at the end of the operation.

In all fractures of the lower extremity, an efficient traction apparatus of some type should always be available at the time of operation. The traction can be applied to the limb in any degree of abduction or flexion, which is

frequently a great advantage, especially in fractures of the upper third of the femur. The position of neutral muscle-pull should be made the most of in any fracture where certain muscles are exerting a strong displacing force. In other words, the reduction should be accomplished and the plaster-of-Paris fixation dressing should be applied without the position of the limb being changed or the traction released at all. This dictum applies in any case, whether operative or non-operative methods have been employed, also irrespective of the type of the internal fixation agent if one has been used. No internal fixation appliance will, for any length of time, withstand the pull of strong muscles at cross angles to the fractured part,



a *b*

FIG. 314.—*a*, Fracture of shaft of femur with overriding of fragments and total absence of new bone-growth, two months after injury.

b, Same case six weeks after reposition of the fragments and insertion of a tibial bone-graft. There is evidence of abundant bone-growth about the inlay and between the fragments as indicated by the arrows.

as screws will pull out and wire will completely cut through the bone if union has not taken place.

Armamentarium Required for Inlay Graft Operation.—(1) Fracture table. (2) Two Lambotte clamps. (3) Lowman clamp. (4) Albee electric bone-jack. (5) Albee electric operating bone set with twin rotary saws, burrs, drills, dowelling attachment, etc. (6) Periosteum elevator. (7) Lane's bone spatula. (8) Osteotomes and mallets. (9) Lion-jaw forceps.

Author's Technic of Inlay Graft Operation for Fractures (Fig. 315).—(Where Loss of Bone Exists see Chapter XVI, p. 544 and Chapter XXX.) If traction is required, the patient is placed on a traction table. The perineal countertraction post and patient are properly adjusted. The foot or

hand is bandaged to the extremity traction plate (Fig. 291). A generous skin incision is made overlying the point of fracture, and when possible should be made to the side of the intended site of the transplant. The fascia and muscles overlying the point of fracture and the fragment ends are opened by scalpel and blunt dissection, and the region of the fracture is well exposed.

If the fracture is an ununited one, and the fragments are in good apposition, merely a part of the fibrous union is removed with a thin sharp osteotome. In executing the inlay technic, the periosseous structures are disturbed as little as possible, and the relationship of the fragment ends is left undisturbed. This is important in minimizing the amount of local trauma. In this connection, it is desirable to emphasize the pronounced inhibitory influence of severe trauma on cellular proliferation, and especially on osteo-

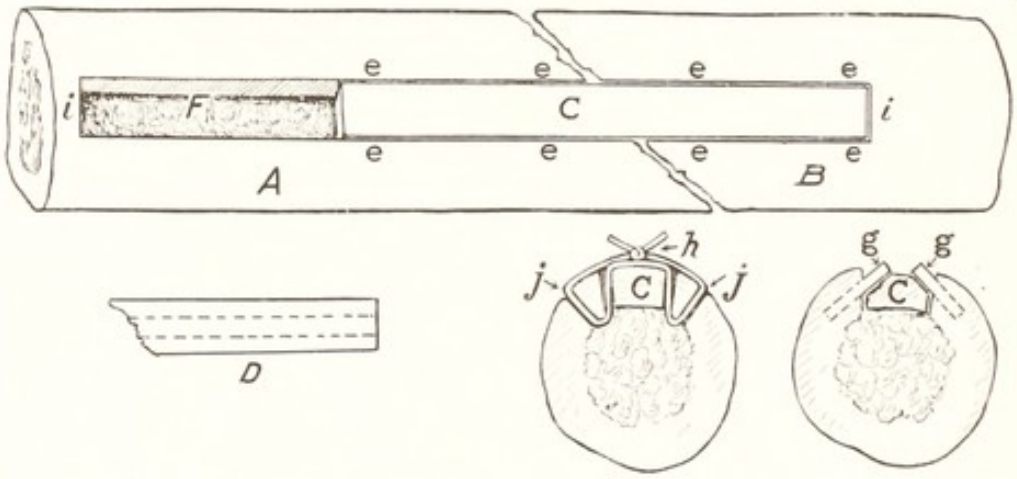


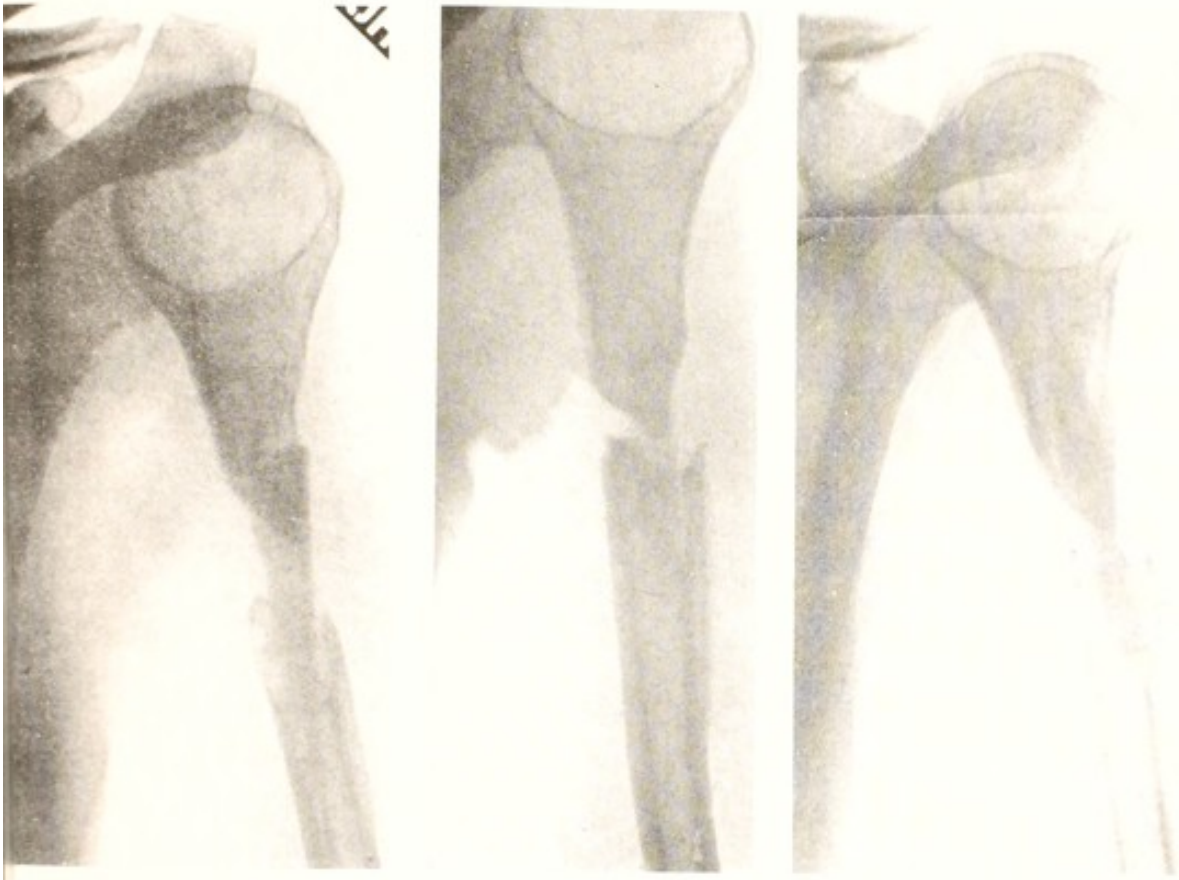
FIG. 315.—Bone-graft inlay method for treating fresh and ununited fractures. (*A*) Proximal fragment. (*B*) Distal fragment. (*C*) Graft sawed from proximal fragment and slid half across point of fracture. The inlay should always be inserted when possible on the side of an oblique fracture as indicated in this drawing. Overriding of fragments and shortening of the limb are then prevented by virtue of the mechanical property of the inlay. (*D*) Portion of bone removed from distal fragment by motor twin saw in forming gutter for graft *C*. Dotted lines represent division of this fragment for making dowel-pegs to be inserted at *gg* at the point *e*. (*e*) Indicates location of drill holes for reception of dowel-pegs to hold graft in position. These holes are made with a motor drill which is the counterpart in size to the dowel cutter used in making the pegs. Therefore the fit must be accurate. (*F*) Gap remaining in shaft following the sliding distally of graft *C*. (*i*) Cuts at end of gutter made by small motor saw in freeing the bone from the gutter. (*j*) The converging drill holes at the side of the gutter showing kangaroo tendon passed through and tied in position securing graft *C*, that is, if tendon is chosen as the fixation agent. Since the author has been able to obtain heavy kangaroo tendon sutures he has used them almost exclusively instead of the bone-graft dowel-pegs for fixation of the inlay graft.

genesis. In no line of work is there greater danger of devitalizing trauma than in bone work, and this applies not only to the bone itself but to the surrounding soft tissues. A resulting infection of any of the involved tissue may interfere with a successful result.

Traumata may be caused by the retraction of powerful muscles and their soft tissues, especially where too short an incision has been employed in the operative treatment of a fracture, from bone elevators or levers, bone clamps, the macerating and jarring effects of dull and blunt chisels, and from drying of the tissues; to prevent the latter, saline compresses should be freely used. The importance of making the skin incision of sufficient length in all operative fracture work should be kept constantly in mind.

The periosteum is incised longitudinally and peeled back on either side in the form of a flap, exposing the bone which is to be removed for the

purpose of forming a gutter in the fragment or fragments, as the case may be. If the inlay graft is to be obtained from the proximal fragment, the periosteum on this fragment is not disturbed, because it is always desirable that the graft include periosteum, as well as endosteum and marrow substance. In fresh fractures the graft material can practically always be taken from the fragments themselves, as the osteogenetic function of this bone has not been impaired. In most of our later cases of non-union, the graft material has also been taken from the fragments, with uniform success. In such cases, however, the inlay fragment should always, when possible, be obtained from the upper fragment and slid downward into the distal fragment. This is important on



a *b* *c*

FIG. 316.—These *x*-rays are illustrative of the untrustworthiness of the intramedullary graft. In *a* a long graft is shown extending into the narrow cavity of the distal fragment for about 2 inches about 5 weeks after its insertion. In *b* and *c* progressive loosening of this graft is shown resulting in failure notwithstanding the fact that primary union followed the operation and there was no infection at any time. Two such operations were done in this and both resulted in failure. An inlay graft was then inserted by the author and resulted in immediate union. (See Fig. 317.)

account of the large amount of rarefaction which is always present in the distal fragment of a pseudarthrosis of long standing, and the relatively smaller amount of osteoporosis in the proximal fragment.

The author's inlay technic varies somewhat according to the individual cases and requirements. The strength of the graft can be made to vary within wide limits. Its thickness will vary according to whether it is obtained from the upper or the lower portion of the antero-internal aspect of the tibia. Unless there is some reason to the contrary, it is better, as a rule, to obtain the graft from the lower part where the bone cortex is thicker, stronger, and osteogenetically more active. The crest of the tibia at its

lower third furnishes the strongest graft on account of its increased thickness of cortex and the fact that two cortical tables meet here.

In small bones, such as those of the forearm, the inlay is best held in place by kangaroo tendon, either placed in drill holes to the side of the groove or wrapped completely about the bone ends. In fresh fractures of large bones, such as the femur, where the marrow cavity has not become filled with new-formed bone and there is nothing to prevent the inlay from slipping into the marrow cavity, the graft and gutter beds are made wider at their periphery than at their marrow side.

The fragment ends are freed and strong traction is applied by means of the traction screw on the fracture table. Lambotte clamps or the Albee jack are placed on each fragment, and the bone is manipulated into apposition



FIG. 317.—Same case as Fig. 316. *X*-ray taken 3 months after author inserted a tibial graft 6 inches long by a cabinet-maker technic shown in Figs. 318 and 320. Solid union is shown with graft amalgamating itself into the cortex of the humeral fragments.

and adjusted so that the ends fit together perfectly. Loose fragments are replaced in their proper positions, or are removed, as seems best. When the ends are in apposition, they are held so either by strong traction or by the use of a Lowman clamp placed on the fragments, or, if the motor has been used with the Albee jack, the latter not only adjusts the fragments but also holds them securely in their proper position and alignment. If the fragment ends cannot be brought into perfect apposition, it is not of serious moment when the inlay graft is used. It is not necessary to shorten the limb in order to get satisfactory apposition, as it would be if metal fixation plates were being used. The graft can safely be allowed to span a hiatus of any length.

The graft to be employed is usually removed from the fractured bone, generally the proximal fragment, and then slid into a groove one-half its

length, which has been prepared for it in the distal fragment. In a femur, the sliding inlay should be about 5 to 6 inches long.

In ununited fractures of large bones, where the marrow cavity is filled with a bone-plug which prevents the inlay from slipping into the medullary canal, and in all the smaller bones, and in all individual cases where the mechanics are favorable, the twin motor-saw alone is used in removing the inlay graft and preparing its gutter bed. In fractures of long bones where the difficulty of fixation is great, the inlay is held in place by bone-graft pegs or heavy kangaroo tendon, or both, as seems best, but usually by kangaroo

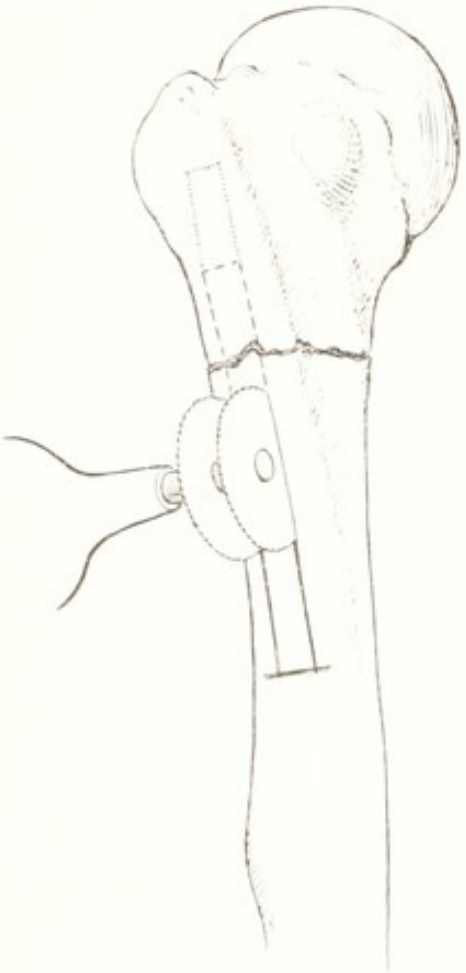


FIG. 318.

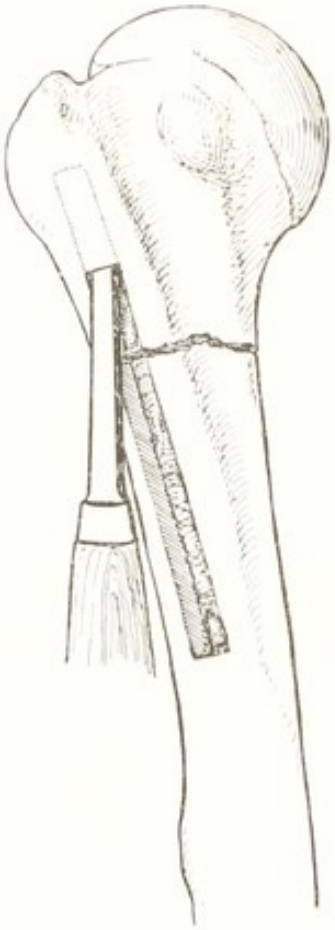


FIG. 319.

FIG. 318.—Preparing gutter for inlay tibial graft in a fracture at the surgical neck of the humerus.

FIG. 319.—Strips of bone are removed, forming a cortical gutter in lower fragment and lower part of upper fragment. A tunnel under the projecting humeral head is being prepared so as to lengthen gutter and get a longer contact of graft to upper fragment.

tendon alone. The fragments are motor-drilled on each side of the gutter and the tendon is placed as indicated by the diagram (Fig. 315). When the graft and its gutter bed are formed wholly by the twin saws, the graft is slightly narrower than its bed (exactly twice the thickness of the saw-cut), which allows space for heavy kangaroo tendon to be placed between the graft and gutter wall on each side.

In the case of small bones, such as the radius or ulna, the method of inserting the fragments with the tendon is very effective in holding the insert firmly in place. In severe comminuted fractures from gunshot or other causes, where there is a space to be spanned and the length of the limb is to be

maintained by the inlay, it is best to make the graft larger at its middle with shoulders at the ends of the fracture fragments or to tongue-and-groove the ends of the graft and bone cortex of gutter ends. The grooves should be in the extremities of the fragments, and the tongues on both ends of the graft. Any tendency to shortening of the limb by muscular pull, etc., causes the tongue and groove joints to become all the more firmly locked, and is thus a sure preventive of shortening. The graft, however small, will in time hypertrophy under the action of Wolff's law, and will assume the size and strength of the bone whose substance it is supplying. The value of the graft in this type of cases cannot be overestimated.

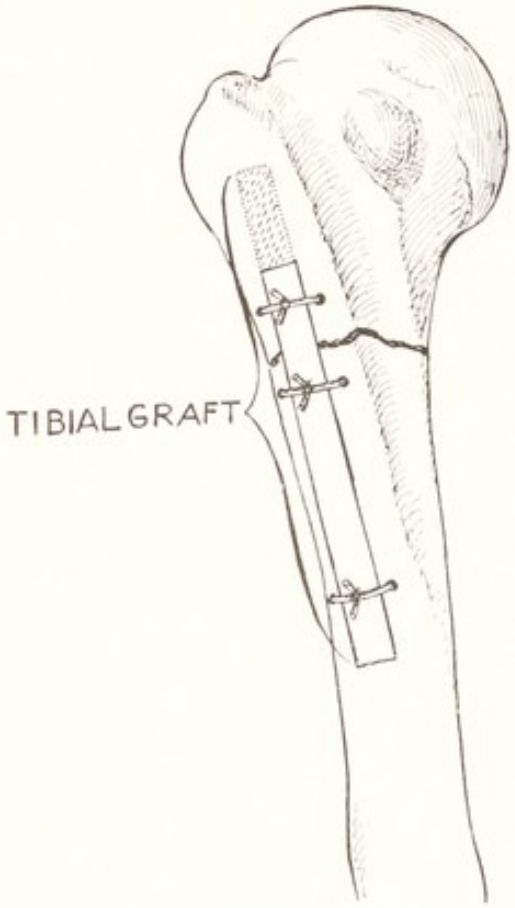


FIG. 320.—Inlay graft fixed in place with kangaroo tendon.

An important point in the technic of bone-grafting in its application to all types of fractures is that the transplant should be of *sufficient length*. In the case of the intramedullary graft, this might afford a great deal of difficulty, but with the inlay graft it is accomplished with ease. A graft 6 inches long can be inlaid as easily as one 2 inches in length. Several unsuccessful results have come to the attention of the author, in which he is sure that the contributing causes of failure were the shortness of the graft, the employment of the intramedullary method, and the fact that the graft did not extend sufficiently beyond the sclerotic fragment ends to offer adequate and exact contact with vascular osteogenetic bone. In one of these cases the inlay graft had been used, but the technic had been most defective and the unsuccessful result was not surprising. The case was a long standing ununited fracture with marked sclerosis of bone extending into each fragment for about 1½ inches, as was shown by the *x*-ray. The graft insert was only about 2 inches long and did not even extend through the eburnated bone. The graft should have been not less than 5 inches long, thus extending well into the vascular osteogenetic bone of both fragments, beyond the sclerotic area. This is an important technical point, and cannot be too strongly emphasized.

In pseudarthrosis, the inlay graft may vary from 4 to 6 inches in length, never less than 4, according to the size of the bone fracture, the extent of osteogenetic impairment, or the amount of comminution. If the comminution is extensive or if the fracture is of long standing, resulting in an unusual amount of osteoporosis in the fragment ends, it is preferable to obtain a transplant from the sound tibia, in which case the graft bed should be prepared first and packed with a saline compress, in order to secure a sufficient hemostasis. Two parallel saw-cuts are made lengthwise in the fragment ends, extending through the complete thickness of the cortex and into the marrow cavity. The distance between the motor twin saws is readily adjusted, according to the diameter of the bone and the point of

fracture, and the smallest diameter at which the saw-cuts are to be made. The graft is then removed from the tibia, either from the crest or from the antero-internal surface, according to the strength required, with the twin saws adjusted as they were in making the gutter. In this way, an accurate fit is assured.

In small bones, such as the ulna, where it is desired to have the graft as small as possible as well as to make a snug fit, the twin saws may be moved slightly further apart when removing the graft from the tibia, thus making the graft very slightly larger than the gutter which is to receive it. The cuts should extend 2 to 3 inches into the end of each fragment, if the transplant is to be obtained elsewhere, as, for instance, from the tibia and they

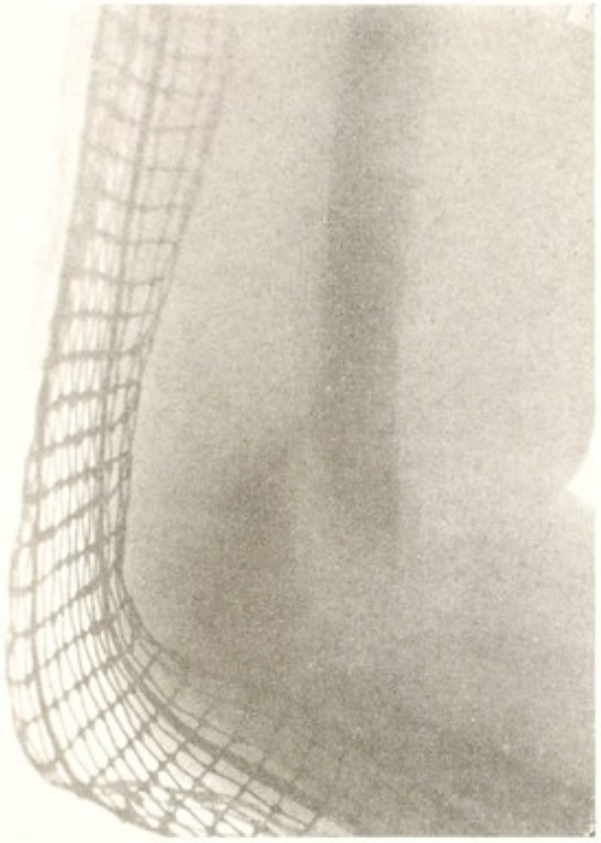


FIG. 321.—Before treatment. Shows distal fragment displaced posteriorly with distal end of proximal fragment well forward.

should always extend far enough to reach well into active osteogenetic bone of each fragment. While the saws are in the act of cutting, they are constantly sprayed with saline solution, supplied by squeezing a saline compress over the saw or by the drip of the author's saline syringe.

The ends of the graft, as well as the strips of bone which, when removed, produced the gutter graft beds, are cut for the purpose of removal with a circular saw so small that it does not encroach upon the walls of the gutter at the sides.

If the graft is to be obtained from one of the fragments, the twin saw-cuts are made twice as long into that fragment as into the other (recipient) fragment. The strip of bone thus obtained is slid endwise into the gutter in the recipient fragment. The fragments are fixed by holding the inlay in place by heavy kangaroo tendon or by bone-graft pegs, as the circumstances indicate. The kangaroo tendon is passed through holes drilled by the motor

in the cortex on each side of the gutter. The tendon, two strands in each fragment, is threaded through from one side of the gutter to the other and is then pulled up from the gutter in the form of loops under which the inlay graft is inserted and forced into place, and then the kangaroo tendon ligatures are tied over it. The bone removed in the form of bone-dust by the twin saws causes the graft to be just enough smaller than the gutter to allow room for the kangaroo tendon.

Numerous small fragments of bone are inserted between the ends of the fragments and about the graft just before closing the wound. These fragments should be of active osteogenetic bone, and are best made by rongeur forceps. Macewen was the first to point out that the smaller the bone-graft fragments the greater their *relative* osteogenesis; in other words

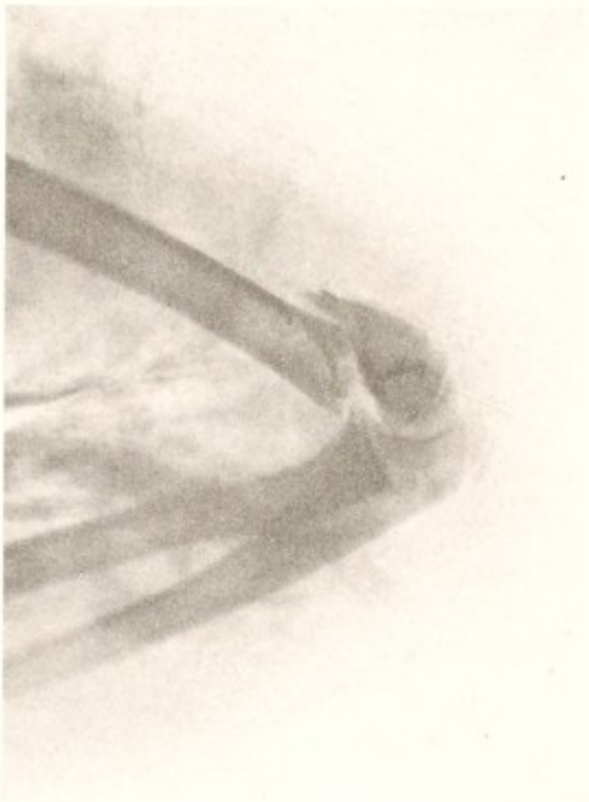


FIG. 322.—After treatment. Same as Fig. 321. Shows the mechanical effect of acute flexion in case of a supracondylar fracture near elbow-joint.

the sum of the surfaces of the comminuted grafts is greater than that of the piece of bone from which they were obtained. This has been repeatedly verified by the author from both surgical and experimental experience.

Slivers of cortical bone (each about $1\frac{1}{2}$ to 2 inches long) preferably consisting of all the bone layers, may also be placed between the periosteum and the fragments at the point of fracture and parallel with the shaft of the bone. If the graft is being removed from a healthy tibia, these are removed from the sides of the gutter wall. If the graft is a sliding graft, they are obtained by splitting up the short piece of bone removed from the lower fragment, provided the bone is not too sclerotic, in which event they can be obtained from the gutter wall at the upper end of the proximal fragment. If it is not desired to use this short piece of bone from the lower fragment, it is inserted to fill up the space left by sliding the long graft from above.

By this technic, foreign bodies are entirely avoided. The material used

is either autogenous bone, or absorbable material. The fit of the inlay and the pegs *must* be accurate, by virtue of the motor cutting tools employed.

This technic also allows ideal coaptation of the graft to its bed; that is, every graft should comprise four different tissues, namely, periosteum, compact bone, endosteum, and marrow substance; and this is the only technic which permits the coaptation of each of these individual elements to those of the recipient bone. In several cases where there had been non-union and loss of bone following severe comminution, or osteomyelitis with death of the complete diameter of the ends of the fragments after Lane plating, amputation or marked shortening was avoided by spanning the areas with long inlays. In one case, where $2\frac{1}{2}$ inches of the tibia had been destroyed by osteomyelitis, the graft was placed so as to span the granulating cavity and, although it was impossible to cover the graft at the affected point on account of a large sinus in the skin, nevertheless granulation slowly covered up the graft, none of which sequestrated, and a perfect result was obtained.

The author, however, does not wish to go on record as recommending implantation of a bone-graft in any region where there is a sinus or other evidence of infection, although the foregoing case proves that the graft can be implanted with success in cases where the infection is *attenuated*. On the other hand, in the case of gunshot fractures at the battle front, in which bits of clothing or other foreign bodies are likely to be present in the wound, such operations should never be attempted for at least two months after complete healing of the soft parts has occurred. (For further details of gunshot fractures, see Chapter XXX on War Surgery.)

Technic for Inlay Graft with Wedge Cross-section.—The following technic, involving the use of dowel pegs, is here described, although in practically every instance the author uses kangaroo tendon ligatures instead of the pegs, whether the graft is of wedge-shaped contour or right-angled and fashioned with a twin saw.

The removal of both long and short grafts is started by making parallel cuts, $\frac{1}{32}$ to $\frac{1}{16}$ of an inch deep, with the twin saws adjusted at a suitable distance apart, depending upon the size of graft and gutter to be formed. The purpose is to outline a graft of uniform width throughout its whole extent. These parallel saw-cuts are then continued through the cortex to the medullary cavity, with the single motor-saw held at such an angle as to cause the cuts to converge in approaching the medullary cavity in order to prevent the graft when pressed tightly into position from slipping into the medullary cavity. The ends of the graft are freed with transverse cuts made either with a very small motor-saw or a narrow osteotome. The thickness of the saw-blade makes sufficient difference in the size of the graft and gutter to allow the inlay when slid into position to sink slightly below the borders of the gutter, thus furnishing a margin of the gutter sides above the graft into which holes are drilled obliquely to receive the autogenous dowel pegs, if it is decided that these are to be used to hold the graft in place.

The inlay, which has a wedge-shaped cross-section, is pressed tightly into position and held there firmly by a Lowman or other bone clamp while the holes are drilled and the dowel pegs inserted. It may be necessary or wise to allow the graft to sink a fraction of its diameter below the edge of the bed. The pegs are obtained by splitting the short segment (removed from the distal fragment for the groove for the inlay) into two or three fragments, and pushing them through the author's motor lathe or dowelling instrument. Each of these dowels, which is long enough to make two or three fixation pegs, is driven lightly into the holes over the inlay, and while

an assistant holds its distal end with the forceps, the surgeon cuts off the peg with the small motor-saw at the desired place. The remaining portion of the dowel is then used in like manner for additional pegs.

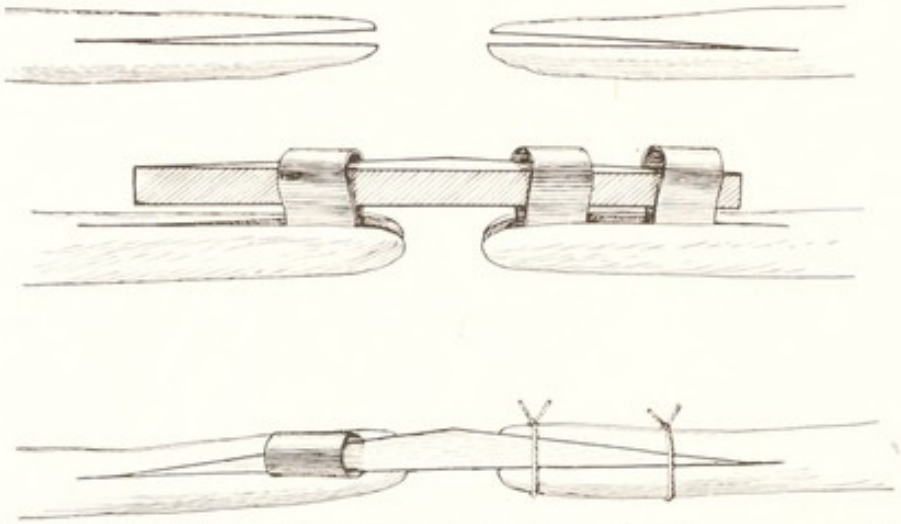


FIG. 323.—Author's "fish-pole" technic of inserting a double wedge-ended inlay graft into a small bone where there is loss of bone substance and the fragment ends have become conical. In such cases the bone back from the ends is osteoporotic and flexible thus allowing a graft of a thicker dimension to be forced into place by the thin metal skids shown.

Eight of the author's series of ununited fractures had previously been unsuccessfully operated upon by the intramedullary technic. These failures are largely explained by the fact that this technic affords a faulty histologic

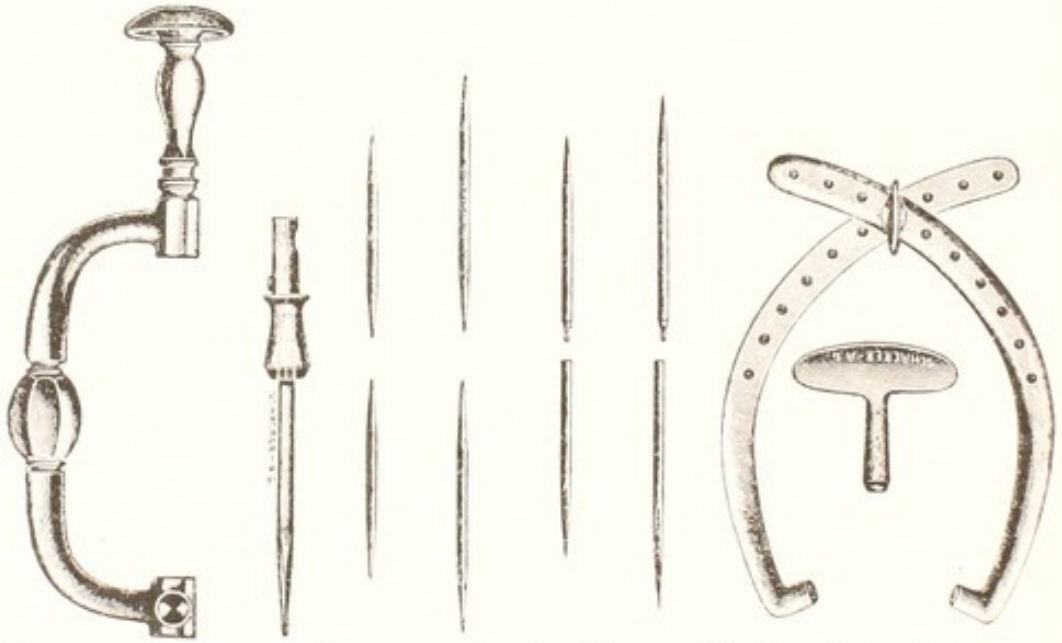


FIG. 324.—Steinmann's instruments for the direct application of extension apparatus to bones. A puncture is made down to the bone, a hole drilled completely through it from side to side and a skewer introduced through the hole and made to protrude through a puncture in the skin on the opposite side. After dressings have been applied to the punctures, Steinmann's coupling apparatus is adjusted as shown in Fig. 325.

contact of graft to host fragments, even when well executed, and violates the fundamental laws of tissue transplantation, *i.e.;* the coaptation of like tissues and layers of the graft and host bone.

Two important advantages of the inlay technic as applied to ununited fractures are: First, the ease with which sufficient contact with osteogenetic bone beyond the sclerosed area can be secured; second, the readiness with which this contact can be varied in accordance with the difficulties encountered. The more desperate the case and the more frequently it has been unsuccessfully operated upon, the longer must be the inlay transplant. One of the author's series, an ununited fracture of the radius and



FIG. 325.

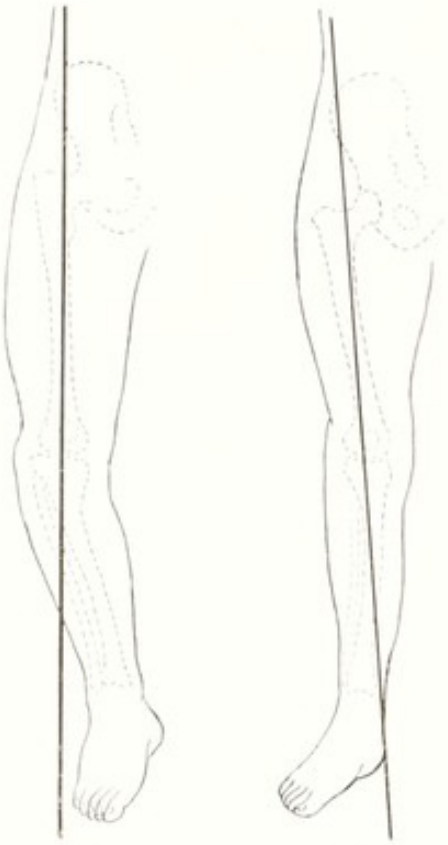


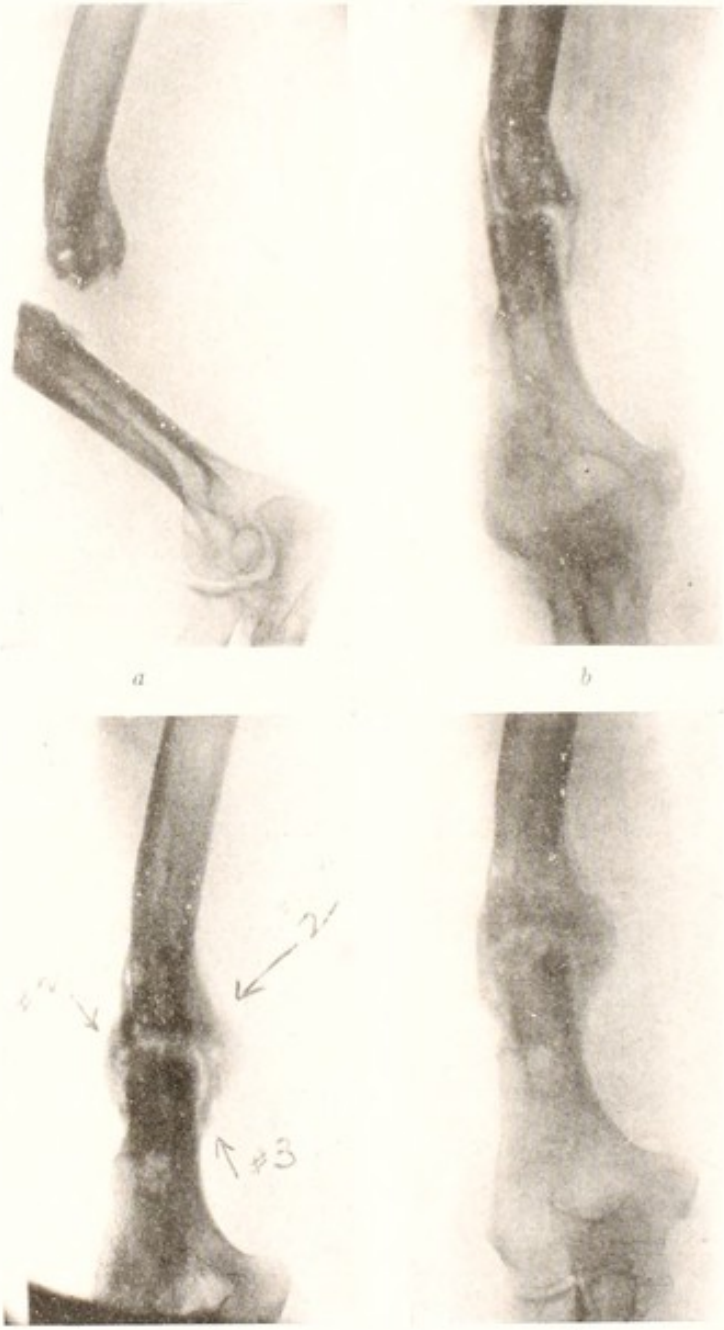
FIG. 326.

FIG. 325.—Steinmann's pins applied to lower end of femur, with weight attachment. Although the author does not approve of this method as a rule, nevertheless in certain difficult cases encountered in industrial as well as in military surgery, its use is often justified. Inasmuch as the application of these pins requires rigid surgical technic, and since the indication for surgical intervention is urgent, the author believes it to be a more trustworthy and reliable procedure to undertake an open operation directly at the seat of the fracture. Cases of infection have occasionally been seen following the use of Steinmann's method, hence it is not entirely devoid of danger.

FIG. 326.—Illustrating the displacement of the foot which occurs in the event of faulty alignment of fracture of the tibia. With reference to a weight-bearing line passing downward through the anterior superior spine and the center of the patella; *a*, in *outward* bowing of the tibia, the *external* malleolus lies *inside* the line; *b*, in *inward* bowing of the tibia, the *internal* malleolus lies *outside* this line. (After Jones.)

ulna, had been operated upon unsuccessfully 7 times, including the use of Lane's plates, silver wire, nails, and intramedullary grafts, and it was then pronounced impossible to secure union (Figs. 329 and 330). The inlay grafts employed were very long, extending to the tips of the styloid processes and well beyond the eburnated area in the upper fragments. In five weeks, there was firm union. The *x*-ray showed that throughout its extent there was firm union of graft to that portion of the distal fragment beyond the eburnated area. There was, however, no union between the fragments themselves or between the eburnated area in the ends of the fragments

and the graft. The result would undoubtedly have been a failure had the graft inlays been short and had they not extended well beyond the areas



a *b*

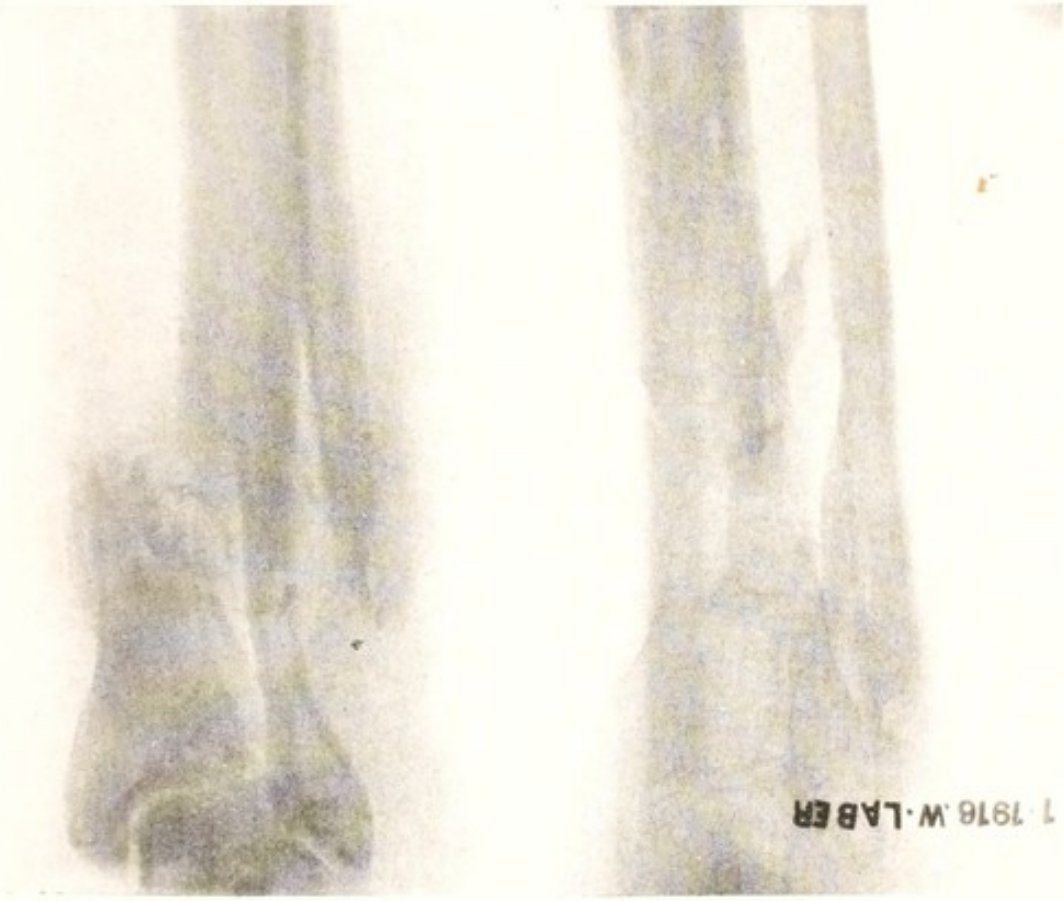
c *d*

FIG. 327.—*a*, Ununited fracture of the humerus at the junction of the middle and lower thirds, with loss of bone substance. Fracture of three months' duration. On account of the unfavorable nature of the case, a tibial bone-graft was recommended; the patient, however, refused to allow the graft to be removed from the tibia, and hence it was necessary to employ the author's sliding graft. *b*, Six weeks after operation at which a sliding inlay graft 3 inches long was dragged down from the upper into the lower fragment. Slivers of bone were obtained from the upper end of the groove and placed subperiosteally with one half in contact with the upper and one half in contact with the lower fragment. These slivers are shown clearly in position in the *x*-ray photograph. *c*, *X*-ray 10 weeks after operation, showing marked osteogenesis from the sliver grafts at the arrow points "2" and "3." *d*, Four months after operation, showing complete consolidation. The active osteogenesis from the external sliver grafts is strikingly well shown in this case.

of the fragment ends. Again, it would have been most difficult to have inserted medullary grafts without breaking the ulnar graft while inserting

the radial transplant, or *vice versa*. To the author's knowledge, a united fibula has been broken in attempting to insert the intramedullary graft into the tibia. It would have been most difficult to have reached and secured satisfactory contact with osteogenetic bone beyond the eburnated zone. This difficulty, however, is inherent in the intramedullary technic, and no doubt was largely responsible for the previous failure from this operation in this particular case.

A strong argument for the inlay technic as compared with the intramedullary, is its universal applicability to all types of fractures of the long bones, however near the joints they may be. A good illustration is an ununited fracture of the tibia in good apposition near the ankle-joint, where



a *b*

FIG. 328.—*a*. Compound comminuted fracture of tibia and fibula followed by infection and loss of substance.

b. Same case after a strong tibial bone-graft had been inserted spanning a hiatus of about one inch of the tibia.

the fibula has become united. The accessible portion of the fibrous union is removed. There is no occasion to disturb the relationship of the fragments. The thickened periosteum is split and peeled sidewise on the lower fragment only, and with the motor twin-saws and a narrow chisel a groove is made in the lower fragment completely to the tip of the malleolus, if the fragment is very short. Then, by means of the same twin saws, a cortical graft 4 or 5 inches long is removed from the upper fragment and slid down into the groove in the lower fragment.

When the fracture is very near a joint, as the ankle, and the lower fragment affords a very short contact, the graft can be extended to the tip of the malleolus so that joint support will be largely supplied by the end of the

graft which is in the end of the malleolus as in a shell, even if by chance bony union should not occur between the graft and lower fragment, provided, of course, that union has taken place between the upper fragment and the

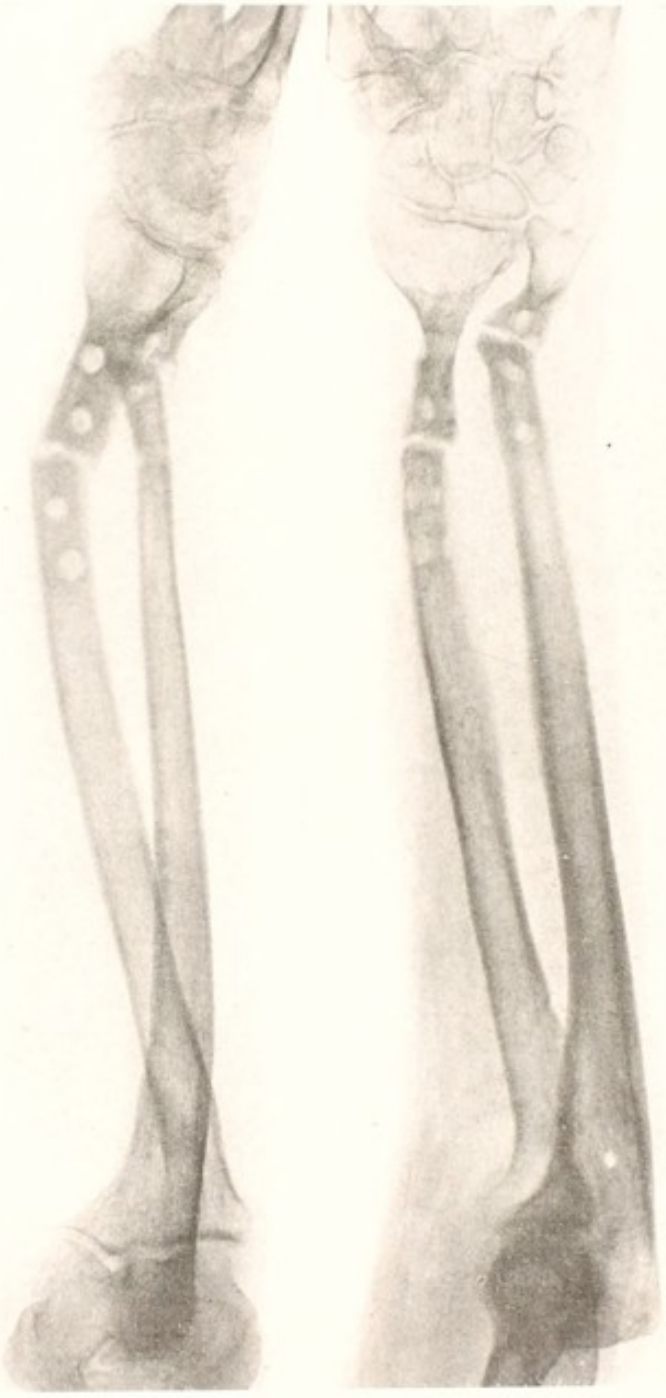


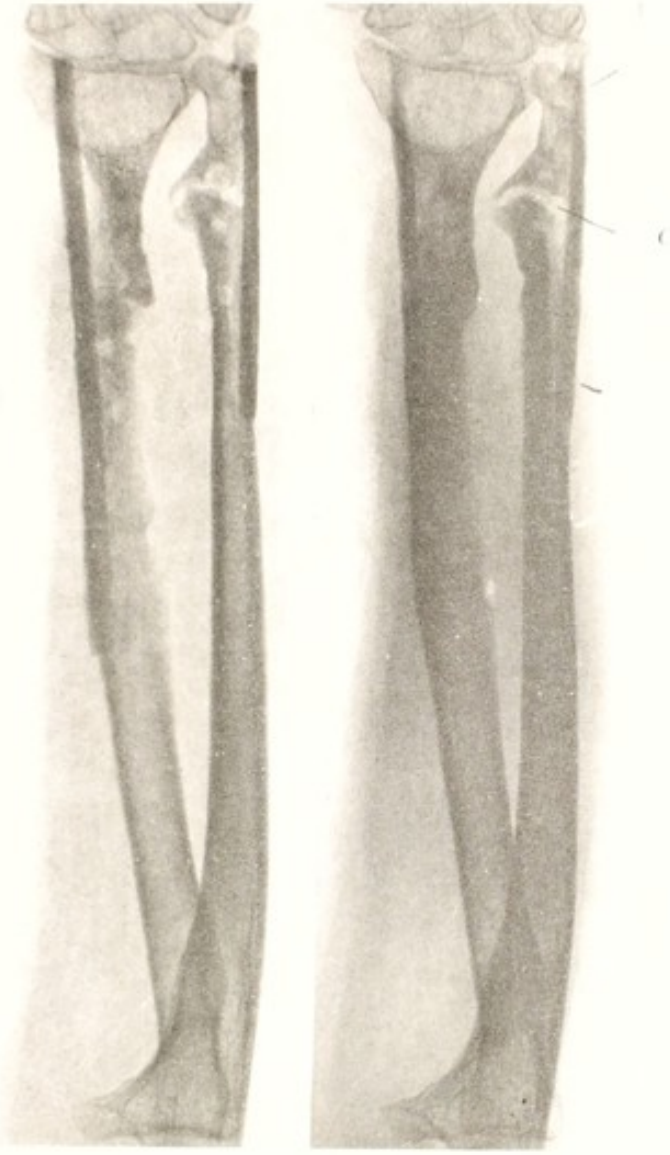
FIG. 329.—Röntgenograms of ununited fractures of the radius and ulna of four years' duration after seven unsuccessful open operations to secure union, including Lane's plating, wiring and intramedullary bone grafting. The röntgenograms show the large holes and bone destruction in both radius and ulna, which originated from the screws of the former Lane's plates and the metal contact of the plate itself.

graft, which should be insured by a long inlay and consequent extensive contact (Fig. 330).

In exceptional instances, there is no necessity for using any means to hold the graft in place.

To fix the inlay in place, the question arises of choosing between bone-

pegs and heavy kangaroo tendon placed in drill holes or wrapped entirely around the bone when it is small, as in the case of the forearm bones. At the present time the author almost invariably employs kangaroo tendon, resorting to bone-pegs only in exceptional instances.

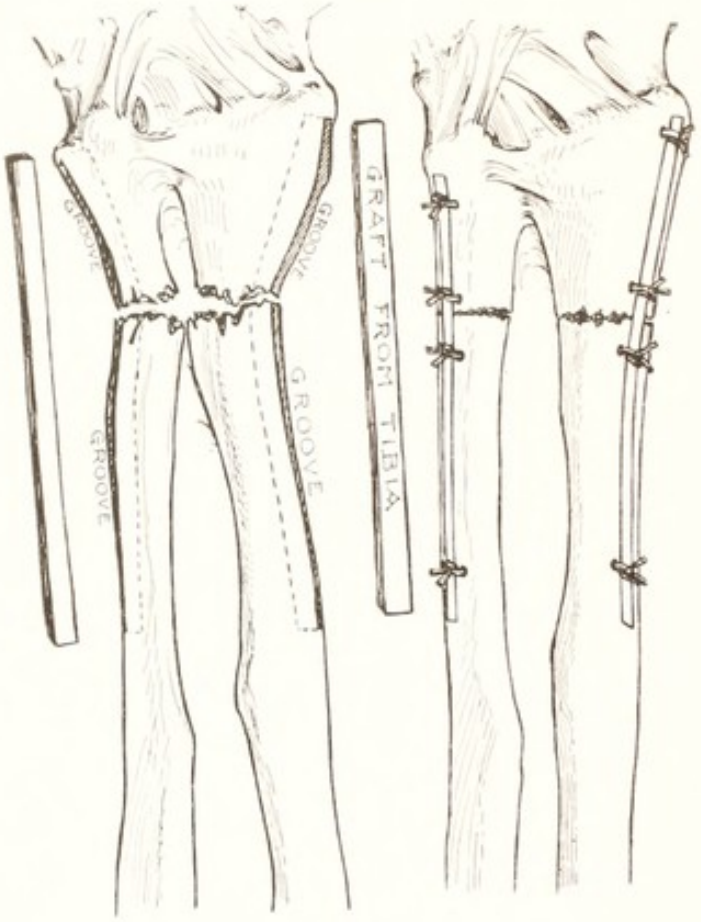


A B

FIG. 330.—A is a roentgenogram taken five weeks after the successful implantation of tibial inlay grafts; B was taken six months after the operation and shows that the grafts have lost their sharpness of outline and are taking on the density and characteristics of the bone in which they are inserted. On account of the desperate nature of the case, very long implants were used and the wisdom of this is shown at C, where there is no union between the fragments or between the proximal fragment and the graft for a space of two-thirds of an inch from the end of the fragment, although there has been firm union for five months, because of the long graft coming in contact with the vascular-osteogenetic bone back of the sclerosed bone at the ends of the fragments.

An important mechanical feature of the inlay which should not be overlooked is that if it is inserted in proper relationship to the forces which are causing displacement, it becomes by its own inherent mechanics a most effective fixation agent, irrespective of the means used to keep it in place. An illustrative case is that of a very stout woman with an ununited fracture of the tibia about 1 inch from the ankle-joint, and of one year's duration.

There was marked displacement of the lower fragment and foot posteriorly. The bone ends were freshened and the lower fragment was forced forward into place. Although there was a strong tendency for this fragment to spring back into its old position, a long inlay inserted into the inner side of the fragments held them securely by virtue of its mechanics, without depending upon the kangaroo tendon and the graft-pegs which held it in place. On the other hand, if this inlay had been inserted in the anterior



A *B*

FIG. 331.—Drawings illustrating the technic carried out in the case of which Figs. 329 and 330 are röntgenograms. *A* indicates grooves and grafts before insertion and *B*, after the insertion of graft and kangaroo-tendon fixation sutures. The grafts were long and were placed into the radial side of the radius and the ulnar side of the ulnar. The radial and ulnar fragments were very satisfactorily separated by drawing them to the grafts with kangaroo sutures as indicated in *B*. This is a special important feature of the inlay graft as compared with that of the intramedullary type in its application to fractures of both bones of the leg or forearm.

or the posterior surface of the tibial fragments, its fixation force would have been wholly dependent upon the tendon which held it in place.

The author has repeatedly and successfully used the bone-graft for spanning tuberculous foci in Pott's disease of the spine and tuberculosis of the ankle- and knee-joints. The cortical bone-graft has always withstood pure tuberculous infection provided it had satisfactory contact with healthy bone on each side of the focus of infection. It will also resist attenuated pyogenic infection under similar conditions, as has been proven by experiments conducted by Phemister and the author, in both surgical and laboratory work (see Albee, "Experimental Study of Bone Growth

and the Spinal Bone Transplant," Jour. A. M. A., Apl. 5, 1913, lx, pp. 1044–49).

The importance of this inherent germ-resisting property of the bone-graft is readily apparent in that it doubly assures its trustworthiness as a general surgical agent (when compared with metal). Especially is this true in its application to compound fractures in which infection is feared or where a mild infection has already occurred. The following is an illustrative case:

A man forty-five years of age came to the author with an infected ununited fracture of the tibia of six months' duration, and gave the following history: six months previously he had sustained a fracture of the lower tibia and fibula. The tibia was immediately plated with two long Lane's



FIG. 332.—Oblique fracture of tibia, repaired by sliding inlay bone-graft. Good alignment of fragments; osteogenesis progressing favorably from graft and host bone. (X-ray six weeks after operation.) This patient had had three unsuccessful operations prior to the bone-graft; one included the insertion of a wire nail subcutaneously under the guide of fluoroscope. Although the author does not advocate the use of the graft as a routine measure in open operations, he believes that any case which has not been satisfactorily reduced in five to six weeks and exhibits no evidence of active callus formation at open operation at the end of that time, should be immobilized by an inlay graft, as was decided in this case.

plates. Infection occurred, and the plates were removed in three weeks' time. The wound continued to discharge profusely, and an *x*-ray examination revealed a sequestration of the complete diameter of the upper fragment of the tibia, from the upper screw holes of the Lane plates down to the end of the fragment. The discharging sinus was increased in size, and the sequestrum, about $2\frac{1}{2}$ inches long, comprising the entire diameter of the tibia, was removed. The cavity thus produced was packed, and the leg was put up in a plaster case, making use of the united fibula to prevent approximation of

the remaining tibial fragments and consequent shortening of the leg. At the end of eight weeks, the sinus was still discharging a considerable amount of seropurulent material and, on account of the large cavity between the fragment ends, the prognosis as to when the sinus would heal was most uncertain.

As the patient was very anxious to have something done immediately to get union of the tibia, it was decided to make the attempt, and with the use of the motor twin-saw a strong cortical graft was dragged from the upper fragment into a groove made with the same instrument in the lower fragment. (The cavity was first cureted out carefully and filled with tincture of iodin, 3.5 per cent., and the whole operating outfit was then changed.) The inlay was slid into place from the upper fragment, spanning a hiatus of $2\frac{1}{2}$ inches, and held with peg grafts which were made on the operating table by splitting into three portions with the motor-saw the fragment of bone removed from the lower fragment in making the groove for the inlay, and then shaping these portions into three long pegs by means of the motor lathe. On account of the large size of the sinus, it was impossible to cover about an inch of the center of the graft, where it spanned across the sinus opening. However, much to our gratification, the convalescence was most satisfactory; granulations covered the exposed portion of the graft very rapidly, and there was firm union between transplant and fragment in six weeks' time. In four months' time, the action of Wolff's law had caused the graft to hypertrophy, and the hiatus between the tibial fragments had completely filled in and the long bone had apparently become as strong as it had ever been.

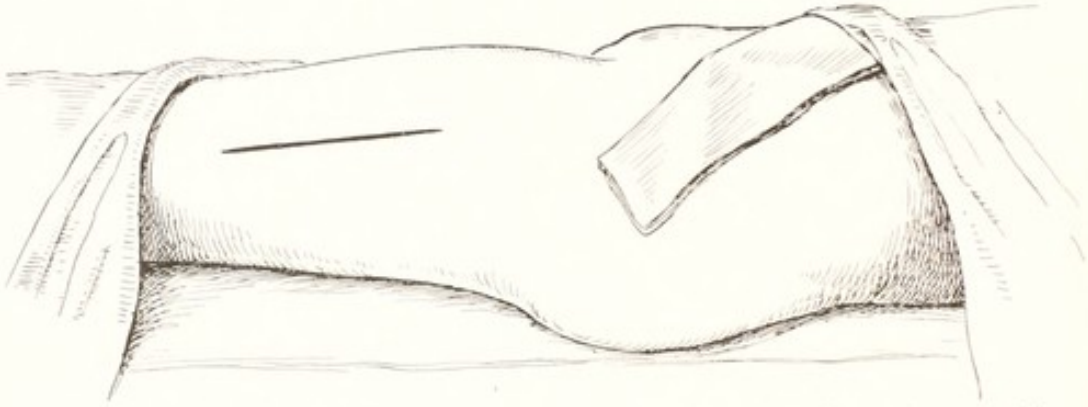


FIG. 333.—Linear incision in the external aspect of the thigh midway between hip and knee, for exposing the shaft of the femur. By retracting the quadriceps inward and the vastus externus outward, the anterior surface of the femur is thoroughly exposed for the insertion of a bone-graft or other operative procedure upon the anterior aspect of the shaft.

This case has a very important bearing in demonstrating the striking superiority of the bone-graft as compared with internally inserted metal. The graft was inserted into a wound which even showed macroscopic evidence of infection; nevertheless, it healed in rapidly and has given no trouble since, although it is now over four years since the operation. The surgical technic of inserting a metal plate must be of the most rigid and special type in order to avoid infection in clean cases, as pointed out by Lane; and if the slightest infection occurs, it is very likely to extend the whole length of the plate and to its screws, and the plate must come out. In this case, as well as in several others, the inlay graft was successful and resisted infection that was already present.

In view of these experiences, the value of this method in compound comminuted fracture from gunshot or other causes, mildly infected or not, is apparent.

Experimental work on the dog demonstrated still more conclusively the bacteria-resisting properties of the bone-graft. Wounds have become virulently septic on the second and third days after operation, laying bare the graft which was bathed in pus at the bottom of the wound. Nevertheless, either a portion or the whole of the grafts "took" and lived.

Whatever be the modes of internal fixation, whether the Lane plate or the inlay graft, the limb should be firmly immobilized in a plaster-of-Paris splint, as nearly as possible in the position of neutral muscle-pull, *i.e.*, a posture of the limb which causes the relaxation of those muscles which have a displacing influence in that particular fracture. If this be done, inlay or peg grafts, Lane's plates, or spikes in the femoral neck, will not bend

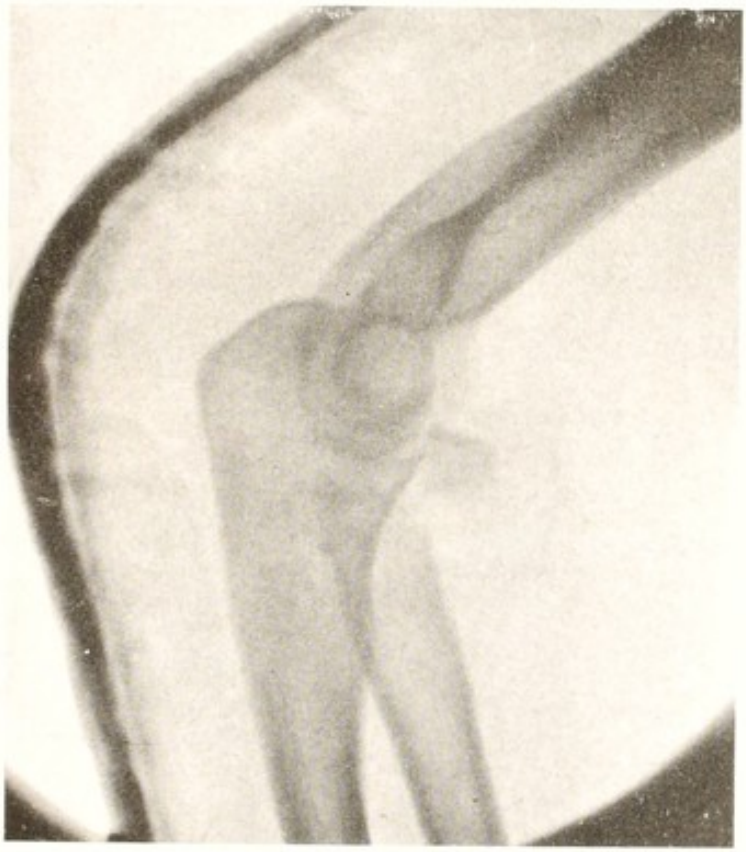


FIG. 334.—Fracture of the head of the radius from a transmitted blow through the radial shaft from a fall on the hand. In such cases the loose fragment should be removed as a primary treatment and the corners of the remaining portion of the head excised.

nor break during the period of the postoperative fixation. Weight-bearing, function in the presence of non-union or soft callus, and bone absorption are the causes for the yielding of internal metal fixation splints.

In all cases of persistent non-union, where syphilis and other systemic conditions are contributing causes of meager callus formation, these conditions should be treated before operation is undertaken.

Contra-indications to Operation.—These do not differ from those applying to operations in general. Infected abrasions of the skin or ulcers near the field of operation are to be carefully avoided; patients with actively suppurating wounds or abscesses in any part of the body should not be operated upon because of the danger of metastatic infection at the field of operation, which predisposes the tissues to lowering of local resistance from trauma and to general depression arising from the operation.

The most scrupulous aseptic technic should always be observed.

Fixation Dressing.—The plaster-of-Paris splint applied over a thin Shaker flannel or cotton wadding to protect the bony prominences, has, in the hands of the author, proved to be by all means the most satisfactory. It can readily be split into a bivalvular splint by means of the author's motor-saw, or other special saw, or by the Stillé cutter. The splint can then be easily removed for necessary treatment, etc.

Other satisfactory splints are Stimson's moulded plaster-of-Paris splints. Splints of tin or wood-plastic splints of felt, papier maché, celluloid, etc., have been used, but are greatly excelled by plaster-of-Paris for the usual fixation dressing.

As stated elsewhere, the limb should always be placed in such a position that displacing muscles are relaxed by approximating their insertion and origin as nearly as possible. An illustration would be the flexion-abduction posture used in fractures at the lesser trochanter for the purpose of relaxing the psoas magnus and short trochanteric muscles which pull the upper fragment into that position.

After-treatment of Ununited Fractures or Pseudarthrosis.—On account of the sluggish osteogenesis of the bony elements making up a pseudarthrosis,

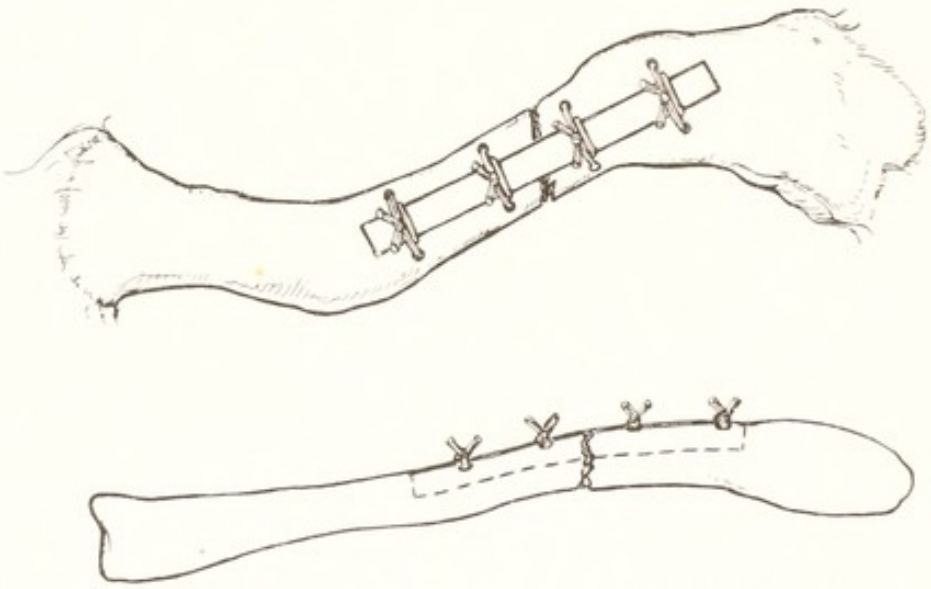


FIG. 335.—Drawing of inlay graft inserted for an ununited fracture of the clavicle.

a support should be continued much longer than in the case of fresh fractures. In the more desperate cases, some support should be continued for three to four months, because the callus formation from the bone ends is slow at best and all stress may be borne by the graft, which will hypertrophy sufficiently if in the meantime it is protected from breaking.

Baking.—Baking by hot air is particularly efficacious in fractures about joints, and should be begun at the same time as the massage and passive motion (provided only that the *x*-ray shows union to be complete), and should immediately precede those exercises.

Hot compresses, consisting of towels or pads of cotton covered with gauze, wrung out of very hot water, may in certain cases be of service.

Liniments.—Liniments have no special therapeutic effect except that they encourage massage or rubbing. Strong lotions which are likely to blister the skin, should not be employed.

Ununited Fracture of the Clavicle.—The inlay graft for ununited fractures of this bone is the operation of choice.

H. H. M. Lyle (Annals of Surg., September, 1914) reports a case of ununited fracture of the clavicle in which he implanted a bone-graft 6 by 1.5 cm. taken from the tibia. The graft was fastened as a splint on the outside of the bone, spanning the point of non-union, by means of kangaroo tendon passed through the graft and clavicle. Twenty-seven days after the operation, the graft having become displaced upward and producing pressure necrosis of the skin, was removed. "The graft was smooth and clean, and apparently viable, indicating that bone regeneration had already begun." The wound healed in a few days, and a week later blood injections, according to the Bier method, were begun. Bony union and a satisfactory result were obtained. Lyle remarks that in this situation, when the soft parts are thin and it is difficult to secure immobilization, a bone-graft should not be used as a splint but rather as a means of stimulating bone-growth, and that this is the chief therapeutic value of the graft; and that he obtained better results from the use of this bone-graft than from thick ones. This case is a strong argument in favor of the inlay technic, which would have brought the surface of the graft level or flush with that of the clavicle itself, and there would have been no danger whatever of pressure necrosis of the overlying skin (Fig. 335). The graft should consist of the full thickness of the tibial cortex with periosteum, endosteum, and some marrow-substance, and should be obtained from the upper portion of the tibia where the cortex is not so thick. Such a graft, held in place by kangaroo tendon, furnishes perfect fixation.

REFERENCES

UNUNITED FRACTURES

ALBEE, F. H.: "Bone-graft Surgery." Phila., W. B. Saunders Co., 1915.

ALBEE, F. H.: "The Inlay Bone-graft as a Treatment of Ununited Fracture; Report of 15 Successful Cases." Amer. Jour. of Surg., Jan., 1914, xxviii, 21–26.

ALBEE, F. H.: "The Inlay Bone-graft in Fresh Fractures." N. Y. Med. Jour., May 23, 1914.

ALBEE, F. H.: "Original Surgical Uses of the Bone-graft." Surg., Gyn. and Obst., June, 1914.

ALBEE, F. H.: "The Inlay Bone-graft versus Lane Plates in the Treatment of Fractures." Amer. Jour. of Surg., March, 1915.

ALBEE, F. H.: "The Inlay Bone-graft in the Treatment of Fractures, Joint Tuberculosis and Certain Deformities." The Lancet Clinics, April, 1915.

ALBEE, F. H.: "Original Surgical Uses of the Bone-graft" (condensed). Detroit Med. Jour., Feb., 1915.

ALBEE, F. H.: "Meine Verwendung der Knochentransplantation." Verhandl. d. deutsch. orthop. Gesellsch., 1915, xxxv, 112.

ALBEE, F. H.: "A New Fracture-Orthopedic Operating Table." Surg., Gyn. and Obst., June, 1918.

MARTIN: Surg., Gyn. & Obst., Aug., 1906.

ARNAUD: "Greffe osseuse pour pseudo-arthrose." Lyon med., 1914, cxxii, 1448.

BAKER, S. C.: "Bone-grafting in Ununited Fractures." J. South Car. M. Ass'n, Seneca, 1913, ix, 303–306.

BARBET, P.: "Les Greffes osseuses dans le traitement des pseudarthroses diaphysaires acquises." Bull. gén. de thérap. (etc.), Par., 1914, clxvii, 141, 169, 197, 231.

BRICKNER, W. M.: "Metal Bone-plating a Factor in Non-union. Autoplastic Bone-grafting to Excite Osteogenesis in Non-union of Fractures." Am. J. Surg., N. Y., 1914, xxviii, 16–20.

DOS SANTOS, R.: "Tratamento operatorio das fracturas fechadas." Med. contemp., Lisb. 1914, xxxii, 99, 107.

FRIEDRICH, W.: "Ueber Knochenplastik bei Pseudarthrose." Zentralbl. f. Chir. u. mech. Orth., Berl., 1914, viii, 281–283.

GANGOLPHE: "Pseudarthrose congénitale." Lyon méd., 1914, cxxiii, 15.

GEDROITS, V. I.: "Several Cases of Bone-plating Operation in Complicated and Ununited Fractures." Syezed rossiysk. khirurg., Mosk., 1913, xii, 188–196.

JÜNGLING, O.: "Ueber pseudoarthrosen im Kindesalter." Beitr. z. klin. Chir., Tubing., 1914, xc, 649–742.

LISOVSKAYA, SOFYA N.: "Treatment of Ununited Fractures and Pseudarthrosis by Injection of Comminuted Periosteum." Khirurg. Arkh. Velyaminova, St. Peterb., 1913, xxix, 742–753.
PETROFF, N. N.: "Treatment of Pseudarthroses." Ibid., 1914, xxx, 23–32.
ROBINSON, E. F.: "Treatment of Ununited Fractures." Railway Surg. J., Chicago, 1913–14, xx, 269–275.
WATKINS, J. T.: "Concerning Ununited Fractures." Calif. State J. M., San. Fran., 1914, xii, 197–201.
YOUNG, J. K.: "Vicious Union in the Neighborhood of Joints." Am. J. Surg., N. Y., 1914, xxviii, 29–31.
HAWLEY, G. W.: "Ununited Fractures with a Study of Bone Repair." Am. J. Orth. Surg., Phila., 1914, 15, xii, 245–252.
HELBING, C.: "Ueber Pseudoarthrosen und Nachbehandlung der Frakturen." Ztschr. f. ärztl. Fortbild., Jena, 1915, xii, 206–211.
HENDERSON, M. S.: "Transplantation of Bone in Ununited Fractures." Journal-Lancet, Minneap., 1914, xxxiv, 615–620.
HENDERSON, M. S.: "Operative Treatment of Delayed Union of Fractures." Railway Surg. J., Chicago, 1914–15, xxi, 429–436.
PARKER, R.: "On the Use of Small Bone Fragments in Ununited Fracture." Pro-Roy. Soc. Med., Lond., 1913–14, vii, Surg. Sect., 275.
TEOFILO, M. B.: "La pseudo-artrosie i ritardi di consolidazione delle fratture in rapporto alla terrapia coll' acido osmico." Clin. Chir., Milano, 1915, xxiii, 415–430.
TROUT, H. H.: "Autogenous Bone-grafts versus Lane's Plates." Ann. Surg., Phila., 1915, lxi, 717–724.
TROUT, H. H.: "Treatment of Ununited Fractures." South M. J., Nashville, 1915, viii, 502–512.
WILDEY, A. G.: "Ununited Fractures Treated by Long-axial Drilling of the Fractured Bone-ends." Brit. J. Surg., Bristol, 1914–15, ii, 423–428.
BERGEL, S.: "Die Behandlung der verzögerten Callusbildung und der Pseudarthrosen mit Fibrininjektionen." Berl. klin Wchnscher., 1916, liii, 32–36.
BILLON, L.: "Un traitement conservateur pour les pseudarthroses par grande perte de substance osseuse diaphysaire." Rév. gén de clin. et de thérap., Par., 1915, xxix, 791.
"Bone-grafts and Ununited Fractures." Lancet, Lond., 1916, ii, 284–286.
DEAN, E. F.: "The Treatment of Ununited Fractures by the Use of Bone-graft." Colorado Med., Denver, 1916, xiii, 268–272.
GULEKE: "Ueber pseudarthrosen." München med. Wchnschr., 1916, lxiii, 265.
JONES, R.: "Malunited and Ununited Fractures." Brit. M. J., Lond., 1916, i, 809–814.
LARKIN, R.: "On Malunited and Ununited Fractures." Brit. M. J., Lond., 1916, i, 900.
MORRILL, L. T.: "Non-union of Fractures." J. Kansas M. Soc., 1916, xvi, 131–139.
VACCARI, A.: "Patogenesi e cura dei ritardi di consolidazione delle fratture." Ann. di med. nav., Roma, 1915, ii, 157–181.

CHAPTER XVIII

FRACTURE OF NECK OF FEMUR. FRACTURES OF PATELLA AND OLECRANON. HABITUAL DISLOCATION OF PATELLA. FRACTURE OF THE TARSAL BONES. FRACTURE OF THE CARPAL SCAPHOID

FRACTURE OF THE NECK OF FEMUR

In an ununited fracture of the femoral neck, the history of the case together with the classical signs of shortening, eversion, disability, and the *x*-ray evidence are usually sufficient for diagnosis. For further information upon the clinical course of this fracture, the reader is referred to text-books on

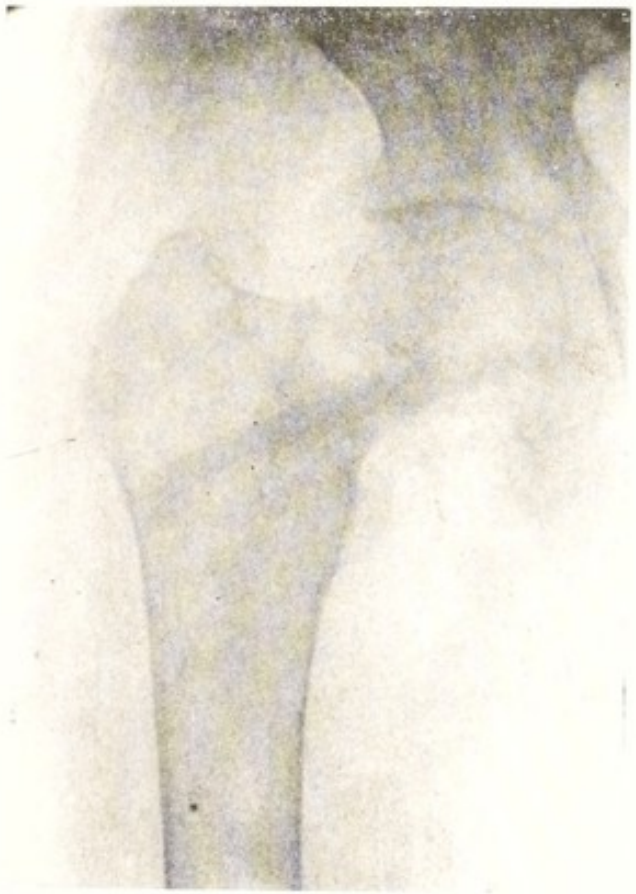


FIG. 336.—Ununited fracture of the femoral neck of two-years' duration, three months after the insertion of a tibial bone-graft peg, showing firm union.

surgery and to those on fractures. In this book we shall devote ourselves chiefly to the question of correction of the disability resulting from fractures of the femoral neck by surgical procedure.

There is no fracture in the body concerning which the attention of the profession has so greatly increased of late years as in the case of fracture of the hip. The chief reasons for this are the increased interest which the profession has been forced to take in traumatic industrial surgery because

of the advent of the workmen's compensation law; and, second, the frequency of the fracture in the recent war.

Fracture of the neck of the femur is by all means the most disabling of all types of simple fractures. These fractures were formerly regarded as occurring mainly in old age. Recent personal statistics as well as those of other surgeons who have large fracture clinics, show a large number of fractures of the femoral neck occurring in individuals below the age of forty-five or fifty. Senile osteoporosis, associated with thinning of the cortex and absorption of many of the lamellæ of the spongiosa of the neck is the

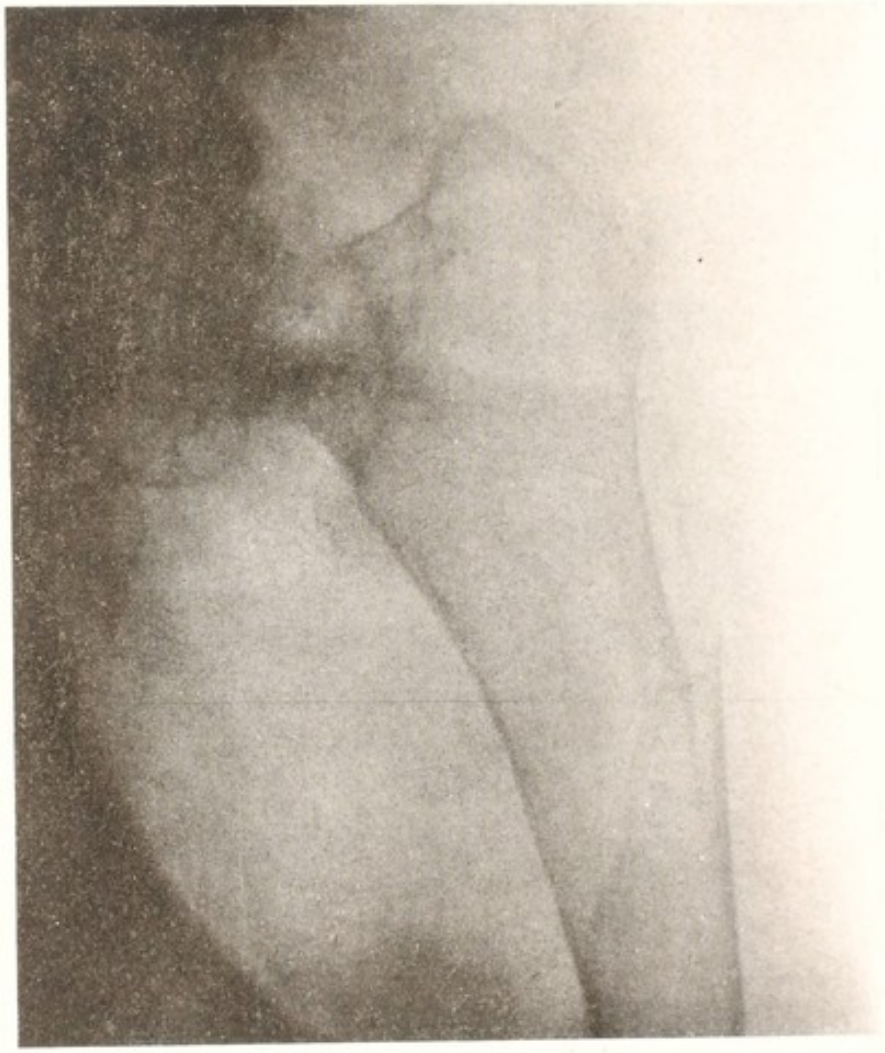


FIG. 337.—Same case as Fig. 336. This patient fell four months after insertion of the bone-graft peg and sustained an oblique fracture of the shaft of the femur 3 inches below the trochanter. The union at the neck remained undisturbed.

chief cause of the increased frequency of this fracture in the aged; and, as would be expected, traumata need be much less severe to cause fracture in the aged than in younger individuals. There seems to be no object, as far as treatment or prognosis is concerned, in classifying these fractures further than by the single term "fracture of the neck." The terms intracapsular and extracapsular are inaccurate and misleading. The capsular insertion on the neck of the femur is oblique, thus causing the joint to include more of the neck on its anterior and inferior surfaces than on the posterior and superior, and therefore practically every fracture of the neck is partially or completely intracapsular.



FIG. 338.—Old ununited fracture of the neck of the femur in a woman sixty-three years of age. Duration of fracture about one and one-half years. The arrow points to the interval between the fragments of the neck.



FIG. 339.—Old ununited fracture of the neck of the femur. Same case as shown in Fig. 338 two and one-half years after the fracture.

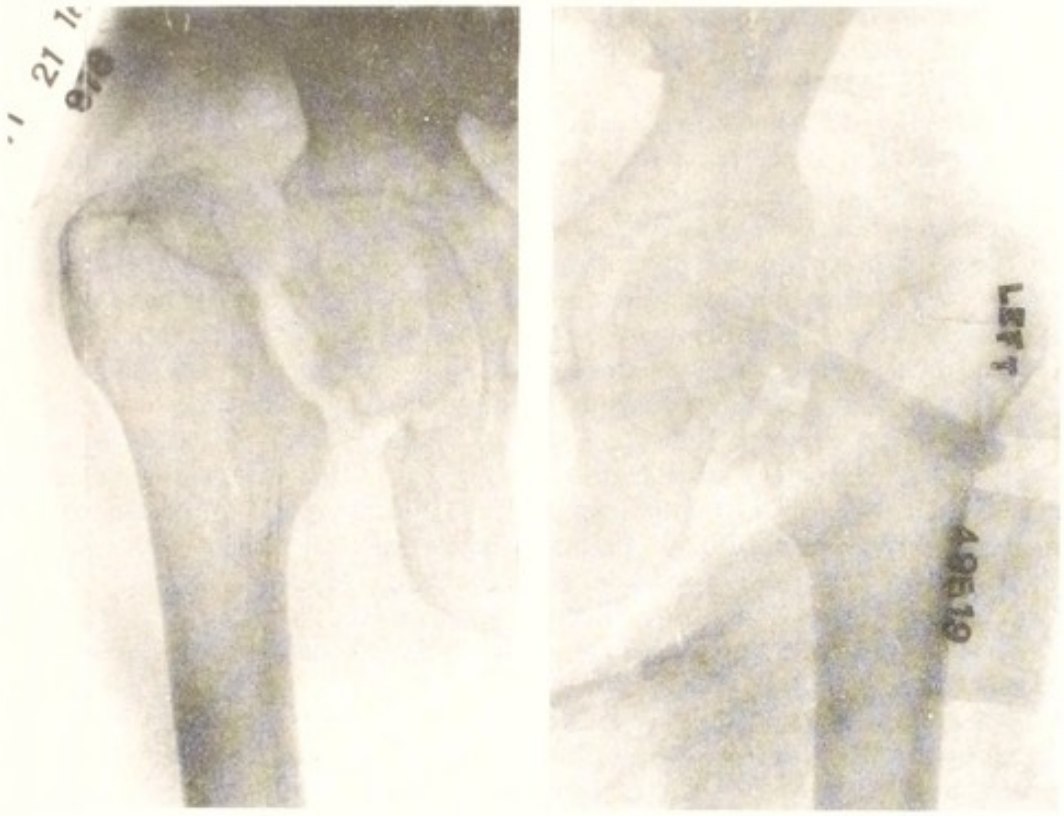


FIG. 340.—Same case as shown in Fig. 339 about four months after the insertion of a tibial bone-graft peg, with firm union resulting.



FIG. 341.—Ununited fracture of one and one-half years' duration in neck of femur following abduction treatment. Young man of twenty-four years. Firm union followed the insertion of a tibial bone-graft peg.

Furthermore, most fractures are oblique and diagonal, and are only infrequently strictly transverse. If any classification is used, that of Stimson is by all means the preferable one, *i.e.*, subcapital or fracture through the neck, and fracture at the base of the neck. A fracture is apt to occur in one of these two places, either at the junction of neck with head or with trochanter. The associated outward rotation in epiphyseal separation or fracture occurs as frequently and is often more pronounced than in fractures of the neck, which fact cannot be explained by a more fragile posterior portion of the neck. The predominance of the external rotators, especially the short trochanteric muscles, is believed to be the more tenable explanation



a *b*

FIG. 342.—*a*, Ununited fracture of neck of femur of one year's duration; *b* shows the bone-graft peg in position. This radiograph also illustrates the impossibility, in some cases of exerting sufficient traction to get the head and neck in perfect alignment.

of external rotation. The natural weakness of the femoral neck is still further emphasized by the fact that it gives way so completely in conditions of increased malleability of the bones, such as in rickets.

Shortening of the limb depends upon decrease in the angle between the femoral neck and the shaft, or upon sliding by of the fragments.

TREATMENT OF FRACTURE OF THE NECK OF THE FEMUR

An authority in commenting upon the poor results obtained in treatmen of fractures of the femoral neck states: "At first one can hardly appreciate how startling these results are unless one has carefully studied various series of statistics, and wherever the usually accepted principles of practice are employed, the long side splints with Buck's extension, there the average results are uniformly unsatisfactory."

Of value in this connection, are the conditions existing in 16 cases of fracture of the hip observed by Scudder many years after the accidents.

"In only 2 cases, or 12 per cent., could it be said that the leg was functionally useful."

Walker studied the records of 112 cases of fracture of the neck of the femur treated in Bellevue Hospital between 1906 and 1907. Only 15 cases, or 13 per cent., recovered good function.

Unquestionably Whitman's abduction method offers better results than the foregoing. Certain men, however, have not obtained the favorable results secured by Whitman.

Non-operative Treatment of Fracture of the Neck of the Femur.—The author uses the Whitman abduction treatment of fracture of the femoral neck except in those cases in which he believes that the bone-graft peg offers better chance of rapid and successful union. (See discussion concerning the indications for the use of the bone-graft peg in this chapter.)

Whitman's abduction treatment is briefly as follows (Orth. Surg., 1910, p. 589): After anesthetization, the patient is placed on a Hawley table, or, in lieu of the latter, on a box about 7 inches high placed on an ordinary table and with a sacral support for the pelvis, and the extended limbs are held by assistants. The sound limb is then fully abducted to act as a guide. Traction is now made on the injured member, which is slowly abducted, while at the same time the surgeon supports the joint with his hands and gently presses the trochanter downward. When the deformed neck impinges on the upper border of the acetabulum, the contact is readily perceptible to the operator, but the limitation of abduction is readily overcome. When a degree of abduction has been attained equal to that on the sound side, restoration of the normal relationship of the femoral shaft and neck is practically assured. The next procedure is to correct external rotation, after which the abducted position is maintained in a long plaster-of-Paris spica from toes to costal border, and the spica retained until bony union has occurred.

In case the fracture of the neck is complete, Whitman's procedure is somewhat different, viz.:

The sound limb having been abducted, flexion of the injured limb is first performed to free any reduplication of the capsule from between the fragments. The femur is then extended and rotated to its normal position, after which the necessary amount of traction and countertraction is applied until actual measurement shows that all shortening has been overcome. While an assistant slowly abducts the femur, the surgeon, by pressure on the joint below, slowly forces the fragments against the anterior portion of the capsule. Complete abduction is the ideal mechanical position for this condition, for the following reasons: (*a*) It renders the capsule tense (thus favoring proper contact and position of the fragments); (*b*) it brings the great trochanter into apposition with the roof of the acetabulum (thus counteracting any tendency to upward displacement); and, furthermore, (*c*) it relaxes the muscles which, if in contraction, would favor deformity.

If flexion and adduction deformity persist, as is frequently the case after fracture of the neck of the femur, the deformity may often be relieved by moderate force. Again, if non-union has resulted, the upper extremity of the femur may be forced forward beneath the anterior superior spine of the ilium, and the limb fixed in abduction and extension by a Lorenz spica, according to Whitman, who follows Lorenz's original suggestion.

If non-union persists in spite of the methods above suggested, recourse may be had to the author's open operation (about to be described) for the insertion of a bone-graft peg to retain the fragments in proper position and alignment.

In cases of old ununited fracture of the femoral neck of long duration, where the fracture occurs near the head, with considerable rarefaction and disintegration of the latter, it is sometimes advisable to remove the head and insert the great trochanter into the acetabulum. This procedure gives a very serviceable articulating body to replace the femoral head.

Cotton offers the following objections to this treatment: "First, many men are inclined to doubt the locking of the upper fragment at the limit of abduction, believing rather that tension on the abductor muscles gives the limit of abduction; second, there is real danger that in less expert hands the fragments may be forced by one another, not jammed together; third, plaster spicas in stout patients do not hold abduction firmly."

At best, fracture of the neck of the femur is one of the most difficult problems in all surgery. The anatomico-mechanical conditions, the poor blood supply, the sluggish osteogenesis, and the difficulty of fixation are all potent adverse influences for securing satisfactory union and good functional results, and it is believed that if ever radical measures are justifiable they are indicated in the primary treatment of this desperate condition.

The obstacles to union in fracture of the inner two-thirds of the neck of the femur (aside from the obstacles appertaining to faulty union in the case of all fractures in general) are as follows:

1. **Mechanics.**—The mechanics of this fracture differ from all others in that the mechanical advantage of end-to-end stress is not present, as in the shaft of the long bone, in that the stress from muscle-pull and weight-bearing comes at right angles to the long axis of the cervical fragments at the point of fracture.

2. **Deficient Osteogenesis.**—Sluggish bone-growth in this region is the result of (*a*) the small amount or possibly the entire absence of periosteum (the chief cause), and (*b*) poor blood supply.

3. **Intracapsular Location of the Fracture.**—This occurs within the second largest joint of the body and early callus formation (according to Cotton) is dissolved or its production is inhibited by the synovial fluid.

4. **Interposition** of capsule and other soft tissues between the fragments.

5. Relatively **small diameter** of the neck, because of its proximity to a ball-and-socket joint.

As the British Fracture Committee has stated, good results have hitherto been obtained in 23 to 28 per cent. of all fractures of the neck of the femur under all forms of treatment. Other statistics place the percentage of good results as low as 13 per cent. A very large number of cases of fracture of the hip have been coming to the author in which the very best mechanical treatment had been administered, by the Whitman abduction method, by traction, etc., and still there was non-union. In analyzing this mass of unfavorable results, the question arises: *why* has there been failure of union? The answer is that every method of treatment that has ever been applied to this condition, prior to the author's introduction of the bone-graft peg, served to eliminate none but the first of the obstacles to union (which have just been enumerated), namely, the unfavorable mechanical conditions. In other words, all these non-operative methods consisted essentially of fixation. The metal spike did not solve the problem, for it increased to only a very moderate degree the mechanical fixation ordinarily obtained by Whitman's abduction method and in no way altered the remaining four obstacles to union. Furthermore, it can be said from experience that the metal spike causes intense destruction of bone. In many cases coming to the author in which the metal spike had been used and on which he subsequently did his bone-graft peg operation, the entire femoral neck had been reamed

out in both proximal and distal fragments to such an extent that the hole thus made would easily admit a finger. It was even difficult to obtain a bone-graft sufficiently large to fill the hole. In one case a graft measuring more than one-fourth the diameter of the upper end of the tibia was required for this purpose.

There has been no mortality whatsoever in the author's practice, in the performance of his bone-graft peg operation for fracture of the hip. (In considering the human indications for this procedure, we are not taking into consideration the old lady of eighty who is not an operable risk for any department of surgery.) Furthermore, the damage to the tibia in obtaining the graft is of no consequence, as has been proved in the more than 1600 cases to date in which the author has removed the graft from the tibia without fracture or complication of any sort in that member.

It seems to us of great importance to consider more fully the most potent of the obstacles to union, namely, defective osteogenesis and its contributory factors, poor blood supply and deficiency of periosteum.

Defective Osteogenesis.—The sluggish bone-growth in the neck of the femur was forcibly impressed upon the author ten years ago in experimenting on dogs and rabbits to determine the relative osteogenetic activity of bones from different parts of the body. For still further emphasis, one has only to study a series of *x*-ray plates in cases of pseudarthrosis of the neck of the femur. In almost every case there are erosion and absorption of bone, often to the extent of entire loss of both the capital and distal fragments. There is never the active proliferation or overgrowth of bone which always occurs in cases of pseudarthrosis in the long bones, the most striking feature in fracture of the femoral neck being osteoporosis with loss of bone substance.

Poor Blood Supply.—Solution of continuity of the neck cuts off all possibility of subsynovial blood supply from the proximal fragment. The only source of blood supply remaining is that from the ligamentum teres. On account of possible torsion or angular stress which may come upon this ligament, the blood supply from this source is precarious. In certain cases, the circulation from this ligament has become so strangulated that the head of the femur has become discolored from lack of blood. It is obvious that the blood supply to the bone on both sides of the fracture must be very meager, because the femoral neck is surrounded entirely by joint-space. This is in marked contrast with the conditions existing in fracture of any long bone, where a blood supply is available not only from the nutrient artery and periosteal vessels but also from those of the overlying soft tissue.

Deficiency of Periosteum.—Since the periosteum is under the capsular insertion, it is meager at best, possibly entirely wanting, and certainly insufficient to afford an adequate blood supply.

Fixation by Bone-graft Dowel-pegs.—Epiphyses, condyles, tubercles, trochanters, tuberosities, bone fragments, etc., may be very satisfactorily secured to the bone from which they have been fractured by the employment of bone-graft dowel-pegs which are aseptically and speedily made by the author's dowel-instrument (see Figs. 346 and 347). Their accurate fit is secured by employing the proper drill to make the hole into which they are driven. An irregular piece of bone is an undesirable substitute for the dowel-peg with its ground-glass-stopper fit. The former leaves gaps to be filled with hematoma, prevents access of new blood-vessels, invites infection, etc.

The material from which the dowel-pegs are made can always be obtained from the crest of the tibia, if it cannot be more readily obtained in the original field. Enough has already been said to emphasize the superiority of the bone-graft pegs over metal nails or screws. Screws of dead bone or ivory

have a certain theoretical value, in that they become absorbed, as a rule, after a very long time. From a practical standpoint, however, they act precisely as foreign bodies in the bone and soft tissues, and may at any time have to be removed.

Certain surgeons, stimulated by the poor results of mechanical treatment, have employed the metal spikes to insure better approximation and fixation than could be obtained by non-operative measures. This method has not given uniformly good results because of the failure of sufficient callus formation.

An illustrative personal case is that of a woman, thirty years of age, suffering from a fracture of the neck of the femur which remained ununited after eight weeks. There was no destruction of the fragments from friction, nor was there any systemic disease to inhibit callus formation. It was a favorable case, and a tin-plated square steel spike, $3\frac{1}{2}$ inches, was driven in a good position longitudinally through the center of both fragments of the neck, which were in excellent apposition. The convalescence was uneventful. The wound healed by first intention, and at no time was there a temperature above half a degree after the day following the operation. The operation, however, was a failure, and non-union occurred. A skiagram taken four months after the operation, showed that the spike, owing to its own weight and bone-destroying influence, had dropped through the lower portion of the capital fragment and no longer engaged it. The metal spike had not only destroyed bone, but had inhibited callus formation in the region where osteogenesis is at a low grade, and to such a degree that it prevented union, or at any rate was a contributing cause of non-union.

To avoid the disadvantages of metal, the author began in 1912 to use a bone-graft peg as a substitute for the metal spike (Albee in Murphy's Clinics, June, 1913). If this bone-peg is placed in the cervical fragments by the technic described elsewhere, internal fixation is furnished in a mannre equally satisfactory to that offered by the metal spike, while the disadvantages of a metallic foreign body are avoided and the advantages of a living bone-graft gained.

The bone-graft peg is recommended primarily not for its fixative but chiefly for its stimulative osteogenetic and osteoconductive properties. Aside from these intrinsic values, it further stimulates bone-growth in its host (*i.e.*, the fragments of the neck), partly through Roux's law of irritation. Thus, as time goes on, fixation becomes more perfect between the graft and its host, whereas in the case of the metal spike, with the lapse of time the cancellous and cortical bone surrounding it are more and more eroded, so that the spike becomes looser and looser with progressively decreasing fixative properties.

A strong autogenous bone-peg, accurately fitted into a hole drilled longitudinally through the neck of the femur with the fragments in good position, offers unquestionably the ideal condition for the rapid and satisfactory union in good position of this difficult fracture. In other words, the influences adverse to union, enumerated elsewhere, are better overcome by this procedure than by any other treatment; furthermore, every argument for the autogenous inlay graft in ununited and selected fresh fractures of the shaft of long bones, applies with equal force to fractures of the neck of the femur.

Soft tissues are removed, if present, from between the ends of the fragments; the fragment ends are secured in good position; callus formation is stimulated by the presence of the graft, at the same time that the graft produces bone-growth itself; and an osteogenetic bridge is furnished capable

of conducting both blood-vessels and bone-cells from one fragment to the other, from the vascular region of the trochanter of one fragment to the cancellous bone of the poorly nourished capital fragment.

Indications for Bone-graft Peg in Fracture of Neck of Femur.—This operation is believed to be indicated in all ununited fractures of the neck of the femur and in most unimpacted fresh fractures in operable subjects at any age.

After conservative treatment, weight-bearing should be prohibited for at least a year. The employment of the bone-graft peg reduces this time by at least six months.

Technic.—A most careful iodin preparation of a wide field should always be made. The pubes should be shaved on the day before operation and other preparation started at that time.

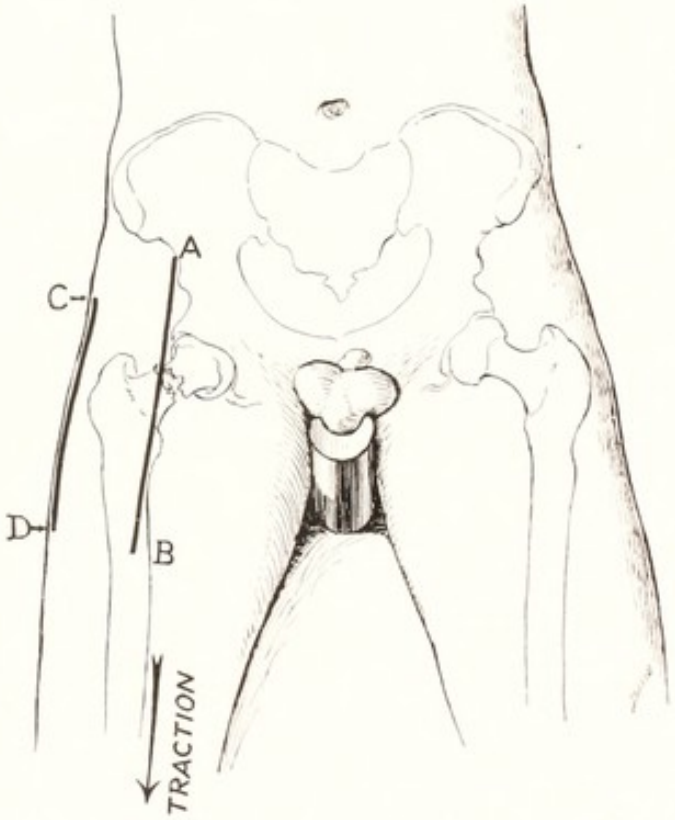


FIG. 343.—Drawing representing patient on author's traction table. *AB* and *CD* are skin incisions.

The patient should be placed upon some traction table which will permit simultaneous abduction and distraction. The point of fracture is approached by an incision beginning at a point one finger's breadth inside the anterior-superior iliac spine, curving downward to terminate at a point 3 to 5 inches below at the inner border of the sartorius (Fig. 343). The internal border of the latter muscle is exposed and retracted outward, as is also the tendon of the rectus femoris. The iliopsoas muscle is next exposed and retracted inward. The point of fracture is developed by blunt dissection, and all soft tissue is released from the interval between the fractured ends. The latter are then cureted and freshened.

The limb is now put under traction and sufficient abduction applied to bring the fragments into good apposition, as determined by inspection and palpation through the anterior wound. An incision 2 to 3 inches in length is next made over and just below the great trochanter, which is thus exposed

(Fig. 343). With a long hand-drill of small caliber, the proper direction for the motor-drill is determined by trial, as shown by observation through both wounds. The point of election for inserting the drill is at the base of the great trochanter on its external aspect, $^1/_3$ to $^1/_2$ inch below the trochanteric origin of the tendinous sheath of the vastus externus. This sheath is split for a distance of 1 to $1^1/_2$ inches, exposing the muscle fibers of the vastus externus, which in turn are split and the drill inserted. The exact point of insertion can be located by palpation, as a little depression just below the external surface of the base of the great trochanter. The drill hole should be situated in the center of the neck in both distal and proximal fragments and parallel to the neck.

The Drill Should Exactly Follow the Double Inclination of the Femoral Neck, i.e., Upward and Forward (Figs. 344 and 345).—The angle between the long axis

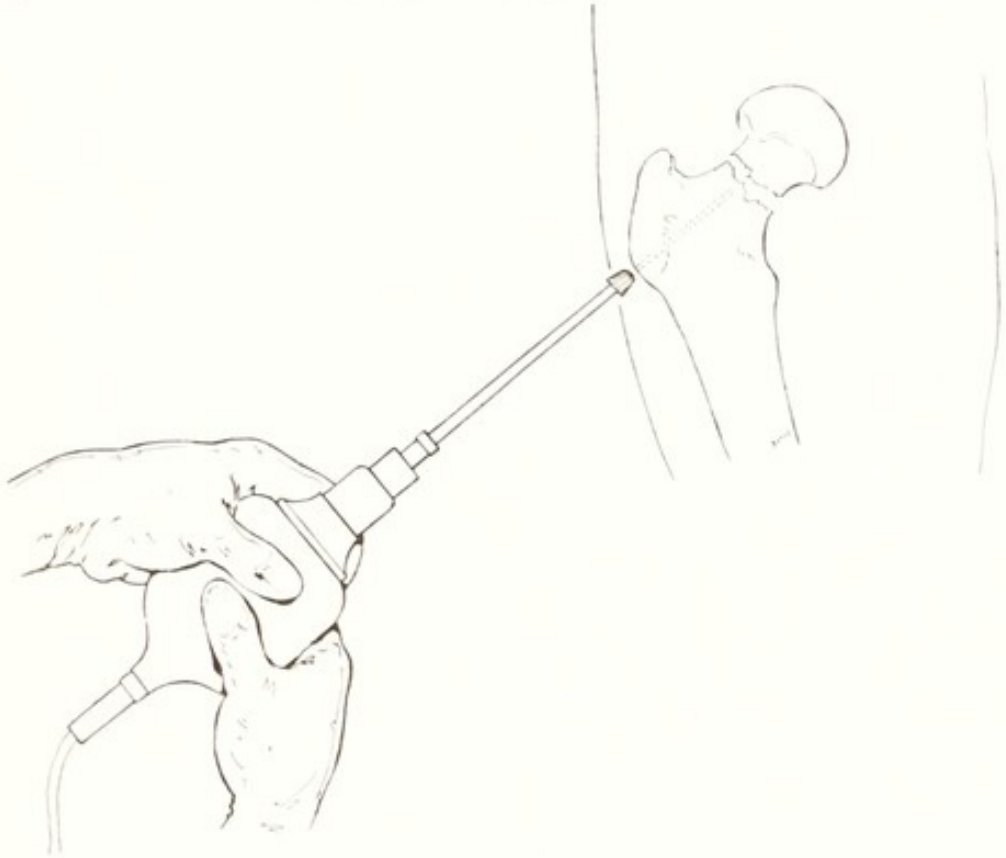


FIG. 344.—Insertion of motor drill into outer side of great trochanter at point determined by hand drill.

of the neck and the transverse axis of the condyle (the forward inclination) is in two-thirds of the cases 5 to 10 degrees, or, on the average, according to Piersol, 12 to 14 degrees. The angle between the neck and the shaft of the femur (the upward inclination) is, according to Rodet, 131 degrees in the child and the adult, and 128 degrees in the aged, or, according to Piersol, 110 to 144 degrees. Therefore, the drill must be directed approximately 12 to 14 degrees forward and 125 degrees upward, in order to have it pass without deviation from the proximal into the distal fragments. If these rules are not carefully observed, the drill will pass out below the distal fragment and emerge below the head, thus defeating the object of the operation. Variations in these angles of inclination can be determined with considerable accuracy by close scrutiny of the *x*-ray plate prior to and during operation.

The small hand-drill may have to be re-inserted in order to locate the proper track for the motor-drill. The motor-drill should be held ready by

the operator for insertion into the track of the hand-drill as it is withdrawn by the assistant. The motor-drill which forms a hole $\frac{1}{2}$ inch or more in diameter, is pushed through the distal fragment until the burr end of the drill appears between the fragments as determined by inspection through the anterior wound. Just as the end of the drill is engaging the broken end of the proximal surface, a reading is taken upon the graduated drill-shaft at its entrance aperture in the great trochanter, so that by comparing the initial reading with additional records subsequently taken, it can be determined just how deep the capital fragment is being penetrated (Fig. 345). By studying the radiogram, the length of this fragment can be very accurately determined, and hence the desired depth of the drill hole obtained. This distance is usually 4 to 6 cm. When the fracture has occurred near the head of the capital fragment and is consequently short, the drill hole should

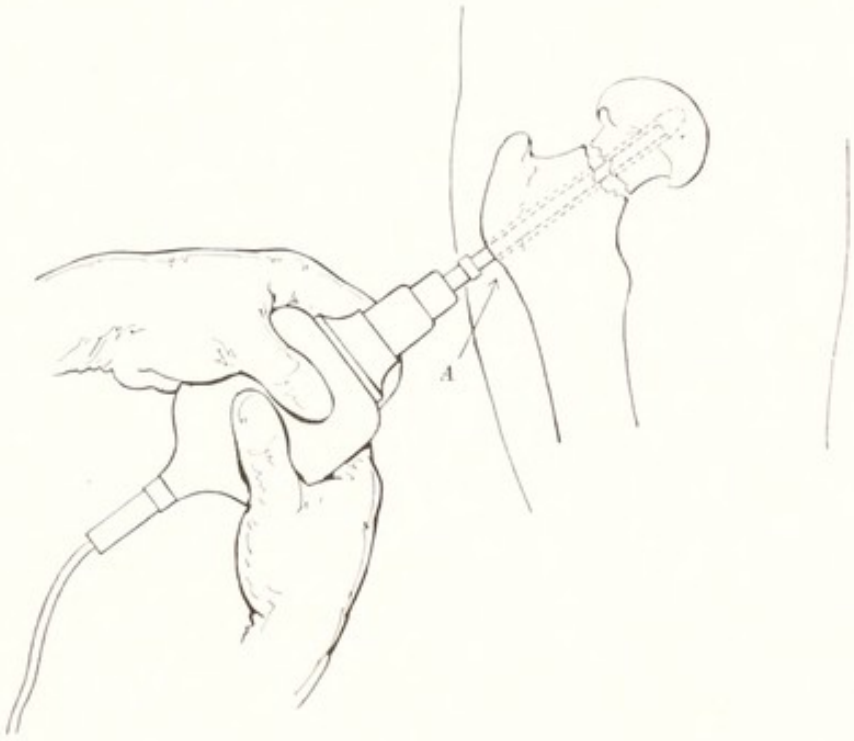


FIG. 345.—When the end of the burr has reached the space between the fragments and is ready to enter the capital fragment, a reading on the graduated shaft of the burr is taken at *A*, one is then able to tell by a study of the röntgenogram just how far the burr should penetrate this fragment.

extend close to the articular cartilage of the head. This total distance from the trochanter is usually about 6 to 8 cm.

The drill is disengaged from the motor and left in place in the femoral neck, to avoid any possible displacement of the fragments while the tibial graft is being procured.

The crest of the lower portion of the tibia (usually of the same side) is laid bare, and an area of the desired size and shape is mapped out on the periosteum with a scalpel. The desired length of graft can be determined by the graduated scale on the motor-drill. The cross-section of the graft should be just large enough to be shaped into the peg when the dowel-shaper is used.

It must be emphasized that the dowel-cutter should be large enough so that during the shaping of the graft a certain amount of periosteum and

marrow will cling to it. This necessitates a dowel-cutter with an aperture of at least $\frac{1}{2}$ inch in diameter.

The graft material having been obtained from the *crest* of the tibia, the dowel-shaper is placed in the motor, which in turn is set upon the instrument table close to the edge. The author's "pencil-sharpener" cutter (see Fig. 346) is now inserted in the dowel-shaper and while an assistant gently presses the belly of the motor and the dowel-shaper against the table, the

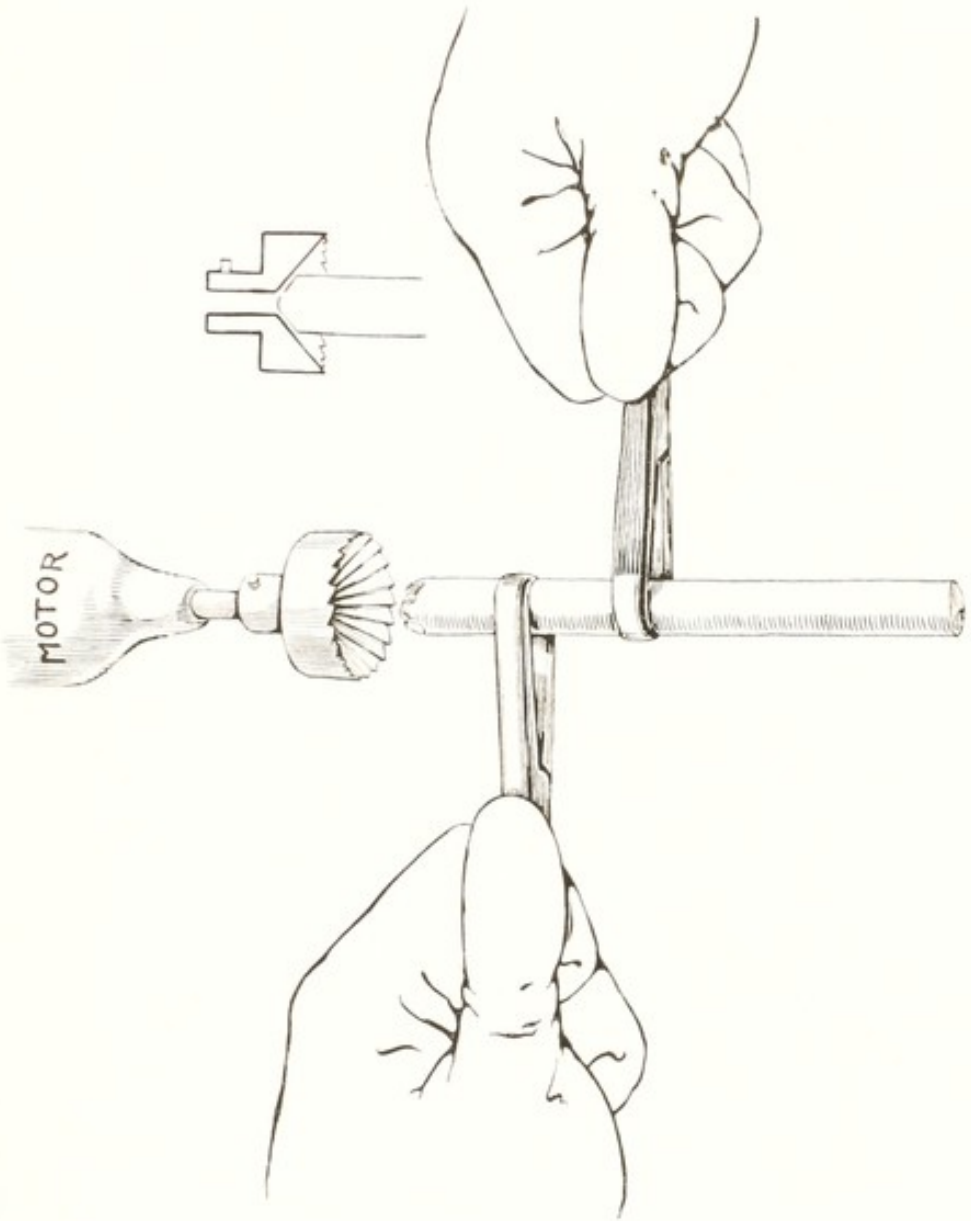


FIG. 346.—Author's rotary bone-peg "sharpener," for the production of a bluntly-conical tip on a tibial graft facilitating its introduction into the dowel-cutter and into the drill-hole in the femoral neck.

surgeon feeds the end of the graft into the "sharpener" while the motor is in action, thus producing a bluntly conical tip which facilitates the entrance of the graft into both the dowel-cutter and, later, into the drill hole in the femoral neck. The "pencil-sharpener" is now replaced by the dowel-cutter. The graft, held by one strong clamp or two smaller ones, is gradually pushed into the dowel-cutter while salt-solution is continually dropped upon it by a nurse from a large sponge saturated with the solution, or from the author's spray syringe (Fig. 347).

Since the author's publication of this operation in June, 1913, many operators have employed this technic. Some of them, however, have chosen to use an irregular piece of bone instead of the accurately shaped dowel-peg, with its glass-stopper fit, as described above. An example of this has been the use of the full diameter to half the diameter of the fibula, which furnishes a graft with corners and flat sides, which when driven into a round hole illustrates the old misfit of "a square peg in a round hole," and produces the following conditions: (1) the fragile cancellous bone of the femoral neck is crushed and compressed by the angles of the graft, thus obliterating

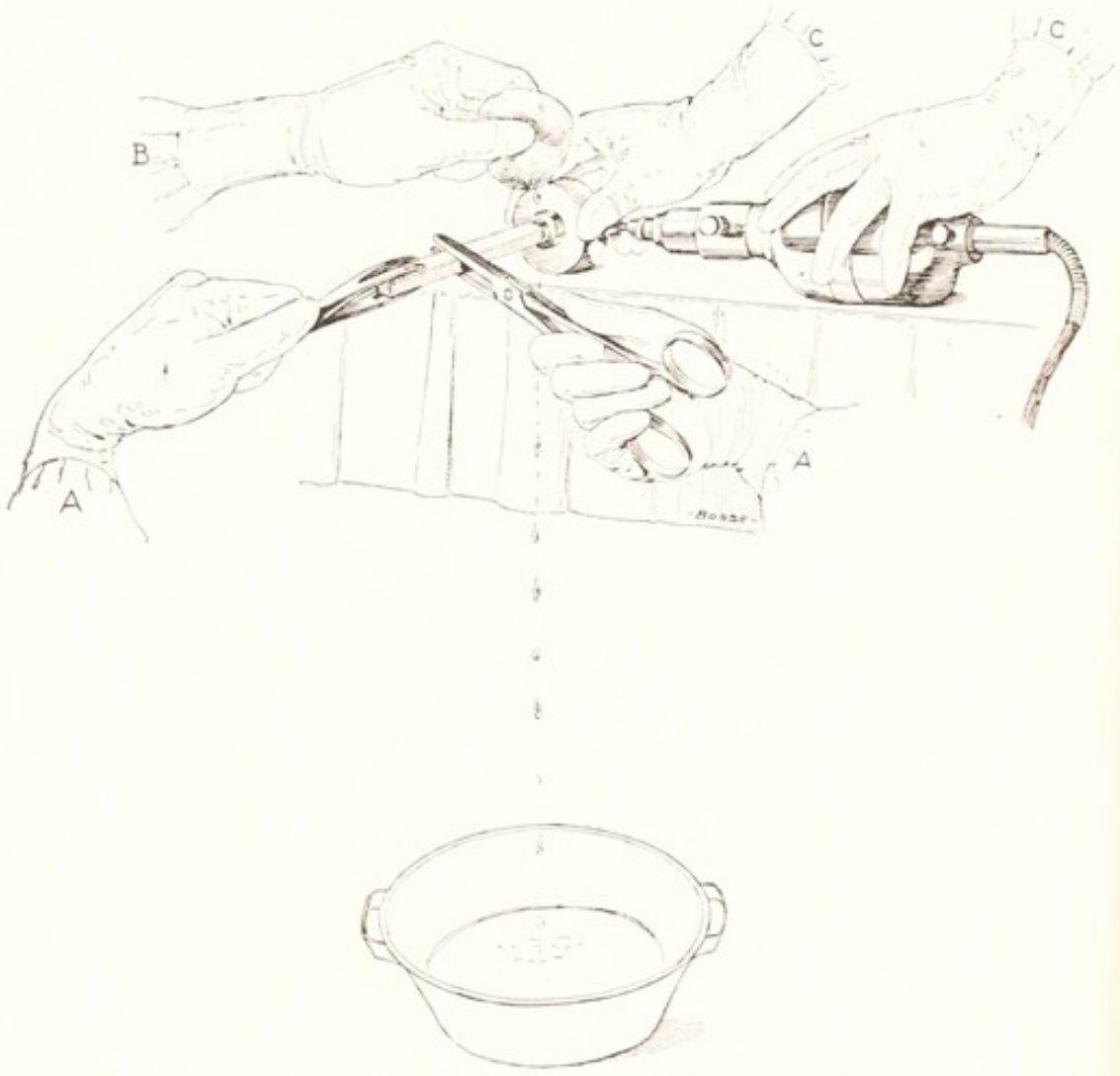


FIG. 347.—Author's motor-driven lathe. *A* is surgeon grasping and feeding the bone into dowel shaper. *B* is nurse supplying normal saline drip. *C* illustrates assistant's manner of holding the motor and the lathe securely upon the edge of instrument table while the dowel is being shaped.

blood-vessels and preventing access of nutriment; (2) between the flat surfaces of the graft and the curved surface of the drill hole in the neck, there exist "dead spaces," and one of two things happens, viz.: these spaces will be filled either with air temporarily or with blood-clot. In the former instance, blood-vessels are unable to traverse the air space. In the latter instance, they will be unable to extend from graft to neck until organization of the blood-clot takes place.

In strong contrast to these unfortunate conditions are the ideal circumstances attending the use of the doweled graft, viz., the fit is so accurate on

account of the machine work of dowel cutter, and drill, that the resemblance to a ground-glass stopper in a bottle is almost perfect, there is no appreciable space between graft and drill hole, and no compression to interfere with the immediate establishment of blood supply and nutrition. The conditions

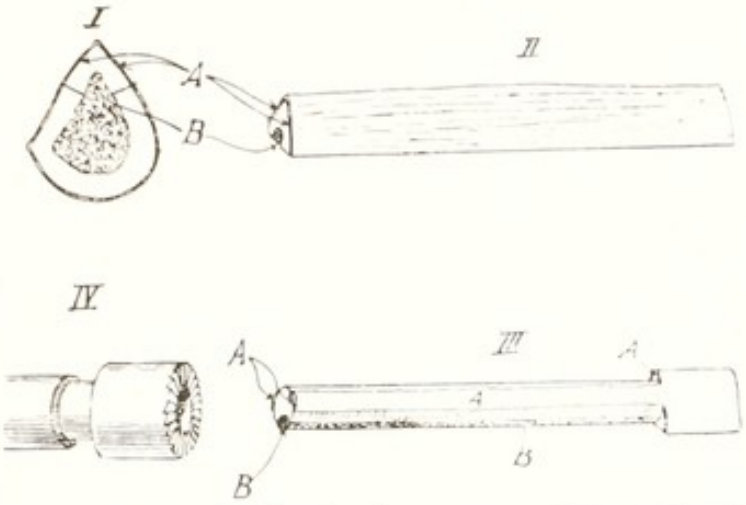


FIG. 348.—*I.* Cross-section of tibia, showing amount of bone taken from crest. *II.* Graft removed from tibia. *III.* Graft shaped into cylinder by dowel, showing 2 strips of periosteum and strip of marrow tissue. *IV.* Dowel shaper, which always should be of sufficient diameter so that periosteum and marrow substance will remain on the dowel graft.

are very favorable for the early budding of blood-vessels from host-bone to graft. Close approximation of graft and host is favorable for early bone-union. The glass-stopper fit prevents the synovial fluid from entering the neck and possibly having an inhibitory effect on new bone-growth.

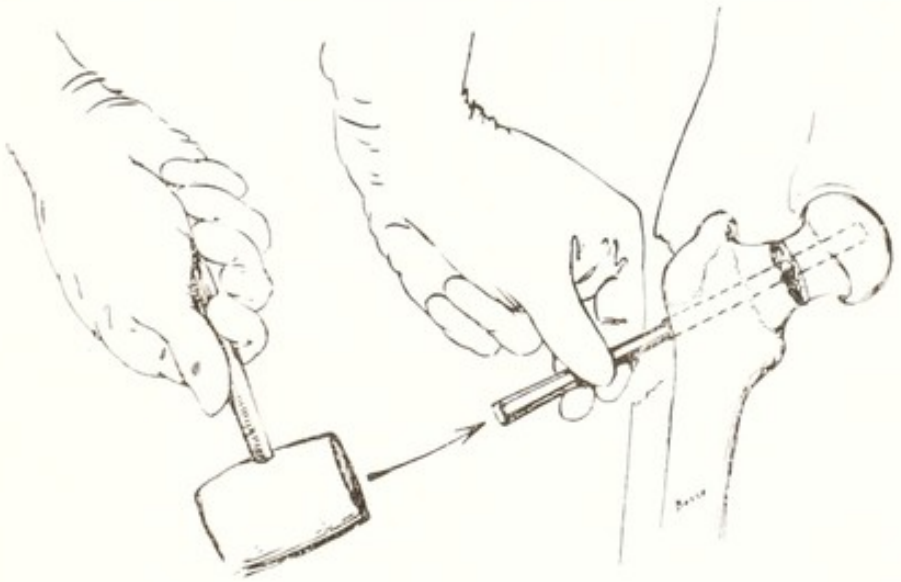


FIG. 349.—Bone-graft dowel-peg being driven home with author's "bone-set" instrument and mallet.

When the graft-peg is ready, the drill is withdrawn from the femur and the peg inserted. The fit must of necessity always be accurate because the dowel-cutter is the counterpart of the drill used. This accuracy of fit is very important. Too tight a fit is undesirable because pressure anemia of the surrounding cancellous bone would be produced. Too loose a fit or an irregu-

lar, inaccurate fit would not assure good fixation or favor immediate bony union between graft and host fragments.

The graft is driven home by means of the author's "bone set," which is an exact facsimile of the carpenter's nail set, and is used in exactly the same manner.

Before closing the anterior wound, fragmented grafts containing all the bone layers and obtained from the tibia are placed in and around the dowel graft in the slight interval which exists between the fragments of the neck, after which these fragments are artificially impacted by placing the tip of a large wooden mallet-handle against the great trochanter and striking the mallet head several strong blows with the palm of the hand.



FIG. 350.—With fragmented grafts (*A*) placed between the capital fragments and around the dowel graft, artificial impaction is being produced by placing end of the mallet handle at *B*.

The deep fasciæ are approximated with interrupted sutures of No. 2 chromic catgut; the skin wound is closed with a continuous suture of No. 1 plain catgut.

The limb is put up in abduction (Whitman's position) in a plaster-of-Paris spica extending from the toes to the axilla (Fig. 351). The amount of abduction varies in every case of pseudarthrosis of the neck of the femur. Whitman's directions to employ the limit of physiological abduction do not serve as an infallible guide in fracture of the femoral neck in such cases. It is the amount of erosion and the extent of loss of length of the neck which determine the amount of abduction to be employed. When the neck is very much shortened, abduction causes the tip of the trochanter to impinge on the side of the pelvis above the rim of the acetabulum, as the distal fulcrum point of a lever, and further abduction causes an increasing separation of the fragments of the neck. This, of course, is highly undesirable,

in that the ends of the fragments should be in close approximation. It is thus readily seen that the amount of abduction which should be employed in these cases is an individual problem, to be determined by inspection of the fragments while the wound in the capsule is open. The shorter the neck from erosion, the less should be the degree of abduction.

The long spica should be worn for six weeks and followed by a short one worn for an equal period. In muscular men, the abduction plaster may need to be supplemented by stickers applied to the limb and traction secured by this means. In fresh fractures, the period of support above prescribed is usually sufficient, but the surgeon should be guided by the *x*-ray in determining this question. Weight-bearing should not be allowed inside of six months.

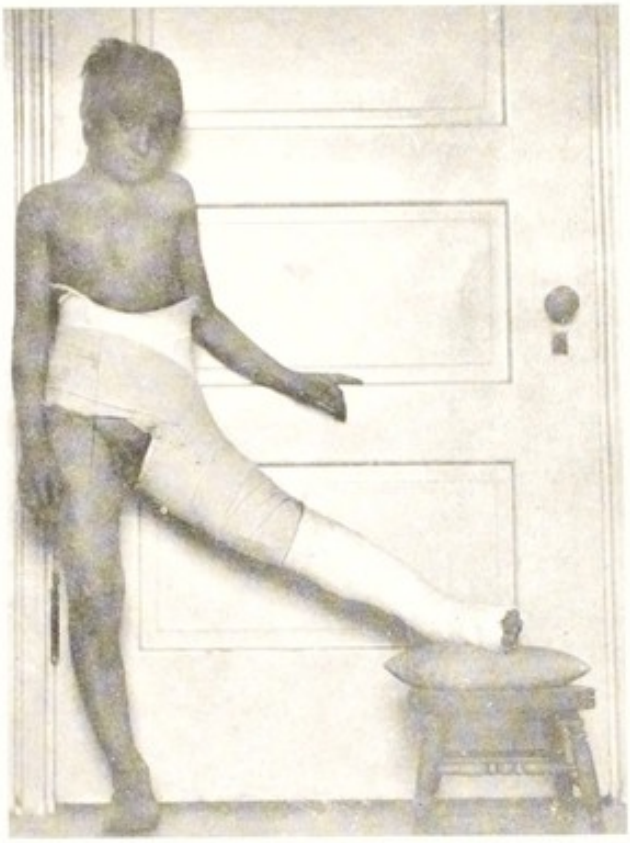


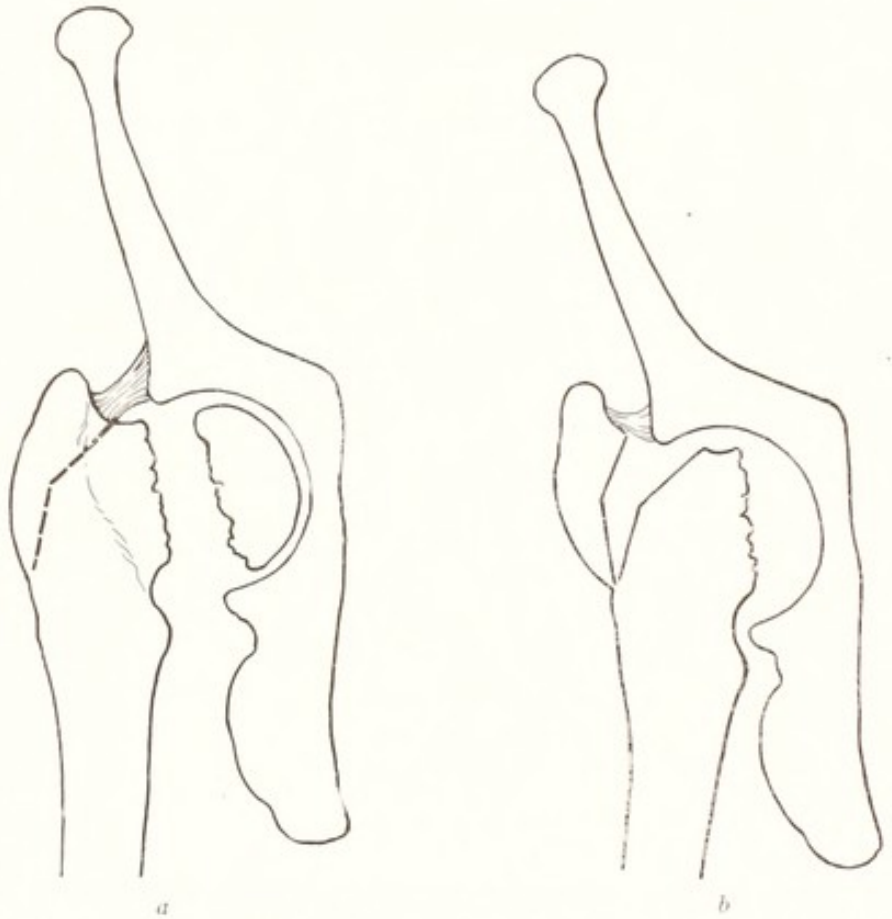
FIG. 351.—The abducted position, secured by long plaster-of-Paris spica splint, used in epiphyseal separation and in fracture of the neck of the femur.

Transplantation of the Head of the Femur to the Trochanter in Old Ununited Fracture of the Neck of the Femur.—Colonel Brackett has devised a very practical and ingenious operation for old fractures of the neck of the femur of long duration "when there has already been absorption of practically the entire neck of the femur and when the partly atrophied head consists only of the articular portion."

The technic is as follows: The joint is best exposed by the inter-muscular route, between the tensor fasciæ femoris and gluteus medius, by an incision from the anterior-superior spine to the middle of the trochanter, turning downward, parallel to the line of the femur for a few inches, then starting again at the angle of the oblique and vertical positions of the first, a curved incision is carried backward and upward 3 or 4 inches. The tensor fasciæ femoris and gluteus medius are separated, the muscle attachments on the outside of the trochanter are removed subperiosteally, or with a thin

bone attachment, and the top of the trochanter removed so as to save the attachment of the gluteus minimus and pyriformis. These muscles are then all turned backward and upward, and the upper and anterior portion of the capsule exposed, to the edge of the acetabulum. The capsule is opened longitudinally to its fibers, on the upper portion of its anterior surface, saving the attachment of the Y-ligament, if possible, which, however, cannot always be done.

The capsule above the opening is then detached from the femur and retracted outward and backward; the trochanter is cut off just below the level of the upper edge of the head, and the inner portion is rounded to correspond to the curve of a $1\frac{1}{2}$-inch to 2-inch radius, saving the anterior and inner



a *b*

FIG. 352.—Old ununited fracture of the neck of the femur with erosion of most of head and neck and with marked osteoporosis of the remaining shell of the head. The trochanter is separated with osteotome (as shown by dotted lines (*a*)) and forced outward with the overlying soft structures below as a hinge. The removal of the head then allows the neck to be displaced into the acetabulum (*b*).

cortex. The outer portion is either cut off obliquely, or a wedge taken out, near the outer surface, allowing the outer cortex to be pushed inward. The free surface of the head is thoroughly freshened, covering this area, so as to make a corresponding curve to the rounded top of the trochanter. In abduction of the leg, the convex surface which has been fashioned on the trochanter, is brought directly into the concave head, and in this position is firmly held against it. In this way the femoral head with its freshened surface is placed directly on the freshened cancellous surface of the trochanter, an ideal condition for the vitalizing union of the poorly nourished fragment. The head is not placed directly on the top of the trochanter, for this would not allow the best position in the acetabulum, but on the inner and upper

sides, which gives to it a somewhat oblique angle, partly resembling its normal direction, but without the normal neck. The stitches are placed in the capsule but not tied until the leg is put into position of abduction, and the head seen to be in the relation to the end of the trochanter which is desired, in order that this contact can be assured, and the position of the leg is then maintained until the plaster is applied. The stitches are then tied and the outer attachment of the capsule which has been freed is secured with the muscle attachment. The attachments of the gluteus medius and minimus, and pyriformis, are either secured to the outer side of the trochanter, or are inserted into the wedge-shaped depression, which has been

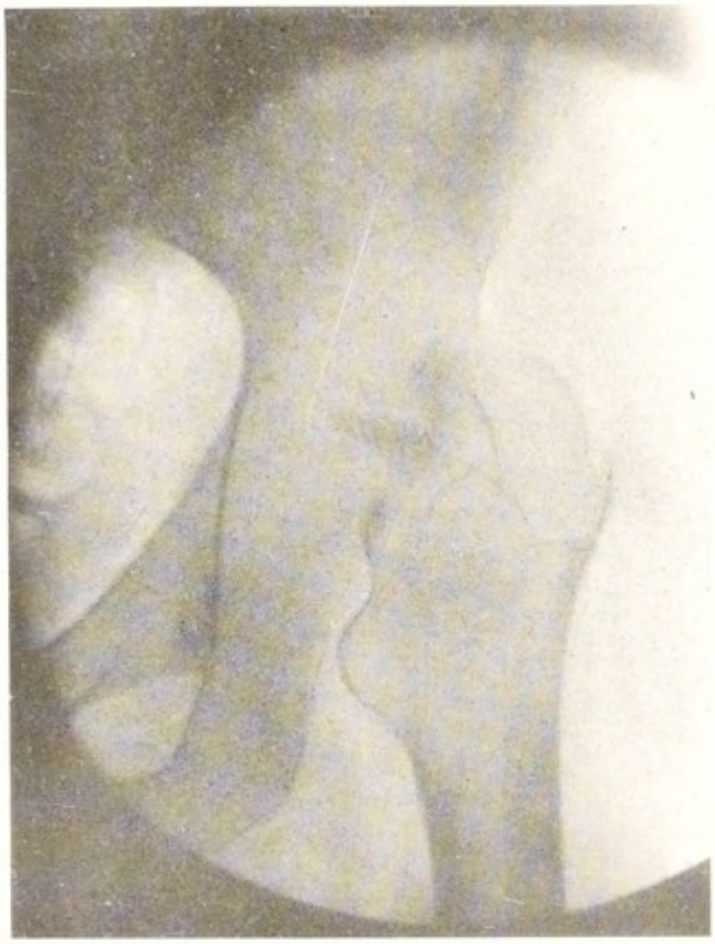


FIG. 353.—Old ununited fracture of neck of femur, close to head. Rarefaction of head which was removed and the stump of the neck introduced directly into acetabulum. (See Fig. 352.)

made, in order to round off its upper and outer end. The wound should be tightly closed in layers, a plaster spica is applied, including the foot of the affected, and the other leg, to the knee, and extending well up to the lower thorax on the opposite side from the operated leg. As a rule, the extreme degree of abduction is not required, and less inversion than in the Whitman method with the fresh fractures. This fixation is maintained for eight to ten weeks, fixation with an ambulatory plaster, but without weight-bearing for about two months more, and beginning weight-bearing with active motion at the end of this period. The ideal treatment would seem to be fixation by removable plaster at the end of the first eight or ten weeks, with beginning massage and gentle passive motion; but unless this can be carried out with very intelligent precision, the complete fixation is the safer plan. The bone contact between the two fragments cannot be made over the entire surface

of the head, so that considerable bridging in of new bone is necessary, for which sufficient time must be allowed, and a change in the angle of union between the trochanter and head has been observed after too early motion or strain. The motion must be brought back slowly, for the capsule must be partly newly formed and newly attached, and a considerable amount of flexibility must be developed before all the potential motion can be expected. There is no diminution in the shortening, or at least not a practical amount, for there is too much adaptive contraction of all structures to allow any decided change in the relative position of the leg to the pelvis. A greater range of motion, however, is possible than might be expected, an entirely practical amount of flexion abduction and rotation results. The amount of this depends somewhat on the oblique position of the head on the trochanter, and on the rounding off of its overlapping portions.

FRACTURE OF THE PATELLA

Fracture of the patella is of two kinds: (1) transverse, and (2) vertical, irregular, or comminuted. The subjects are usually adult males.

1. Transverse Fracture

This type is usually the result of muscular action, and usually occurs in the effort to prevent one's self from falling. With the knee bent at an angle of 60 to 90 degrees and the ligamentum patellæ taut and drawn tightly against the femoral condyles, the pull of this, the largest muscle in the body, is suddenly exerted with full force at its insertion on the top of the patella, fracturing the latter and tearing the lateral expansions of the quadriceps tendon. The degree of separation of the fragments varies; there is always considerable, and there may be extreme, separation, the upper fragment sometimes being drawn up to the middle of the thigh.

The line of fracture is regular and almost exactly transverse. After the accident, tags of torn periosteum and fascia fall in between the fragments and quickly become adherent. The fragments are often rotated forward or backward on their transverse axis. Long-standing cases have an elongated fibrous band connecting the fragments.

Although the patient can walk, he does so with difficulty, swinging the leg forward and locking it in hyperextension before putting his weight upon it, but in some cases pain prevents the patient from walking and also from lifting the foot when lying down.

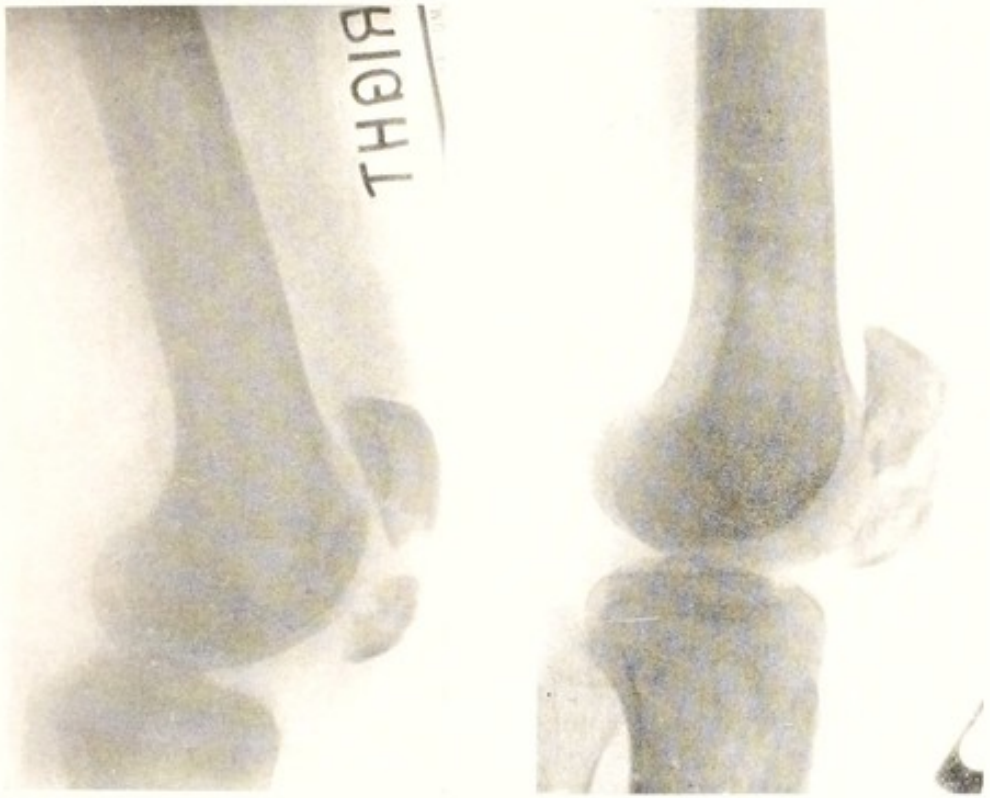
The diagnosis of transverse fracture is evident at a glance upon inspection of the radiogram. Clinical diagnostic features are: (*a*) inability to extend the leg, to raise the foot from the bed while recumbent, and voluntarily to straighten the flexed knee; (*b*) rounded swelling of the knee, the result of effusion; (*c*) palpation of the fragments, the interval between them, and their mobility.

This fracture occasionally requires differentiation from rupture of the quadriceps and from rupture of the ligamentum patellæ or tearing out of its insertion, viz.,

1. *Quadriceps Rupture.*—The patella can be moved downward *in toto*, leaving a palpable gap *above* it, at the site of rupture.

2. *Rupture of the Ligamentum Patellæ or Avulsion of its Insertion.*—The patella can be moved upward *in toto*, leaving a gap *below*, at which point the signs and symptoms are localized.

Treatment.—*Autogenous Bone-graft for Ununited Transverse Fracture of the Patella.*—The usual treatment for fracture of the patella consists of exposing the line of fracture and uniting the fragments with either absorbable or non-absorbable sutures. Formerly, metal wire, such as silver or phosphor-bronze wire was used; but recently, and partly due to the author's efforts,[1] the surgical pendulum has been swinging away from nonabsorbable material and kangaroo tendon has been largely used. The metal wire formerly used was, as a rule, either placed in a drill hole in each fragment, or in such a way as to encircle the patella. The degree of separation of the fragments depends largely upon the amount of laceration of the capsule and connective tissue on either side of the patella. Muscle-pull may interfere



a *b*

FIG. 354.—Transverse fracture of patella. *a*. Before operation, showing separation of the fragments when the knee is flexed. *b*. After approximation of the fragments and insertion of an inlay tibial bone-graft which can be plainly seen bridging the cleft between the fragments.

with the union of the patella fragments, however carefully the clots and fibrous material are cleared from between them or whatever may be the material used to hold the fragments in close apposition. Not infrequently a refracture occurs, either immediately or remotely after operation, in spite of every precaution. Fibrous union, with a varying degree of separation of the fragments and a proportional amount of disability in the extremity, is a more frequent unfortunate result. To remedy either of these conditions, Rogers has suggested that an autogenous bone-graft be taken from the crest of the patient's tibia and implanted on the front of the patella to bridge the line of fracture. It is believed that this is an important step and that it offers a trustworthy means of relieving this condition. It would seem, however, that Rogers' technic can be much improved by using the author's inlay method, which he has not only applied to relieve fibrous union and refracture,

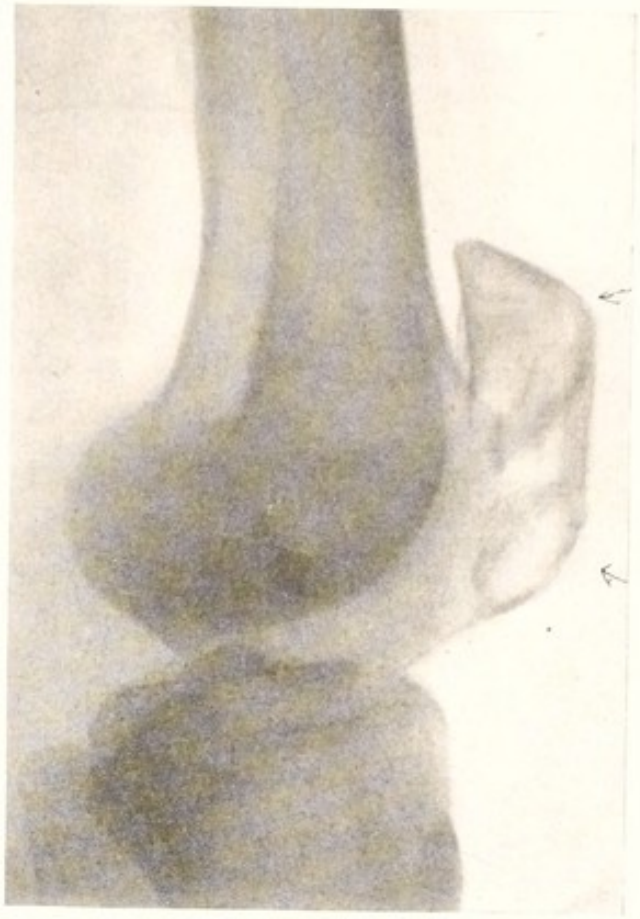
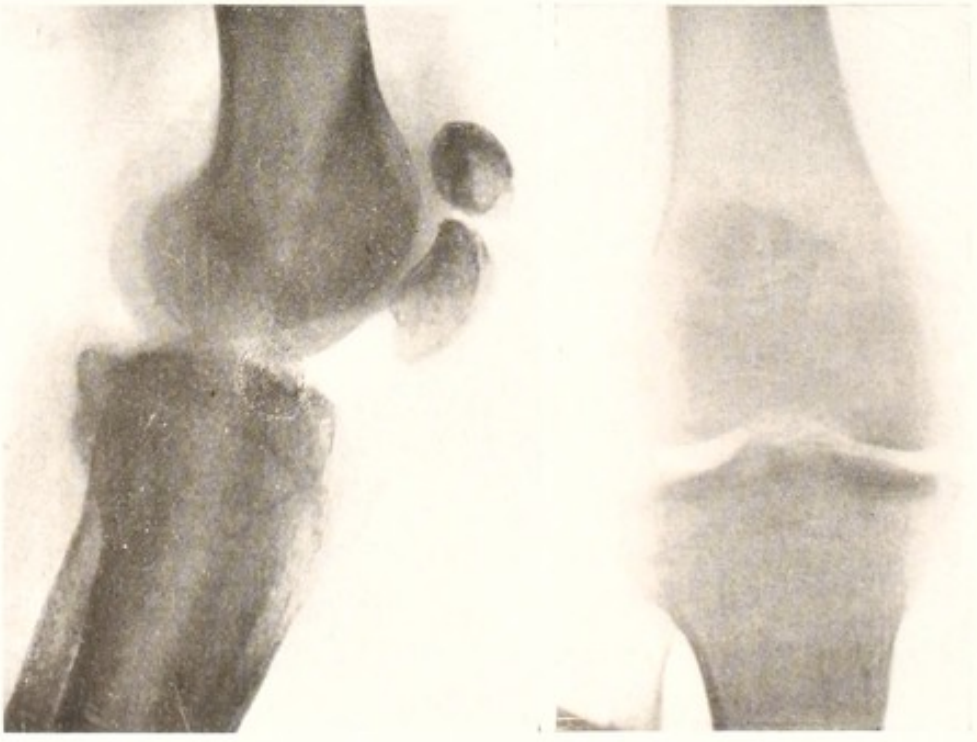


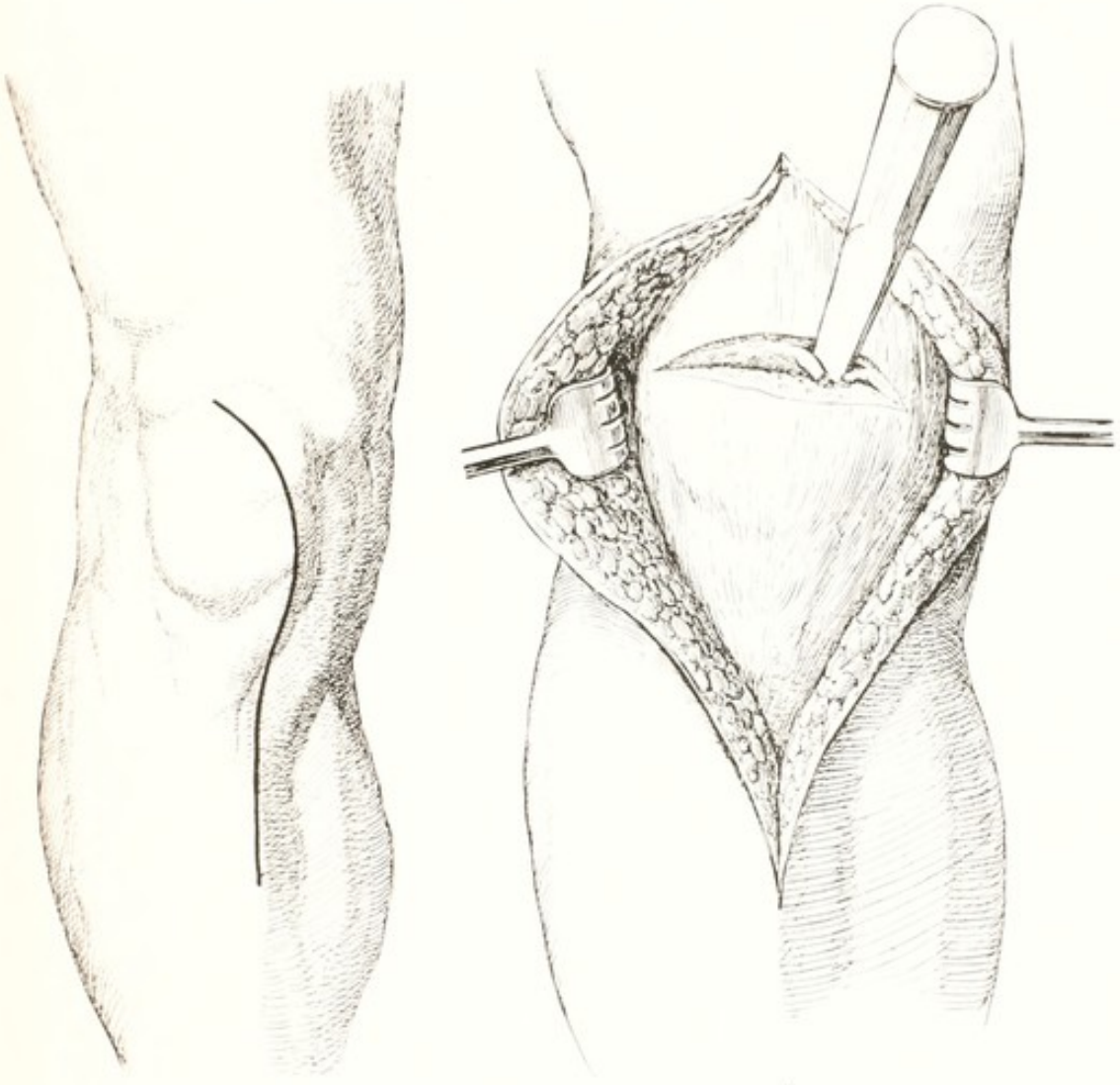
FIG. 355.—Later view of same case shown in Fig. 354. The inlay bone-graft has undergone considerable hypertrophy. Proliferation of new bone is well marked at the extremities of the graft, indicated by the arrows.



a *b*

FIG. 356.—Transverse fracture of the patella. In *a* the fragments had been held together by silver wire in an unsuccessful attempt to secure union. *b*, After operation by the author with insertion of his "double-T" inlay bone-graft, the outlines of which can be seen in the patella.

but which he offers as a means of securing immediate and solid bony union in certain fresh fractures of the patella (see Figs. 359 to 364). In other words, the inlay graft is a reliable preventive of fibrous union and refracture, as well as a remedy for those conditions when they already exist, and it obviates the employment of a foreign body. Besides affording slight and imperfect contact, a graft placed on the anterior surface of the patellar fragments is likely, on account of its superficial location, to produce pressure necrosis of the soft overlying tissues (see also Fracture of the Clavicle, Chapter XVII).



a *b*

FIG. 357.—*a*, Incision for approach in non-union of the patella for the insertion of a graft from upper end of tibia. *b*, Removal of fibrous union.

Technic.—As in all bone-graft operations on the extremities, a tourniquet is applied to the upper portion of the thigh. The fracture fragments are approached by a U-shaped flap, the apex of whose convexity lies over the ligamentum patellæ, its base over the femoral condyles. All fibrous tissue between the fragments is carefully removed; in the case of refracture or fibrous union, the fragment ends are freshened. The fragments are approximated, and the lateral rents in the fibrous capsule are repaired at the sides with interrupted sutures of small kangaroo tendon. The central portion of the anterior surface of the patella is then denuded of its periosteum and

peri-osseous tissues by turning back laterally flaps of these structures on each fragment.

An outline of the bone to be removed, about one and one-fourth by three-fourths of an inch, is made on the anterior surface of the patella with



Fig. 358.—Ununited fracture of the patella in which union has been secured by a double cross-shaped tibial graft, which is seen in place in anterior part of patella. This is same case as Fig. 356.

the point of a scalpel. With the small motor-saw, cuts are made to a depth of one-third of an inch along the outlines already made. The fracture surfaces of the fragments are tilted forward and with the small motor-saw

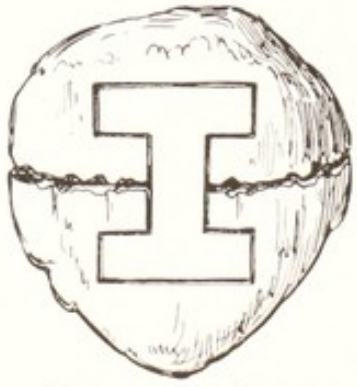
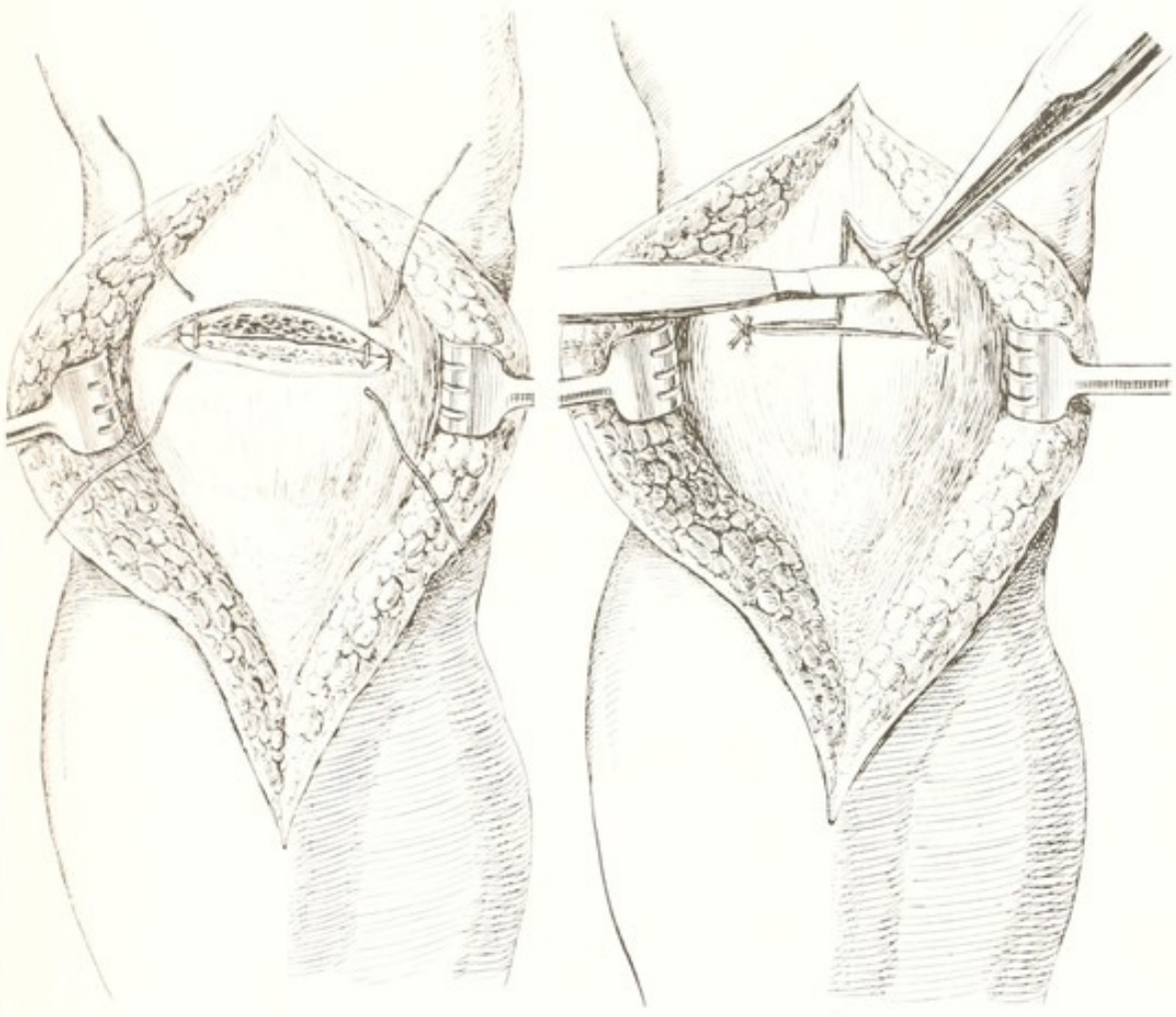


Fig. 359.—Type of the inlay graft applied to fracture of the patella.

and a narrow, thin, sharp osteotome the bone within the previously made saw-cuts is removed to a depth of one-third of an inch from the anterior patellar surface.

With the patellar fragments in good apposition, careful measurements

are made of the inlay gutter with calipers. The antero-internal surface of the upper portion of the tibia, where the surface is broad and the cortex thin, is exposed and, by means of the caliper measurements or a wax model of the gutter in the patella, the outline of the inlay graft required is made in the periosteum. The cortex in this portion of the tibia is of the proper thickness for the graft. The inlay is inserted with its periosteal surface anterior, and the periosteal flaps of the patella are pulled over it with interrupted chromic catgut sutures. The rents in the capsule are then sutured with kangaroo tendon as far as the sides of the patella. To insure greater fixation, the



a *b*

FIG. 360.—*a*, Placing of kangaroo sutures with aponeurosis at the outer edge of the patella for the purpose of holding the fragments together while inserting the graft. *b*, Separating the periosseous structure from anterior surface of patella.

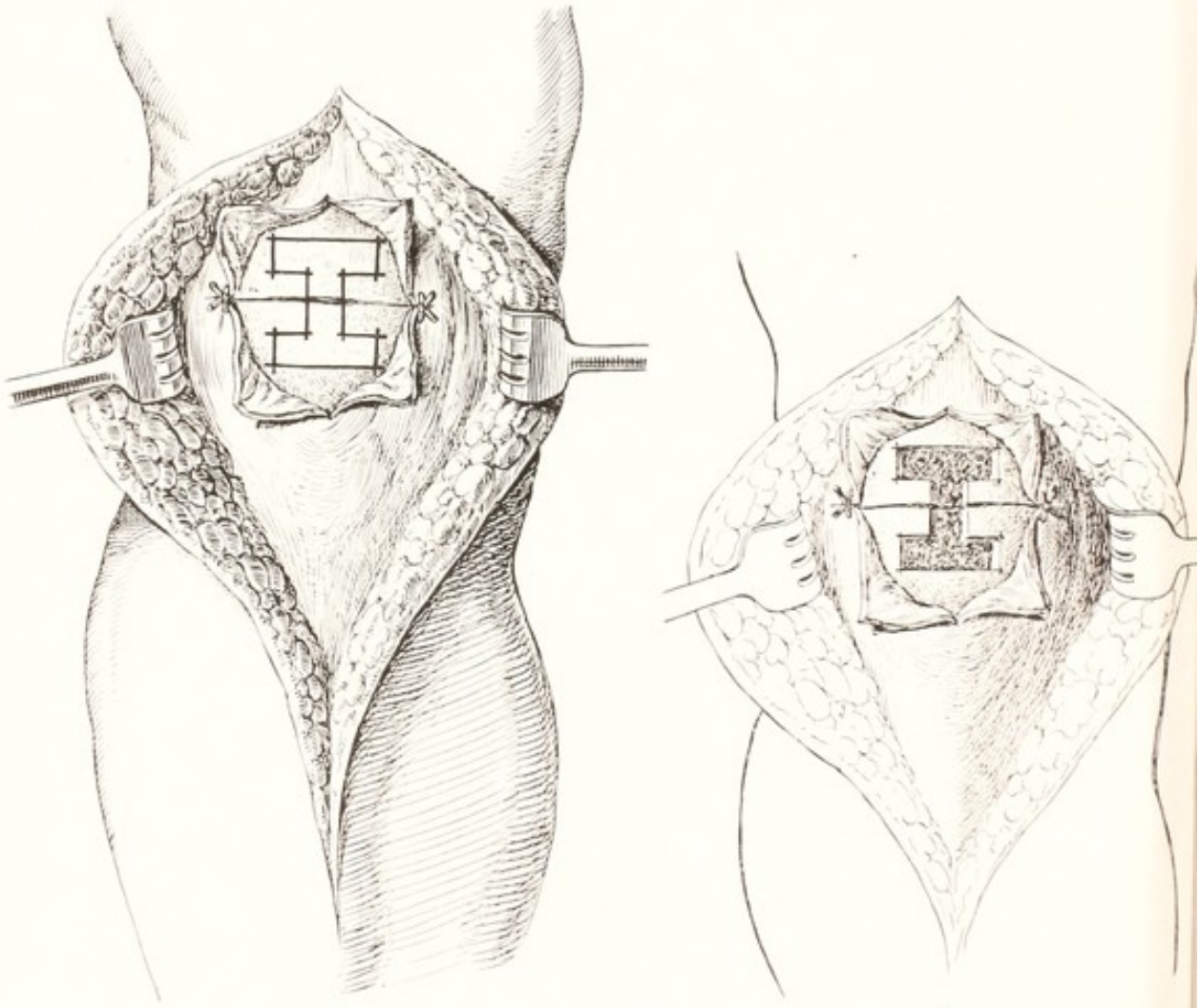
fragments are securely held by a figure-of-8 suture of medium-sized kangaroo tendon passed laterally to the anterior portion of the ligamentum patellæ and quadriceps tendon, directly above and below the fractured bone, crossing in front of the transplant. The skin incision is closed by a continuous suture of No. 1 plain catgut. The limb is immobilized in a plaster-of-Paris splint for four weeks.

This operation is of the greatest advantage where there have been a fibrous union in an old case and a separation of the fragments coincident with a shortening of the quadriceps tendon and muscle, and when the fragments cannot be brought into close apposition this space can be spanned by a long graft, which, as the result of hypertrophy, will entirely, or to a large degree,

fill in the hiatus between the fragments. It is advisable to stimulate osteogenesis by placing fragmented grafts about the inlay.

2. Vertical, Irregular, or Comminuted Fracture of the Patella

This type is due to direct trauma, usually a fall. There is little, if any, separation of the fragments. The lines of fracture are irregular, and may be ragged. There is no interposition of soft tissue between the fragments, as in the case of transverse fracture. The fracture is frequently compound.



a *b*

Fig. 361.—*a*, Saw cuts made with author's small motor-saw for the purpose of forming inlay cavity for the reception of the graft. *b*, After removal of bone between saw cuts to depth of about $\frac{1}{3}$ of an inch.

The diagnosis of this type depends chiefly on radiography, in the absence of which pain, loss of function, localized tenderness, mobility of the fragments, and the very small interval between them (in contradistinction to the wide gap between the fragments in the transverse fracture) are sufficient.

Treatment.—These cases, due to direct trauma with little or no separation of the fragments, do well under immobilization in a plaster-of-Paris splint from toes to groin continued for a period of five to six weeks. Or a posterior wire splint can be used with the leg strapped to it and elevated on pillows to relax the quadriceps, and with coaptation splints applied to the

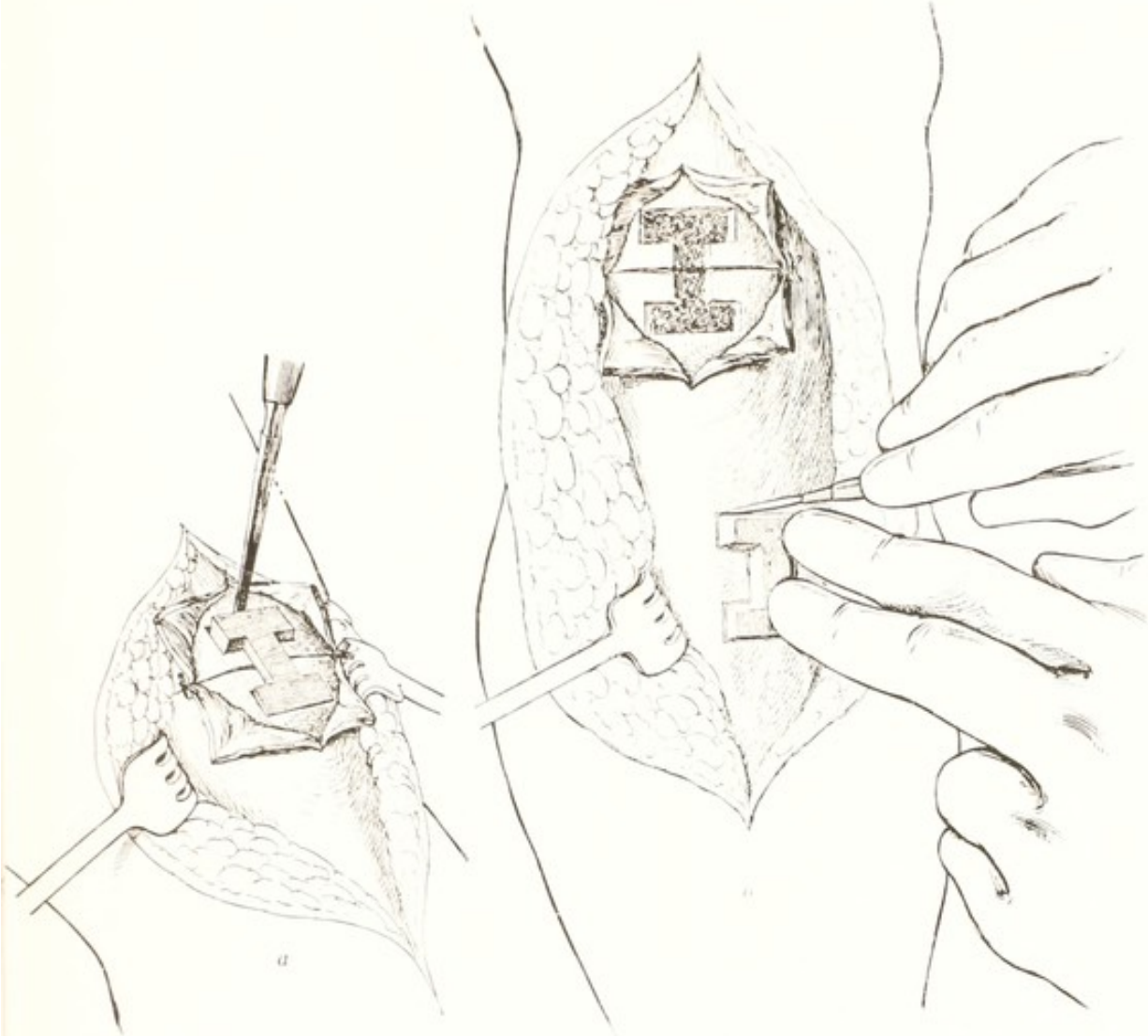


FIG. 362.—*a*. Obtaining mould of proposed graft in sterile paraffin softened in hot water bath. *b*. Mapping out proposed graft in periosteum of upper end of the anterior-internal surface of the tibia.

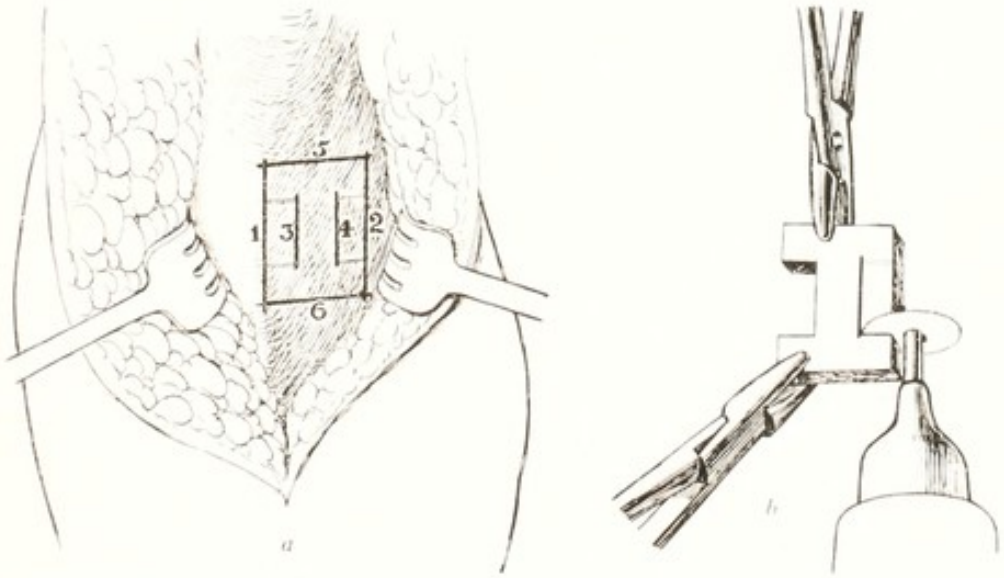
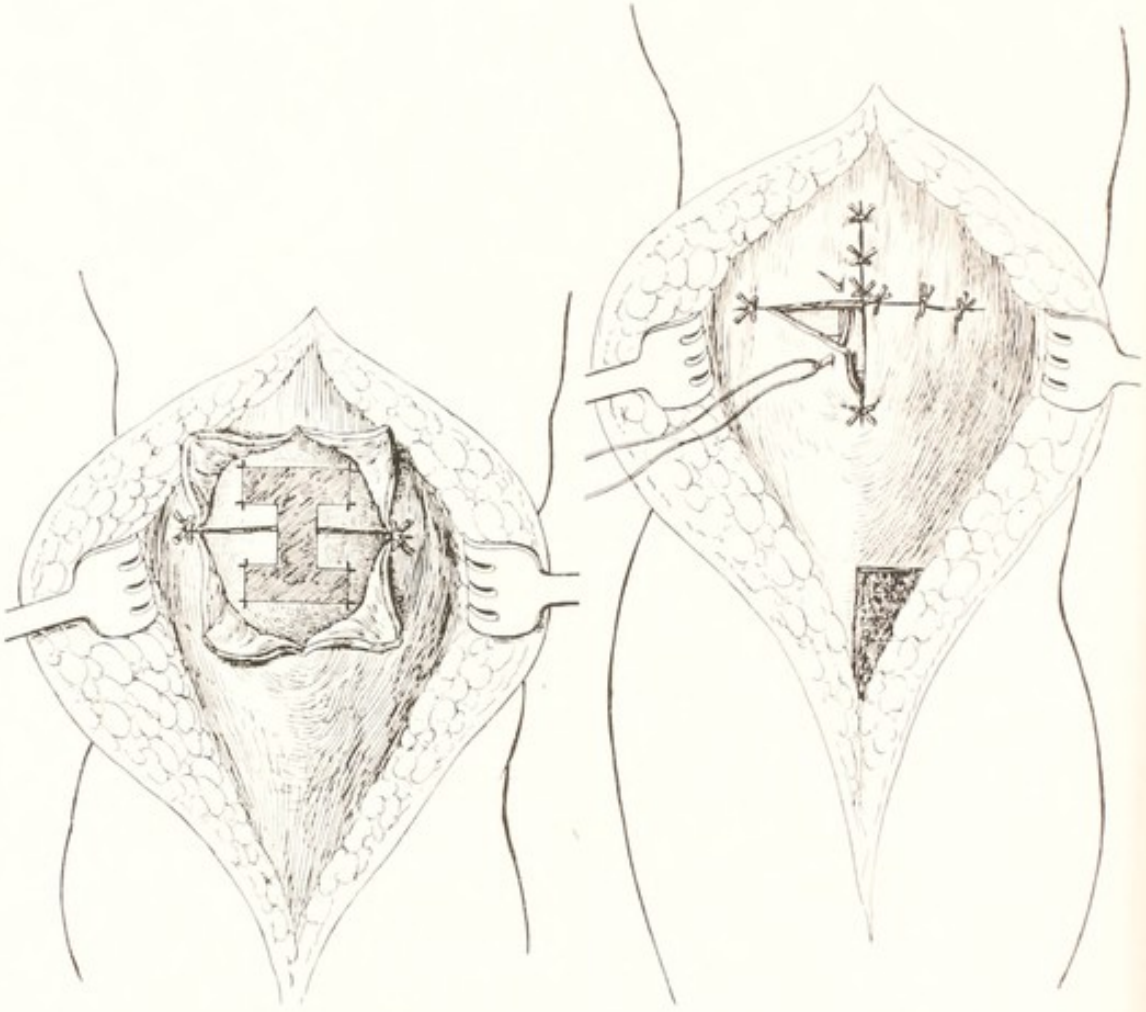


FIG. 363.—*a*. With author's small motor saw cuts 1, 2, 5 and 6 are made through the cortex and a quadrilateral piece of bone removed. *b*. Following the pattern the graft is further trimmed into the shape of a double T.

front of the thigh, to insure its relaxation. At the end of five to six weeks the patient can get about on crutches with a light posterior splint on the leg, and massage combined with very light passive motion may then be instituted. Weight-bearing should be cautiously used, at first without flexion.



a *b*

FIG. 364.—*a*, Graft in place. *b*, The placing of interrupted sutures of fine kangaroo tendon with dense periosseous structure overlying patella is usually sufficient to hold the graft in place.

FRACTURE OF THE OLECRANON

This not uncommon fracture is due either to direct trauma (the usual cause) or to overactivity of the triceps. In most cases the fracture is cleanly cut and transverse, and there may be considerable separation of the fragments (Fig. 365). In children the fracture may result from a fall on the elbow.

The symptoms consist of loss of extensibility of the forearm, of varying degrees of severity. With the forearm extended, mobility and crepitus may be obtained by grasping and moving the olecranon. Radiography offers the most certain means of diagnosis.



FIG. 365.—Ununited fracture of the olecranon of eight months' duration following operative fixation by silver wire. The resultant loss of bone substance is considerable.

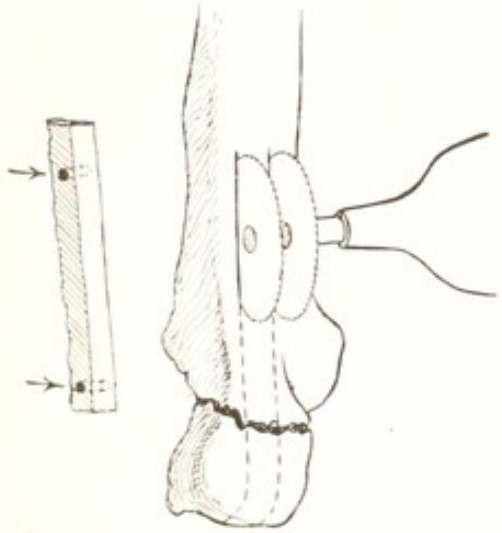


FIG. 366.—Technic of sliding inlay graft for fracture of the olecranon process. Arrows indicate drill hole in graft.

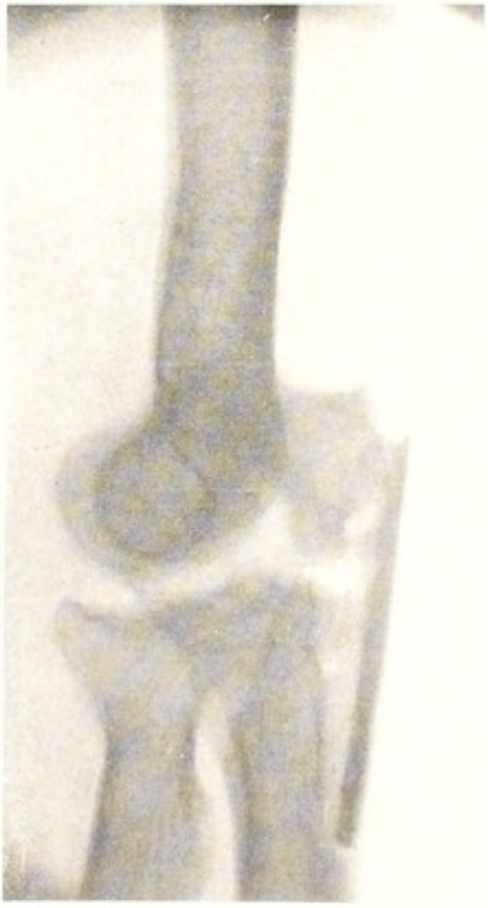


FIG. 367.—Ununited fracture of the olecranon following operation suture eight months before a tibial graft was inlaid and the extensive hiatus between the olecranon fragments was filled with fragmented graft. Complete union and filling in of hiatus is shown.

Treatment.—In fresh fractures of the olecranon, exposure by incision, drilling the fragments, and the insertion of kangaroo tendon for their fixation is believed to be the best method of treatment. In ununited fractures of this process, the inlay graft, held in place by kangaroo tendon, can be easily applied on account of the superficial location of the olecranon, and promises better results than those offered by any other procedure. The graft is inlaid to the tip of the olecranon, on the one hand, and as far into the shaft on the other as the amount of bone sclerosis indicates (Figs. 366 and 367). A sliding graft, or one obtained from the tibia may be used, as conditions indicate; or a peg graft may be used instead of the inlay, as the surgeon may elect. For this particular fracture, the peg should be made with a generous head; this can easily be done by not pushing the graft completely into the dowel-cutter. The forearm is flexed, and the insertion of the triceps into the olecranon split in equal halves down to the bone; the center of this end-surface of the olecranon is then selected and a drill hole (using the proper-sized drill) is bored completely through the olecranon fragment and into the long (shaft) fragment of the ulna for a distance of approximately 1¼ inches. The drill is then withdrawn, and the peg (about ¼ inch in diameter) driven home.

HABITUAL DISLOCATION OF THE PATELLA

The affection is encountered chiefly in females, and is usually unilateral. It may be congenital or due to weakness of the rectus femoris, or to underdevelopment of the patella. The usual etiological factor is defective development of the external condyle, probably of congenital origin, so that it allows the patella readily to slip over it. Some cases are of traumatic origin. In still others, the presence of knock-knee causes the ligament and patella to lie more externally than normal, and thus predisposes to slipping.

If the dislocation recurs with great frequency, there is very little associated pain. If the tendon is under increased tension when slipping occurs, there may be effusion into the joint. Dislocation is induced by a misstep or sudden movement, with the quadriceps muscle relaxed (such as suddenly turning around), or on extreme flexion of the leg (such as sitting down or squatting). The insecurity and consequent weakness are a source of the greatest mental distress, particularly to women of nervous temperament.

Treatment.—The usual direction of congenital or habitual dislocation of the patella is outward, and the external condyle is often found to be on a horizontal plane relatively much below that of the internal condyle, thus giving the appearance of rotation of the lower end of the femur, so that the external condyle is farther back and the internal condyle farther forward than normal. When the leg is extended, the patella usually takes its normal position between the condyles, but upon flexion is found to be displaced outward, and even to lie over the external condyle or somewhat external to it.

Various methods have been devised to correct this displacement, but of the procedures which have been practised those where correction was attempted by using the soft tissues have been far less successful in securing permanent control than those where the correction was attempted by providing bony obstruction to redislocation.

Krogius (Zentralbl. f. Chir., Mar. 5, 1904) reports 2 cases (one double) in which it was evident that the patella was drawn outward by the tense outer portion of the capsule, against which the relaxed and stretched inner portion offered but weak resistance. He devised the following operation for controlling the displacement:

The first step is the approach to the knee by Kocher's incision. Second, an incision is made extending from slightly above the patella down a few inches in front of its outer edge to the insertion of the ligamentum patellæ through the iliotibial band, tendinous expansion of the vastus externus and fibrous capsular wall. Third, the formation of a bridge-shaped flap on the inner side of the patella, connecting below with the tendinous expansion of the vastus internus and fibrous capsule and above with muscle and fascia. Fourth, the transplantation of the flap, left attached at both sides, across the patella at its outer edge.

In the first case, after six months the patella again began to slip outward, although complete dislocation did not occur. In the second case, the result was perfect after three months.

Whitlock (Brit. Jour. Surg., July, 1914) states: "Outward luxation of the patella may be the result of direct violence applied to the inner edge of the patella, but quite as often follows sudden muscular action."

Knock-knee, undue laxity of the ligaments, especially of the capsular, and more particularly a deficiency of the external lateral ridge of the external condyle, all predispose not only to the occurrence but to the recurrence of the disability. A sudden muscular contraction with the leg extended or in mid-flexion, especially if the knee is inverted and the foot and leg are everted, is sufficient cause for displacement. Eversion of the leg brings the insertion of the ligament further out, and affords a straighter pull for the extensor muscles. Reduction is generally easy.

The advice of the text-books is to extend the knee, fully flex the thigh to relax the rectus, manipulate the knee-cap by pushing it medially, at the same time correcting any rotation. The quadriceps with the knee extended, may be pulled down to aid relaxation. If these manipulations fail, they may often be successful with the joint in slight flexion instead of extension.

Recurrence may happen only occasionally, usually unexpectedly in the course of flexion, or it may occur very frequently, the patient learning to replace it himself. Such repeated recurrences in time produce a relaxed, weakened, and uncertain joint. The recurrence may be prevented by a knee-cap or by a bandage. As a rule, the annoyance to the patient is so great that more radical treatment is demanded.

One operative procedure consists of reefing the medial side of the capsule, with or without opening the joint. Another consists of transplanting the insertion of the patellar ligament medially. These operations have occasionally been performed with good results, according to Whitlock, but he offers as a third method that of re-inforcing the patellar ligament by grafting the tendon of the gracilis into it (Tenney, Ann. Surg., 1908, xlviii, 7313).

Dumferline (Surg., Gyn. and Obst., April, 1912) described a technic which he has used successfully. He reflects a semilunar flap of skin and fascia from the medial and posterior surfaces of the knee, far enough back to enable him to reach the tendon of the semitendinosus muscle; the base of the flap crosses the line of the patella and the patellar ligament. The semitendinosus muscle is dissected as low as possible. The patellar ligament is split, a portion being turned up to be sutured to the cut end of the tendon of the semitendinosus. The medial portion of the capsule and the fascia are then plicated with several sutures, chromic catgut being used for both tendon and fascia.

Whitlock's method consists of turning forward a long horseshoe-shaped flap of skin and fascia, with its base in front and its apex reaching backward to the line of the medial hamstrings, the base corresponding with the line of the medial

margins of the patella and the patellar ligament. The ligamentum patellæ is exposed in its course for about three-fourths of an inch by dividing the thin capsular fascia overlapping its anterior surface, and a thin Kocher fenestrated blunt dissector is thrust through the ligament from behind forward, so as to separate the fibers as near its middle as possible, making a space of half an inch vertically. This is done without entering the general synovial cavity of the joint. The ligament is then split for half an inch or more, and prepared to receive the end of the gracilis tendon. This tendon is found by taking the sartorius muscle as a guide; the fascial attachment of the sartorius is divided above and posteriorly so that its edge may be thrown forward. The slender tendon of the gracilis is then seen lying proximal to that of the semitendinosus, and parallel with it are some vessels and a nerve which should be avoided. The gracilis tendon is isolated and divided as near its tibial attachment as possible. It is brought forward and threaded through the fenestrated director, and passed through the patellar ligament, and is sutured with chromic catgut. Whitlock states that the gracilis was chosen partly because of its superficial position and its very long and supple tendon, but mainly because it is primarily an adductor in its action and innervation, being supplied by the obturator nerve. It is a less important flexor of the knee than the semitendinosus. The altered position of the transplanted tendon acts as a tie, fixing the ligamentum patellæ and preventing the passage of the patella outward during full extension of the knee, while it tends also to rotate the joint medially. In cases in which there is great flaccidity of the capsule or the tendon, transplantation is fortified by reefing the capsule.

Goldthwait (Am. Jour. Orth. Surg., vol. i, No. 3) reports 11 cases operated upon for dislocation of the patella. Through a 5-inch incision, beginning at the tubercle of the tibia, the patellar tendon was exposed and split into halves. The outer half was freed from its attachment to the tubercle and drawn inward under the remaining half, and sutured securely to the periosteum, together with the expansion of the tendon of the sartorius muscle at the inner side of the anterior surface of the tibia. A number of cases have suffered recurrence after this operation.

Murphy (Murphy's Clinics, vol. iii, No. 4, Aug., 1914) reports his method of dealing with congenital luxation of the patella, which consists of exposing the joint freely through two longitudinal incisions, one on each side of the patella, and turning the patella with the ligamentum patellæ to one side. With a broad gouge to correspond with the under surface of the patella, a segment of bone lying between the condyles is removed, to deepen this intercondylar groove. A flap of fascia and fat is then turned in from above and sutured over this denuded bone area, to prevent ankylosis of the patella to the femur. The patella is placed in position resting on this fascial flap, and the inner portion of the fibrous capsule is drawn over the patella and sutured to its fibrous covering.

The extent of trauma to the joint surfaces suggests the great possibility of adhesions and limitation of joint motion, while the absorption of the fascial fat-flap covering the incised bone area would furthermore tend to cause adhesions and limitation of joint function.

Graser (Deutsche Gesellsch. f. Chir. and Zentralbl. f. Chir., July 9, 1904) presents his method and reports several cases in which the outer condyle of the femur stood considerably further backward than the inner condyle when the leg was rotated outward. He effected a cure of the dislocation by performing a supracondyloid osteotomy of the femur and twisting the condyles

so as to bring the outer portion forward and the inner condyle farther backward. This procedure carries forward the insertion of the ligamentum patellæ or upper end of the tibia with the outer condyle of the femur, thereby minimizing its efficiency. He recommends the procedure only when the posterior of the outer condyle is marked.



FIG. 368.—Luxated patella outward.

Author's Operation for Habitual or Congenital Dislocation of the Patella.—Judging by the number of methods devised for the correction of this deformity, particularly those procedures which utilize the soft parts as a means of correcting the dislocation, as well as by the case reports following

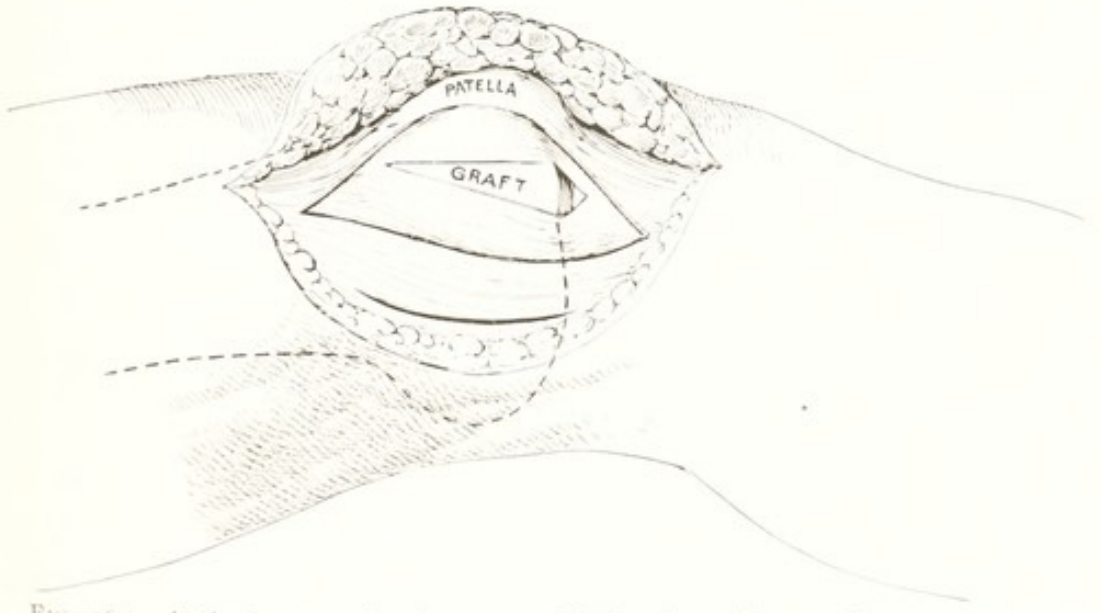


FIG. 369.—Author's operation for outward dislocation of the patella, showing shape of graft in position, lifting anterior portion of external condyle to block the recurrence of the dislocation.

such operations, it can safely be said that no method has proved universally satisfactory. Following soft-tissue operations for purposes of fixation, in many cases redislocations have occurred after varying periods of time, as might reasonably have been expected. Grafted or reefed soft tissue, whether ligament or fascia, can withstand little strain, and will gradually pull out if

any great amount of traction is placed upon it. The most secure anchorage for tendons, fascia, or ligaments is offered by bone tissue, and even then unless great care is exercised and the ligament itself directly united to the bone, independently of the suture material, one cannot feel assured that the new anchorage will remain intact. Any foreign material sutured into bone, if sufficient strain is placed upon it, will gradually pull through by virtue of its destructive action.

Inspierd by the numerous failures of the various methods reported by various operators, the author devised a method which from personal experience makes a strong appeal by its rational and trustworthy means of restoring a displaced patella without interfering with joint function, without the removal and destruction of portions of the joint and without any appreciable chance of failure. Instead of attempting to rectify the deformity by a complicated procedure or by subjecting the joint to trauma, a simple change in the architecture of the outer condyle of the femur is sufficient permanently to obviate the danger of displacement.

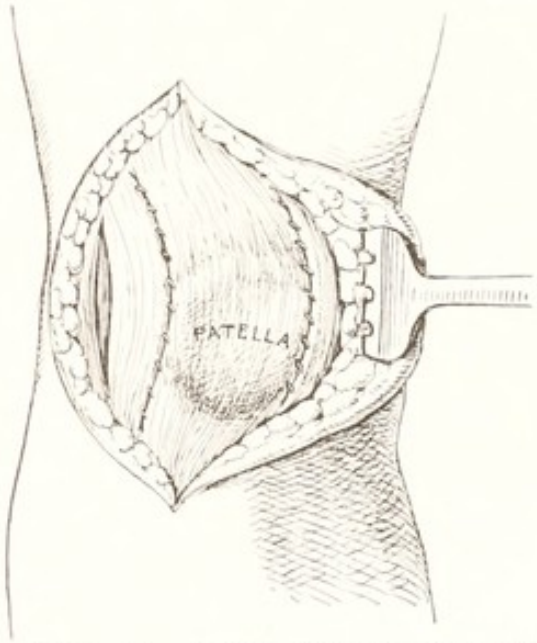


FIG. 370.—Patella fixed in position by wedge graft under external condyle and plicating sutures.

Technic.—A semilunar skin incision is made at the outer border of the patella, sufficiently long to reach below the tibial tubercle and to a point above the external condyle. Avoiding undue disturbance of the underlying joint structures, the external condyle is penetrated with a broad thin osteotome on its external surface, making a bone incision from 1½ to 2 inches long, and situated about one-half to three-quarters of an inch below its anterior articulated surface and nearly in line with the long axis of the femur. This bone incision allows the anterior surface of the external condyle to be elevated to a plane above the internal condyle, by producing a greenstick fracture near the intercondylar groove, the object being to place a permanent and rigid obstacle in the way of outward displacement of the patella.

When the anterior segment of the external condyle has been obliquely elevated to a sufficient degree to secure the desired obstructing effect, the width of the bone-gap thus formed is measured, and a section of bone sufficiently large to fill this cuneiform opening is removed from the crest of the tibia through the lower portion of the original skin incision, extended below the tubercle for this purpose. This bone-graft wedge can be easily and quickly procured by the use of the motor-saw. Before the graft is removed, it is drilled obliquely in one or two places with a motor-drill so that it may be pegged to the under portion of the external condyle after it has been put in position. Dowel pins, made from an additional portion of the bone removed from the crest of the tibia at the time the graft is obtained, and rounded by the motor lathe to fit the drill holes in the graft, are driven into place.

The cancellous structure of the condyle is easily penetrated by the bone-graft pins, but if any difficulty is encountered, the motor-drill can again be inserted into the holes already made in the graft and these prolonged into the

external condyle. The ligaments and tendinous expansions are sutured over the graft by kangaroo tendon, thus securely holding the elevated portion of the condyle. The skin wound is closed by a continuous mattress



FIG. 371.—Skiagram of case of recurrent subluxation of the patella, shows tibia wedge-graft in position under the elevated femoral condyle. (Albee, in International Clinics, Vol. iv, 27th Series, 1917.)

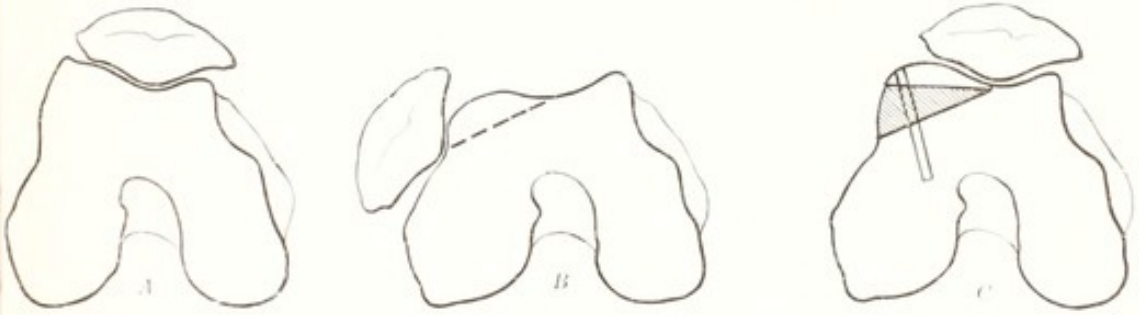


FIG. 372.—*A* indicates the normal size and anterior prominence of the external femoral condyle. *B* indicates the flattened external condyle with a consequent luxation of the patella outward. *C* indicates anterior lifting of the condyle to block the recurrence of the luxation of the patella with the wedge graft (dark area) in position. The graft is usually held by a ligature of kangaroo tendon placed in drill holes in it and the split portions of femur anterior and posterior to it.

suture of plain catgut, without drainage, and the leg from toes to groin is encased in a plaster-of-Paris splint in which it is allowed to remain for three weeks; at the end of this time passive motion and massage are begun.

The advantages of this procedure are that with no sacrifice of joint cartilage, a minimal amount of joint injury is produced at the time of operation, thereby greatly lessening the dangers of limitation of motion and the forma-

tion of adhesions, and that the permanent blocking of any further tendency to displacement of the patella is effected by the actual elevation of the external condyle or an actual restoration of the normal mechanico-anatomical conditions. The soft parts are not interferred with. The only further suggestion in the case of extremely lax and stretched internal capsular ligaments is their plication with kangaroo tendon; this, however, is usually unnecessary, for if the external condyle is propped well forward, all requirements are fulfilled.

FRACTURES OF THE TARSAL BONES

General Considerations.—Incorrect diagnosis is still frequently made in a large percentage of the cases of fracture of the tarsal bones, although numerous contributions to the subject have appeared. Several years ago the author (N. Y. State Jour. of Med., Nov., 1911) presented a study of this subject, being actuated by the fact that so many incorrect diagnoses and hence so many errors of treatment are being repeatedly made in some of our best fracture clinics.

Many of these cases are diagnosticated and treated as sprain, contusion, Pott's fracture, and, if the injury is of long standing and does not seem to be severe, as flatfoot or "rheumatism." These errors in diagnosis are due in great measure either to failure to use the *x*-ray as an aid in diagnosis or to inaccuracy or lack of intelligence in the interpretation of the plate.

The frequency of tarsal fractures is emphasized by Cabot and Binney, who state that in eleven years at the Massachusetts General Hospital, 204 cases of Pott's fracture were treated, and 83 cases of fracture of the astragalus and os calcis in the same time.

Astragalus and Os Calcis.—The type of injury which produces these fractures is usually a severe blow on the bottom of the feet, such as a fall from a height over 10 feet; however, occasionally much less severe injury is sufficient to cause the fracture, *e.g.*, alighting from a street car in rapid motion. It is in these latter cases of inconsequential trauma that incorrect diagnosis of "rheumatism" or flatfoot is frequently made. The muscular force of the powerful gastrocnemius and soleus muscles often pulls off a part of the heel portion or produces a fracture through the body of the os calcis.

It is difficult to determine by exactly what mechanism these fractures are produced, because the various conditions involved are numerous. The conditions differ materially from those which exist in fractures of long bones not situated in such close proximity to many complicated joints. And it is obviously impossible to ascertain the amount of equinus, varus, or valgus the foot happened to be in at the time of injury. The tibia many times acts as a battering ram, transmitting the full weight of the body, and either causes a crushing break of the astragalus or drives its posterior part down into the os calcis. In this event, the anterior fragment is often displaced upward, thus locking the foot in the equinus position by its impingement on the anterior part of the lower end of the tibia.

Another frequent condition encountered is a comminution of both the astragalus and os calcis at the posterior border of the former bone. This condition is often overlooked, even when good skiagrams have been produced, on account of inexperience in *x*-ray interpretation. The author has seen a number of such cases, where men of inexperience unreasonably persisted in their belief that they could intelligently interpret skiagrams, yet failed to see the comminution and made a diagnosis of "sprain."

Os Calcis.—Again the force may be entirely transmitted through the astragalus and expended on the os calcis, causing a variety of comminuted



FIG. 373.—Fracture of os calcis, with upward displacement of the posterior fragment and almost complete loss of the longitudinal arch.

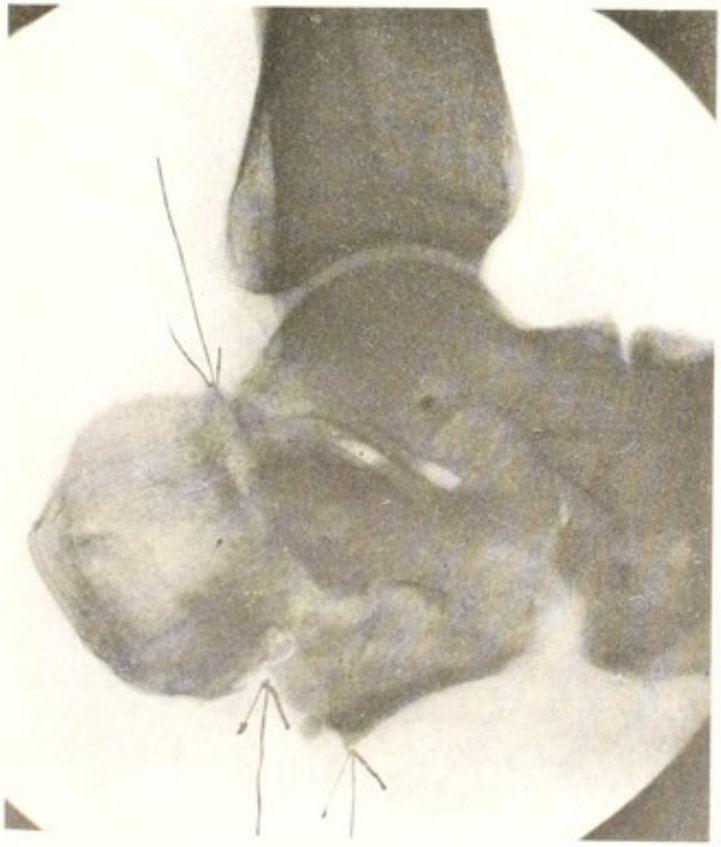


FIG. 374.—Comminuted fracture of the os calcis. In such cases it may be necessary to tenotomize the tendo Achillis in order to force the posterior fragment downward into its proper position.

fractures, or a linear fracture through the body, usually just under the posterior part of the astragalus. The author has seen no cases of isolated fractures of the sustentaculum tali, but has found it only incidentally to a crushing fracture of the whole anterior part of the os calcis. Other causes of fracture of the os calcis are direct violence and contraction of the muscles attached to the tendo Achillis. However, in a great majority of cases, fractures of the os calcis are true compression fractures, and are generally due to a fall from a height on to a hard floor or pavement. In this instance, the astragalus is not often fractured because it is protected from the direct force of the blow by its situation between the two malleoli, and possibly because of the crescentic outline of its upper articular surface.

Astragalus.—As has already been suggested, the astragalus, because of its protected position, is much less likely to suffer from crushing traumata,

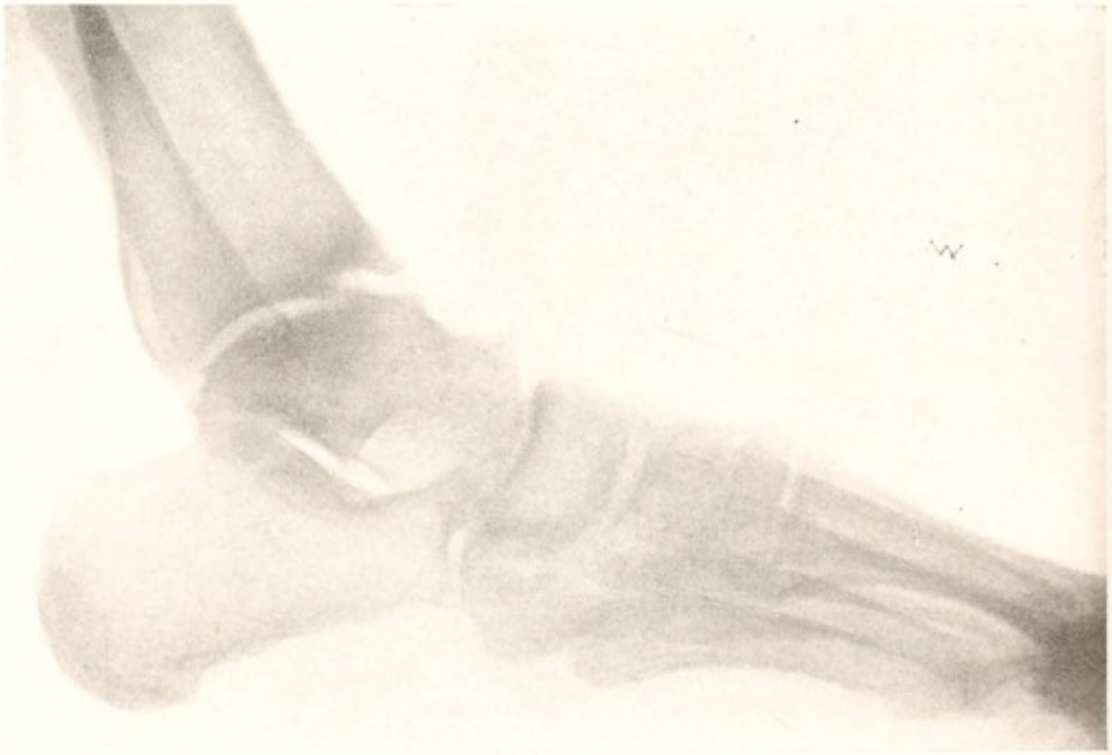


FIG. 375.—Comminuted fracture of the superior articular surface of the body of the astragalus and the contiguous surface of the tibia with impingement of these surfaces preventing dorsal flexion. The removal of these locking surfaces restored dorsal motion.

although it is occasionally fractured in this way. Hamilton reported 1 case in 10 fractured by direct violence. Gaupp found 16 out of 61 cases. A description of all the possible types of fracture of this bone would be an endless task and of doubtful value, even by means of right-angled radiographs. It is frequently very difficult to discern the minute details of the fracture, and it is here that stereoscopic radiography is of the greatest value (Fig. 375).

The astragalus may be divided clinically into two parts, a protected part (body) and an exposed part (head and neck). The former is almost always broken by a crushing or transmitted force similar to that which produces fracture of the os calcis. The body may be split into two or more fragments, or may be severely comminuted. The head and neck are exposed to direct crushing blows on the front of the foot and to twisting strains. A case in point is that of a male forty-five years of age, referred to the author's clinic for flatfoot. A carefully taken history disclosed the fact that three years

before he had stepped off a merry-go-round while it was still in motion, and had received a severe twist of the foot. At the time of the accident, he went to one of our best hospitals, where he was told he had a "sprain" for which he was accordingly treated. Pain and crepitus had been constant since the accident. The lesion proved to be a fracture through the neck of the astragalus. The pain in this case was located chiefly under the external malleolus; this is a very frequent complaint, and is undoubtedly due to the faulty static conditions produced. The affection usually responds to intelligent flatfoot treatment; however, if there



FIG. 376.—Partial dislocation of the astragalus from the "battering ram" effect of the tibia in a fall. The posterior portion of the astragalus has been driven downward into the os calcis which has been comminuted at the same time that the head and neck have been dislocated upward and forward. A plastic resection of the head and part of the neck of the astragalus restores function almost completely especially dorsal flexion which was entirely inhibited.

is an overgrowth of bone or callus at this point in long-standing cases, its removal is essential.

Treatment of Fracture of the Astragalus.—The treatment consists of immobilization for four weeks, prohibition of weight-bearing for six weeks, passive motion and massage at the end of the second month. In immobilizing a fracture of the astragalus, a plaster-of-Paris bandage should be applied with especial attention directed to the position of the foot, which should always be at right angles to the leg, and without inversion or eversion, varus or valgus. Any loose fragments from the upper articular surface should be removed.

If a fracture of the neck has occurred and the head is displaced, it should be replaced through an incision, if necessary, or removed if completely

detached. If the body of the bone has been rotated or displaced, it should be restored to its normal position. If there is a severe crush or comminution, a complete astragalectomy will undoubtedly yield a better functional result than conservative treatment.

Treatment of Fracture of the Os Calcis.—*Recapitulation.*—A fall in an elevator or from a height, striking on the plantar surface of the foot, is very likely to produce a fracture of one of the tarsal bones, especially the os calcis, which is by far the most common fracture. These fractures of the os calcis

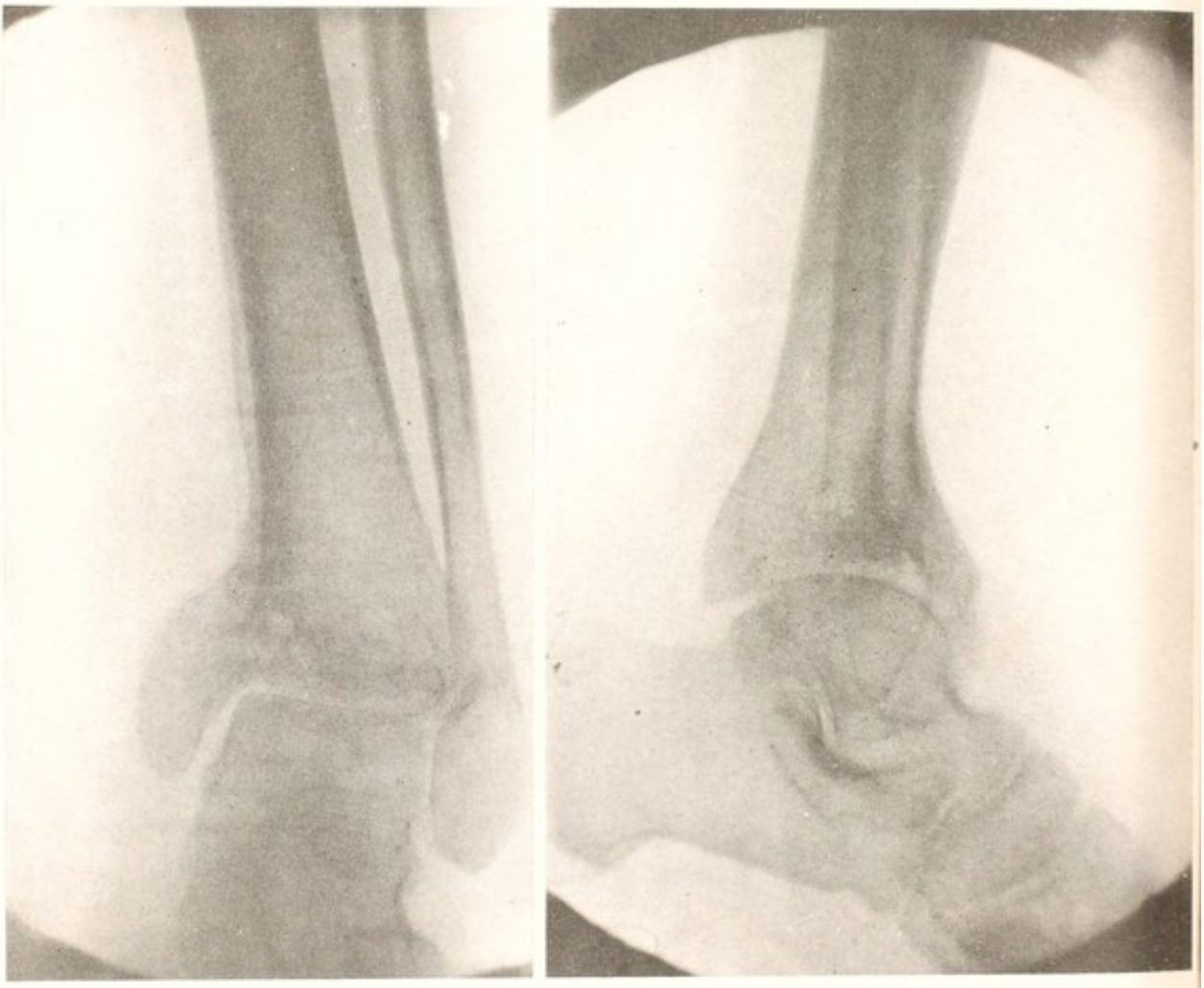


FIG. 377.—Skiagrams of malunited fracture. Showing malunion and varus deformity, with extreme obliquity of astragalus with tibia. (Albee, in International Clinics, Vol. iv, 27th Series, 1917.)

may be classified in four groups: First, the one in which the fracture runs transversely through the central portion of the bone, with displacement upward of the posterior fragment by the pull of the tendo Achillis, second, when a portion of the bone is torn away by muscle-pull; third, where there is a fracture of the sustentaculum tali; and, fourth, where there is comminution, especially in the region where this bone articulates with the posterior portion of the astragalus.

The type of case in group I (transverse fracture through the central portion of the bone) alone will be considered in this connection.

The chief consideration in the treatment of all fractures of the os calcis, and especially this one, is to preserve or restore the arch of the foot. From the functional as well as from the cosmetic standpoint, this is most important.

Method of Reduction of Posterior Fragment.—The patient is anesthetized to full muscular relaxation; the foot is brought into full plantar flexion for the purpose of relaxing the tendo Achillis; the heel is grasped firmly, and an attempt is made to pull it downward into its proper position. In order to loosen the fragment and break up the impaction, it may be necessary to force the heel laterally (both right and left). It may then be possible to bring down the fragment. If this fails, as it is apt to on account of the difficulty

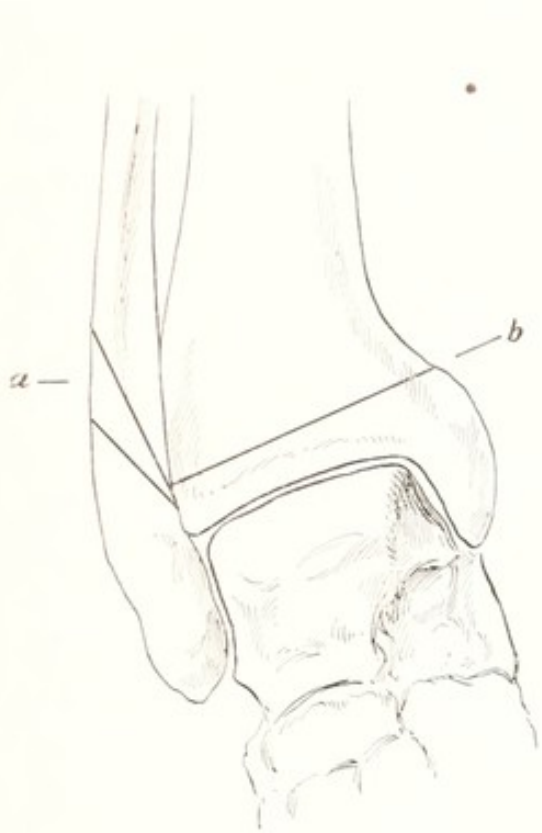


FIG. 378.

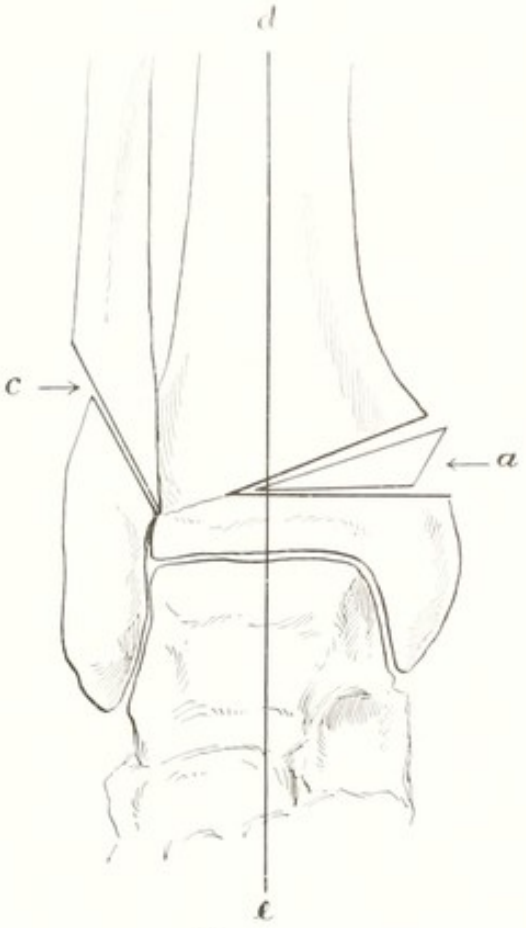


FIG. 379.

FIG. 378.—Diagram made from skiagram of Fig. 377 showing malunion and consequent extreme varus deformity. *a* is wedge-shaped piece of bone removed from fibula, when doing the osteotomy. This space is closed when deformity is corrected; *b* is the line of osteotomy of tibia. A wedge cavity between the tibial fragments is opened at this point, then the deformity is corrected and the wedge graft from the fibula at *a* is inserted at this point. (Albee, in International Clinics, Vol. iv, 27th Series, 1917.)

FIG. 379.—Diagram made from skiagram taken after operative correction. *a* is the fibula-graft placed into cuneiform cavity between inner side of tibial fragments after correction of deformity. The cavity at *c* in fibula is at the same time completely closed by the correction. The line *d e* indicates the ideal restoration of alignment accomplished. (Albee, in International Clinics, Vol. iv, 27th Series, 1917.)

of securing a sufficient grip on the heel, Cotton has advised thrusting a steel spindle (or what is more convenient, a small urethral sound) through just in front of the tendo Achillis. With this hold there is no difficulty in bringing the fragment down, if not more than a week or two has elapsed since the fracture. In old malunited fractures open cuneiform osteotomy of the inferior aspect of the bone at the point of fracture will be necessary before attempting to bring the fragment down. The incision is made directly over the inferior aspect of the plantar surface of the foot. It is usually safer to tenotomize the tendo Achillis.

In some instances internal fixation is advisable, and in these cases the bone-graft peg is by all means the ideal agent.

Author's Technic of Bone-graft Peg for Ununited Fracture of the Os Calcis.—The most satisfactory incision is one which passes along the outer side of the tendo Achillis down to the edge of the plantar skin, and then internally around the posterior part of the heel. The skin flap thus outlined is freed from the posterior end of the os calcis and retracted inward. Care should be taken to keep close to the bone in elevating this flap, so as not to interfere with its circulation.

With the posterior calcaneal fragment in good position, a hole about ⅜-inch in diameter is made longitudinally in the fragments with the author's motor-drill. The drill should be inserted in the center of the posterior end of the os calcis, driven through, and then disengaged from the motor and left *in situ*, while the peg is prepared. A strip of bone of sufficient size to be shaped into a dowel-peg is then removed from the crest of the tibia with the motor-saw. With the surgical lathe, held by an assistant on the edge of the instrument table, this strip of bone is pushed into the doweling instrument, which shapes it into a round peg that will exactly fit into the drill hole in the os calcis. The drill is then withdrawn from the os calcis, the peg is inserted and driven home with blows of the mallet. The end of the peg should be well countersunk into the end of the os calcis (using the special "bone-set") so as not to cause pressure on the overlying skin and consequent necrosis and ulceration.

Fractures of the avulsion type, resulting from muscle-pull, may be treated in a similar way. In this instance, the avulsed fragment is replaced and pegged securely in position by one or two small bone-graft pegs, by a technic similar to that just described.

Fixation Dressing.—The foot is immobilized in a plaster-of-Paris dressing in moderate plantar flexion. A pad of gauze is placed smoothly over the superior and posterior part of the heel, and as the plaster sets it is moulded over this prominence with traction exerted downward. The full arch of the foot is maintained by moulding the plaster well over the dorsal and plantar aspects of the foot. After this treatment, the union in these cases is very prompt. The plaster should be cut down and transformed into a bivalvular splint at the end of two weeks, when active motion of the foot and gentle massage may be allowed. In the case of a fresh fracture, weight-bearing may be allowed in four weeks' time. If the case is one of malunion, this period of time should be somewhat lengthened in accordance with the individual requirements.

Tarsal Scaphoid.—The skiagram has shown that fractures of the tarsal scaphoid are not so uncommon as formerly was supposed. The mechanism is apparently pressure between the astragalus and the cuneiform bones. The symptoms are a marked prominence over the inner aspect of the dorsum and inner side of the foot in the region of this bone, and tenderness elicited by pressure upon this prominence. Fursterer thinks a characteristic symptom is the fact that while compression of the foot from heel to toes produces pain, weight-bearing causes much less discomfort.

Very little can be said about treatment. If the displaced fragment can be reduced and the foot held in inversion, we may expect a good functional result. If this is impossible, an operation to remove the whole bone, or the offending fragment, is indicated. The foot should then be immobilized in plaster-of-Paris in the inverted position for four weeks, and an arch support then applied.

Cuboid and Cuneiform.—Fractures of the cuboid and cuneiform bones are rare and occur as the result of a smashing injury of the foot. There is nothing peculiar in their treatment or prognosis. A good general rule in all tarsal fractures, when the facilities for making an exact diagnosis are lacking, is to put up the foot in inversion and strong dorsal flexion.

Fracture of the Carpal Scaphoid (Fig. 381).—Credit for the recognition of this fracture and for its description belongs to Dr. E. A. Codman of Boston.



FIG. 380.—Dislocation of semilunar bone, and fracture of scaphoid bone. As a rule this bone can be reduced by digital pressure while the wrist is in dorsiflexion. The bone is held in position by strong palmar flexion for a period of three weeks.

Fracture of the scaphoid bone of the wrist is due to a fall upon the hand or a similar accident, which would ordinarily produce a Colles' fracture. It is the most important of the fractures of the carpus. The scaphoid breaks at its slender neck. There is very little displacement of fragments immediately following the accident.

Clinically, the case appears to be a "sprain" of the wrist, there being pain on all motion, particularly extension and radial flexion, with exquisite tenderness to pressure localized over the scaphoid, front and back and especially the floor of the "snuff-box."

Absolute diagnosis cannot be made in a very recent case, and probably

many cases pass as "sprains" which are in reality fractures of the scaphoid. *X*-ray examination is *essential* to the diagnosis of these early cases.

At a later period, diagnosis is more readily made, especially if there is displacement of the fragments; this displacement may be primary or the result of premature and injudicious use of the hand. With the displacement, the signs become more or less characteristic, viz.: anteroposterior thickening of the wrist opposite the scaphoid, with more or less circumscribed tenderness, limitation of radial extension and radial abduction, while ulnar flexion, ulnar extension, and ordinary flexion are unrestricted. If this symptom-complex is persistent for any length of time after an injury, it is almost certain to indicate fracture of the scaphoid, less certainly fracture

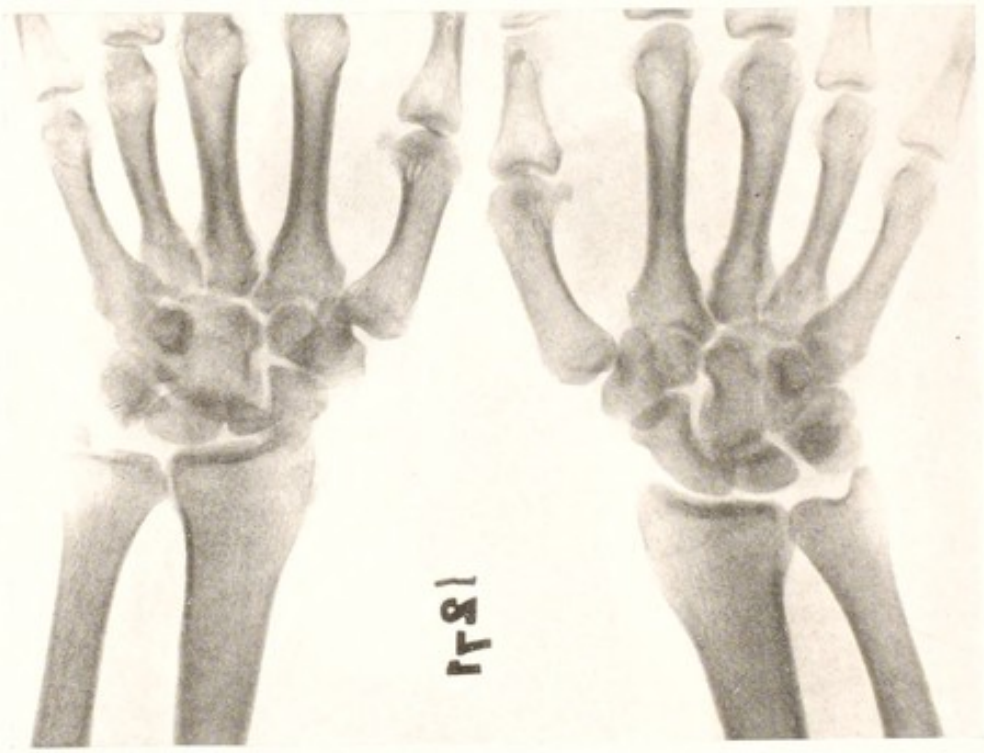


FIG. 381.—Fracture of scaphoid bone and styloid of the ulna (left). Many times in such cases, it is necessary to remove by open operation the displaced fragment.

of any other single bone of the carpus. Limitation of motion is due to displacement of the fragment, there being rarely a third fragment.

In another group of cases of fracture of the scaphoid, function returns to normal without discoloration, thickening, or other disabling feature.

Union in these scaphoid fractures is always fibrous, but in the case of this particular bone this fibrous union is compatible with normal function and, in fact, obviates the necessity of operation.

In cases where there are displacement of the fragment, limitation of movement, and pain during motion, it becomes necessary partially to excise the bone, the fragment usually removed being the proximal one because it is the more accessible. Absence of part of or all the scaphoid is no hindrance to functional activity of the wrist joint.

REFERENCES

FRACTURE OF HIP

ALBEE, F. H.: "Juxta-epiphyseal Fracture of the Upper End of the Femur. The Importance of the Use of Position in its Treatment." Amer. J. Orth. Surg., Feb., 1911.

ALBEE, F. H.: "Case of Ununited Fracture of Neck of Femur of Three and One-half Months' Duration, in Woman of Sixty Years." Case report in Murphy's Surgical Clinics, vol. ii, No. 3, June, 1913, p. 473.
ALBEE, F. H.: "The Bone-graft Peg in the Treatment of Fractures of the Neck of the Femur." Ann. of Surg., July, 1915.
ALBEE, F. H.: "Bone-graft Surgery." Phila., W. B. Saunders Co., 1915.
COTTON, F. J.: "Hip Fractures and their Treatment." Boston M. & S. J., 1914, clxx, 718–723.
EWALD, P.: "Hüftpfannenbruch und intrapelvine Verwölbung des Pfannenbodens." Ztschr. f. orthop. Chir., Stuttg., 1913, xxxiii, 499–513.
COTTON, F. J.: "Hip Fractures." Am. J. Surg., N. Y., 1915, xxix, 96–98.
COTTON, F. J.: "Artificial Impaction of Hip Fracture." Tr. Am. Surg. Ass'n, Phila., 1915, xxxiii, 46–58; Ann. Surg., Phila., 1916, lxiii, 366–371.
COTTON, F. J.: "The Treatment of Hip Fractures." Boston M. & S. J., 1916, clxxv, 438–440.
GIVHAN, E. G.: "Fracture of the Hip." Internat. J. Surg., N. Y., 1916, xxix, 59–61.
LEMON, C. H.: "Is it Possible to Obtain Bony Union in Intracapsular Fractures of the Hip-joint?" St. Paul M. J., 1916, xviii, 87–98.
MURPHY, J. B.: "Ancient Fracture of Rim of Acetabulum with Displacement of Head of Femur; Arthrotomy of Hip-joint; Reduction of Fracture." Surg. Clin., Phila., 1916, v, 725–729.
SICARD, J. A., AND GASTAND, P.: "Hanche forcée avec fracture spontanée du col fémoral." Bull. et mém. Soc. méd. d. hôp de Par., 1916, 3 s, xl, 1132–1138.
WHITMAN, R.: "The Treatment of Hip Fractures." Boston M. & S. J., 1916, clxxv, 734.
BRACKETT, E. G., AND NEW, MAY S.: "Treatment of Old Ununited Fracture of the Neck of the Femur by Transplantation of the Head of the Femur to the Trochanter." Boston M. & S. J., 1917, clxxvii, 351–353.

CHAPTER XIX

CONSTITUTIONAL AFFECTIONS PRODUCING GENERAL AND LOCALIZED DISTORTIONS

In this chapter we shall consider those constitutional affections, many of them of obscure origin, which lead to either general or localized deformities of the bones and joints, as follows:

I. Rickets and its deformities (including genu valgum, genu varum, anterior bow-legs, cubitus valgus and cubitus varus).
II. Infantile scurvy.
III. Osteomalacia.
IV. Osteogenesis imperfecta.
V. Fragilitas ossium.
VI. Acromegaly.
VII. Osteitis deformans (Paget's disease).
VIII. Leontiasis ossium.
IX. Chondrodystrophia fetalis.
X. Hypertrophic pulmonary osteo-arthropathy.
XI. Hemophilic joints.

I. RICKETS AND ITS DEFORMITIES

Definition.—A chronic constitutional disease associated with malnutrition, occurring chiefly in children and manifested principally by changes in the bones. It is, however, a very complex pathological process, involving, besides the bones, the muscles, ligaments, tendons, mucous membranes, and nearly every organ in the body.

Varieties.—Rickets has become classified in the following manner:

1. *Infantile Rickets.*—This is the commonest and most typical clinical form and is developed between the sixth month and second year of life.

2. *Late* or *recrudescent rickets* is occasionally encountered.

Etiology

Predisposing factors are poor food, unhygienic surroundings, deficiency of fresh air and sunlight, racial predisposition (*e.g.*, Italians and negroes). The immediate cause of rickets is at present unknown.

Pathology

To comprehend the pathology of rickets, it is necessary to have a clear understanding of the normal histology of bone-growth. The skeleton in the fetus has two primitive types: the connective tissue and the cartilaginous. The latter, to which all the long bones of the body belong, develops into bone, not by a general conversion of the cartilage, but by changes localized chiefly in the region of the junction of the epiphysis and diaphysis. In this region the cartilage cells proliferate, forming a series of well-marked zones. In

the first, the cells are irregularly distributed; in the second, they arrange themselves in columns. The second zone can be subdivided into two portions according to the shape of the cells. In the first they resemble the usual cartilage cells; in the second they appear to be much swollen. In the next zone these cartilage cells are enveloped by a layer of calcareous tissue, and longitudinal blood-vessels, emerging from the marrow cavity of the diaphysis, are distributed between each one of the columns of cartilage cells. These blood-vessels bring with them osteoblasts which range themselves along the calcareous tissue, converting it and the enclosed cartilage cells into bone lamellæ. This process accounts for the longitudinal growth of the bone.

The peripheral growth of the bone takes place through the activity of the periosteum of the shaft; as new bone is deposited on the outer layers, it is absorbed in the marrow cavity through the activity of the osteoclasts.

In rickets all these forms of bone-growth and absorption are impaired. At the epiphyseal line, instead of regular columns of cartilage cells, there is no regularity whatever and the longitudinal blood-vessels, instead of being so arranged as to penetrate between the columns of cartilage cells, run in all directions and are much more numerous than under normal conditions. They seem to have their origin, not from the bone marrow, but from the perichondrium and therefore bring with them few or no osteogenetic cells. The cartilage cells, therefore, are not converted into bone but persist, thus giving the impression that there is unusual proliferation of cartilage, causing a wide, thick proliferating zone. As a matter of fact, it is very difficult to decide whether this appearance is due to abnormal proliferation or to diminishing ossification. Throughout the entire bone, as at the epiphyseal line, there is diminution in the calcium content. Whereas normally the inorganic salts represent twice the quantity of the organic, in rickets the ratio is reversed.

The activity of the periosteum and endosteum is also perverted. There is unusual periosteal proliferation producing a flat layer of irregular bone very poor in calcium content. The endosteum too proliferates, converting the marrow into fibrous tissue with occasional islands of irregular bone.

Macroscopically these changes are evidenced by thickening of the bones in the neighborhood of the epiphyseal lines and by deformity due to the inability of the bone to withstand the normal stress and strain. Thus the weight of the superimposed body, working upon the spine and the lower extremities, and muscular traction working on the upper extremities, cause a bowing of the long bones.

In those bones which are preformed by connective tissue (skull bones, etc.) the rachitic process is confined to changes resembling those produced by the abnormal periosteal activity of the long bones. There is an unusual production of soft, irregular bone which can be easily dented by the finger of the physician, giving a peculiar crackling sensation. When one of these bones is sectioned, the trabeculæ are found much increased in size and on pressure, ooze blood and serum.

Symptoms

The following is a typical picture of rickets:

1. *Large head*, open fontanels and craniotabes. 2. *Prominent abdomen*. 3. *Narrow chest*. 4. *Enlarged epiphyses*. 5. *Beaded ribs*. 6. *Curvature of the long bones*. 7. *Skin pale*, subcutaneous tissues flabby, typical weazened look.

Additional physical signs of rickets are:

8. *Delayed Dentition*.—When the teeth do appear, they are irregular, soft, and decay easily.

9. *Muscles poorly developed.*

10. *Walking delayed.*

11. *Pads* on *dorsal surfaces* of hands and feet hard and adherent to the overlying skin. This peculiarity was first noticed by Tubby (ref.: Brit. Med. Jour., Oct. 15, 1898).

12. Various *respiratory disorders.*

13. *Enlargement* of *liver* and *spleen.*

14. *Separation* of the *recti muscles* over the protuberant abdomen.

15. *Intestinal Derangement.*—Constipation or diarrhea.

16. *Persistent sweating of the head at night*, resulting in loss of hair over the occiput from attrition.

Differential Diagnosis

Rickets may be confused with congential syphilis and with infantile scurvy. Also, special stigmata may be confused with analogous conditions seen in other maladies.

1. **Syphilitic epiphysitis** is characterized by the following:

   (*a*) *Other signs* of syphilis.
   (*b*) *Age.—Under ten months* (usually the third).
   (*c*) *Tender, edematous, hot, painful, cylindrical swelling.*
   (*d*) *Loosening* and *separation* of the *epiphysis* which is movable on the shaft with crepitus, or lies in a purulent cavity.
   (*e*) *Improvement* under *antisyphilitic treatment.*
   (*f*) *Parental history* of syphilis.
   (*g*) *Pseudoparalysis* commoner than in rickets.

2. **Infantile Scurvy.**—The following clinical signs aid in differentiation:

   (*a*) Swelling not limited to the epiphyseal cartilage, but encroaches on the shaft.
   (*b*) Subperiosteal hemorrhages.
   (*c*) Age, eight to ten months.
   (*d*) General signs of scurvy.

DIFFERENTIAL DIAGNOSIS OF SPECIAL STIGMATA

Stigmata	Mistaken for
Enlarged head	Hydrocephalus.
Delayed dentition and large fontanel	Cretinism.
Pseudoparalysis	Cerebral or spinal lesion.
Delayed walking	Delayed development.
Curvature of spine	Tuberculous vertebræ.

General Treatment

Spontaneous cure of rickets is of doubtful occurrence. An *appropriate diet*, on the other hand, will uniformly effect a cure. The dietetic régime must be begun early, and consists of copious allowances of fat (cream, milk, cod-liver oil, and butter, etc.), liberal allowance of vegetables, with a sufficient amount of nitrogenous food.

Plenty of *sunlight* and *fresh air* are indispensable adjuncts. The patient should remove to the country or seashore whenever possible.

Phosphorus (although it is used on purely empirical grounds) may be administered in cod-liver oil or olive oil, in 1/200-grain doses, three times a day, after meals, or dispensed as phosphate.

Iron is recommended as a corrective of the anemia.

Calcium chlorid and lactates are of debatable value.

The Deformities of Rickets

The osseous deformities of rickets will be considered as follows:

1. Cranium and face.
2. Torticollis.
3. Spinal.
4. Chest.
5. Arms, cubitus valgus and varus.
6. Rachitic pelvis.
7. Deformities of the lower limbs, coxa vara and valga, genu valgum (knock-knee) and varum (bow-legs), and flatfoot.

1. Cranium and Face

The circumference of the skull is increased, in severe cases 1 or 2 inches, due partly to hydrocephalus and partly to osseous thickening.

The cranial conditions vary with the severity of the disease and the age of incidence. In young infants the parietal and frontal bosses are very prominent; the bone may be 1/2 inch in thickness. The sutures remain open longer than usual, the anterior fontanel frequently remaining patent until the end of the third year.

Craniotabes is characterized by scattered areas, about a quarter of an inch in diameter, in which "egg-shell crackling" is elicited on palpation. The condition depends on defective development or absorption of the bone from pressure.

The typical rachitic skull is marked by its prominent square forehead, fulness of the frontal bones laterally, flattening of the occiput and vertex, and sloping of the supraorbital regions, with more or less exophthalmos.

The palate is high and adenoids are troublesome. The chief defect in the face is abnormal development of the lower jaw, so that the incisor teeth are arranged transversely, the others diverging from them and pointing inward.

2. Rachitic Torticollis

This resembles the ordinary form of wry-neck. It may possibly be due to softening of the vertebræ and weakening of the muscles and ligaments.

3. Rachitic Spine

To differentiate it from Pott's disease, the spine in rickets causes no pain when the child sits erect, nor is there muscle spasm or rigidity. In addition, hyperextension of the legs with the patient prone is unaccompanied by pain or rigidity and demonstrates slight or no impairment of the flexibility of the spine.

The child sits "tailor-fashion," with legs crossed. The usual abnormal spinal curvature is *kyphosis*, which is even and gradual from lower dorsal to sacral regions, and is not accentuated at any one spot. There is marked lordosis of the cervical vertebræ, and the head is tilted laterally (pseudo-lordosis) (see Chapter XII, section on Rickets).

Scoliosis is induced by abnormal postures, obliquity of the pelvis during nursing, and by carrying the child with the spine in a posture of lateral curvature.

These spinal anomalies are due to muscular weakness, relaxed ligaments, and osseous deformity. Kyphosis tends to undergo spontaneous cure.

Treatment of a Rachitic Spine.—*Kyphosis* calls for absolute recumbency on a Bradford-Whitman frame, alternated at intervals, for comfort, by the prone position on the frame, hygienic and dietetic treatment being rigidly carried on at the same time.

Scoliosis.—The outlook here is not so good. Treatment should be early and thorough, and should be executed along the lines detailed in the chapter on Scoliosis.

Mention must be made of the exaggerated normal lordosis incidental to the so-called "rachitic attitude" (*e.g.*, feet wide apart, thighs flexed, knees bent, back lordotic, shoulders thrown back). This is probably due in large part to coxa vara deformity. It is superinduced partly by the prominent abdomen. Whitman implies that the lordosis is usually compensatory to exaggerated normal kyphosis.

4. RACHITIC CHEST

The thorax is circular in outline, with *lateral grooving* most marked in the axillary line. Another, *vertical groove* exists at the costochondral junction. A third, *oblique groove* follows the attachment of the diaphragm and is known as Harrison's sulcus; it is most marked at the sides of the chest.

Anteroposterior enlargement with prominence of the sternum constitutes the "*pigeon-breast*" of rickets. Another clinical phenomenon is the beading of the ribs, the "*rachitic rosary*," at the costochondral junction.

The treatment of a rachitic chest consists of well-ordered respiratory exercises, supplemented by the removal of adenoids and other postnasal obstructions. Spontaneous cure is the rule.

Gibney (Internat. Clinics, vol. iv, 1893, p. 239) has noted exaggerated curves of the clavicle and subluxation of its sternal end in rickets.

5. PROMINENT ABDOMEN

The prominent abdomen, so characteristic of rickets, is due to enlargement of the viscera, flatulence, and to atony of the abdominal muscles.

6. HUMERUS, ULNA, AND RADIUS

The following rachitic deformities have been noted:

(*a*) Dorsal convexity of the forearm.

(*b*) Lateral curvature of the humerus, resulting in

(*c*) Cubitus valgus and cubitus varus.

(*d*) Curvature of the radius may be confused with Madelung's deformity (subluxation of the wrist).

(*e*) Spindle-shaped periosteal thickenings of the phalanges of the fingers and toes and of the metacarpal and metatarsal bones.

Spontaneous cure of these deformities is the rule, operation being rarely necessary.

CUBITUS VALGUS AND CUBITUS VARUS

Although these two deformities occur not only in rickets but also as the result of trauma, they demand special consideration.

With the arms hanging at the sides, palms forward, the forearm is normally slightly abducted, *i.e.*, the long axis is not in line with the long axis of the humerus but makes an angle of about 164 degrees with it, the "carrying angle." When this angle is less obtuse than normal, the condition of cubitus valgus exists; and when the angle is greater than normal cubitus varus is the deformity. In other words, if the forearm is displaced too far to the radial side, the condition is cubitus valgus; if too far to the ulnar side, cubitus varus.

The causes of these conditions are trauma, heredity, and rickets. The changes in the humerus are due to oblique postures of the lower end of the humerus, often seriously interfering with the carrying angle, producing undue strain on the shoulder-joint in the act of lifting and carrying objects, and may result in compensatory scoliosis.

Treatment.—When cubitus varus calls for surgical intervention, supracondylar osteotomy should be performed.

7. RACHITIC PELVIS

The rachitic pelvis is characterized by decrease of the anteroposterior diameter of the inlet, due to encroachment of the sacral promontory; flattening of the lateral aspect of the pelvis on account of inward thrust of the femora against the acetabula; narrowing of the pelvic angle; approximation of the tubera ischii; and flaring of the iliac crests from the weight of the superimposed viscera.

The clinical importance of a rachitic pelvis is the obstacle it presents to parturition, and the details of such pelvic dystrophy are to be found in works on obstetrics.

Treatment.—The only relief for this pelvic obstruction is surgery. Symphyseotomy was the procedure of choice until supplanted by pubiotomy, which was advocated by Gigli in 1893. It has occurred to the author that, inasmuch as the pelvic deformity is unalterable and that after healing from pubiotomy has occurred the same operation must needs be repeated at each subsequent pregnancy, permanent enlargement of the pelvic inlet could be secured by maintaining the separation of the divided os pubis by means of an inlay bone-graft.

8. LOWER LIMBS

(*a*) **Rachitic coxa vara** is not common and not severe. Its symptoms are the same as in essential coxa vara. For a correct diagnosis, röntgenography is necessary. It may be compensatory to an outward curvature of the shaft of the femur. A few cases undergo spontaneous cure. Aside from treatment of the rachitic disease in general, treatment of the deformity conforms with that laid down elsewhere for the treatment of coxa vara (see Chapter XIV).

(*b*) **Coxa Valga.**—Primary rachitic coxa valga is rare. It is usually secondary to inward curvature of the lower part of the femoral shaft.

(*c*) **Rachitic Genu Valgum** (Knock-knee).—Genu valgum or knock-knee (see Fig. 382) occurs almost wholly in early childhood, and is usually due to rickets; occasionally to infantile paralysis, frequently to heredity.

During the early stage of rickets, it should be unnecessary to emphasize the importance of establishing a proper constitutional treatment. This should be supplemented by local massage, corrective manipulations and exercises. Accurate tracings should be kept during this period as a record for determining progress. If distinct improvement is not manifest, or the age of two years has been reached with considerable deformity, more radical measures are indicated.

Treatment by Braces.—Corrective braces should be applied to all cases of knock-knee of any severity up to the age of two and a half years. One of the simplest and most efficient braces is that devised by Thomas, which consists of a light steel upright with a trochanter pad at its upper end, with free motion in a joint opposite the hip articulation and a padded band to encircle the pelvis at the level of the anterior-superior spines. The lower end of the upright is rounded and bent at right angles, and inserted into the anterior portion of the heel of the shoe. The knee is fixed by a posterior bar attached to a thigh and calf band, as shown in Fig. 383. When the brace is applied, the knee is held backward and outward under tension by an internal lateral pad fastened to the posterior band upright by straps and buckles or by roller bandage. In severe cases, the uprights are bent to conform some-



FIG. 382.—Rachitic bow-legs and knock-knees. The children show the stigmata of rickets, and the child with knock-knees also has anterior bow-legs. (Taylor "Orthopedic Surgery.")

what to the limb, and as the deformity recedes they are gradually straightened until slight overcorrection of the deformity is secured.

The braces are removed daily for massage and manipulations. In children of two years or over, of large size and with severe deformities, braces should be worn at night as well as through the day. The duration of brace treatment varies from six months to a year, and depends on the degree of deformity, the efficiency of the apparatus, and the age of the child. In mild and favorable cases the night brace alone serves to correct the deformity.

Operative Treatment.—Operative treatment is indicated in all cases where the deformity is at all marked in children over three years of age. It is most satisfactory at all ages, excepting during the acute stage of rickets.

The operation of choice is, by all means, osteotomy, although Blanchard obtains excellent results by osteoclasis. Personally, the supracondylar

osteotomy, as advocated by MacCormac, is preferred (Fig. 384). This may be accomplished by a narrow osteotome or saw. A sharp osteotome, half an inch in width, is the preferred instrument. The field of operation is prepared in the usual way, the limb is rotated inward and placed upon a sand-bag opposite the point of bone section. With the cutting edge of the osteotome parallel with the long axis of the femur, it is pushed cornerwise through skin and the underlying structures to a point on the external surface of the shaft of the femur, about a finger's breadth above the upper border of the external condyle. A few taps of the mallet incise the periosteum.

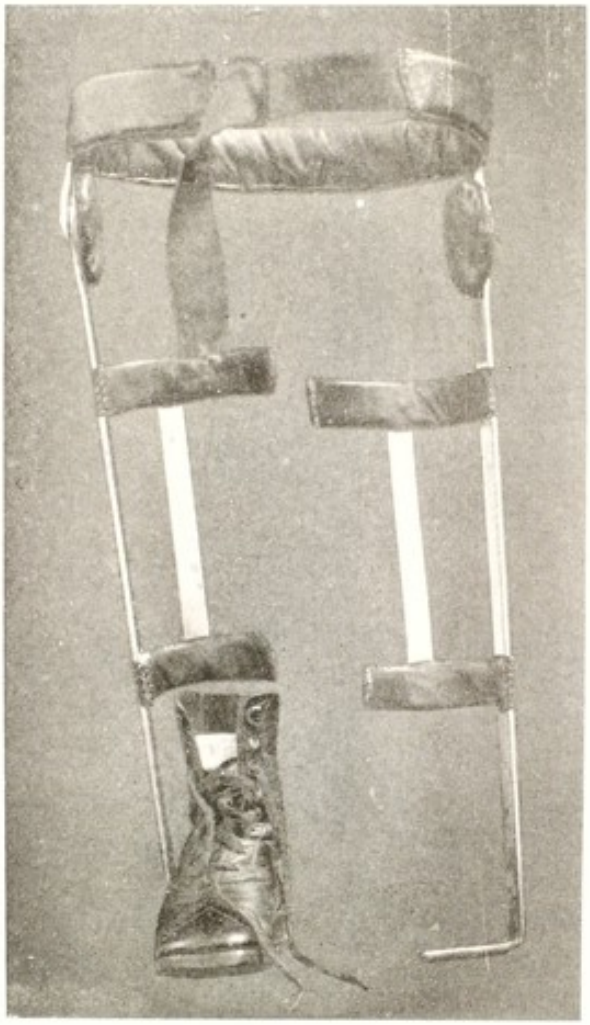


FIG. 383.—Thomas knock-knee brace with pelvic band. The pelvic band may be divided also, the two parts being joined by straps. (Whitman.)

The osteotome is then turned at a right angle to the femur and a gauze sponge is placed around the osteotome and in contact with the skin. By repeated blows of the mallet, two-thirds of the outer femur-shaft are cut transversely, with the chisel held as in Fig. 384, as in this way the possibility of driving the chisel too far through and entering the popliteal space is lessened. A greenstick fracture is then made of the remaining portion of the shaft. There may be some bleeding from the osteotome wound. It is, however, far preferable to leave it unsutured and allow the excess blood to escape, rather than to contribute to a hematoma in the soft parts by suturing the wound.

The deformity is then well overcorrected and placed in a plaster-of-Paris spica from the toes to include the pelvis.

If the deformity is bilateral, both legs are operated and a double spica is applied after the dressing. In this case, it is applied with the limbs widely abducted, and to strengthen the plaster a piece of splint board long enough to span the distance between the limbs just below the knees is incorporated in the last layers of the plaster bandage. This position of the limbs favors the use of the bed-pan and prevents soiling of the dressings.

The dressing should remain on for eight weeks, and it should be determined in each case whether the plaster dressing should be followed by knock-knee braces for a longer period. In some cases of marked rachitic involvement, supports should be worn for several months.

In certain cases where in addition to the femoral deformity there is a severe deformity at the upper end of the tibia, this may be rectified at a second operation by an osteotomy at the tubercle of the tibia. In exceptional cases, where the deformity is wholly in the tibia, an osteotomy of that bone may be sufficient.

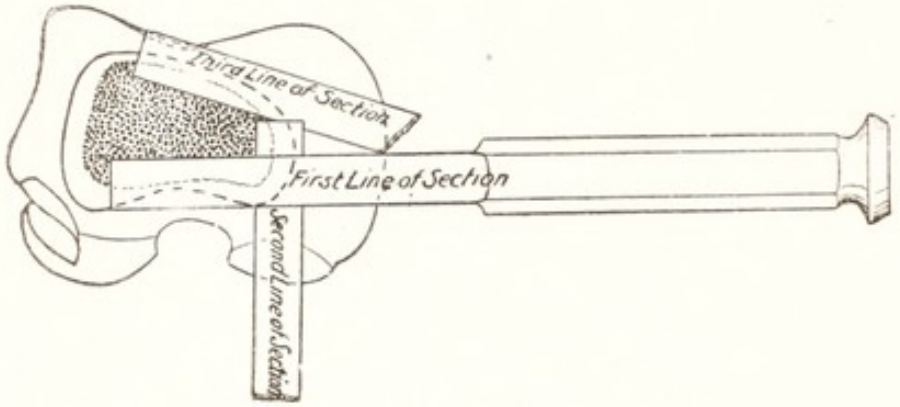


FIG. 384.—Original lines of section of the femur in supracondylar osteotomy. (Diagram shows a cross-section of the femur above the condyles, viewed from above.) (Binnie.)

(*d*) **Genu Varum** (Bow-legs).—As this deformity (see Fig. 385) is usually due to rickets, the outline of the general treatment is precisely the same as for knock-knee, and the milder cases are treated by expectancy, massage, and braces. The application of braces here has a broader field of usefulness and the prognosis is more favorable than in knock-knee.

The deformity of bow-legs is usually wholly confined to the tibia, and is most commonly found in the lower two-thirds of this bone. When the deformity is that of a general bowing of the tibia, brace treatment may be sufficient up to two and a half years of age; beyond that time, the treatment should always be operative.

Treatment by Braces.—Where the deformity is in the lower two-thirds of the tibia, the Knight brace is the one of choice (Fig. 386). This consists of two steel uprights attached to the shoe below; a soft leather pad for pressure over the inner condyle of the femur is attached to the upper end of the inner upright. The outer upright extends to the head of the fibula, and the two uprights are joined by a calf band. The bowed leg is drawn toward the inner bar by a broad leather cuff laced about the leg inside of the outer bar.

As the deformity recedes, the inner bar is bent until overcorrection is secured, as in the case of knock-knee treated by the brace method. This is usually accomplished in young children in from six to twelve months.

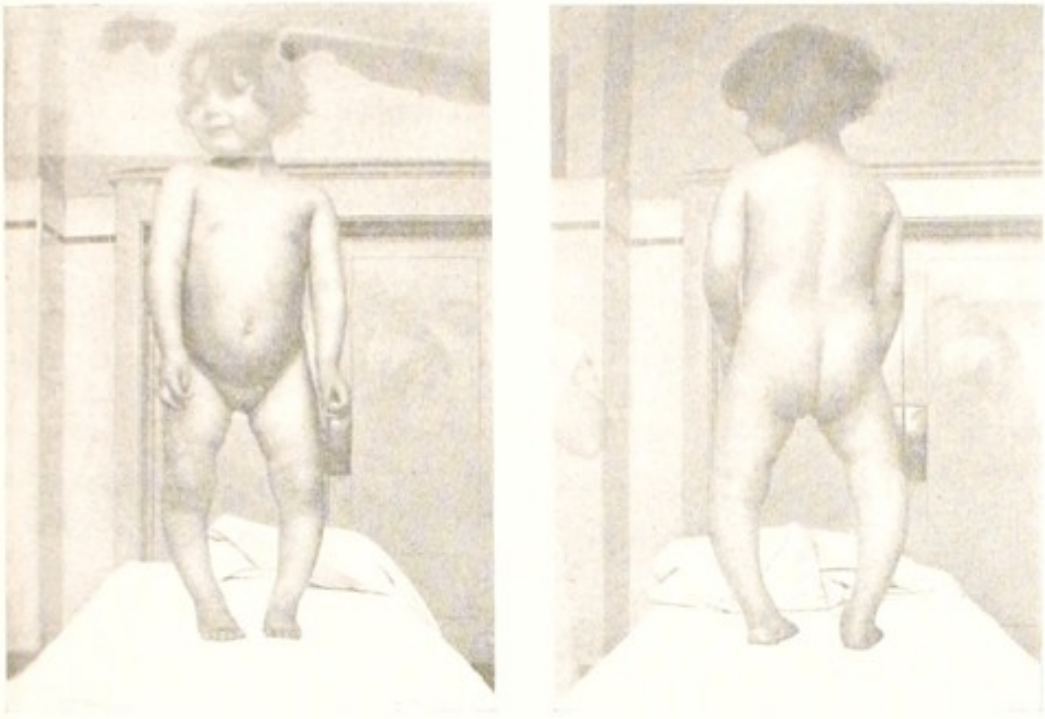


FIG. 385.—Genu varum (bow-legs) from rickets. Note the other rachitic stigmata —enlargement of lower epiphysis of radius, protuberant abdomen and large square head.

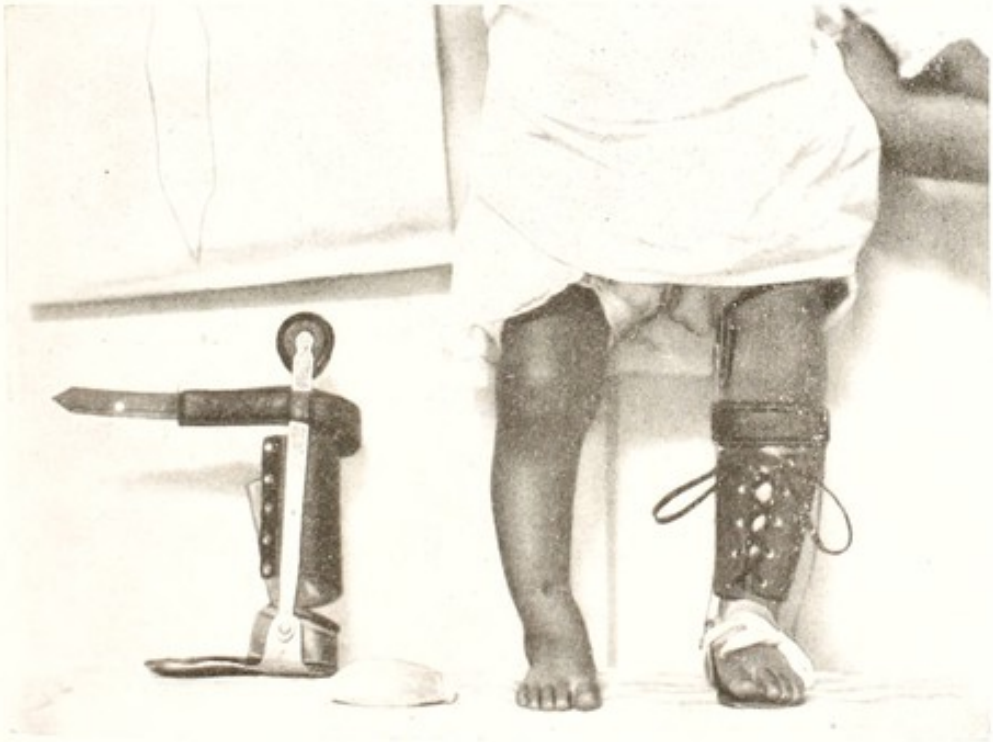


FIG. 386.—Moderate bow-legs in child of two, with Knight's splint. A pencil tracing of the deformity is shown at the upper left-hand corner. (Taylor.)

If the deformity is higher up and associated with outward bowing of the knee, a longer apparatus is necessary, with no joint at the knee. Such a brace is very similar to the short brace just described, except that the inner upright extends to the upper third of the femur and the outer upright to the pelvis, where it is attached to a pelvic band. A joint is placed in the outer upright opposite the hip articulation. The leather lacing encircles the knee and upper part of the leg, and serves to improve the contour of the leg by drawing it to the inner upright.

The corrective action of the brace progresses by bending the uprights to a better position from time to time.

Operative Treatment.—The operation of choice is that of osteoclasis by the Grattan osteoclast (see Fig. 387), except where the curve is sharp and situated near the knee- or ankle-joint (the chair-deformity). Here the osteoclast has the same disadvantage as in knock-knee. On account of the nearness to a joint and the increased density of the bone cortex at that point, it is diffi-

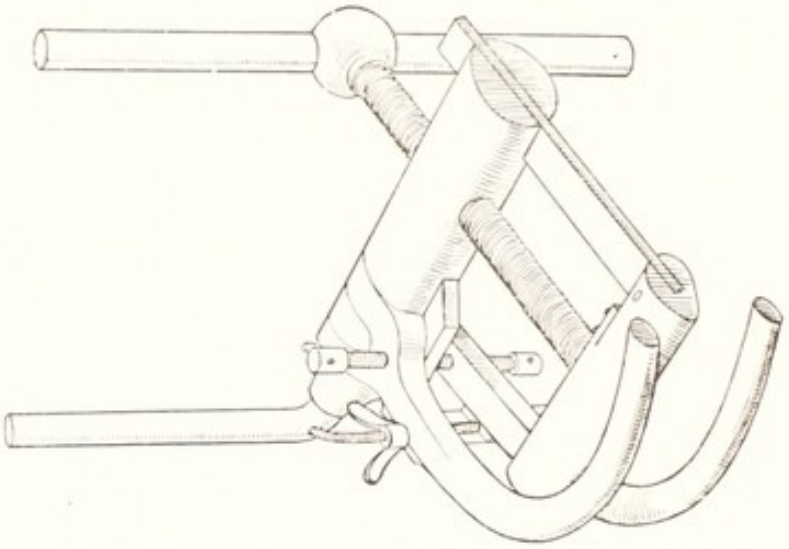


FIG. 387.—The Grattan osteoclast used principally for the correction of bow-legs. It has also been used for correction of knock-knee and malunited fractures. Mr. Grattan, of Cork, whose name it bears, used it to crush and overcorrect club feet. (Albee, in Johnson "Operative Therapeusis.")

cult to direct the force so as to produce a fracture at the maximum of the curve. Under these conditions, linear osteotomy is preferred.

Osteoclasis.—In osteoclasis, the point of greatest deformity should always be selected for fracture. The best instruments are those devised by Thomas and Grattan. With the arms of the osteoclast from $3\frac{1}{2}$ to 5 inches apart, the concave side of the limb is placed against them, and the maximum of the convexity is opposite the plunger. The limb is then firmly held on either side of the arms by an assistant, while the plunger or breaking bar is rapidly screwed down until fracture occurs, and then quickly reversed. The immediate release of the pressure of the plunger is imperative in order to prevent sloughing of the skin and underlying tissues. The limb is overcorrected and fixed by a plaster-of-Paris dressing.

Manual force over a Lorenz wedge or the edge of the operating table padded with a folded sheet is sufficient to produce the fracture in many cases of young children (Fig. 388).

Osteotomy.—An osteotome, half an inch wide, with the cutting edge parallel with the long axis of the leg, is pushed corner-wise through skin and

subcutaneous tissue to the internal aspect of the tibia. It is then turned to a right angle to the limb and the tibia is weakened on the inner side sufficiently to allow fracture by manual force. The limb is overcorrected until the fibula is also broken. A plaster-of-Paris splint is applied, reaching from the toes to the mid-thigh region, with the leg in the overcorrected position. This is to remain on from six to eight weeks.

(*e*) **Anterior Bow-leg.**—*Synonyms.*—Anterior curvature of the tibia; chair deformity; saber-shins.

Description.—While there may be evidence of general rachitis in children suffering with genu varum and genu valgum, anterior curvature of the tibia, on the other hand, is almost invariably incidental to generalized rachitic distortion of the legs. The tibiæ are flattened from side to side and are usually bent inward or outward as well as forward. The sharp-edged, anteriorly curved crest has given origin to the term "saber-shin."

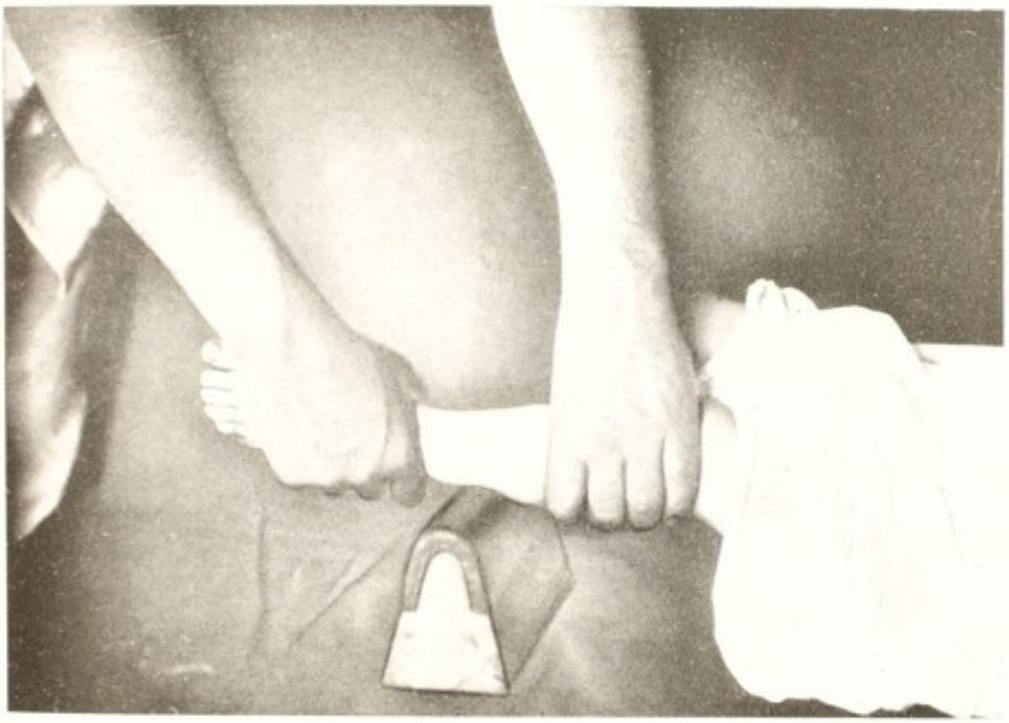


FIG. 388.—Manual osteoclasis of bow-leg over wooden wedge. (Taylor.)

A common cause of the condition, aside from weight-bearing, has suggested the synonym "chair-deformity," whose modus operandi is as follows: The young child with its naturally short legs is set upright in a chair, the posterior surface of its tibia coming to rest on the edge of the seat at a point somewhere in the lower half of the tibia. The point of rest is the fulcrum of a two-armed lever; the long upper arm (thigh and rest of body) being fixed, the malleable condition of the rachitic tibia allows the short lower arm, weighted by the foot, to sink toward the floor.

Treatment.—A cuneiform osteotomy with base anteriorly is performed by the technic already described. The fracture of the tibia and fibula is completed by manual force. Tenotomy of the tendo Achillis is unnecessary if correction of the deformity is prevented while the foot is in the "position of a right angle to the leg."

(*f*) **Flatfoot.**—Flatfoot, due to relaxed ligaments, incident to rachitis, will be found described in another chapter.

II. INFANTILE SCURVY (SCORBUTUS)

Synonyms.—Scurvy rickets; Barlow's disease. The disease bears no relation to rickets. It is merely an incidental co-existence when the two are found associated.

Etiology.—Defective diet is the basis of every case. The severest cases have subsisted largely on farinaceous foods. It is rare in breast-fed infants.

Pathology (Fig. 389).—Spontaneous hemorrhage and rarefaction of the bones are the underlying pathological features.

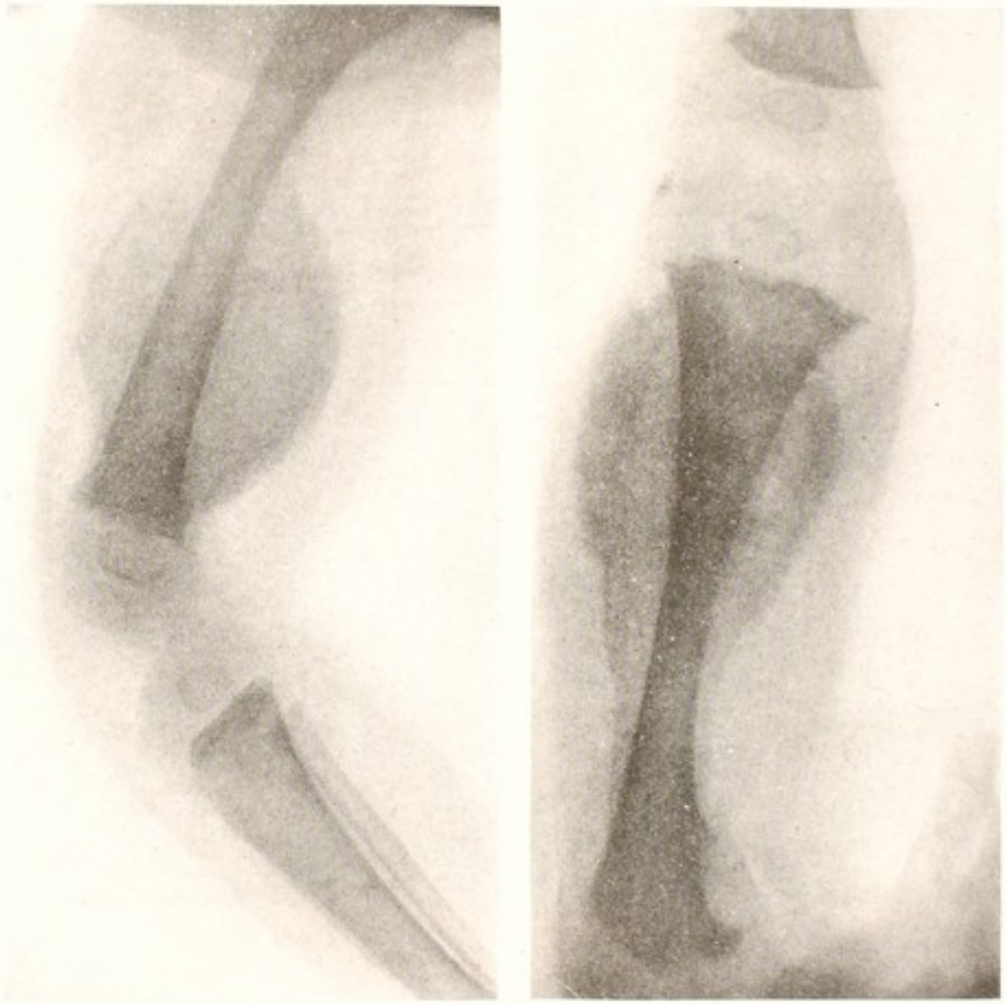


FIG. 389.—Extreme case of scorbutus. The extensive hemorrhagic exudate beneath the periosteum in this case is especially well shown by the *x*-ray.

Postmortem findings in a fatal case are as follows:

Extravasation of blood in the deep *muscles*, swelling and serous infiltration of the superficial muscles. *Periosteum* thickened, vascular, with subperiosteal hemorrhage. Separation of the *epiphysis* in extreme cases with blood-clot between epiphysis and metaphysis. *Interosseous hemorrhages. Rarefaction* of the *cancellous tissue* (ribs and epiphyseal junctions particularly). Submucous, subcutaneous, subdural, and visceral hemorrhages common.

With these changes, the ordinary rachitic signs may be present.

Clinical Features.—A poorly nourished infant of six to eighteen months is the usual subject.

Common signs and symptoms are tenderness on motion, fretfulness,

pseudoparalysis, red, swollen, spongy gums. Fluid swellings without signs of attendant inflammation overlie the long bones in the legs, ten times as frequently as in the arms. The skin of the legs is yellowish or else white, tense, and shiny. Exophthalmos is not rare, and is due to subperiosteal hemorrhage in the orbital plates. Depression of the sternum from separation of the costal cartilages has been noted. Hemorrhage may also occur from the genito-urinary tract, nose, stomach, and intestines.

Treatment is dietetic, and consists of *fresh food*, particularly fresh milk, raw meat, fresh fruit juices, potato, cream, etc. Cod-liver oil and iron are useful adjuncts.

III. OSTEOMALACIA

This disease of the bones is characterized by absorption and disappearance of their lime-salts. It is a disease of adults, chiefly females, and in them is incident to pregnancy and lactation.

Pathology.—The bones are characterized not only by absorption of their lime-salts but also by congestion of the marrow with increase of its lymphoid and fatty constituents. A thin shell of bone represents the cortex, which bends or breaks. Spontaneous fractures, often marked by malunion, are common.

Clinical Features.—Constant pain, increased on exertion, is experienced in the spine and pelvis. There is difficulty in walking, typified by a waddling gait. Muscular weakness is evident and the knee-jerks are accentuated, and ankle clonus and muscular tremors are present.

The pelvis is the first to suffer deformity, by extreme lateral flattening, producing a sharp anterior beak. The spine becomes kyphotic or scoliotic. The ribs are laterally compressed. The long bones are bent or suffer spontaneous fracture.

Prognosis.—The outlook is bad.

Treatment.—Salutary, hygienic surroundings, salt baths, cod-liver oil, phosphorus, bone marrow, etc., have been separately and collectively employed, with varying success.

Double oöphorectomy in non-pregnant women has occasionally checked the disease.

IV. OSTEOGENESIS IMPERFECTA

This rare condition is characterized by multiple fractures during intrauterine existence or in infancy and childhood.

Etiology.—Heredity is the only strong factor. The disease may involve an entire family.

Clinical Features.—The fractures are almost painless. They unite slowly with a minimal formation of callus and with frequent deformity. The long bones are generally affected, the femur most often. Curvatures occur independently of fractures. Deformity follows malunion. Scoliosis is sometimes seen.

Pathology.—The *x*-ray shows a thin cortex with a relatively large medullary cavity. The marrow is red, vascular, soft, and trabeculæ are few.

Treatment.—No preventive or curative treatment has yet been suggested.

V. FRAGILITAS OSSIUM (Figs. 390 and 391)

This affection is closely related to if not identical with the above disease.

VI. ACROMEGALY

This affection is characterized by hypertrophy of the hands, feet, head, and face, and by tumor of the pituitary body.

Etiology.—Its cause is unknown. Heredity may be influential in some cases; in others, there is a recent history of acute infectious disease. It is more common in women than in men. The age of onset is variable.

Clinical Features.—The appearance is typical, as follows: (Fig. 392). *Head* enlarged, enlargement involves soft tissues as well as bones, and the external occipital protuberance is very prominent. *Face* has been described as "leonine," orbital and zygomatic arches prominent, nose big, and its sep-



FIG. 390.—Fragilitas ossium producing coxa vara.

tum wide. *Jaw* prognathous, lower lip prominent, ears large. *Hands* and *feet* increased in size, fingers and toes broad, nails small. *Kyphosis* frequently of the cervical region. *Clavicles* broad. *Sternum* thick, wide, and long, its lower part thrust forward. *Chest* flattened laterally and increased antero-posteriorly. *Ribs* increased in width until they are almost approximated one to another, producing dyspnea.

Other features are: *skin* and *subcutaneous* tissues thickened. Husky voice, dyspnea, cardiac dilatation and weakness, enlargement of liver and spleen. Intermittent or persistent glycosuria, with death from diabetic coma, is not unusual. Severe, persistent headache is occasionally felt. Hemianopsia and optic atrophy are not uncommon.

Prognosis.—Duration of the disease, ten to twenty years or more. The onset is insidious, development slow, and may be stationary with recrudescences. Death occurs from exhaustion or dilatation of the heart, as a rule. Acute cases are associated with sarcoma of the pituitary body.

Pathology.—The essential changes are hypertrophy of the bones and cartilages with hypertrophy and hemorrhage of the marrow. The pituitary body shows simple hypertrophy with colloidal degeneration or adenoma, or else sarcoma or glioma.

Differential Diagnosis.—The disease may be confused with myxedema, Paget's disease, and "leontiasis ossea."

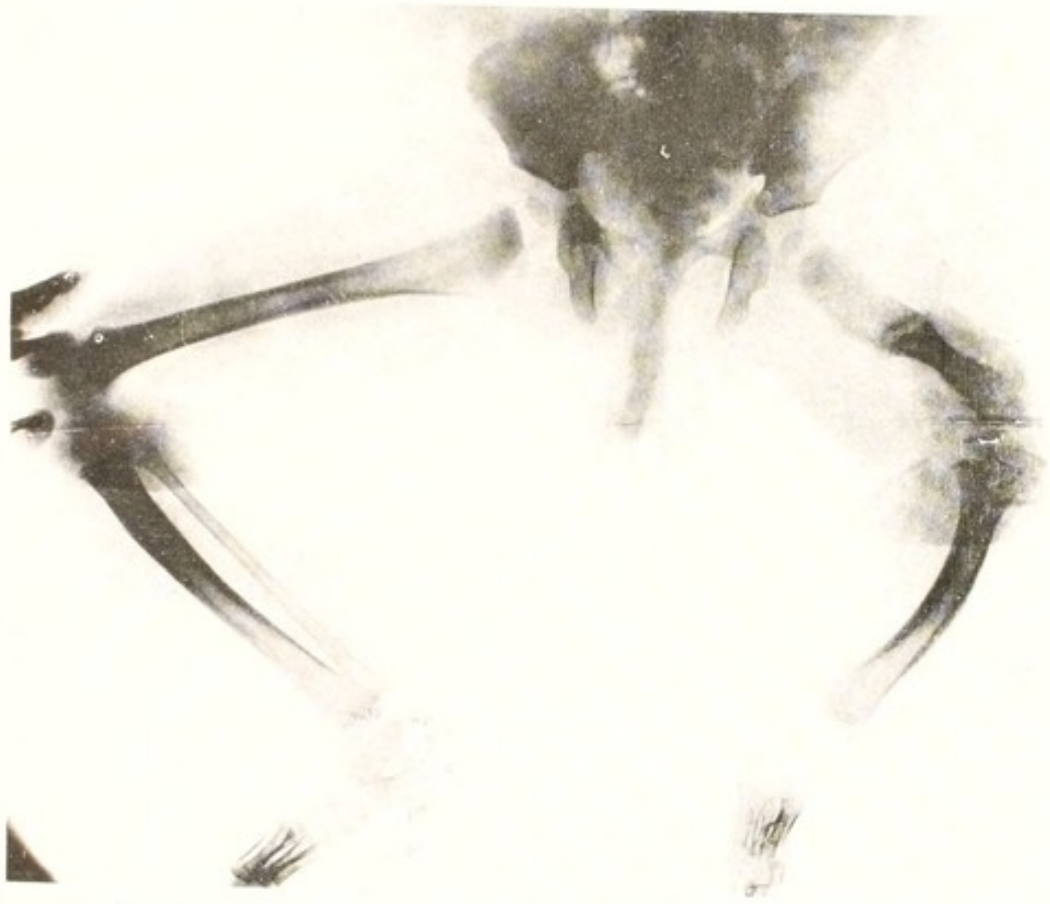


FIG. 391.—Fragilitas ossium. Showing result of multiple fractures and interference of growth.

Treatment.—There is no procedure known to affect the course of the disease, with the exception of occasional retardation of symptoms by administration of extract of pituitary body. Operative treatment: ablation of pituitary body.

VII. OSTEITIS DEFORMANS

This disease was first described in 1877 by Sir James Paget, and is commonly named after him "*Paget's disease*."

Definition.—Osteitis deformans is a disease of the bones of obscure origin, characterized by enlargement, softening and distortion of the skeleton.

Etiology.—It affects chiefly male adults about forty-three years of age who tend toward premature senility. In the majority of instances, arteriosclerosis co-exists, and occasionally arthritis deformans.

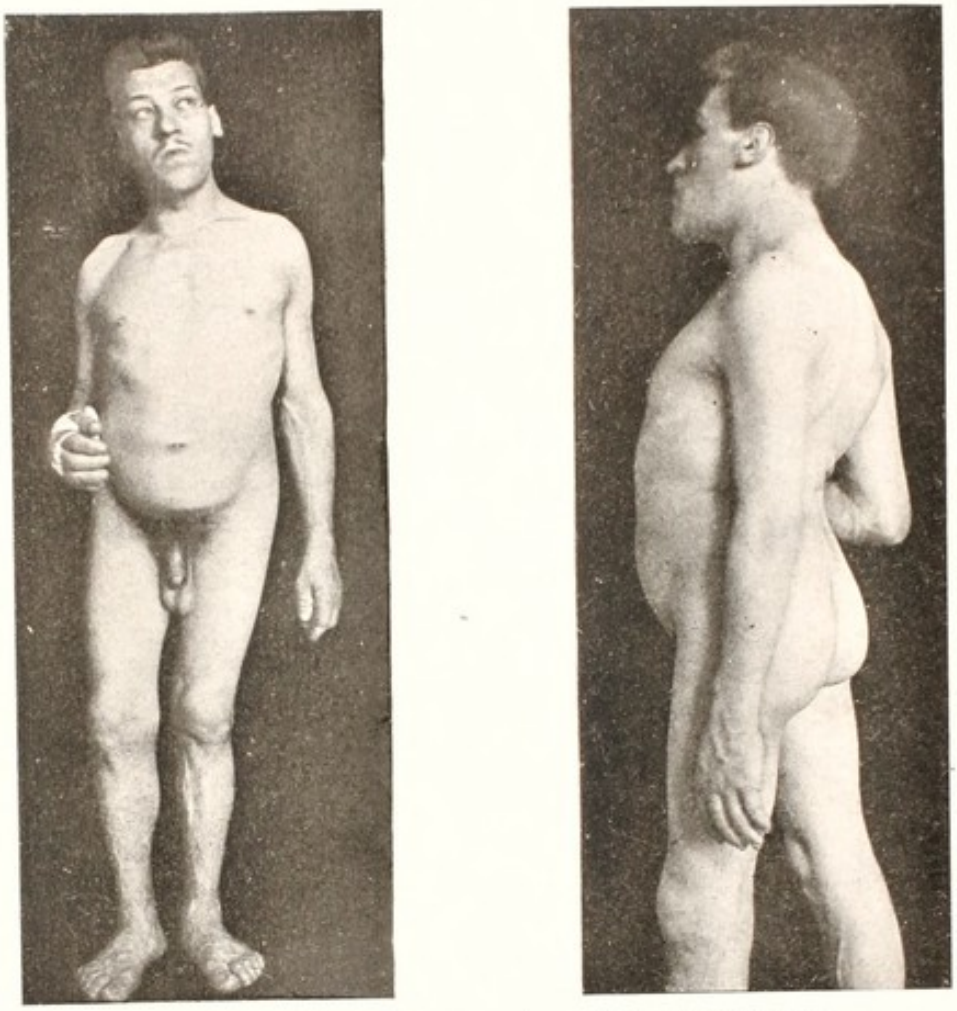


FIG. 392.—Case of acromegaly. (Falta and Myers.)

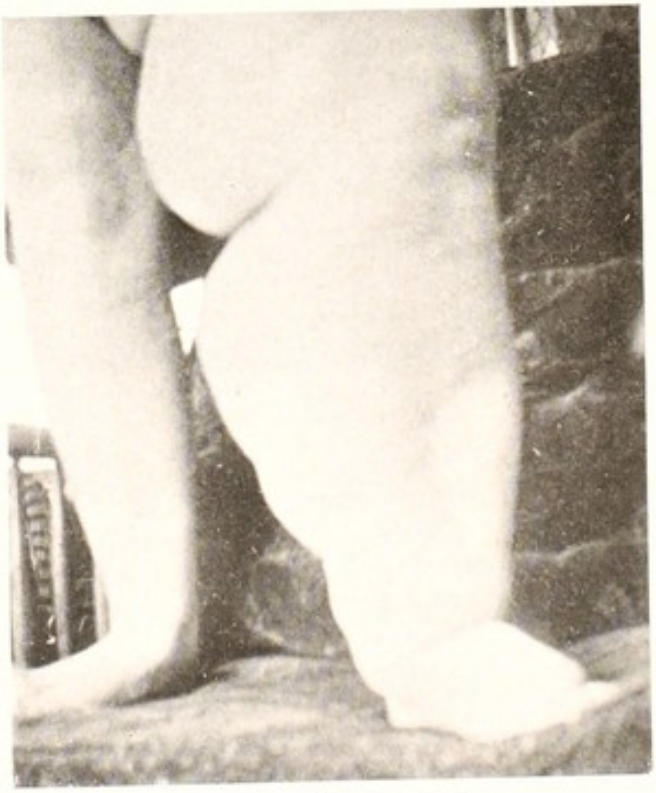


FIG. 393.—Elephantiasis.

Pathology (Fig. 394).—Thickening is accompanied by softening of the bones, but they eventually become hard. The compact bone is chiefly affected, its thickness being 4 or 5 times greater than normal. There is a combination of rarefying and productive osteitis, the former in the interior of the bone, the latter under the periosteum. The bones become heavier, thicker, curved, and white. Microscopically, the condition is chronic osteitis. Rarefaction and osteogenesis proceed synchronously. Sarcomata are common in bone thus affected.

Clinical Features.—The onset is insidious. There are preliminary pain in the limbs, stiffness of the back, and malaise. The condition is first appreciated by the rapid decrease in height, increase in size and girth of the head (tightness of the hat-band), and curvature and thickening of the legs.



a *b*

FIG. 394.—*a*, Localized Paget's disease in tibia causing bow-leg; *b*, Coxa vara due to Paget's disease. (Ostitis deformans.)

The attitude, when the disease is fully established, suggests that of the anthropoid apes, *e.g.*, legs bowed out, body inclined forward at the hips, spine bowed, shoulders rounded, head dropped forward.

Associated symptoms are neuralgic pains in the head, body, and legs, from pressure on the nerves and spinal nerve roots issuing from their foramina. Ossification of the spinal ligaments leads to rigidity of the vertebral column.

Fractures are rare, but when they do occur they heal readily. Ankylosis of the costovertebral articulations impedes respiration.

The disease is occasionally mistaken for spondylitis deformans.

Prognosis.—The disease is incurable. It may exist for twenty years. Death ensues from some intercurrent affection, as pneumonia and sarcoma of the affected bones.

Treatment is only palliative.

VIII. LEONTIASIS OSSEA

An osseous disease affecting the bones of the face. It occurs mainly in adolescents of from ten to thirty years of age. No definite cause can be assigned.

The pathological condition is hyperostosis. Bony masses form, accompanied by diffuse hypertrophy of the corresponding bone. The maxillæ are the usual sites, but the nasal and frontal bones are occasionally involved. The orbital and nasal cavities and their accessory sinuses are gradually obliterated, causing severe pain by pressure on the cranial nerves.

The enlargement is symmetrical. Additional changes are exophthalmos, epiphora, and obstructed nasal breathing and mastication.

The most striking feature of the disease is the leonine character of the face. In the final stages, the patient becomes blind from exophthalmos, deaf, and suffers excruciating pain from pressure on the cranial nerves.

Rarely the affection is diffuse, involving the cranial as well as the facial bones.

Diagnosis.—The lion-like appearance of the face with the gradual obliteration of the facial cavities is pathognomonic, but the condition is sometimes confused with acromegaly, osteitis deformans, sarcoma, or syphilis.

Treatment.—There is no treatment known which affects the condition.

IX. CHONDRODYSTROPHIA FETALIS (Fig. 395)

Synonym.—Achondroplasia.

Definition.—A disease of intra-uterine life, from the third to the sixth month of gestation, due to atrophy of the epiphyseal cartilages, followed by premature ossification.

Etiology.—Heredity is marked in some cases. Occasionally, cases of sporadic cretinism or infantilism are encountered in the same family. An analogous condition in animals is seen in the dachshund.

Clinical Features.—The disease begins about the third intra-uterine month, terminates about the sixth month, and is always concluded before birth. The severest cases probably die before birth.

Appearance When Born.—Cranium high and bulging; bridge of the nose absent; tongue often protrudes; chest narrow. The main feature is the extreme stunting of the legs, which are about half their normal length, with the bones thick, short, and curved, and the epiphyses prominent. Joint movements are usually limited. Another striking feature is the wide divergence of the middle and forefinger or the middle and ring finger.

After adolescence, the disproportion between the body and the limbs is accentuated, these cases forming the commonest type of dwarf. In women, extreme shortening of the true conjugate diameter of the pelvic inlet (it sometimes measures only 2 to 3 inches) necessitates operative delivery.

Diagnosis.—In infancy it is necessary to distinguish the disease from cretinism. In the latter, there is very little disproportion between the limbs and the body. From adult cretins, the normal temperature, healthy skin, muscular tone and intellectual acumen, and the normal genitalia, mark the chondrodystrophic.

Treatment is unavailing.

X. HYPERTROPHIC PULMONARY OSTEO-ARTHROPATHY

A chronic symmetrical disease of the bones, joints and soft parts, chiefly affecting the phalanges (Fig. 396).

Etiology.—Causes other than "pulmonary" may produce the disease, but *bronchiectasis* is the most prolific source.

It is much more common in males than in females, and in those of the middle period of life. It is generally incidental to suppuration within the thorax, and to congenital heart disease, syphilis, psoas abscess, and to diarrhea less frequently. But in all these latter some pulmonary disease is usually present; hence the condition seems to be due to a *toxemia* resulting from impairment of the respiratory exchange of gases.



FIG. 395.—Chondrodystrophia fetalis. The abnormal osteogenesis in the region of the epiphyseal cartilage, characteristic of this condition, is well shown.

Pathology.—The structural changes in the bones are as follows: Hyperplastic periosteitis with the formation of new subperiosteal bone; sclerosis of the cancellous tissue, with the formation of new compact bone and with consequent narrowing of the medullary canals. There are intermittent effusion into the joints and erosion of the articular cartilages. The peri-articular tissues are thickened. Clubbing of the fingers and toes precedes the joint changes; the nails become large, broad, brittle, and sharply incurved ("parrot-beaked clubbing"). The terminal phalanges are thickened transversely and anteroposteriorly.

Clinical Features.—The onset is insidious, with slight stiffness of the wrists and ankles, followed by slight swelling and discomfort.

Two clinical groups are recognized, viz.:

(*a*) *Arthropathic*, in which the joint conditions are paramount.

(*b*) *Osteopathic*, tenderness of the bones being the leading feature. The osteopathic type may permanently succeed the arthropathic.

The striking feature of the disease is its definite symmetry.

Although the hands and feet are the sites chiefly involved, many other bones and joints have been found postmortem to be affected.

Diagnosis.—On account of its rarity, this affection is mistaken for gout, rheumatism, and arthritis deformans, also for neuropathic arthropathies, tuberculous dactylitis, and acromegaly.

Prognosis.—The outlook is dependent upon arrest of the primary process.

Treatment.—For the arthralgia, the salicylates and local applications sometimes give relief.



FIG. 396.—Secondary osteoarthropathy due to Pott's disease, showing enlargement of liver and spleen. (Bradford and Lovett.)

XI. HEMOPHILIC JOINTS

Children and adolescents of hemophilic tendencies occasionally suffer spontaneous hemorrhage into the joints.

Pathologically, following repeated hemorrhages, the synovial membrane becomes thickened and reddish brown; degeneration and rarefaction of the cartilages occur, resulting in irregular weakening of these structures, and intra-articular adhesions form.

Clinically, the onset is with pain, swelling, and distention of the capsule. Reflex muscular contraction causes temporary deformity of position; the knee, the commonest situation, becomes flexed. Recurrence is usual.

Diagnosis must be made from tuberculous and syphilitic arthritis; this is usually done by the family history.

Treatment.—Prophylactic protection of the joints from trauma and strain should be carried out.

Operative interference is not indicated.

For combating the hemophilic tendency, calcium chlorid is of less value than fresh animal serum. Leary has advocated the use of fresh rabbit serum (ref.: "The Use of Fresh Animal Sera in Hemorrhagic Conditions," Boston, Med. and Surg. Jour., 1908, clix, 73–79), and has reported several

cases of material improvement from its employment. Recent investigations, however, seem to indicate that human serum is much more certain in its effect on hemorrhagic diatheses.

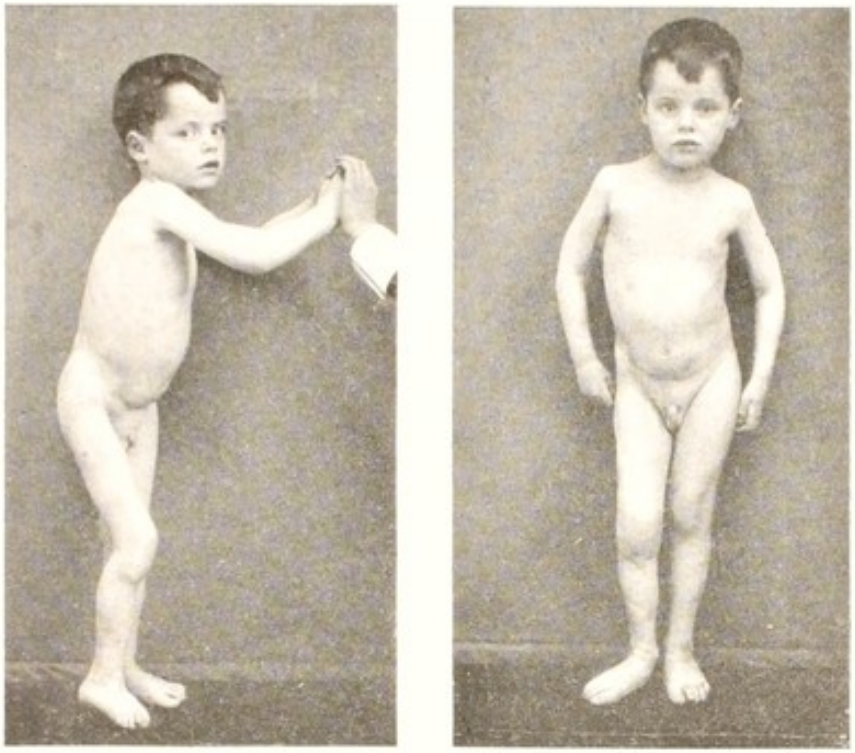


FIG. 397.—Scleroderma morphea resulting in flexion deformity of hips and valgus deformity of feet. (Kindness of Sir Robert Jones, Liverpool, Eng.)

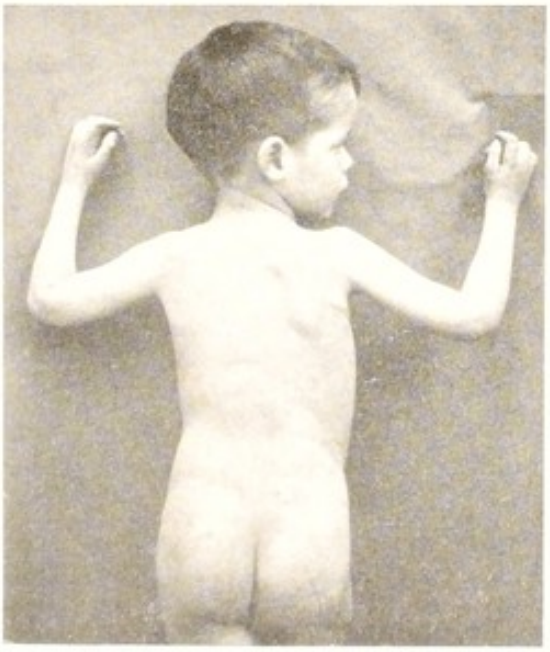


FIG. 398.—Scleroderma morphea. Same case as Fig. 397. This photograph shows the pigmented macular areas in the skin of the back. (Kindness of Sir Robert Jones, Liverpool, Eng.)

REFERENCES

RICKETS AND ITS DEFORMITIES

VIRCHOW: Archiv, Bd. v, 1853.
SHATTOCK: Path. Soc. Trans., 1881.

Railton, T. C.: Brit. Med. Jour., June 16, 1894.
Monti: Kinderheilk., in einziger Darstellungen, Heft. 2, 1900.
Escher: "Zur Frage der angeborenen Rachitis." Jahrb. f. Kinderheilk. Naturfor, Bd. lvi.
Little, W. J.: Holmes' System of Surgery, 3d ed.
Duplay: Gaz. des Hôp., 1891, p. 1337.
Jenner, Sir William: Med. Times and Gaz., vol. i, 1860.
Clutton: St. Thomas's Hosp. Rep., 1884, p. 103.
Cautley, Edmund: Brit. Med. Jour., Jan. 4, 1896.
Ransford: Brit. Med. Jour., 1887, vol. i, p. 1213.
Palm: Practitioner, vol. xiv, 1890, pp. 275–320.
Barlow and Berry: Keatinge's Cyclopedia of Dis. of Children, vol. ii, p. 225.
Jones, Robert: Brit. Med. Jour., Feb. 7, 1896, p. 341.
Hutchison, R.: Brit. Jour. of Childr. Dis., vol. ii, p. 222.
Roos, E.: "Über späte Rachitis." Zeitschr. f. klin. Med., Bd. xlviii, Hefte 1 and 2, 1903.
Rötter and Lauenstein: Arch. f. klin. Chir., Bd. xi, 1890.
Karewski: "Die Chirurgischen Krankheiten des Kinderaltes." Stuttgart, 1894.
Kirmisson: "Les Difformités acquises," p. 216.
Keetley, C. B.: Illus. Med. News, Sept., 1888. Ann. of Surg., vol. ii, p. 308.
Lucas: Lancet, June 9, 1893.
Carpenter: "Syphilis as a Rickets-Producer." Brit. Jour. Chil. Dis., vol. v, No. 2, p. 41.
Guérin: Trans. Inter. Med. Cong., 1881.
Dick: Path. Soc. Trans., vol. xiv, p. 289.
Baginsky and Bernhardt: "Rachitis." Eulenburg's Encyclopedia, 3, Auflage, 1889.
Dingwall-Fordyce, A.: Brit. Med. Jour., Apr. 28, 1906.
Wells, T. H. Sanderson: Brit. Med. Jour., July 8, 1905.
Joachimsthal: Handbuch d. Orth. Chir., 1904, vol. i, p. 72.
Hébert: Rev. d'orth., Nov. 1, 1905, p. 543.
Engel: Zeitschr. f. physiol. Chem., vol. xi, 1905.
Sharples and Darling: Boston Med. & Surg. Jour., 1903, p. 148.
Reyher: Jahrb. f. Kinderheilk., 3 F. xi, 4, 1905.
Kassowitz: "Die normale Ossification u. Rachitis." Wien, 1885.
Makins: "Rickets," in Treve's System of Surgery.
Feiss, H. O.: Amer. Jour. of Orth. Surgery, Jan., 1896.
John: "Über das Auftreten multipler Spontänfrakturen in früher Kindersalte." Breslau, 1903.
Comby: Le Rachitisme, Paris, 1892.
Tubby: Brit. Med. Jour., Oct. 15, 1898.
Phocas: Rev. d'orth., Jan., 1894.
Spitzy: Zeitschr. f. orth. Chir., Bd. xiv, Hefte 3 and 4, p. 593.
Lane, Arbuthnot: Guy's Hospital Reports, vol. xxix, p. 32.
Fisher, Theodore: Jour. of Children's Dis., Jan., 1906.
Gibney: Internat. Clinics, vol. iv, 1893, p. 239.

CUBITUS VALGUS AND CUBITUS VARUS

Philip Hoffman: Trans. Amer. Orth., vol. xv, 1902.
Joachimsthal: Handb. d. Orth. Chir., pt. v.
Kirmisson: Les. Difformités acquises.
Whitman: Orthopedic Surgery; 3d ed., p. 689.
Treves: System of Surgery, vol. i.
Berger and Banzet: Chirurgie orthopédique.
Peckham: Amer. Jour. of Orth. Surgery, April, 1906, Cubitus Varus Showing Deformity of Lateral Curvature of the Spine, Corrected by Osteotomy.
Nunn: Clin. Soc. Trans., 1892.
Von Lesser: "Über Cubitus valgus, Dissert." Dorpat, 1882. Arch. f. pathol. Anat. u. Physiol. u. Physiol. u. f. klin. Med., 1883, xcii, 1.
Porter: Jour. of Anat. and Physiol., xxix, pp. 488–496.
Rieffel: "Etude sur le cubitus valgus et varus." Rev. d'orth., 1897.
Hübscher: "Über den Cubitus valgus femininus." Leipzig, 1899. Deutsche Zeitschr. f. Chir., Bd. 51, Heft. 5 and 6.
Miraillié: "Un Cas de cubitus valgus double." Rev. d'orth., 1896, p. 146.
Tilanus: "Über einen Fall von Cubitus valgus." Zeitschr. f. Orth. Chir., 1891, Bd. Heft. 2 and 3.
Lorenz: Wiener klin. Wochenschr., 1903, No. 18.
Nicoladoni: "Über den Cubitus varus traumaticus." Präger Zeitschr. f. Heilk., 1884, S. 38.

DAVIS, G. G.: Ann. of Surg., 1899.
BRADFORD AND LOVETT: Orthopedic Surgery, 3d ed. p. 516.

INFANTILE SCURVY

BARLOW, SIR THOMAS: Med. Chir. Transac., 1883, vol. lvi, p. 159. Bradshaw Lectures, R. C. P., Lancet, 1894, vol. ii, p. 1073.
SUTHERLAND: Encycl. Med., vol. xi, p. 62.
Transactions of the American Pediatric Society, 1898, vol. x, p. 5.

OSTEOGENESIS IMPERFECTA

LOVETT, R. W. AND NICHOLS, E. H.: "Osteogenesis Imperfecta." Brit. Med. Jour., vol. ii, 1906, pp. 915–922.

LEONTIASIS OSSEA

HORSLEY: Practitioner, 1895, New Series, vol. ii, p. 12.
STERNBERG: Nothnagel Spec. Path. u. Therap., Bd. vii, Teil ii Abteil ii, 1899.
STEPHENSON: Brit. Med. Jour., 1900, vol. i, 1230.

CHONDRODYSTROPHIA FETALIS

THOMPSON, SIR JOHN: "Achondroplasia." Ency. Med., vol. i, p. 55.
BRADFORD AND LOVETT: Orth. Surg., 3d ed., p. 282.

HYPERTROPHIC PULMONARY OSTEO-ARTHROPATHY

THOMPSON, SYMES: Med. Chir. Transac., vol. lxxxvii (exhaustive bibliography on pp. 120–124 of that volume).
RANVIER: Rev. de Méd., 1890, 30.
WHITMAN: Pediatrics, 1890, vi, Nos. 4 and 5, with bibliography.
JANEWAY: Amer. Jour. Med. Sci., Oct., 1902, with bibliography.

PAGET'S DISEASE

JONES, S. F.: "Osteitis Deformans (Paget's Disease)." N. Y. Med. Record, December 28, 1912.
WRANY: "Prager Viertljahr," vol. I, 1867, p. 79.
WILKS: Trans. Path. Soc., London, 1868–69, xx, 273.
RULLIER: Bull. de l'École de Médicine de Paris, 1912, 04.
PAGET: Trans. Med. Chir. Soc., London, lxv, 382.
PAGET: Trans. Path. Soc. of London, 1884–85, xxxvi, 382.
SYMMONDS: Guy's Hospital Reports, 1881, xxv, 99.
BARLOW: Brit. Med. Jour., June 16, 1883, 1178.
PICK: Lancet, 1883, ii, 1125.
STILLING: Virchow's Archiv, cxix, 542, 1890.
THIBIERGE: Archives Gen. de Med., 1890, i, 52.
GIBNEY, V. P.: New York Med. Rec., April 19, 1890, xxxvii, 452.
JOUCHERAY: "De l'osteite deformante maladie osseuse de Paget." Monograph, Paris, 1893.
THIBIERGE: Bull. et Mem. de la Soc. Med. des Hôp., x, 116, 1893.
TAYLOR, H. L.: New York Med. Rec., Jan. 21, 1893, p. 65.
WATSON, A.: Quart. Jour. Med. and Surg., Melbourne, 1894, p. 45. Johns Hopkins Hospital Bulletin, 1898.
GUTHRIE: Trans. Med. Soc. of London, xvii, 355, 1894.
WESTERMAN, J.: Nederl. Tijdschr. v. Geneesk, ii, 938, 1895.
CLUTTON, H. H.: Trans. Path. Soc., London, 1895, xlvi, 138.
DE HALL: Lancet, London, April 18, 1896, 1064.
LEVI: Bull. de la Soc. Anat., de Paris, 1896, No. 13, 430.
PACKARD, STEELE AND KIRKBRIDE: Am. Jour. Med. Sci., cxxii, 559.
WILSON: Phila. Med. Jour., Feb. 15, 1902.
MENETRIER AND GAUCKLER: Rev. Française de Med. et de Chir., No. 40, 1903.
SCHMIEDEN: Deutsch. Zeitschr. f. Chir., 1903, lxx, 207.

Sonnenberg: Fortsch. a. d. Gebiete der Röntgenstr., 1904–05, viii, 420.
Roberts: Ann. Surg., 1904, xxxix, 438.
Daser: Münch. med. Wochenschr., 1905, liii, 1635.
Hochheimer: Charite-Annalen, 1905, xxix, 29.
Auffret: Rev. d'Orthop., 1905, No. 6.
Saunders: West London Med. Jour., 1906, 27.
Medea and Da Fano: Morgagni, No. 6, 1906.
Bardenheur: Deutsch. med. Wochenschr., 1906, xxxii, 525.
Tedeschi: Semano Med., Buenos Aires, 1906, xiii, 993.
Mackay: Lancet, London, Sept. 22, 1906, p. 787.
von Kutscha: Wiener klin. Wochenschr., 1906, p. 1461.
Apert and Bornait-Legeule: Bull. et. Mem. de la Soc. Med. des Hôp. de Paris, 1907 xxiv, 235.
Schlesinger: Mitteil. d. Gesellschaft f. innere Med. u. Kinderheilk., in Wien, Feb. 21, 1907, p. 61.
Stanley: Lancet, London, 1907, i, 889.
Waterhouse: Lancet, London, 1907, i, 1215.
Cohn, T.: Berl. klin. Wochenschr., 1907, No. 24.
Wetterer: Archiv f. Phys. Medezin, 1907, ii, 210.
Chartier and Descomps: Nouvelle Iconographie de la Saltpêtrière, 1907, p. 84.
Bramwell: Trans. Med. Chir. Soc., 1908, p. 254.
White, Sinclair: Brit. Med. Jour., 1908, ii, 1675.
Glaessner: Wiener klin. Wochenschr., 1908, cxxxix, 321.
Parkes-Weber: Brit. Jour. Children's Diseases, March, 1908.
Klippel and Weil: Nouv. Icon de la Saltpêtrière, Paris, 1909, xxii, 1–23.
Pascarolo and Bertolotti: Nouv. Icon. de la Saltpêtrière, 1909, xxii, 253.
White, R. M.: Brit. Med. Jour., 1909, ii, 12.
Maier: Charité-Annalen, 1909, xxxiii, 755.
Matsuoka: Deutsch. Zeitschr. f. Chir., 1909, cii, 515.
Hann, R. G.: Brit. Med. Jour., 1910, i, 135.
Vasek: Centralbl. f. Chir., 1911, No. 31, 1063.
Higbee and Ellis: Jour. Med. Research, 1911, xxiv, 43.
Stahl, B. Franklin: Am. Jour. Med. Sci., April, 1912, cxliii, 525.
Shirmer: Centralbl. f. d. Grenz. d. Med. u. Chir., 1908, xi, 561.
Elsner: New York State Jour. Med., 1910, x, 287.
Czerny: Wiener med. Wochenschr., 1893.
Butlin: Sir James Paget's Report, Med.-Chir. Trans., 1877, lx.

CHAPTER XX

INFANTILE PARALYSIS

GENERAL CONSIDERATIONS

Synonyms.—Spinal infantile paralysis (J. von Heine); epidemic poliomyelitis; Heine-Medin's disease; acute poliomyelitis; anterior poliomyelencephalitis, etc.

Definition.—An acute infectious and communicable disease, occurring in both epidemic and sporadic forms, caused by the invasion of the central nervous organs, the spinal cord, and brain by a minute, filterable micro-organism which has now been secured in artificial culture and is distinctly recognizable under the higher power of the microscope. The special localization of the lesions, in the majority of instances, in the anterior horns of the grey matter of the spinal cord, has given origin to the common name, poliomyelitis anterior, although this nomenclature is inexact inasmuch as the cerebrum as well as the spinal cord is generally involved.

Historical Note.—Jacob von Heine, in 1840, was the first to differentiate this type from other forms of paralysis, and the first to emphasize the symptomatology of both the acute and the chronic stages of the disease. Practically the only contribution to our knowledge of the disease in the thirty years succeeding Heine was the discovery by Duchenne and Erb of the electrical reactions. Medin, in 1887, was the first to recognize the widespread epidemic character of the disease. The epidemiology of the affection in Sweden was subsequently especially studied by Wickham, Harbitz, and others. The United States and Canada have been the scenes of serious outbreaks of the disease in the past fifteen years. In Sweden, Norway, and parts of Austria, it assumed epidemic proportions. New York city has been visited by several severe outbreaks. In 1907–08 there were about 2000 cases, with a mortality of 6 to 7 per cent.; while in the most recent epidemic in the summer of 1916, in that city there were 9290 cases with 2393 deaths (a mortality of more than 25 per cent.), according to approximated corrected totals of Surgeon Lavinder of the U. S. P. H. S. (ref.: Public Health Reports, vol. xxi, No. 44, Nov. 3, 1916, p. 3050). These latter figures, it will be noted, are in excess of the total number of cases reported in 1910 for the entire United States.

ETIOLOGY

In an address delivered before the New York Academy of Medicine, in July, 1916, during the recent great scourge of the disease, Simon Flexner stated clearly and concisely our present knowledge of the nature and manner of conveyance of infantile paralysis, and excerpts from his remarks will be incorporated in the following statements of the etiology of the disease (ref.: S. Flexner, "Address before the New York Academy of Medicine, July 13, 1916," published by Rockefeller Institute for Medical Research, New York).

The Infectious Agent.—A filterable, ultramicroscopic virus has been repeatedly demonstrated by Flexner to be the specific micro-organism causing infantile paralysis. Although ordinary bacteriological tests by artificial cultivation and microscopic examination have failed to demonstrate its exact

morphological and histological character, its relationship to the disease has, nevertheless, been abundantly proved by inoculation tests on monkeys in whom a disease corresponding to infantile paralysis in human beings has been developed.

Location of Micro-organism or Virus.—Infected individuals harbor the virus of infantile paralysis in the central nervous organs and the mucous membranes of the nose and throat and intestines with great constancy, while it has been found less frequently in other internal organs but *never in the circulating blood of a patient.*

By inoculation tests on monkeys, it has been furthermore demonstrated that healthy persons who have been in intimate contact with cases of infantile paralysis may become contaminated with the virus, which finds lodgment in the mucous membrane of the nose and throat, and that such individuals may convey the infection to others, chiefly children, while themselves remaining free from the disease.

Relation of the Virus to Types of the Disease.—The virus is invariably present *in the nervous organs and upon the mucous membranes of the nose, throat, and intestines of all cases*, whatever the type or severity of the disease, whether the abortive form with paralysis entirely absent or so slight as to escape detection, or the meningeal form resembling acute meningitis, or the ordinary paralytic form.

Avenues of Discharge of the Virus.—The *known channels* of *elimination* of the micro-organism from the infected individual are the secretions of the *nose*, *throat*, and *intestine*. In contaminated healthy persons it also escapes in the secretions of the nose and throat. Other means of escape have been accredited to biting insects (particularly the stable-fly and the bedbug), which were thought to be able to inoculate healthy individuals with infected blood, but failure of experimental work with the stable-fly and the fact that blood cultures of patients suffering with the disease have been found negative, have invalidated this theory. Experiments on animals have so conclusively demonstrated that the invariable channels of egress of the virus are the mucous membranes of the nose and throat, that it is practically certain that the virus seeks to escape from the human body in the same manner. And this is true not only in animals inoculated through these membranes, but also when inoculation is practised through the abdominal cavity, and the blood or the brain itself. Elimination by the intestines ensues upon swallowing the infected nasal and pharyngeal secretions.

Method of Infection by the Virus.—The virus, having entered the nasal and pharyngeal mucosa, multiplies there and is carried thence by way of the lymph-channels, which connect the upper nasal passages with the interior of the skull, to the brain and spinal cord. It is doubtful if the virus gains access to the body through the intestinal tract or as the result of insect bites, but the possibility of such sources of infection in isolated cases cannot be denied.

Resistance of the Virus.—The striking physical property of the virus is its great power of resistance. This natural resistance is favored by its being contained in the moist nasal secretions which enable it to withstand the most prolonged and intense summer heat, thorough drying, and the action of chemicals such as glycerin and carbolic acid which are germicidal for most other bacteria. Drying of the human secretions, therefore, not only does not destroy the virus but increases the danger of its dissemination by conversion of the secretions into dust. In common with many other micro-organisms the virulence of the virus is decreased by bright daylight and sunlight; and, conversely, darkness favors its survival in the secretions.

The location of the virus in the nasal secretions favors its transmission by coughing, sneezing, kissing, and by the fingers or articles contaminated by these secretions, as well as by the intestinal dejecta.

Transmission by Parasites.—It has been practically proven that neither *mosquitoes* nor *lice* are able to take the virus from the blood of infected monkeys or to retain it for a time in a living state. *Bedbugs*, although made to take up blood from infected monkeys, did not convey the virus by biting healthy monkeys. Early experiments seemed to indicate that the *biting stable-fly* was able to withdraw the virus from the blood of infected and transmit it to the blood of healthy monkeys, but these early experiments were not later confirmed. It is to be noted, moreover, that while the virus of infantile paralysis may appear in the blood of experimentally inoculated monkeys, it has never been detected in the blood of human beings suffering with the disease. The *domestic fly* may readily become contaminated with the virus-laden human secretions and convey the virus to food and individuals, and it has been proven experimentally that house-flies thus contaminated with the virus remain infective for forty-eight hours or more. Although insects are probably not active agents in the dissemination of infantile paralysis, they nevertheless, as Flexner pointedly remarks, fall under suspicion as being mechanical carriers of the virus of that disease.

Domestic Animals as Transmitters.—Diseases accompanied by paralysis are not uncommon in domestic animals, poultry, pigs, dogs, cats, and, in rare instances, sheep, cattle and horses. Occasionally humans living in the same neighborhood with the infected animals have been stricken with paralysis. That this occurrence, however, is merely a coincidence has been established by experimental studies which have differentiated the two affections; these paralytic diseases of animals are quite different in many respects from infantile paralysis of human beings.

Routes of Travel.—Where the disease is epidemic, it follows the routes of ordinary travel by sea or land, that is, as Flexner remarks (*loc. cit.*) "the distributing agency is intimately connected with human beings and their activities."

Fate of the Virus in the Body.—Destruction of the virus is more rapid and complete in the interior of the body than in the mucous membranes of the nose and throat. This has been proven experimentally in monkeys in whom the virus has been noted to disappear from the brain and cord while still present in the mucous membranes mentioned, having been detected for as long a period as six months in the nose and throat. It is more difficult to determine the presence of the virus in humans than in monkeys on account of its relatively low infectivity for the latter until adapted to them by one or more passages through the animal, when it becomes readily detected by inoculation tests. The existence of occasional chronic human carriers is unquestionable; for example, in one case the virus was detected in the mucous membrane of the throat five months after the acute onset of the attack, as recorded by Flexner (*loc. cit.*, p. 8).

Variability of Epidemics.—Great fluctuations in epidemics are known to occur, not only in the number of cases but also in the death-rate. For example, the sporadic cases which are almost endemic in every large community and from which no extension of the disease takes place, are in sharp contrast to the flagrant epidemics such as the one which afflicted New York City in the summer of 1916 with its total of over 9000 cases, with more than 25 per cent. mortality. This fluctuation depends upon several factors, some of which are of reasonable certainty, viz.: the variations in virulence of the virus; the instability of its virulence is exemplified by the low degree of

the infective power of the human virus toward monkeys, even during a fulminant epidemic, on the one hand, and the exaltation of its virulence acquired after repeated passages through monkeys on the other hand. After attaining this infectiousness toward monkeys, it may be passed from one animal to another through a long series without deterioration; finally, however, it undergoes gradual attenuation of virulence until it returns to its original or to a subnormal state of activity. Flexner directs attention to the analogous behavior of epidemics of the disease (*loc. cit.*, p. 9) viz.: the onset, rise, and fall in number and severity of cases, corresponding with the introduction, on the one hand, of a new virus which undergoes exaltation of virulence by repeated human passages; or, on the other hand, a residual virus is present from a former epidemic which, as the result of a resting stage and repeated passages through victims of the disease, takes on new potency equal to or greater than that which it originally possessed.

A second, less plausible explanation of variability in epidemics, is the varying degree of susceptibility among children, the usual subjects of the infection.

Individual Susceptibilities.—Individuals exhibit considerable variation in their susceptibility to infantile paralysis, comparatively few adults and by no means all children being susceptible. No age is absolutely immune, although the younger the child the greater is its susceptibility. The selection of certain children in a family group will undoubtedly be found to be a more apparent than a real selection, as physicians learn to be on the lookout for the light, abortive attacks with fleeting or totally absent paralysis, so that further study and research will doubtless confirm the assumption that there is a greater general susceptibility than has hitherto been supposed to exist.

Period of Infectivity.—The danger of communication is probably greatest in the very early and acute stage of the disease. This statement is based on the observations by Flexner and others that in experimental work the virus is viable only four to five weeks, on the average, in animals except in the occasional instances of chronic carriers. Flexner therefore states (*loc. cit.*, p. 11) that cases of infantile paralysis which have been kept under supervision for a period of six weeks from the onset of symptoms are practically free from danger.

Acquired Immunity.—One attack protects from subsequent infection. This is true of all forms of infantile paralysis, the paralytic, meningeal, abortive, etc. The basis of this immunity to subsequent infection, whereby the blood of humans and monkeys that have survived the disease is capable of destroying or neutralizing the effect of the virus, rests on the presence of immune bodies which are produced in the internal organs and are yielded to the blood. These immune, or antibodies, protect the individual against the virus of infantile paralysis as long as they persist, and, according to Flexner (*loc. cit.*) their presence has been detected twenty years or longer after recovery from the disease. This protection is afforded irrespective of the case, the immune bodies being present in the blood in even the mildest attack.

A SUMMARY OF RECENT CONTRIBUTIONS TO OUR KNOWLEDGE OF IMMUNOLOGY AND OTHER ASPECTS OF INFANTILE PARALYSIS

Neutralization of the Virus of Poliomyelitis by Nasal Washings.—Amoss and Taylor (Jour. of Exp. Med., vol. xxv, No. 4, April 1, 1917) make the following deductions from their studies on the subject:

"1. The results of 56 experiments have shown that washings of the nasal

and pharyngeal mucosas possess definite power to inactivate or neutralize the active power of poliomyelitis.

"2. This power is not absolutely fixed but is subject to fluctuation in a given person. Apparently inflammatory conditions of the upper air passages tend to remove or diminish the power of neutralization. But irregularities have been noted, even in the absence of these conditions.

"3. Too few tests have been made thus far to ascertain whether adults and children differ with respect to this neutralizing property in the nasal secretions. While the inactivating property was absent from the secretions of one child during the first days of poliomyelitis, it was present in another to whom immune serum was administered, and in still another on the fifteenth day of illness, when convalescence was established.

"4. The neutralizing substance is water-soluble and appears not to be inorganic; it appears to be more or less thermolabile and its action does not depend upon the presence of mucin as such.

"5. It is suggested that the production of healthy carriers through contamination with the virus of poliomyelitis may be determined by the presence or absence of this inactivating or neutralizing property in the secretions. Whether this effect operates to prevent actual invasion of the virus and production of infection, can only be conjectured. Probably the property is merely accessory and not the essential element on which defense against infection rests. It is more probable that other factors exist which help to determine the issue of the delicate adjustment between contamination and infection."

The Relation of the Meninges and Choroid Plexus to Poliomyelitic Infection.—Under the above caption, Flexner and Amoss base upon their observations the following conclusions (Jour. of Exp. Med., vol. xxv, No. 4, Apr. 1, 1917):

"Among the mechanisms which defend the body from infection with the virus of poliomyelitis is the meningeal choroid plexus complex, which normally is capable of excluding the circulating virus from the central nervous organs. The complex plays a part also in preventing infection from virus present upon the nasal mucosa.

"Aseptic fluids which irritate, inflame, or even slightly alter the integrity of the meninges and choroid plexus, diminish or remove their protective function.

"Normal monkey or horse serum, isotonic salt solution, and Ringer's and Locke's solutions, when injected into the meninges, promote infection with the virus of poliomyelitis introduced into the blood, the nose, or the subcutaneous tissue.

"Simple lumbar puncture and the withdrawal and return of the cerebrospinal fluid in normal monkeys, hemorrhage having been absolutely avoided, do not promote infection with virus injected into the blood; while the replacement of the cerebrospinal fluid of one monkey with that of another does, in some instances, lead to infection. Simple lumbar puncture attended with even one very slight hemorrhage opens the way for the passage of the virus from the blood into the central nervous tissue and thus promotes infection.

"Hence changes in the structure or function of the meningeal choroid plexus, too slight to be detected by chemical and cellular changes in the cerebrospinal fluid or the morphological alterations, suffice to diminish in an essential manner its protective powers.

"Of all the irritant fluids tested, immune serum alone injected into the meninges is not succeeded by infection from the virus introduced into the blood.

"The protective property of the immune serum is capable of overcoming the promoting action of normal monkey and horse serum and the other irritants mentioned.

"The importance first of the meningeal choroid plexus complex in preventing infection with the virus of poliomyelitis and next of immune serum in offsetting the disadvantages and dangers arising from defects in the mechanism is apparent, as is the bearing of the experiments reported on the serum therapy of epidemic poliomyelitis."

Survival of Poliomyelitis Virus for Six Years in Glycerol.—The durability of the virus of infantile paralysis is discussed by Flexner and Amoss at considerable length (Jour. of Exp. Med., vol. xxv, No. 4, Apr. 1, 1917). Their conclusions follow:

"The virus of poliomyelitis contained within the spinal cord and medulla of human beings and monkeys withstands glycerolation for many years. The specimens tested had been kept for four and six years, respectively, in 50 per cent. glycerol at refrigerator temperature.

"The symptoms and lesions caused by this virus are identical with those produced by that contained in the more recently collected spinal cord and medulla.

"The specimens had lost a part of their activity under the conditions described, necessitating larger and repeated doses to induce infection. Whether this difference is due merely to quantitative reduction in number of viable micro-organisms or to qualitative alterations under the influence of the mildly antiseptic glycerol has not been determined.

"An ineffective inoculation of tissue containing the virus does not increase resistance, but rather diminishes it, so that a subsequent injection, inadequate in itself, may cause experimental poliomyelitis.

"This power of survival under adverse conditions may not be without significance in respect to the recrudescence of poliomyelitis in a given locality and after a lapse of years. Hitherto this phenomenon has been accounted for by assuming a fresh importation of a virus of a pronounced pathogenic power. It is possible that the explanation in some instances resides in the renewed activity of specimens of the virus surviving from a previous epidemic, while in other instances a fresh introduction actually takes place from a remote focus of infection.

"The infectious nerve tissue employed in these experiments did not yield in culture streptococci or other bacteria."

The Globoid Bodies in Poliomyelitis.—Amoss ("The Cultivation and Immunological Reactions of the Globoid Bodies in Poliomyelitis," Jour. of Exp. Med., vol. xxv, No. 4, Apr. 1, 1917) stated that the globoid bodies, micro-organisms described by Flexner and Noguchi (Jour. of Exp. Med., 1913, xviii, 461) have been shown to bear a definite relation to epidemic poliomyelitis. They are very difficult of cultivation. In general, they have fulfilled Koch's law of causation. They have been detected microscopically in the nervous tissue of human beings and monkeys who had the disease.

Streptococci in Poliomyelitis.—Bull concludes an article on this subject (Jour. Exp. Med., vol. xxv, No. 4, Apr. 1, 1917) with the statement that "we have failed to detect any etiological or pathological relationship between streptococci and epidemic poliomyelitis in man or true experimental poliomyelitis in the monkey."

PATHOLOGY

The widespread character of the lesions is the striking feature of the disease. The affection can no longer be regarded merely as a lesion of the anterior

horns of the spinal cord, but as a widespread poliomyelitis and encephalitis with meningeal complications and lesions of the lymphatic system and parenchymatous organs.

A. Pathology of the Acute Stage

Meninges of Brain and Cord.—*Dura.*—The dura is usually normal in appearance and free from adhesions, but occasionally it is thickened and adherent to the pia.

Pia-arachnoid.—The pia is hyperemic and moist but without exudates, and is sometimes the seat of small capillary hemorrhages. *Microscopically*, there are noted small-celled infiltrations about the meningeal vessels, particularly in the lumbar and cervical swellings. This infiltration extends into the fissures of the cord so that on opening the meninges transverse fibers of pial tissue divide the surface of the cord into irregular transverse ridges. The degree of meningeal involvement is much greater than the gross appearance would indicate.

Cerebrospinal Fluid.—The cerebrospinal fluid is usually increased in amount, but clear. This increase is indicated by the force with which the fluid escapes on spinal puncture; if the pressure is low, the escape occurs drop by drop; if high, it may in some instances spurt from the needle with considerable force. While the fluid is usually clear at the onset of the disease, it may become slightly turbid in the preparalytic stage and again become clear as paralysis is established.

Spinal Cord.—Before the meninges are opened, the cord feels more indurated than normal; this is due to hyperemia and edema. On section, the cut surface bulges, appears moist, and the grey matter is hyperemic, resembling a red H, or in other instances, the redness is limited to the anterior horns which may show foci of infection.

Microscopically, there is an infiltration of small round-cells about the vessels and continuous with that affecting the pia mater, while a diffuse infiltration affects the entire myelin tissue. Although the grey matter is more affected than the white, no part of the cord at the cervical and lumbar enlargement entirely escapes. The anterior spinal veins and artery are congested with equal intensity. Hemorrhage, when it occurs, is probably the result of corrosive action of the virus upon the vessel walls.

The motor ganglion cells of the grey matter are affected as a sequel to the vascular and perivascular infiltration and edema. There is at first a temporary suspension of function with consequent regressive paralysis, while at a later stage of the process they degenerate and disappear, and are replaced by glia cells. Ganglion cells which have undergone necrosis do not regenerate, while those less seriously injured undergo partial or complete restoration of function. Although destruction of ganglion cells always takes place in an area affected by a high degree of infection, some of the ganglion cells may remain apparently normal. The phagocytic cells which participate in destruction of the ganglion cells are made up of lymphocytes and nuclear cells arising from the glia.

The cervical and lumbar swellings of the cord are the areas chiefly affected. The anterior horns suffer most in the cervical locality, while both anterior and posterior horns may be equally affected in the lumbar region. Involvement of the white matter of the cord is a late event, apparently consequent upon peri-vascular infiltration and focal hemorrhages in the white matter and denoted clinically by inco-ordination, ataxia, spasticity, and exaggerated reflexes.

The anterior root fibers have been observed to undergo early degeneration in some instances. Congestion and infiltration of the membranes covering the posterior root fibers occur, while the spinal ganglia become infiltrated and edematous or may undergo necrosis; this involvement results in acute pain during the preparalytic stage.

Medulla and Pons.—Lesions of these structures are the cause of the vast majority of deaths from this disease, by producing bulbar paralysis with cessation of respiration or cardiac insufficiency. The pathological changes consist of ascending hyperemia and infiltration following the pia upward from the cord and are frequently accompanied by hemorrhagic foci from the congested vessels and edema of the tissues covering the floor of the fourth ventricle.

Infiltration of the motor nuclei of the cranial nerves with regressive changes in the ganglion cells and consequent nerve paralysis, is sometimes observed. If the vagus center is affected, there occur tachycardia, arhythmia, etc. Affection of the vasomotor centers is accompanied by profuse sweating; of the vomiting center, by projectile vomiting; of the thermal center, by elevation of temperature.

Brain.—Hyperemia, infiltration, and edema of the cortex and white matter of cerebrum and cerebellum may occur and are manifested clinically by such conditions as spastic monoplegia, convulsions, epilepsy, mental derangement (cerebral lesions), or by tremors, acute ataxia, and nystagmus (cerebellar lesions).

1. *Cerebellum.*—Lesions of the cerebellum are similar in character and detail to those found in the cerebrum and are manifested by a wide range of clinical phenomena which consist mainly of tremors and ataxia.

2. *Cerebrum.*—Infiltration from the involved pial vessels may extend over the cerebral hemispheres and central gyri and even through portions of the substance of the hemispheres. Cerebral lesions are expressed by several clinical varieties, *e.g.*, hemiplegia; mental and moral deficiency; amaurosis, etc.

Lymphatic System and Spleen.—Any or all of the lymphoid tissues may be hypertrophied, viz.: swelling of the tonsils, acute enlargement of the solitary follicles and Peyer's patches of the small intestine, acute inflammation of the mesenteric glands, thymus, and of the superficial and deep lymphatic glands.

Enlargement and hyperemia of the spleen with hyperplasia of the Malphigian bodies are sometimes observed.

Lungs.—Congestion and areas of bronchopneumonia are not uncommon.

Liver.—Disseminated focal necroses with hyaline degeneration are quite constantly observed. These areas of focal necrosis may number as many as twenty or more. Attempts at repair of these lesions are rapid.

Kidneys.—Renal lesions vary from hyperemia, edema, and incipient degeneration in the mild cases, to an acute exudative nephritis in fulminant cases of the disease. Anuria, rather than retention of urine, is encountered clinically in some of these cases.

B. Pathology of the Chronic Stage

The essential lesions of the chronic stage are cicatrization of the affected portions of the spinal cord, with consequent atrophy of all the organs of motion and locomotion, viz.: muscles, tendons, bones, and joints.

Spinal Cord.—The lesions in the cord consist of areas of cicatricial tissue corresponding to the portions of the cord affected, and are accompanied by

atrophy of the anterior horns and, in some instances, of nearly half the cord. Entire absence of nerve elements, and shrinkage of the anterior horns with segregation and atrophy and increase in the amount of connective tissue, accompany these changes in the anterior cornua, while a similar retrograde metamorphosis affects the motor nuclei.

Muscles.—Profound changes take place in the muscles of the paralyzed limbs. These changes consist principally of rapid diminution in size and a degeneration atrophy of irregular character. Fatty degeneration gives the affected muscle fibers a yellowish white appearance, in sharp contrast with the normal red of the unaffected portions. There is apparently fusion of the degenerated fibers, so that individual fibers cannot be differentiated. Vulpius (Tr. of Infantile Paralysis, William Wood & Co., 1912, p. 22) calls attention to areas of streaky degeneration sometimes seen in muscle bundles lying side by side with healthy fibers, the so-called "tabby-cat" muscles. A peripheral deposit of fat about the affected muscle tends to favor its complete degeneration. Certain undersized muscles may exhibit, instead of the yellowish white color of degeneration, a heightened red appearance, disuse atrophy, or overstretching. Associated changes in paralyzed muscles consist of shortening, wasting or overstretching (as the result of malposition), and compensatory hypertrophy.

Tendons.—Disuse atrophy results in diminution in size and power of the tendon. This weakness, with its attendant danger of rupture on exertion, is most marked, as Vulpius points out (*loc. cit.*, p. 24), where the tendon is intersected by degenerated muscle, as in the case of the quadriceps tendon.

Skeleton.—Osteoporosis affects the bones in some instances, and occasionally distortion of the long bones occurs. The former is the result of disuse atrophy; the latter is produced by long-continued faulty position and unequal stress. The long bones are more slender and delicate when affected with osteoporosis, the cortex is rarefied, the medulla attenuated, and they are decreased in length (shortening may amount to 5 to 8 inches in extreme cases).

Joints.—Changes in the joints are incidental to disuse and distortion from malposition and irregular muscle-pull. These abnormal forces produce relaxation and overstretching of the capsule and ligaments, which result in an unstable, abnormally mobile joint in which subluxation or dislocation may occur. In cases in which the paralysis is incomplete in the muscles operating about a given joint, marked contractions may occur, with unilateral shortening of the capsule.

SYMPTOMATOLOGY AND CLINICAL COURSE

A consideration of the symptomatology and clinical course of infantile paralysis falls naturally into four divisions, viz.: I. Acute stage; II. Paralytic stage; III. Stage of recovery; and IV. Stage of degeneration.

I. Acute Stage

Incubation Period.—In common with all other infectious diseases, infantile paralysis has its period of incubation and symptoms are not evident immediately after infection. This period varies widely, from as short an interval as two days to one as long as two weeks, and occasionally longer. The usual incubation is, according to Flexner (*loc. cit.*, p. 10) about eight days.

Prodromal Symptoms.—Before the disease actually begins, certain slight though definite signs of constitutional disturbance are quite evident. The

commonest of these aura or prodromata are irritability, malaise, weakness, dizziness, or even vertigo which may be attended by more or less ataxia, the latter resulting in tremors, stumbling gait, and accompanied by frequent falls. Ataxia and its attendant symptoms, just enumerated, are more common in children than in adults, and the child's stumbling, insecure gait, is undoubtedly the cause of the trauma which frequently precedes the onset of the disease. That trauma is usually an accidental factor, the result of ataxia and inco-ordination, and therefore a complication rather than a cause of the disease, has been conclusively established by Lovett, who found that in only 2 out of 47 cases with a history of trauma could the accident not be excluded as due to ataxia and inco-ordination.

Onset.—The symptoms of onset are those of an illness having the general symptomatology of infection, with added indications of cerebrospinal irritation, but without motor disturbances; the symptoms are therefore identical with those encountered in the so-called abortive forms of the disease.

Following the prodromal symptoms enumerated above, the onset of the disease is, as a rule, very acute, usually with marked acceleration of the pulse rate to 140–150 (a very constant feature of onset), with a sharp rise of temperature to 102° or even 104–106°F. and with respirations mounting rapidly to 40–60 per minute. Coincidently with this febrile triad, are noted meningism, basilar headache, tremors, inco-ordination, ataxia, convulsive movements, vomiting, obstipation, and retention of urine, occasionally accompanied by chilly sensations or true rigors. In other cases the onset is like that of typhoid. Other initial symptoms besides those just enumerated are pain in the nape of the neck, between the shoulders, and in the lumbar region. There may be stiffness of the neck or of the whole spine from meningeal irritation. In some cases severe pain is experienced in the arms or legs when touched, the muscles and nerves being so tender as to cause the case to be mistaken for polyneuritis. Pain, in some instances, is so severe that the patient dreads the slightest movement or disturbance. Hyperesthesia of the extremities is not uncommon. Muscle tremors, varying from slight twitchings to convulsive movements great enough to throw the patient from his bed, are sometimes encountered. Retention of urine is often sufficient to require catheterization, while suppression is not infrequent; in any case, the total twenty-four-hour amount is diminished.

The symptomatology is so varied and of such fundamental importance that it may profitably be discussed in greater detail, with the clinical features arranged by systems, viz.:

1. **Circulatory System.**—(*a*) *Epistaxis* is quite common and is probably due to congestion of the nasal mucous membrane incidental to localization of the virus at that point. It is fair to assume, then, that hemorrhage from the blood-vessels of the upper nasal passages is due to the direct action of the virus on their walls.

(*b*) *Heart.*—Marked acceleration is quite constant, the rate noted by various observers ranging from 100 to 150 in adults and as high as 200 in children in the acute stage, with a decline, however, after onset of the paralysis.

(*c*) *Pulse.*—The pulse is usually weak and flabby, and sometimes arhythmic. The origin of acceleration of the heart and pulse is probably to be found in excitation of the accelerator branch of the vagus nerve by direct action of the virus on the accelerator center in the medulla or by the direct irritant action of the virus on the heart muscle. Increase of the pulse rate is not necessarily a concomitant of the hyperpyrexia in this disease.

(*d*) *Vasomotor Disturbances.*—These are indicated by profuse sweating, a frequent feature of the disease, by conjunctivitis, by congestion alternating with blanching of the face, and by ecchymoses, cyanosis, and lowered surface temperature of the extremities later in the disease.

2. **Temperature.**—Chilly sensations may be experienced, or occasionally a distinct rigor may be observed. In children, the latter may be expressed by a slight convulsion.

The onset of the disease is usually marked by an abrupt rise in temperature to 102°, or in extreme cases to 104–106°; this level is maintained for a short period, when the temperature drops rapidly (crisis) to approximately 100°. The temperature is variable and it is not an absolutely reliable index of the severity of an attack unless it is accompanied by a correspondingly severe train of initial symptoms, in which case an extensive invasion by the virus and a proportionately severe paresis may be predicted. The temperature usually drops to about 100° prior to the onset of paralysis and remains at that level until paralysis is established, when it usually falls to normal. A correspondingly subnormal surface temperature is present in the paralyzed limbs.

3. **Respiratory System.**—*Respiration.*—In cases with severe onset or with profound lesions, serious disturbance of the respiration occurs. An initial increase to 40–60 per minute is frequent. This derangement of respiration is due to various causes, viz.: (*a*) excitation of the phrenic nerve at its point of origin with the spinal branches of the spinal accessory; (*b*) irritation of the vagus innervation of the diaphragm in conjunction with rigidity of the neck and hyperextension of the head from spasm of the muscles innervated by the cervical plexus. After the onset of paralysis and the return of the temperature to normal, the respirations are correspondingly reduced in rate except in the case of the acute ascending (Landry's) type of paralysis, in which the respirations either remain rapid or continue to be accelerated after a preliminary drop in rate, and in addition become feebler and slightly irregular. This persistence of rapid breathing is of grave prognostic import, presaging paralysis of the muscles of respiration or the diaphragm. In the latter instance, recession of the epigastric region during inspiration and its protrusion during expiration are noted.

Dyspnea and *tachycardia* indicate affection of the vagus. The Cheyne-Stokes syndrome is an accompaniment of both types of respiratory paralysis.

Paralysis of the muscles of one side of the chest may cause immobilization of that side while the respiratory excursions of the unaffected side are normal. Another form of respiratory obstruction is rapid paralysis of respiration from a bulbar lesion which may occur in the event of only a mild paresis with normal temperature and complete consciousness.

4. **Digestive System.**—The most important affection of the digestive tract is a more or less severe paralysis of all parts of the alimentary system, which is manifested at the onset of the disease by anorexia, vomiting, foul breath, sordes about the mouth, and, most serious of all, obstinate constipation accompanied by colicky pains, tympanites, and meteorism. Diarrhea often precedes the beginning of constipation and appears to be an effort of nature to eliminate the virus.

Vomiting is often projectile and forcible. If frequently repeated after evacuation of the stomach, it is often an indication of irritation of the vomiting center in the medulla. "Coffee-ground" vomitus sometimes occurs as a late symptom in many fatal cases; whether due to altered blood from epistaxis is not certain.

The most serious and also the most constant complication referred to the

digestive system is constipation. It is dangerous chiefly because it blocks the main channel of elimination of the virus of the disease, which is present in large amounts in the digestive tract. Experiments on monkeys have indicated that the virus becomes active in the intestinal mucosa only in the absence of peristalsis. The constipation of infantile paralysis is very resistant to cathartics and enemata.

Diarrhea is commonest in the abortive form of the disease. When it occurs in familial groups one of whose members is suffering with a frank type of infantile paralysis, it undoubtedly indicates infection with the virus. The dejections are large and foul-smelling.

5. **Genito-urinary System.**—Urinary disturbances almost invariably occur. The twenty-four-hour amount is uniformly subnormal with occasionally albuminuria and, infrequently, acute exudative nephritis. The bladder symptoms encountered are frequent micturition, retention or suppression. Retention is common, is due to temporary paralysis of the bladder walls, and usually requires catheterization. Incontinence is rare and indicates paralysis of the vesical sphincter. Anuria and suppression usually occur only in fatal cases.

6. **Skin.**—Various disturbances have been noted to affect the skin and its auxiliaries. Sweating may be excessive, but it is not a constant feature. Hyperesthesia is not infrequent, while derangement of the temperature and tactile sensibilities may occur. Congestion of the paralyzed limb, with lowering of its surface temperature, the result of vasomotor disturbance, is common.

Many varieties of skin rash have been observed, and occasionally with considerable frequency. The eruption most frequently observed is an erythema resembling measles. Other types of rash are the scarlatinal, purpuric, urticarial, herpetic, etc. The important point to remember is that a skin rash occurs with greater frequency than is generally supposed, and that on this account infantile paralysis may readily be mistaken, in its early stages, for one of the exanthemata.

7. **Psychoses.**—Restlessness, emotional disturbances, such as hysterical attacks, and signs of mental confusion have been noted by various observers.

8. **Pain.**—Pain and tenderness are among the earliest and most reliable symptoms of the disease. The commonest manifestation of pain is occipital headache, associated in some cases with intense pain between the scapulæ and in the lumbar region of the spine.

Exquisite muscular tenderness quite frequently precedes and accompanies the paralysis. Pressure is more provocative of pain than is movement of the affected limb. This distress may be constant or paroxysmal and may cease after paralysis is fully established or it may continue for a variable length of time after its onset, lasting in some cases for several weeks or months.

Pain of another character is that due to peripheral neuritis and associated with hyperesthesia of the skin and agonizing pain along the nerve trunks extending into the posterior root ganglia. This neuritic pain may endure for a period of years.

9. **Meningism.**—This is an almost constant feature. The commonest indications of meningism are rigidity and pain in the neck, with more or less retraction, which varies from slight stiffness preventing flexion of the head, to actual retraction or opisthotonos. It is doubtful if the stiffness of the spine is due to actual contracture of the spinal muscles; it is probably a purposeful act superinduced by pain on movement and aimed at its limitation.

10. **Reflexes.**—The patellar reflex is exaggerated in the early stages, but becomes less marked or totally disappears before the beginning of paralysis,

as a rule. A modified Kernig is noted in spastic cases, *i.e.*, when the thigh is flexed to a right angle the patient is unable completely to extend the leg. The superficial and deep reflexes exhibit no constant or characteristic behavior; wide variations occur, corresponding to the types and stages of the disease.

11. **Meningitis.**—Involvement of the meninges is indicated by muscular twitchings, tremors, contortions, or actual convulsions. The convulsions may be mild or of the most intense type, and depend upon the degree of virulence of the virus and the area of nervous tissue involved. The occurrence of convulsions may cause the disease to be mistaken for tetanus, rabies, or eclampsia. Mental confusion, torpor, or delirium may also be encountered.

II. Paralytic Stage

The onset of paralysis is sometimes discovered in severe cases after subsidence of the flagrant initial symptoms; again, the onset may be mild and unnoticed, as in the case of a child who retires to bed in normal condition and is discovered to be paralyzed the following morning. Slight motor weakness and a tendency to fatigue are noted in some cases in the early febrile stage; these phenomena are either stationary or slowly disappear, or go on to a stage of complete paralysis. This preparatory stage may be entirely overlooked.

The paralysis is confined to the motor system alone, but as a rule advances with great rapidity so that its full extent is apparent in a few hours; but in some cases it may continue to spread for one or more days, or, in rare instances, for several weeks.

III. Stage of Recovery

The condition does not, as a rule, remain hopeless as at first appears. The true extent of the paralysis can usually be determined at the end of one week, when the earliest signs of recovery can be detected in slight but definite voluntary movements, and improvement often continues to take place over a period of several months.

The period of regeneration lasts six months or more and may continue for years from the onset of paralysis. Complete recovery is not rare. Certain muscles quite constantly escape, probably on account of the fact that their nerve supply is derived from several segments of the cord, of which not all are usually affected.

IV. Stage of Degeneration

Flaccidity of the affected muscle is soon followed by atrophy, which may continue to the most extreme degree of wasting. This wasting may be masked by fatty infiltration of the muscle and subcutaneous fat.

The electrical reaction of degeneration appears toward the end of the first or the beginning of the second week, and is of considerable prognostic importance despite the adverse criticism of certain observers. To the *faradic current*, excitability is always diminished during the first few days, but if it has not entirely disappeared at the end of the second week, it is highly probable that the muscle fibers which still react to it will recover. On the other hand, total loss of faradic excitability does not necessarily indicate permanent paralysis of the muscle, for not only may it recover its power, but voluntary movement may return before the normal electrical reactions are resumed.

Galvanic Excitability.—Alteration of this reaction is of much more serious prognostic value. Partial or complete reaction of degeneration with the characteristic slow muscular contraction, indicates that the fibers have been damaged beyond recovery.

Phenomena associated with the stage of degeneration are: constipation (from lack of muscular exercise), which may become chronic; defecation is extremely difficult in cases of partial or complete paralysis of the abdominal muscles; disturbances of the pain and tactile sensibilities; paralysis of the bladder in some instances; and decrease of the cutaneous and tendon reflexes in the less seriously affected cases, and their abolition in the paralyzed muscles.

Deformity and Contracture.—Aside from the paralysis and the possibility of its surgical relief, the most important sequelæ of the disease from the standpoint of the orthopedic surgeon are the deformities and contractures.

The question of the etiology of paralytic contractures has given rise to a multitude of theories and provoked keen controversy. In general, a contracture is due, *not*, as is so often erroneously believed, to shortening of the *paralyzed*, but to overactivity of the healthy muscle group antagonistic in action to the paralyzed muscle group. "The normal position of a joint in the living body is determined and maintained by the equilibrium existing between the various muscles surrounding the joint . . . . . brought about by the elastic tension of the muscles and tendons . . . . . also by muscle tone" (Vulpius). Or, in other words, structural shortening occurs because, in the growing period of the child's life, the tonicity and elasticity of normally innervated muscles cause them to remain permanently in a shortened state in the absence (paralysis) of that stress normally brought to bear upon them by antagonistic normal muscle. This structural shortening is secondary to the contraction following unopposed muscle-pull. It should be noted that underlying all is the physiological property of tissue always to "take up slack."

Total paralysis of a limb is followed by relaxation of the joint capsule and a flail-like condition of the joints of the limb. If malposition of the limb is maintained for any length of time, shortening occurs in those muscles whose points of attachment have been approximated, and deformity of the bones accompanies these changes. The more extensive the paralysis, the more severe the contractures, so that subluxation or even complete dislocation may occur.

Hypertrophy of the surviving muscles of a paralyzed limb almost universally occurs, and is a functional compensatory hypertrophy, *e.g.*, of the extensor longus hallucis for the paralyzed tibialis anticus; of the sartorius for the paralyzed quadriceps extensor femoris. Furthermore, compensatory hypertrophy occurs in the sound limb in unilateral paralysis, and the muscles of the arms are similarly affected in cases of paraplegia in which the arms are used as an aid in locomotion.

SPECIAL TYPES OF INFANTILE PARALYSIS

Arbitrary divisions of the infantile paralyses have been made by different observers, none of which is entirely satisfactory. The classification most commonly accepted is that of Wickman, although it is based neither on pathologic anatomy, nor on clinical symptomatology, but on a combination of the two. Wickman recognizes eight forms of the disease, for a detailed description of which the reader is referred to works on medicine.

Müller proposes a classification into four divisions, on an anatomical basis, viz.: (*a*) spinal, (*b*) bulbar, (*c*) cerebral, and (*d*) abortive cases. Pea-

body, Draper, and Dochez (Monograph 4, Rockefeller Institute of Medical Research, June 24, 1912, p. 29) exhibit the best appreciation of acute poliomyelitis from the clinical point of view by their simple classification into three groups of cases, viz.: (1) *Abortive cases, i.e.*, cases of infection which have never become paralyzed; (2) *cerebral* group, in which there is involvement of the upper motor neurones with resulting spastic paralysis; and (3) *bulbospinal* group, the largest division, in which are placed all cases with lesion in the lower motor neurones, and flaccid paralyses. The only objection to this classification is that many cases are not purely of one type, either anatomically or clinically, viz.: most bulbospinal cases show some pathological foci in the brain, while cerebral cases may exhibit lesions extending into the cord.

The limitations of this book prevent a detailed description of the abortive and the cerebral groups of cases, for a further description of which the reader is referred to special works and monographs upon the subject.

The largest group, the bulbospinal, with lesions in the lower motor neurones and flaccid paralyses, is the one with which the orthopedic surgeon is chiefly concerned.

Bulbospinal Type

This type is characterized by flaccid motor paralysis of the muscles supplied by the spinal nerves. The lumbar enlargement of the cord is the part chiefly affected, and hence paralysis of the lower limbs is more frequent than that of the upper. Involvement of the cervical swelling of the cord occurs less often and consequently paralysis of the upper extremities is less frequent. The extent of the paralysis is more notable than its persistence, regression occurring after the type of the paralysis has been reached. The degree of paralysis cannot be measured by the severity of its onset.

Premonitory symptoms are common in this bulbospinal type, and consist of stumbling, falling (in the case of children); and tremors, inco-ordination, and ataxia (in the case of adults).

The onset is sudden, with fever and malaise. Paralysis develops on the second to the fifth day after onset, or it may be delayed for a period varying from two to six weeks. It is progressive (*e.g.*, in the lower limbs, one is attacked twenty-four to forty-eight hours in advance of the other), and involvement of the lower limbs usually precedes that of the arms. The paralysis may remain undetected for some time after its incidence (particularly in infants), and this accounts for the common statement that "complete paralysis developed suddenly."

Following the establishment of paralysis, the constitutional disturbance abates, usually by crisis, the pulse becoming normal or subnormal, the temperature and respirations *pari passu*. Exceptions to this general rule of subsidence of constitutional symptoms are the symptom-complexes, dependent on meningeal irritation or involvement of the sensory fibers, in which pain and tenderness of the spine, hyperesthesia, retention of urine, and intestinal stasis become more marked until the paralysis begins to recede.

Evolution of the paralysis to its full development may consume a period of two days to one week or more. The ultimate condition may be either (*a*) paresis only, with rapid return to normal function, or (*b*) severe initial paralysis of all four extremities, which finally resolves itself into permanent paralysis of only one limb, the other three resuming full normal muscular activity. Although the paralysis usually recedes, in a certain proportion of the cases this does not occur, atrophy and degeneration of the involved

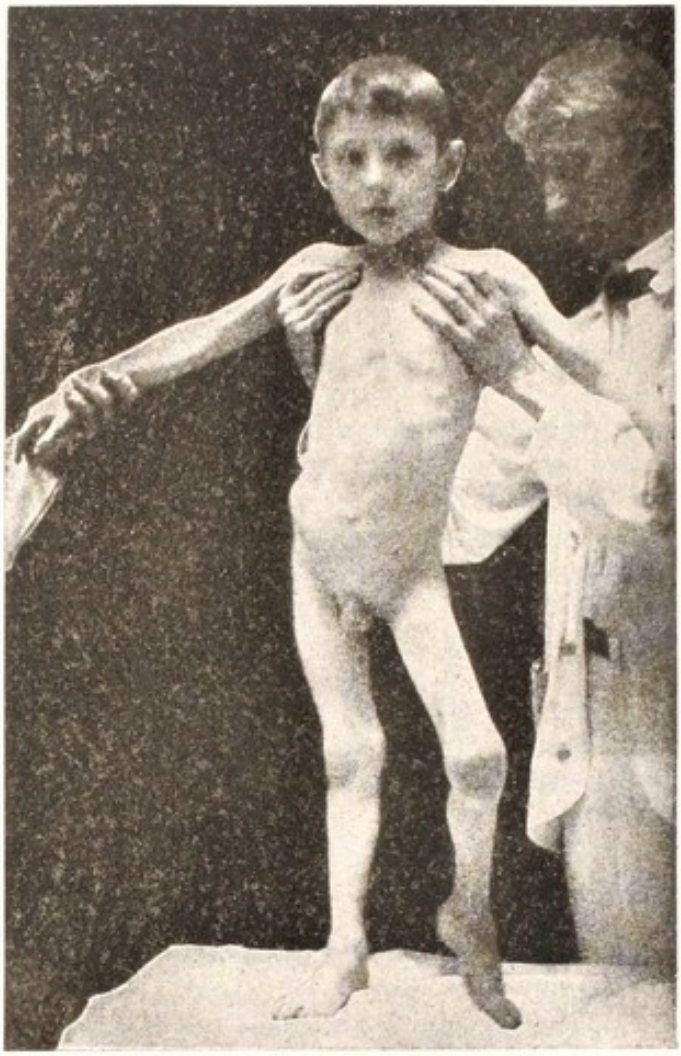


FIG. 399.—Paralysis of the left leg, with talipes equinus and contraction of the fascia at the anterior and outer aspect of the thigh with involvement of the internal rotators and abductors of the leg. Resulting in a position of abduction and eversion. (Bradford and Lovett.)



FIG. 400.—Paralysis of the back muscles, causing saddle-back deformity. (Bradford and Lovett.)

muscle groups subsequently taking place. The first muscle groups to recover are those which were the last to be paralyzed and in which the degree of paralysis was slightest.

Distribution of the Paralysis.—From a clinical study of 400 cases of infantile paralysis of the great epidemic of 1916, in New York City, which were observed at the clinic of the Hospital for Deformities and Joint Diseases,

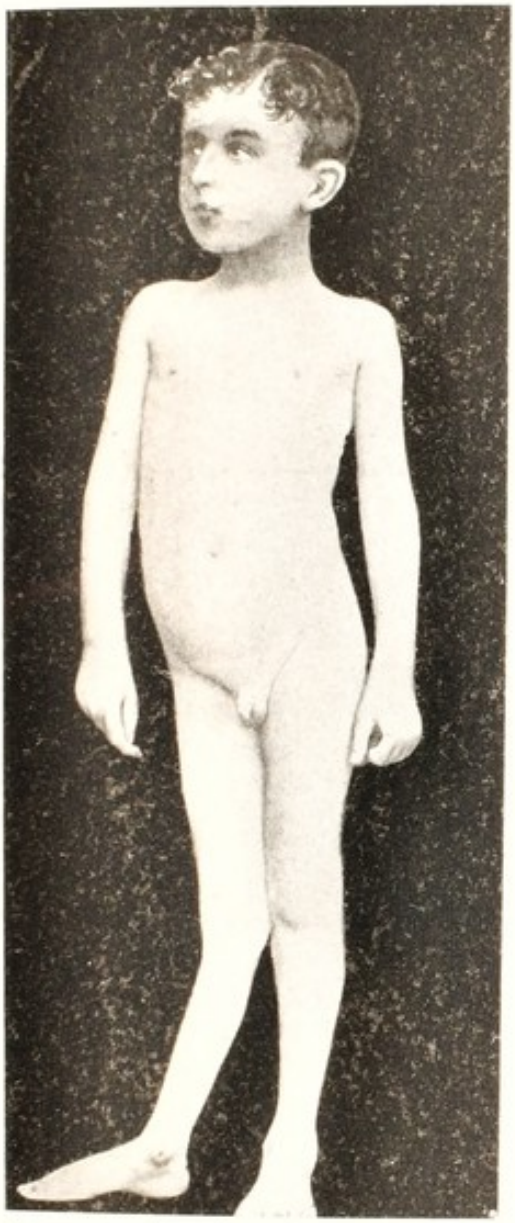


FIG. 401.—Anterior poliomyelitis. Paralysis of the anterior and posterior muscles. Recurvation of the right knee. (Whitman.)



FIG. 402.—Flexion deformity of the hip, knee, and ankle, due to contractions. (Bradford and Lovett.)

S. A. Jahss (Jour. A. M. A., March 10, 1917, vol. lxviii, No. 10) has drawn some interesting conclusions:

Seventy-eight per cent. of his cases showed some involvement of the lower extremities. Thirty-eight per cent. were paralyzed in one limb only, and of these 10 per cent. involved the upper and 28 per cent. the lower extremities. Twenty per cent. of the cases exhibited some form of paralysis of the trunk. The cranial nerves were affected in 13 per cent. of the cases, the seventh (facial) in the majority of the cases.

Whereas in past epidemics the leg muscles most frequently affected were the peroneals, Jahss found that the tibialis anticus and the quadriceps extensor femoris suffered most; while in the arms the deltoid was the muscle of election. In Jahss' series, not all the muscles were completely paralyzed, for some degree of motion persisted in 25 per cent. of all the muscles involved. The usual combination of muscles affected was: in the leg, those muscles supplied by the anterior tibial nerve; in the thigh, the quadriceps, adductors, and hamstrings exhibited a strong tendency to be involved together, a mixture of paralysis of both the lumbar and the sacral plexuses. In the event of paralysis of the external rotators of the hip, the internal rotators were in every instance also affected, the former never being paralyzed alone; while in the arm, a combination of deltoid, pectoralis major, and latissimus dorsi paralysis was frequently observed. The "upper-arm type" or the "forearm type" of paralysis did not occur in any of Jahss' cases. This observer has also noted the futility of judging the extent of muscular paralysis by the reaction of degeneration, since a totally paralyzed muscle, in his experience, often gave normal electrical reactions both to the faradic and galvanic cur-

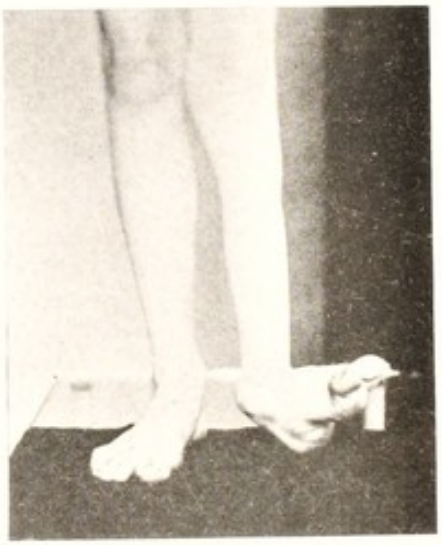


FIG. 403.—Calcaneovalgus deformity from paralysis of the anterior and posterior tibial muscles, the gastrocnemius and soleus.

rents, while a muscle with partial motion often showed various degrees of electrical degeneration.

Jahss found flexion deformity to be the most common in the limbs, although talipes equinus was present in comparatively few of his cases, and he remarks that conditions are just as favorable for flexion deformity at the ankle (talipes equinus) as they are at the knee, hip, fingers, wrist, shoulder, and elbow. For example, a healthy latissimus dorsi with a paralyzed deltoid exerts as pernicious a deforming action at the shoulder-joint as a healthy gastrocnemius with a paralyzed tibialis anticus at the ankle-joint.

The importance of guarding against these deformities in *all* joints, and not alone in the ankle, cannot be overemphasized. The general lack of proper preventive splinting in cases coming to the dispensaries, in whom deformity of the joints is imminent, is astonishing, viz.: (*a*) shoulder cases with deltoid paralysis, (*b*) paralysis of one-half the neck; (*c*) unilateral paralysis of the back; (*d*) complete paralysis of the abdominal muscles, with lordosis; (*e*) paralysis of the internal rotators of the hip with strong, healthy, antagonistic external rotators; (*f*) paralysis of the calf muscles, the patient walking on his heels.

Jahss' tables showing (1) regional distribution, (2) extent of paralysis, and (3) muscle distribution, are of sufficient interest to warrant their insertion here.

(1) REGIONAL DISTRIBUTION (JAHSS)

Region	No. cases involved	No. parts involved	Right	Left	Involved alone	In combination
Leg	280	437	207	230	183	103
Arm	111	139	72	67	45	66
Face	38	...	19	19	24	14
Abdomen	49	79	35	44	1	45
Back	53	91	44	47	...	53
Neck	3	4	3	1	...	3
Sternomastoid	2	...	...	2	...	2
Larynx	3	...	...	...	...	3
Palate	3	...	...	...	...	3
Jaw	1	...	...	...	1	
Eye	1	...	...	...	...	1

(2) EXTENT OF PARALYSIS (JAHSS)

	No. of cases
One leg	45.7% ... 111
Both legs	72
One arm	11.25% ... 41
Both arms	4
All extremities	5
Three extremities	9
Arm and leg (same side)	6
Arm and leg (opposite sides)	5
Trunk	2
Face alone	24
Jaw	1
Arm, leg, face (left)	1
Leg and back*	21
Leg and abdomen*	10
Leg, abdomen, and arm*	10
Leg, abdomen, and back*	6
Leg, back, and arm	6
Arm and back*	2
Arm and abdomen*	2
Leg and face*	5
Arm and face*	2
Leg, arm, back and neck*	2
Leg, arm, back, and abdomen*	8
Leg, back, abdomen and larynx	2
Arm, palate, and face*	1
Leg, palate, and face*	1
Face and eye*	1
Leg, and sternomastoid*	1
Arm, face, and sternomastoid*	1
Arm, back, and abdomen*	1
Leg, arm, abdomen and face*	1
Leg, arm, abdomen, face, and back*	1
Leg, arm, abdomen, back, and neck*	1
Leg, arm, abdomen, back, and larynx*	1
Leg, arm, abdomen, back, and palate*	1
Cases showing no paralysis	32
Total	400

*It may be one or both in any of the parts affected; in order not to lengthen the list, this is not specified.

(3) MUSCULAR DISTRIBUTION (JAHSS)

Muscle	Involved	Partial	Complete
Tibialis anticus	369	101	268
Quadriceps extensor	302	78	224
Peronei (longus and brevis)	251	62	189
Hamstrings	222	77	145
Gastrocnemius and soleus	215	52	163
Extensor longus digitorum	215	66	149
Extensor longus hallucis	215	65	150
Adductors	205	44	161
Internal rotators	173	18	155
Tibialis posticus	171	10	161
Iliopsoas	147	55	92
Gluteus maximus	127	32	95
Flexor longus digitorum	97	29	68
Flexor longus hallucis	97	29	68
External rotators	76	18	58
Deltoid	119	37	82
Pectoralis major	88	25	63
Triceps group	65	30	35
Biceps group	58	24	34
Latissimus dorsi	51	10	41
External rotators	43	1	42
Extensor communis digitorum	34	18	16
Internal rotators	31	3	28
Supinator longus and brevis	26	5	21
Flexor carpi radialis and ulnaris	22	11	11
Extensor longus pollicis	22	12	10
Flexor sublimis and profundus digitorum	20	10	10
Pronator teres (group)	19	6	13
Flexor longus pollicis	16	8	8
Extensor carpi radialis longior and brevis, and extensor carpi ulnaris	15	8	7
Serratus magnus	11	3	8
Trapezius	9	5	4
Rhomboid group	4	...	4
Thenar eminence	3	...	3
Lumbricales and interossei	2	...	2
Abdomen	79	28	51
Back	91	36	55
Face	38	12	26
Neck	4	2	2
Larynx	3	3	
Palate	3	3	
Jaw	1	1	
Sternomastoid	2	2	
Eye	1	1	

DIAGNOSIS

As a rule, the disease is easily recognized in sporadic cases of the spinal type. Confusion occasionally exists in epidemics because of the fact that the disease exhibits such a multitude of clinical types; for example, some cases progress like an acute infection, others simulate an ascending paralysis of Landry's type; in other cases meningeal symptoms reproduce the clinical symptoms of meningitis, while still other cases with hyperesthesia and pain closely resemble polyneuritis.

As Osler wisely remarks (Principles and Practice of Med., D. Appleton & Co., 1912, p. 369): "It seems not impossible that some obscure cases of meningitis are really instances of sporadic poliomyelitis. The same may be

said of the acute encephalitis in children causing hemiplegia." Although the diagnosis is often very difficult on account of the great variations in clinical types, nevertheless certain biological tests, examination of the blood and the spinal fluid, and the biological reactions of immunity, afford material aid in differentiating infantile paralysis from similar diseases.

1. **Blood.**—Peabody, Draper, and Dochez (*loc. cit.*, p. 97) found a constant marked leukocytosis (sometimes as high as 30,000) and only once a leukopenia present in their cases. They also observed a constant increase of 10 to 15 per cent. in the polynuclears, with a diminution of 15 to 20 per cent. in the lymphocytes. They conclude from their observations that "while the blood picture in poliomyelitis is perhaps not any more specific than is the spinal fluid, it is helpful. If taken in connection with other valuable evidence, a leukocytosis of 15,000 to 30,000 is distinctively suggestive of the disease in question, especially if the polymorphonuclear cells are increased at the expense of the lymphocytes."

2. **Cerebrospinal Fluid.**—In the first few weeks after onset of the disease, the vast majority of cases show abnormalities in the spinal fluid, viz.:

(*a*) In the earliest stages, prior to the advent of paralysis: the cerebrospinal fluid is characterized by an increased cell count with a low or normal globulin content, the polynuclears may contribute 90 per cent. of the total, although the cells in most specimens consist almost exclusively of lymphocytes and large mononuclears.

(*b*) After the first two weeks: the cell count is normal or nearly so, while there is an increase in the globulin content; the latter quality may persist for seven weeks or more (according to Peabody, Draper, and Dochez) and may be recognized by Noguchi's butyric acid test, viz.: 0.2 c.c. of spinal fluid, free from blood, is mixed with 0.5 c.c. of 10 per cent. butyric acid solution in physiological salt solution, and the mixture is then heated and boiled for a short period. One-tenth c.c. of a normal solution of sodium hydroxid is then added, and the whole is boiled again for a few seconds. A granular precipitate settles to the bottom of the tube, leaving a clear supernatant liquid. The greater the protein content of the spinal fluid the quicker is the reaction. For fluids weak in protein content, one hour may be required for the reaction to take place, and not more than two hours at the outside.

Similar reactions of the spinal fluid are met with in abortive cases. All fluids examined by the observers above mentioned reduced Fehling's solution. While not specific, the examination of the spinal fluid is of the utmost aid in the diagnosis of the preparalytic and the abortive cases.

3. **Neutralization Test.**—Although the normal human blood serum has some neutralization action on the virus in infantile paralysis, the quantitative limits of the neutralization clearly differentiate it from the serum of those who are suffering with or have recovered from an attack of the disease. These immune bodies do not appear in the serum until about one to two weeks after the onset of the disease. Judging from the results obtained at the hospital of the Rockefeller Institute in New York, biological tests with the sera of suspected cases cannot be considered to give specific evidence as to whether or not a given individual is suffering with the disease.

From peripheral neuritis, it may be extremely difficult to differentiate infantile paralysis in certain of its forms. In both, the paralysis affects chiefly the legs, with atrophy, abolition of reflexes, and often paresis of the bladder and rectum. Osler (*loc. cit.*) points out that loss of the vibrating sensation, tested with a large tuning fork, is more common in peripheral neuritis, and that later the electrical changes and the action of degeneration may be distinctive.

PROGNOSIS

No very definite statement can be made concerning the outlook as regards either life or function. The extraordinary variations in clinical manifestations, the extreme fluctuations in the mortality rates in different epidemics, and the frequently unexpected behavior of the various types of the disease, prohibit accurate prognostication.

In a general way, it would seem at this time that Heine's original dictum that the outbreak *quoad vitam* was good but the outlook *quoad sanitationem* bad, would have to be reversed in view of the recent scourge of the disease in New York City, with a mortality of over 25 per cent.

Fatal Cases.—The prognosis is grave while the disease is progressing and until the paralysis is established. The onset of abdominal breathing with immobile chest indicates paralysis of the diaphragm and usually presages death. The fatal cases are usually of the ascending bulbar and meningeal types. The greatest number of deaths occurs in infants less than one year of age, and in the adolescent and adult periods. The gravity of the outlook is increased the higher the lesion in the cord and the extent of cord involvement. The majority of the deaths occur in the first week of the disease.

Lumbar Puncture.—The amount of spinal fluid, the amount of pressure under which it exists in the spinal canal, together with its albumin content, are clinical data of more or less value in estimating the probability of paralysis and the prognosis of the progressive and regressive stages of the disease.

Spontaneous recovery is frequent in mild cases, while many (a number greater than is usually supposed to be the case) make complete recoveries with no crippling whatsoever, this number including not only the abortive cases, but also those in which a greater or less degree of paralysis was established. The disappearance of the paralysis may be rapid (a few days) or gradual (several weeks or months, or even years). Even in those cases in which recovery is not absolutely complete, the residual paralysis is often so slight as not to seriously interfere with normal activity or the pursuit of occupation. In giving an opinion on the outlook, it is important to bear constantly in mind that this process of recovery of function and muscle power often goes on for months or years, even in a severely paralyzed case which shows little improvement at the termination of the acute stage; and it is to be remembered that only a very small number of the victims of this disease are left severely and helplessly crippled.

Cerebral Type.—Unfortunately, involvement of the cortex is often followed by convulsions, hemiplegia, mental deficiency (idiocy, imbecility, etc.) and epilepsy.

PROPHYLAXIS

The disease has been made notifiable in many countries and in certain states of this country. During an epidemic, congregations of people should be interdicted. The danger of dissemination of the infectious secretions of the nose and throat by kissing, coughing, sneezing, etc., should cause the formation of habits of self-denial, care, and cleanliness and a consideration for the public welfare on the part of individuals, and should be enforced as far as is possible by propaganda by the board of health in the community where the disease is epidemic. Contamination of the fingers of mother or nurse from the nasal secretions, and transference of these secretions to other children by direct contact, or indirectly through contaminated food, is a very real menace in every case of the disease, and such accidents at once

suggest the superiority of the well-regulated hospital over the home as a residence for children who are suffering with infantile paralysis.

In this connection, it is interesting to note the experience of Taylor and Amoss (Jour. Exp. Med., vol. xxvi, No. 5, Nov. 1, 1917) on carriage of the virus of infantile paralysis. They describe a family group containing four children, all of whom showed, in varying degree, symptoms of the disease. Two of the children were proved by inoculation tests to carry the virus of poliomyelitis in the nasopharynx. Of these, one was detected to be a carrier after recovery from a non-paralytic attack of the disease, and the other was discovered to be a carrier about five days before the initial symptoms, attended later by paralysis, appeared. The original case, from which the three others originated, was fatal. The youngest child, after a quite severe onset, was treated with immune serum and made a prompt and almost perfect recovery. The nasopharyngeal secretions of two of the cases, taken one month after the attack, proved incapable of neutralizing an active poliomyelitic virus. They conclude with the remark that "the proposition is presented that every case of poliomyelitis develops from a carrier of the microbic cause, or virus, of poliomyelitis."

Although the rôle played by biting insects, such as the bedbug, stable-fly, etc., in spreading the disease is uncertain, destruction of these insects and protection of the patient from them is desirable. The ordinary house flies, in particular, are prone to collect about the nose and mouth of those sick with infantile paralysis and feed on the secretions, and also collect on the feces in homes where screens are not used. Flies thus contaminated may carry the virus to the mouths of healthy persons, to towels, utensils, food, etc., in the house, and to meats and other food exposed for sale in the markets. Those attendant on cases of infantile paralysis should not, therefore, be permitted to handle food exposed for sale in the public markets.

The most effective safeguard to the public health, however, is the isolation of those sick with the disease and the sanitary control of those associated with them, particularly by restriction of their travels. The best interests of the patient, other members of the family, and of the public, demand hospital confinement instead of the house, not only for the person frankly stricken with the paralytic form of the disease but also for those in whom the diagnosis is doubtful.

Personal prophylaxis is important in the case of those in contact with the patient. This includes the avoidance of spitting, coughing, or sneezing, the free use of fresh handkerchiefs, a frequently repeated toilet of the hands and face, a change of clothing on entering and leaving the sick room (*i.e.*, the use of cap and gown, as in the case of smallpox), and disinfection of the nose and throat with a menthol spray at frequent intervals during the day.

On the other hand, it must be borne in mind that the degree of susceptibility of children as well as adults is relatively small compared with that displayed toward such diseases as scarlet fever, measles, and diphtheria, so that although there is no justification for an hysterical attitude of mind in the event of an epidemic, at the same time no relaxation should be permitted in the methods just outlined to protect the public.

Prophylactic doses of hexamethylenamine are recommended and used by some authorities on account of the fact that the drug is eliminated into the subdural space and naso-pharynx.

On account of the fact that by swallowing the nasal secretions an intestinal flora of the virus may be created in the lower bowel, free catharsis is to be encouraged in persons associated with these cases.

TREATMENT

Aside from absolute rest in bed until the acute symptoms have entirely disappeared and the application of symptomatic treatment as indicated for the individual case at hand, the active therapeutics in the acute stage of this disease is rather limited and is still more or less in the experimental stage. Within the past year, however, a little more light has been thrown upon the questions of *immunization* and *serum therapy* by the researches of the Rockefeller Institute.

I. **Immunization: Neutralizing Substances in Poliomyelitis.**—In discussing the passage of neutralizing substances from the blood into the cerebrospinal fluid in poliomyelitis, Flexner and Amoss in a paper under that title (Jour. Exp. Med., vol. xxv, No. 4, Apr. 1, 1917) draw the following conclusions:

"The cerebrospinal fluid taken very early and quite late in the course of acute poliomyelitis exhibits no neutralizing action on filtered poliomyelitis virus.

"The blood-serum on the sixth day of disease already contains the neutralizing principles.

"The injection of sterile horse serum into the cerebrospinal meninges in monkeys increases their permeability so that they permit the immunity neutralizing principles passively injected into the blood to pass into the cerebrospinal fluid.

"The passage in passively immunized monkeys takes place during a relatively brief space of time and apparently only while the inflammatory reaction produced by the horse serum is at its height.

"It is established for monkeys and rendered probable for man that the intraspinal injection of immune serum in poliomyelitis is curative. In monkeys, normal serum exerts no such action, and at present nothing can be stated definitely regarding the therapeutic effect of normal serum in man except that probably any benefits which may arise from its employment would be attributable not to the action of the serum as such but to the escape of circulating immunity principles in the blood made possible by the aseptic inflammation set up by it in the meninges.

"As the immunity principles appear in the blood only after several days, and the reported favorable effects of the immune serum treatment relate to the first days of illness, the employment of normal serum is thus not indicated, while that of an immune serum is."

II. **The Serum Treatment of Epidemic Poliomyelitis.**—We can find no more authoritative work on this subject than the researches of the Rockefeller Institute. In a report on the serum treatment of 26 cases of epidemic poliomyelitis, Amoss and Cheney, in a paper under that title (Jour. Exp. Med., vol. xxv, No. 4, Apr. 1, 1917) draw the following conclusions:

"1. Serum taken from recently recovered cases of poliomyelitis may be employed in its treatment, and probably yields the best results.

"2. When sterile for ordinary bacteria, free of corpuscles and hemoglobin, and when injected by the gravity method, observing well-known rules of caution, it may be employed without danger.

"3. The serum should be injected both intraspinally and intravenously, the latter either directly or by way of the subcutaneous tissues.

"4. The earlier in the course of the disease the serum is employed in suitable doses, the more promise there is of benefit.

"5. The action of the serum appears to be more precise and definite in arresting paralysis than in rapidly bringing about its retrogression.

"6. The decision to employ the serum should rest upon a clinical examination supported by the results of the microscopic and chemical study of the cerebrospinal fluid.

"7. The question of multiple and repeated injections of the serum has not yet been worked out. In the cases here reported, and especially in the group in which no paralysis existed at the time of the first injection, the pathological process either did not progress at all, or there was extension, . . . the upper segment of the spinal cord became rapidly involved, and was followed by respiratory paralysis and death. Probably in cases in which some degree of muscular weakness develops soon after the injection of serum, reinjection twelve to fourteen hours later may be advantageous. The temperature curve may serve to indicate the time for reinjection.

"8. The favorable results thus far achieved in human beings by means of the immune serum support and extend those obtained experimentally in monkeys, and indicate, as was foreseen, that the milder or less fatal form of poliomyelitis appearing in man is even more amenable to the serum treatment than is the highly fatal disease produced by inoculation in monkeys."

Mode of Administration.—In the cases treated by Amoss and Cheney, the serum was administered both intraspinally and intravenously. The quantity of serum which can safely be given to a child by intraspinal injection within a twenty-four-hour period is obviously limited, according to their experience, but larger quantities are given intravenously. Administration of the larger volumes of serum proved to be an advantage. Some selection of cases was employed; they used it in those cases in which the fever had not lasted more than forty-eight hours. Variations in the dosage of the serum as administered by Amoss and Cheney are seen in the following table roughly prepared from a few of their cases selected at random from their series:

DOSES IN CUBIC CENTIMETERS

Age	Subcutaneously	Intraspinally	Intravenously
33	..	10	20
10	60	20	
3	40	15	20
33	..	20	50
2	30	5	
4	25	10	
2	30	5	
2 mos.	20	5	

The Serum Treatment as Administered by the Department of Health of New York City.—In its weekly bulletin of October 28, 1916, the Department of Health of New York City reports its use of the immune serum in infantile paralysis. It was used in the treatment of 420 patients at the Willard Parker and Minturn Hospitals, and also in co-operation with other physicians. It was employed not only in a number of suitable early cases in the preparalytic stage of the disease but also in some of the advancing acute types with beginning involvement of the muscles of respiration, but in the latter cases the damage had already been mostly done and the serum treatment had very little influence on the course of the malady.

"The diagnosis of the early or preparalytic cases of poliomyelitis was made by the clinical symptoms and findings in the spinal fluid. Fever, nausea, increased irritability, characteristic irregular muscular tremors of fingers, hands, and entire extremities, general muscular weakness, slight but definite

rigidity of the neck, hyperesthesia and possibly slight Kernig. The spinal fluid obtained by lumbar puncture was of great assistance in firmly establishing the diagnosis in some of the clinically doubtful cases. Macroscopically, an estimate of cell increase can generally be made, even at the bedside, by noting in the spinal fluid, when seen by transmitted light, a typical ground-glass appearance, due to the increased number of leukocytes. The presence of red blood-cells must be carefully guarded against, however, by observing a yellowish tinge to the fluid, which is seen when such cells are present in any number. The more detailed laboratory examination will confirm the decided increase in leukocytes, and establish the presence of an increased amount of albumin and globulin.

"The serum was used either fresh without a preservative, or prepared by the addition of 0.2 per cent. tricresol, and passage through a Berkefeld filter. The dose of serum was 10–15 c.c., injected intraspinally after the removal of a somewhat larger amount of spinal fluid, and was repeated every twenty to twenty-four hours, until two or three doses were injected.

"The administration of a dose of serum was followed within a few hours by an increased rigidity of the neck, slight opisthotonos, Kernig, hyperesthesia, and temperature of varying degree. In some cases, especially when treated in the latter part of the acute stage of the disease (fourth to fifth day), the reaction was less marked; in others, especially early cases, more marked. If carefully watched, no harmful effects have been seen to follow. Contra-indications to the repetition of the dose of serum in some of the cases were signs of more marked meningeal irritation. In the spinal fluid, a moderate to marked increase in the polynuclear cells was found, indicating a cellular reaction to the injection of serum:

"For purposes of studying the action of the immune serum, the cases were divided into various groups, depending upon the length of time which had elapsed since the donors of the serum used had had their attacks of infantile paralysis:

"Early convalescent serum, two to six months after the attack.

"Late convalescent serum: from six to twelve months after the attack.

"Group A serum: from one to five years after the attack.

"Group B serum: from five to fifteen years after the attack.

"Group C serum: from fifteen to thirty years after the attack.

"Group D serum: from thirty years and more after the attack.

"The immunization value of the older case sera is still on trial; it is possible that the value of such sera is purely that of normal serum, a rich protein fluid, which also causes a distinct polynuclear cell response. A number of cases were, therefore, in addition treated with normal human serum obtained from healthy donors who had never, to their knowledge, had anterior poliomyelitis.

AMOUNT OF IMMUNE BLOOD OBTAINED DURING JULY, AUGUST, AND SEPTEMBER, 1916

Immune blood	Ounces
1. Convalescent blood (early)	16
2. Group A blood	77
3. Group B blood	206
4. Group C blood	643
5. Group D blood	314
Total	1256 ounces (78.5 pints)

"The results obtained by the Department of Health seemed to be favorable where the serum was used in early suitable cases in the preparalytic

stage. Paralysis followed in some cases, but the mortality was probably favorably influenced by the serum. The later and more severe cases treated after the paralysis had already made distinct headway and was beginning to involve the muscles of respiration, showed in a certain proportion of cases an inhibitory effect of the serum upon further progress, and a possible life-saving result. The results of serum therapy in the hands of the Health Department were encouraging, and justify a continuation of its use in infantile paralysis."

REFERENCES

TAYLOR AND AMOSS: Jour. Exp. Med., vol. xxvi, 5, Nov. 1, 1917.
FLEXNER AND AMOSS: Jour. Exp. Med., vol. xxv, 4, Apr. 1, 1917.
AMOSS AND TAYLOR: Jour. of Exp. Med., vol. xxv, 5, Apr. 1, 1917.
FLEXNER AND AMOSS: Jour. of Exp. Med., vol. xxv, 5, Apr. 1, 1917.
AMOSS: Jour. of Exp. Med., vol. xxv, 5, Apr. 1, 1917.
BULL: Jour. of Exp. Med., vol. xxv, 5, Apr. 1, 1917.
AMOSS AND CHENEY: Jour. of Exp. Med., vol. xxv, 5, Apr. 1, 1917.
FLEXNER AND NOGUCHI: Jour. of Exp. Med., vol. xviii, 1913, 461.
Weekly Bulletin, Dept. of Health, N. Y. C., Oct. 28, 1916.
PEABODY, DRAPER, AND DOCHEZ: Jour. Exp. Med. Monogh. 4, June 24, 1912.
NEAL: New York Med. Jour., 1916.
KLEIN: New York Med. Jour., 1916.
MILLER, BRUSH: *et als.* Bull., J. H. H., 1915.
LOVETT, R. W.: "The Tr. of Infantile Paralysis," Blakiston, 1916.
RÖMER, P. H.: "Epidem. Inf. Paralysis," Wm. Wood & Co., 1913.
Pub. Health Bull. No. 83, U. S. P. S., December, 1916.
JELIFFE AND DEDERER: "Alienist and Neurologist," vol. 37, 1916.
VULPIUS: "The Tr. of Infantile Paralysis," Wm. Wood & Co., 1912.
FRAUENTHAL AND MANNING: "Manual of Infantile Paralysis," F. A. Davis & Co., 1914.
FLEXNER: "Nature, etc., of Infantile Paralysis," N. Y., 1916.

CHAPTER XXI

INFANTILE PARALYSIS (CONTINUED)

TREATMENT OF THE CONVALESCENT AND CHRONIC STAGES

In the preceding chapter, the acute stage only (from the onset to the disappearance of tenderness) was considered. We shall now take up the treatment of the *convalescent* and *chronic* stages of the disease.

The **convalescent stage** is an arbitrary division of the disease, beginning at the end of the acute stage and continuing as long as spontaneous improvement is marked. This period lasts, on an average, about two years.

The **chronic stage** is marked by cessation of improvement. The lesions are stationary and the deformities and paralyses are established.

A comprehensive view of the treatment of the three stages of the disease yields the following:

Acute Stage.—To limit the destructive pathologic process.

Convalescent Stage.—Attempts are made to restore voluntary muscular power and to prevent deformity.

Chronic Stage.—Treatment is chiefly operative, while the therapeutics of the convalescent stage are continued.

TREATMENT OF THE CONVALESCENT STAGE

As has been said, the convalescent stage begins with the cessation of tenderness and ends when spontaneous improvement has ceased; a rough average of its duration is two years from the date of onset. It should be borne in mind at the outset that during the period of voluntary improvement no *operative procedure* aiming at correction of deformity or loss of power should be undertaken. The aim and object of treatment of this phase is to restore the greatest possible amount of efficiency to the inactive, atrophied muscles. A mental picture of the general pathologic process must be kept constantly in mind that treatment may be intelligently managed. It must be remembered that the nerve centers controlling these muscles have, in a certain percentage of cases, been only temporarily *inhibited* in function by a hemorrhagic myelitis, with a consequent impairment of circulation and lowering of the general resistance.

AMBULATORY TREATMENT

The upright position of the patient should be assumed early, for the following reasons: (*a*) recumbency favors sluggish circulation, while (*b*) sitting and standing stimulate the muscles and the nerve centers to restore "balance;" furthermore, (*c*) recumbency and inaction have an untoward effect on the nervous system; and, finally, (*d*) outdoor air is best for the patient on general principles. Therefore, a sitting posture and, soon thereafter, restricted walking should be practised within two or three months after onset, but fatigue should be studiously avoided.

Sitting.—If the abdominal and spinal muscles are too weak to support the torso, the patient should be propped in the chair with pillows. It is

important to be on the lookout for scoliosis at this time, and the patient must be put in a position to counteract its development.

Abdominal paralysis is common, but may be overlooked. The physical signs are inability of the patient to rise from recumbency to a sitting position

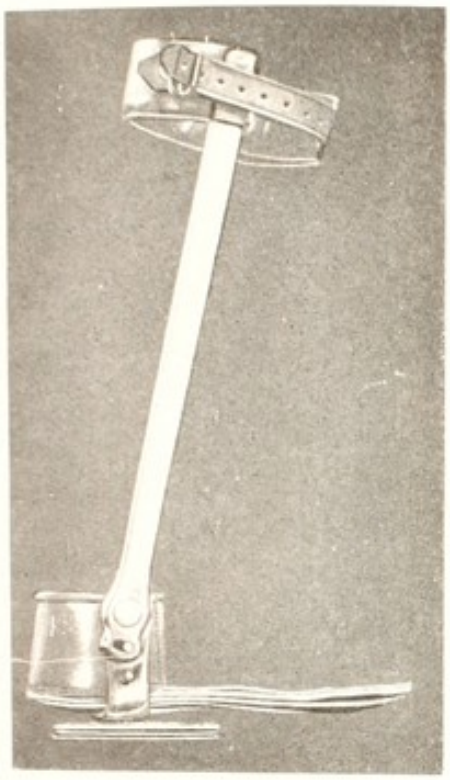


FIG. 404.—A brace with a "limited" joint, permitting slight motion at the ankle. (Whitman.)

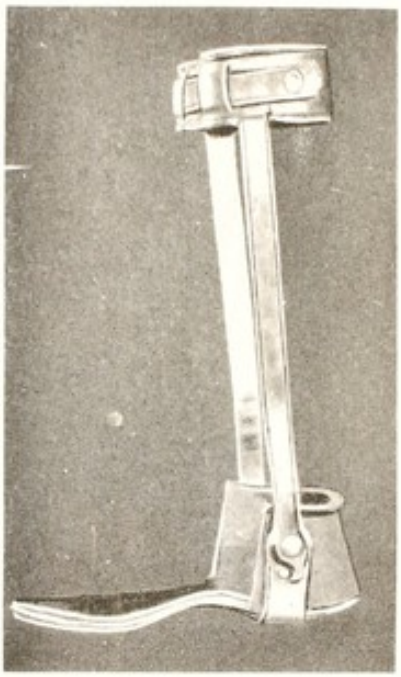


FIG. 405.—A brace with "stop" joint to prevent foot-drop. One upright is often sufficient. (Whitman.)

without assistance and, when upright, protrusion of the abdomen with anterior flexion of the spine. The result, if uncorrected, is eversion of the costal borders from pressure against the protuberant abdomen, and this

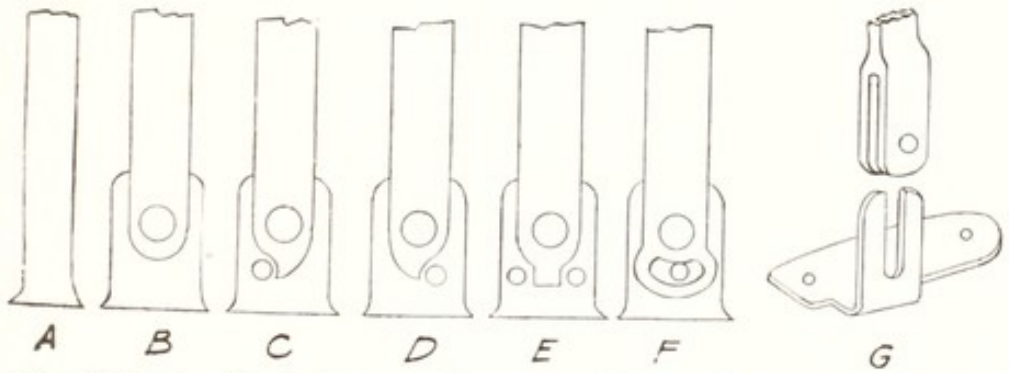


FIG. 406.—Different splint joints at ankle. *A*, no joint; *B*, free joint; *C*, down stopped joint; *D*, up stopped joint; *E* and *F*, limited motion joint; *G*, slip joint. (Taylor.)

deformity may become structural. Unilateral abdominal paralysis is less common. The abdomen should be supported in such cases by a strong corset of heavy duck or other material with inserted supporting steel which may also favor recovery of function by the abdominal muscles.

Walking without Braces.—Even if the patient is able to walk unassisted, the weakened, atrophied muscles are easily fatigued and are thereby injured; hence, the minimal amount of strain should be put upon them.

Braces for Walking.—If the patient cannot stand or walk without aid, or does so with the production of some deformity, *e.g.*, genu recurvatum, recourse must be had to braces, because it is imperative to get the muscles into use, at the same time supporting the limb and preventing the development of deformity. However, some patients, although extensively paralyzed in the legs, can manage to get about without assistance, and in such cases, unless some specific contra-indication exists, braces should be omitted.

Braces should be made as simple as possible, their sole purpose being to support the limbs and prevent recurrence of the deformity. This is of the

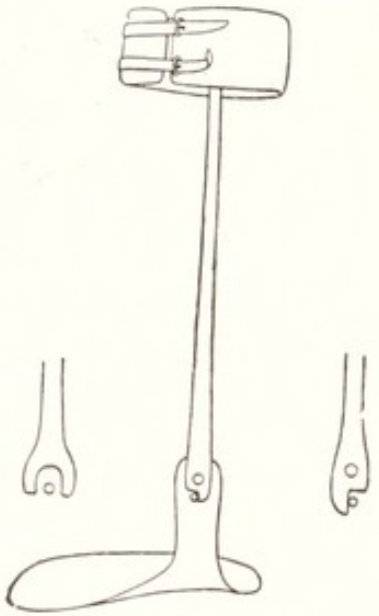


FIG. 407.

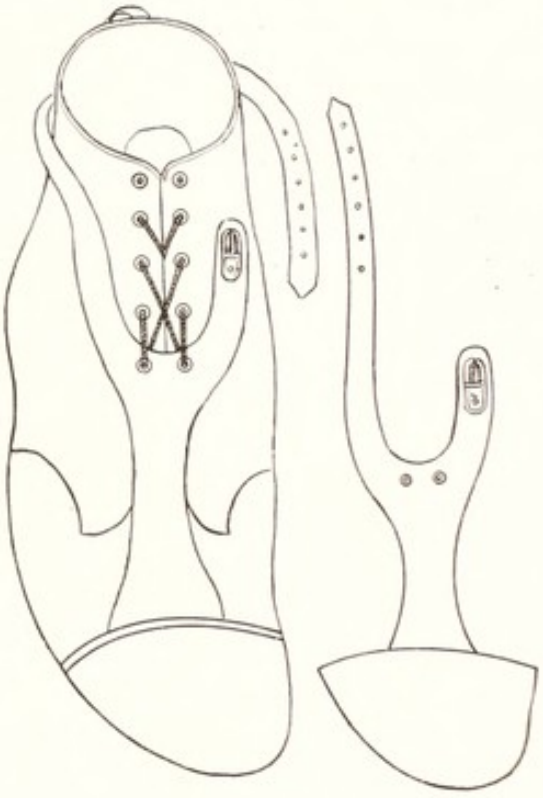


FIG. 408.

FIG. 407.—Apparatus for talipes equinus with stop catch. On the right of the picture is a detail drawing of the stop for talipes calcaneus, in the left a catch allowing slight motion. (Bradford and Lovett.)

FIG. 408.—Shoe devised to prevent toe-drop in mild cases. (After Jones.)

greatest importance because in the growing period of a child's life its ligaments and capsules are easily overstretched, thus permitting irreparable damage to the joints. The brace has to be devised to meet the requirements of the individual case at hand. There is no stereotyped brace that is applicable to all cases. In these days of so many infantile paralysis cases, we feel that it devolves upon us to emphasize the rule that *the architecture of the brace should be draughted by the orthopedic surgeon for each individual.* The brace should be light and as simple as possible, designed to afford the support lacking because of the paralyzed muscles, and should not interfere with the action of muscles capable of functioning.

For certain special types of paralysis, *e.g.*, equinus, it should be made a general rule *never to trust the shoe to support the foot.* Leather can never be

depended upon to withstand constant strain, for wetting causes it to stretch, and therefore a foot plate of metal should be fastened to the brace.

The caliper splint, so frequently worn, wears out easily and causes much trouble, and its use is not favored by the author.

The *quadriceps extensor femoris* is one of the muscles most frequently paralyzed and is then the greatest hindrance to walking, because of flexion deformity of the knee. This should be prevented by a leather knee-cap attached to the upright of the brace. In *gastrocnemius paralysis*, or even slight weakness of that muscle, the heels should be raised to prevent strain and stretching of the muscle by the superimposed body-weight in walking.



FIG. 409.—Jacket attached to caliper splints applied to a case of paralysis of the trunk and both legs. (Bradford and Lovett.)

An elevation of the heel of a half to three-quarters of an inch in young children and 1 to 1½ inches in older children, is necessary, while "barefoot" must be interdicted, even in undressing, and the use of "sneakers" and other heelless shoes must be absolutely forbidden, to avoid not only stretching of the gastrocnemius but the production of permanent talipes calcaneus.

Objections to the use of apparatus are the extra weight and the muscular constriction caused by bands, lacings, etc., which hamper the already weakened muscles, but these objections are outweighed by the advantages gained. Apparatus should *not* be worn except when actually required for walking or to prevent deformity, and should be removed as often as possible.

Balance.—The sense of equilibrium is often greatly impaired or lost by prolonged recumbency, and it is imperative to restore it before walking can be

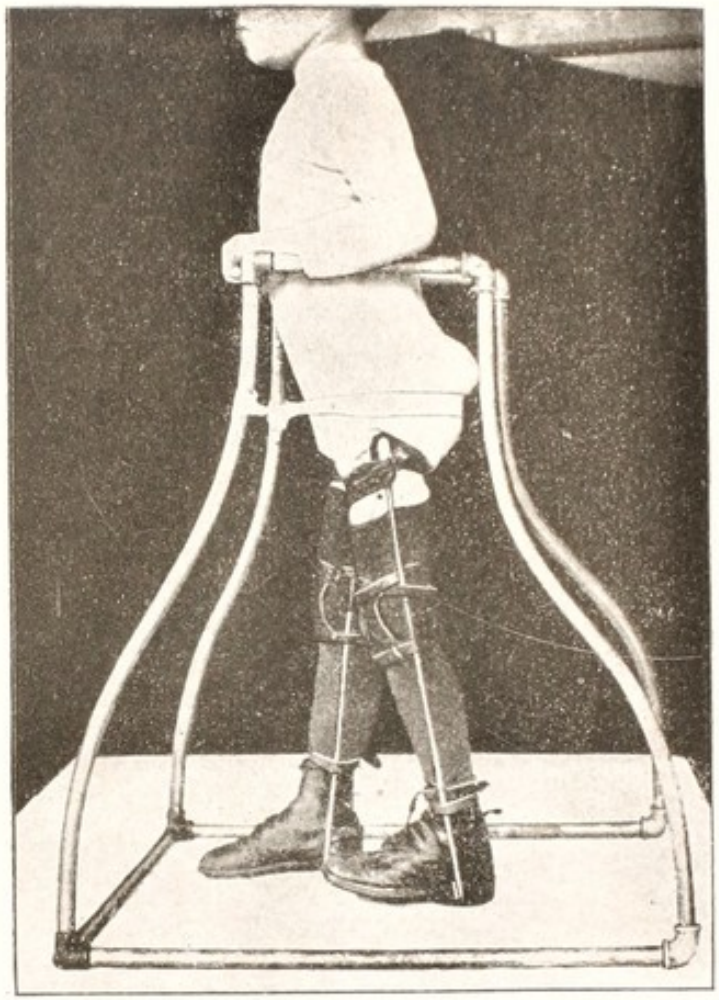


FIG. 410.—Paralyzed child strapped in a walking frame wearing splints to prevent forward dropping of the knee. (Boston Med. and Surg. Journal.)



FIG. 411.—Apparatus with ankle strap to check paralytic valgus. If the upright is applied to the inside with the ankle strap applied to the outside a varus deformity is checked. (Boston Med. and Surg. Journal.)

successfully accomplished. Loss of this sense must be reckoned with as a factor *independent* of the paralysis, for it often happens that a patient may be

able to use crutches while at the same time he is totally unable to stand with the legs completely supported by braces. Such an individual must be drilled in standing with crutches, standing supported by an assistant, by holding on to furniture, etc.

Learning to Walk.—When a patient starts to walk, he should receive manual assistance at first, on account of the frequent defect in orientation. He should be taught to advance both crutches, drag both feet forward, and repeat until progression is possible. In walking thus, the patient forms a tripod, the crutches representing the two forward feet and the patient's feet the posterior foot of the tripod. Hyperextension at the hip is prevented by the Y-ligaments, hence there is no tendency to deformity in this direction, and even in cases with absolute gluteal paralysis walking can be accomplished by dragging the legs behind the body. But with flexion deformity at the hips from contraction of the tensor fasciæ latæ, the center of gravity cannot be brought behind the hip-joints, and in such cases gluteal paralysis is the greatest obstacle to walking and may prevent any form of locomotion except the "tripod" progression just mentioned. In such cases, it is better to walk with one leg at a time than by dragging the legs behind.

Patients with severe paralysis of the back, abdomen, and gluteal muscles require the support of a leather jacket with straps from the tops of the leg splints to the back of the jacket to act as substitutes for the gluteals and prevent flexion at the hips.

ACTIVE THERAPEUTIC MEASURES

Fortunately, the number of cases in which the loss of power consists only of muscular weakness, in contradistinction to complete paralysis, comprises the vast majority of the victims of the disease. The active therapeutic measures of the convalescent stage are divided into two departments:

A. *The prevention of permanent deformity* and

B. *The restoration of nerve and muscle power.*

A. THE PREVENTION OF PERMANENT DEFORMITY

The existence of permanent deformity is an indication of neglect on the part of those having charge of the patient, particularly in the case of deformities of the feet. Permanent deformity is almost always preventable, except in connection with paralysis of the spinal and shoulder muscles.

There are *three stages* in the development of deformity in infantile paralysis, viz.:

1. **Sustained Malposition.**—At this stage the deformity is remediable without the use of force.

2. Lengthening of the soft parts on the stretched side of the joint, with shortening on the other side. In exceptional cases, the joint remains flail-like.

3. Permanent structural bony deformity, due to adaptation of the growing bone to the vicious position.

Varieties of Deformity.—1. Due to *gravity* or to *weight-bearing* in a flaccid extremity.

(*a*) *Talipes equinus* (foot-drop) is the earliest type.

(*b*) *Talipes valgus*, in paralysis below the knee. It is due to weight-bearing with lengthening of those soft parts which have been stretched and contraction of shortened structures.

(*c*) *Genu recurvatum* is due to hyperextension of the knee from paralysis of the hamstrings with the extensor quadriceps unopposed.

(*d*) *Subluxation of the humerus* in paralysis of the muscles about the shoulder. The dependent arm pulls the head of the humerus out of the glenoid cavity.

2. Due to *unopposed muscle-pull.*

(*a*) *Foot.*—The following table of deformities of the foot and the type of paralysis producing them was formulated from a study of 635 cases in the Children's Hospital, Boston, by Lovett and Lucas (Jour. A. M. A., Nov. 14, 1908) and is quoted from Lovett's "Treatment of Infantile Paralysis" (*loc. cit.*, p. 56).

Deformity,	Resulting from paralysis of
Varus,	Peronei.
Valgus,	Anterior tibial.
	Posterior tibial.
	Both tibials.
	Flexor longus hallucis.
	Whole leg (weakened).
	Complete paralysis.
Equinus,	Anterior muscles, paralyzed or weak.
	Complete paralysis (from dangling).
Equinovarus,	Anterior muscles (with persistence of flexor longus hallucis).
	Anterior and external group.
	Paralysis apparently complete (toe flexors remaining).
Equinovalgus,	Anterior and internal muscles.
	Anterior muscles and weight-bearing.
Calcaneus,	Posterior muscles.
Calcaneoval-gus,	Posterior muscles and one or both tibials. Other instances of this type of deformity are flexion at the knee and flexion at the hip. In the former the hamstrings are active and the quadriceps weakened; in the latter the hip flexors predominate over the weakened glutei.

(*b*) *Scoliosis.*—Lateral curvature of the spine may be produced by either gravity or unopposed muscle-pull, or by a combination of the two factors. In either case, it is the result of an effort to secure equilibrium. It occurs not only as a sequel of paralysis of the muscles of the back but also of paralysis of the shoulder muscles or as the result of shortening of one leg following paralysis of its intrinsic muscles. Asymmetry of the spine in these cases becomes necessary to maintain equilibrium, and this curvature may, in time, become structural.

(*c*) *Scapula.*—"Angel-wing" deformity from paralysis of the serratus magnus muscle is due to eversion and prominence of the vertebral border of the scapula.

Whatever the malposition assumed (varus or valgus, scoliosis, genu recurvatum, etc.) it should, in the convalescent stage of the disease, be prevented by means of some form of apparatus, from lapsing into a fixed deformity. It is preferable to restrict muscular activity in a limb rather than to allow a structural deformity to become established. It is equally important to guard against the stretching of muscles and ligaments, a condition which is far more difficult to treat than a contracted muscle. This remark applies more especially to the arm in the case of deltoid paralysis, when the dependent limb drags down the head of the humerus from the glenoid cavity and stretches the capsular ligament, at the same time elongating the deltoid itself; the latter is a formidable variety of paralysis and is extremely resistant to treatment. A sling should be used to support the dead weight of the arm; or the author prefers, in selected cases, his own method of abduction (*loc. cit.*) in a plaster cast to allow the deltoid to shorten, or reefing the capsule (see Chapter XV).

3. *Dislocation.*—Although subluxation of paralyzed joints occasionally occurs, *e.g.*, the humerus, true dislocation from paralysis is confined to the hip-joint.

Paralytic Dislocation of the Hip.—This is often a very disabling condition on account of the slipping of the femoral head from the acetabulum on walking or even on simple adduction. The dislocation usually occurs upward and backward onto the dorsum ilii. Dislocation of the femoral head is induced by paralysis of the intrinsic muscles of the hip with weakening or actual paralysis of the glutei, while the adductor and tensor fasciæ femoris remain normal or are contracted. Therefore, every case of flexion deformity of the hip demands early, careful examination for the possible presence of dislocation and the immediate correction of the deformity.

The disabling features of paralytic dislocation of the hip are the instability of the joint, the accompanying shortening and occasional pain on walking. Not infrequently, a false socket is formed; in other cases, there is no point of anchorage, the head slipping about and producing a very unstable, irritable joint. Attrition may cause disappearance of the atrophied femoral head.

Diagnosis of paralytic dislocation of the hip rests upon the following phenomena: (1) waddling gait, or the gait pathognomonic of shortening of the leg; (2) palpation of the abnormally located femoral head on adduction of the limb; (3) shortening; (4) elevation of the trochanter above Nélaton's line; (5) *x*-ray evidence of the dislocated head.

Treatment of paralytic dislocation of the hip almost invariably demands operative intervention, but previous to the author's publication of two operative procedures, about to be mentioned, no permanent relief from this disabling deformity had ever been suggested. This consists of (1) *bone-graft wedge, to deepen the acetabular cavity*, with *reefing of the capsule* of the hip-joint (see Chapter XXIV, on Congenital Dislocation of the Hip); (2) or, *arthrodesis* of the hip-joint in rare cases of dangle-hip in which the patient has sufficient strength to permit walking with resulting dislocation (see Chapter VI on Tuberculosis of the Hip).

B. RESTORATION OF NERVE AND MUSCLE POWER

At the outset, it must be emphasized that every therapeutic measure employed to develop weakened muscles must be tempered so as *to avoid fatigue*, which, in the case of these atrophied muscles, is detrimental to their welfare and may actually retard their development. It is better to underuse an atrophied muscle than to err in the opposite direction.

Therapeutic measures which aim at the restoration of nerve and muscle power consist of (1) massage, (2) heat, (3) electricity, and (4) muscle training.

1. **Massage.**—If properly performed (and not overdone), massage is of great benefit, for the following reasons: (*a*) it stimulates the venous circulation by emptying the veins, and *pari passu*, (*b*) it invites good arterial flow; (*c*) the same remark applies to the lymphatic circulation; and, lastly (*d*) it aids in the elimination of waste products retained in the muscles and therefore improves muscular nutrition and tone. It must be borne in mind, however, that *massage will not restore muscle power or nerve impulse.*

Vibration is beneficial in conjunction with massage, from its action on the vasomotor centers. Direct blows on the belly of a normal muscle ordinarily cause fibrillar contractions; therefore, in atrophied muscle vibration would, theoretically at least, increase muscle tone.

2. **Heat.**—Heat has a directly specific effect on muscular tissue. It improves the contractile power of partially paralyzed muscle, because the higher

temperature is more favorable to contraction and stimulates the circulation. Furthermore, flooding the part with blood just before massage is administered makes the latter more effective in depleting the veins and thereby causes greater arterial inflow to the part.

3. **Electricity.**—Electricity has hitherto been regarded as a sort of fetish, endowed with mystic power in the treatment of infantile paralysis. Omitting all dissertation on the relative merits of the various kinds of electricity employed, the practical deductions from its clinical application are about as follows:

(*a*) *Faradic Current.*—This produces mild local contraction of the muscle to which it is applied, and is therefore useful only as a means of very gentle, passive muscular exercise.

(*b*) *Galvanic Current.*—The galvanic current is employed on *purely empirical* grounds to improve nutrition, to promote nervous contraction, and for an indefinite general effect which it is supposed to have on the nervous system. Its beneficent effects are doubtful.

(*c*) *High frequency current, sinusoidal current, Morton wave current,* etc., have many champions and some fanatical enthusiasts, but the rationale of their use is doubtful.

It must be remembered that the majority of cases of infantile paralysis improve after the acute attack is ended, whether or not any treatment is administered, and that jubilation over an improvement during (not because of) electrical treatment may divert both the attending physician and the parents from more useful modes of treatment during the critical phases of the convalescent stage.

4. **Muscle Training.**—It is of the highest importance, before any mechanical, physical, or operative treatment can be effectively applied, to ascertain the functional and comparative strength of the affected muscles. The desideratum is *voluntary* muscular contractility and *not* the muscular response to electricity. Before proceeding to the more refined examinations and exercise of specific muscles, it is desirable to note the existence of deformities, to carefully observe the gait, and to make manual examination of the muscles:

GAIT.—Lovett (Treatment of Infantile Paralysis, P. Blakiston's Son & Co., Philadelphia, 1916, pp. 123–126) gives a very clear and concise description of the various abnormal gaits in infantile paralysis, as follows:

Gastrocnemius.—The walk is heavy, the heel is brought down first and there is no spring when the next step is taken. If one side alone is affected the gait is arrythmic, the patient pausing longer on the good foot. When both sides are affected the gait is waddling, with the feet turned outward.

Dorsal Flexors of Foot (Fig. 412).—The patient lifts the knee of the weak side high in order to clear the toes of the paralyzed foot, which "drop" when lifted from the ground. There is a tendency to extend fully or even hyperextend the knee when the foot is brought down. Weakness in one case was so slight as to escape detection by hand resistance, but the mother reported that the child fell down often, and it was discovered that she was unable to walk on her heels with her toes in the air.

Anterior Tibial.—The patient walks with the weight on the inner border of the foot, which is pronated and everted (talipes valgus).

Peroneals.—When the peroneals are weak the patient walks on the outer side of the foot (talipes varus).

Quadriceps.—With a weakened or paralyzed quadriceps muscle the patient may be able to walk unaided in the following ways:

1. The patient keeps the knee from flexing as he walks by pressing the thigh back with one hand.

2. As the affected foot touches the ground the patient hyperextends the knee, thereby locking the joint.

3. The patient walks with the leg rotated outward.

4. With talipes equinus the foot when placed on the ground locks the knee back because it cannot dorsally flex, and thus the knee is held extended and able to bear weight.

5. With strong hamstrings the patient can lock the knee without hyperextending or even fully extending it, simply by bending the whole body forward, the thighs thus carrying the center of gravity forward.

Gluteus Maximus.—In stepping forward with the foot of the weak side the patient lightly touches the foot to the ground and brings the good foot forward again very rapidly, with the knee of the good leg bent. The limp is very marked on account of the extreme



FIG. 412.—Gait in paralysis of dorsal flexors of foot. (Lovett.)

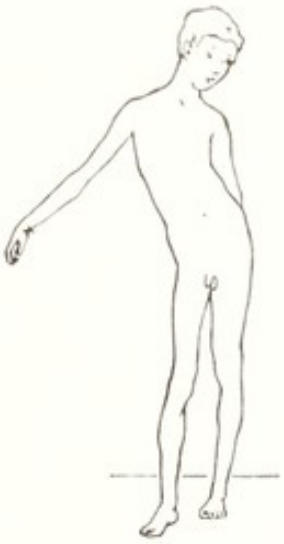


FIG. 413.—Gait in paralysis of gluteus medius of right side. (Lovett.)

dipping on the *good* side. When both gluteals are badly affected walking without crutches is impossible.

Gluteus Medius (Hip Abductor) (Fig 413).—A patient with weak abductors in walking takes his weight on the weak leg and tips his whole body toward that side and reaches out the hand for balance. This tipping and reaching out toward the weak side is



FIG. 414.—Gait in paralysis of hip flexors. (Lovett.)



FIG. 415.—Gait with abdominal paralysis. (Lovett.)

very characteristic of abductor paralysis. In slighter cases it resembles the gait due to a short leg.

Hip Flexors (Fig. 414).—The patient brings the affected limb forward by a forward twist of the pelvis on that side.

Adductors of the Hip.—Weakness of the adductors does not cause a real limp, but it can be detected by asking the patient to place one foot directly ahead of the other in walking. With weak adductors this can only be done by swinging the body.

Abdominal Muscles (Fig. 415).—With weak abdominal muscles the patient stands and walks sway-backed, with the hips flexed and the lumbar spine in strong lordosis and with the abdomen prominent. Unilateral paralysis of the abdominal muscles, and especially of the quadratus lumborum, causes the patient to drop the pelvis on the weak side in taking the weight on the good leg. The position is like that taken by a patient with congenital dislocation of the hip when standing on the affected leg (Trendelenburg's sign).

Back Muscles.—Seriously weakened back muscles make it impossible for the patient to hold the spine erect in sitting, standing or walking. There is generally in these cases a lateral deviation of the spine. The more asymmetrical the paralysis the more rapid the onset of the scoliosis.

MANUAL EXAMINATION OF THE MUSCLES

The voluntary contractability of the weakened muscles may be ascertained by placing the patient in the position most favorable for action of the muscle in question, directing him to perform certain movements, and watching the muscle or tendon for any evidence of response. Much information can also be obtained by *palpation* of the tendons during contraction.

In the case of very small children, too young to understand instructions, the child's voluntary movements must be observed, stimulating them in various ways, such as tickling soles of feet and the skin of the calf and thigh, shifting the child about, observing its movements during struggling and while attempting to grasp objects held before it.

The deformity itself, to an experienced eye, is a very good criterion by which to judge the muscle which is functionally weakened or paralyzed, especially in the case of a young individual in whom the lesion is of long duration; and this, after all, is highly important, since it is *function* that we are primarily interested in improving.

It is also necessary to estimate the relative values of different muscles performing the same movement; this is a matter of prognostic importance, viz.: If "10" represents the strength of the combined muscles which flex the forearm, in one individual "2" represents the power of the forearm muscles and "8" that of the biceps; while in another individual "8" represents the power of the forearm muscles and "2" that of the biceps. In the former case (biceps relatively stronger than forearm muscles) the outlook is decidedly more promising.

EXERCISES FOR MUSCLE TRAINING

In the event of apparently complete loss of power in a given muscle, the patient should *concentrate on an attempt to execute the desired movement* while it is being passively performed for him. It may be that the patient can execute a movement through only a portion of its arc of motion; in such a case, the surgeon or attendant passively completes the normal arc for the patient. *Smoothness* in the completion of the movement is essential to avoid interruption of the patient's mental effort. In giving these muscle exercises, it is advised that resistance be not increased until the easier exercise is readily performed, and that in each exercise the resistance be graded from weak at the beginning of the movement to a maximum at the middle, declining again toward the end of the movement. All exercises should be performed once a day, six days per week, with rest on the seventh day, which prevents the patient from getting stale. Each movement is executed ten or twelve times in succession, but in rhythm sufficiently slow to permit complete recovery of muscular tone between the efforts. The strictest kind of intelligent supervision is necessary, whether the patient is a child or an adult. The affected limbs should be bared during the exercise, to allow careful scrutiny, and the exercise should be performed on a hard table or on the floor, and *not* on a couch or bed.

The examination of the separate regions and muscles and the exercises prescribed for each have been so carefully and intelligently worked out by Lovett that we cannot improve upon them and they are herewith given in full, the tests and exercises being arranged in the order of their strength, those for normal or nearly normal muscles being given first.

LOWER EXTREMITY

THE FOOT

Toes.—*Flexion.*—Flexion of the toes is produced by the following muscles: flexor longus digitorum, four toes (acting on both joints); flexor brevis digitorum, four toes (acting on the

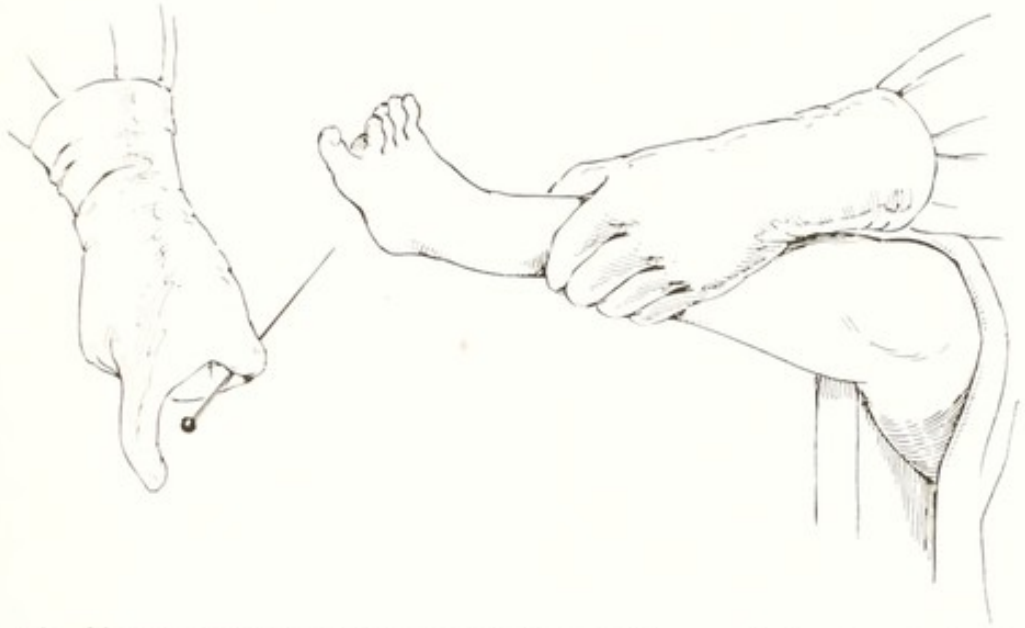


FIG. 416.—Method of eliciting muscle action and detecting paralysis of muscles in infants.

first joint); flexor accessorius, four toes; flexor longus hallucis, big toe; flexor brevis hallucis, big toe; flexor brevis minimi digiti, one toe; lumbricales, four toes; interossei, three toes.

EXAMINATION FOR TOE FLEXION (Fig. 416).—1. The patient lies on the back or sits and bends the toes toward the sole of the foot, to "make a fist" with the foot. Complete paralysis of all toe flexors is rare.

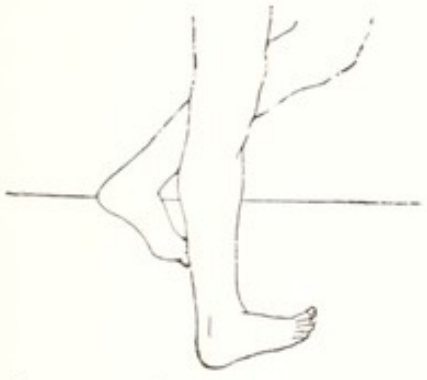


FIG. 417.—Examination No. 3, dorsal flexion. (Lovett.)

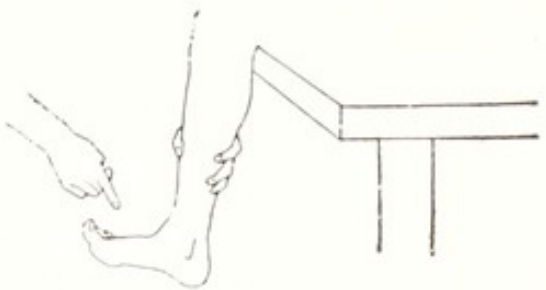


FIG. 418.—Examination No. 4, dorsal flexion. (Lovett.)

EXERCISES FOR TOE FLEXORS.—101. The movement described in 1 (see Examination) is performed, (*a*) with resistance and (*b*) without resistance from the surgeon, who places one finger across underneath the toes and pushes up against them.

Extension.—Extension is produced by the following muscles at the metatarsophalangeal joints: extensor longus digitorum; extensor brevis digitorum; extensor proprius hallucis; interossei; lumbricales (Cunningham).

EXAMINATION.—2. The patient sits or lies on the back and bends the toes toward the dorsum of the foot. The surgeon may resist the movement with one finger placed on the dorsal surface of the toes. Normal toe extensors should be able to overcome considerable resistance.

EXERCISES.—102. The patient performs the movement described in 2, (*a*) with resistance, (*b*) without resistance.

Ankle.—*Dorsal Flexion* (flexion).—Dorsal flexion of the foot is produced by: tibialis anticus; extensor longus digitorum (Piersol); extensor communis digitorum (Cunningham); extensor proprius hallucis; peroneus tertius.

EXAMINATION.—3. The patient stands on the foot to be tested and raises the front of the foot from the ground until he is balanced on the heel. For the performance of this motion the tibialis anticus and other muscles must be nearly normal. The toe extensors alone probably do not have power enough to perform this movement (see Fig. 417).

4. The patient sits with the foot hanging free and tries to raise the foot against resistance on the dorsum, the leg being steadied. If the foot can be raised above a right angle in this position but 3 cannot be performed, the muscles are not normal but may be classed as good. If they cannot perform it gravity must be eliminated as in the following test (see Fig. 418).

5. The patient lies on the affected side with the affected leg held firmly down on the table and the foot in plantar flexion and attempts to bring it into dorsal flexion. If the muscles act only in this position, they are very poor; if they do not act, they are paralyzed. Care must be taken not to confuse the rebound from extreme plantar flexion with real action of the dorsal flexors.



FIG. 419.—Examination No. 8, plantar flexion. (Lovett.)

EXERCISES.—103. The patient performs the movement described in 3.

104. The patient performs the movement described in 4 with and without resistance.

105. The patient lies on the affected side and dorsally flexes the foot while the leg is held firmly down on the table. This eliminates pronation of the foot.

106. The patient lies on the face with the knee flexed at right angles and the lower leg directed vertically upward. The surgeon studies the leg during attempted dorsal flexion of the foot (*a*) with the finger under the dorsum of the foot resisting the movement; (*b*) with gravity assisting the movement.

Plantar Flexion (Extension) *of the Ankle.*—The muscles concerned are: gastrocnemius; plantaris; soleus; tibialis posticus; peroneus longus and brevis; flexor longus digitorium; flexor longus hallucis.

EXAMINATION.—6. The patient stands on the affected side with the sound knee bent and steadied by holding the surgeon's hand with his own, rises on the ball of the affected foot (attempts to stand on tip toe). Normal plantar flexors can raise the body-weight about 10 times without flagging.

7. The patient walks on tip toes. An affected muscle may be strong enough to permit this when it is too weak to perform the preceding movement (see Examination 6).

8. The patient lies on the face with the feet projecting over the end of the table and attempts plantar flexion against the resistance of the surgeon's hand. When a patient is unable to stand, this test will indicate the amount of power in the muscles involved (see Fig. 419).

9. The patient lies on the affected side with the leg held and attempts plantar flexion at the ankle. The tendo Achillis must be closely watched in this attempted movement to see if any contraction of it occurs, as the tibial, peroneal, or long toe flexor may cause slight plantar flexion when the gastrocnemius is wholly paralyzed and in the latter case the outlook is less good.

EXERCISES (Fig. 420).—107. The movement is described in 6 (see Examination).

108. The movement is described in 7.

109. The movement is described in 8.

110. The patient performs the movement described in 9, (*a*) with resistance, (*b*) without resistance on the sole of the foot.

111. The patient lies on the face with the knee flexed to a right angle and the lower leg directed vertically upward and plantar flexes the foot, (*a*) without assistance, (*b*) with assistance on the dorsum of the foot.

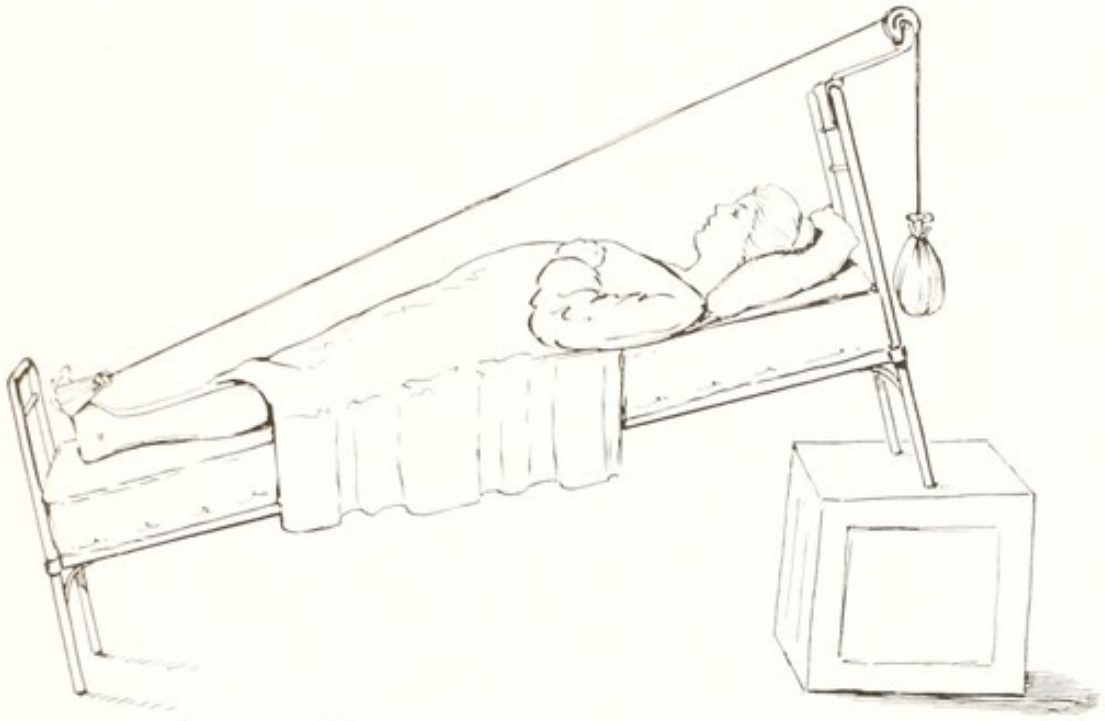


FIG. 420.—Exercise for weakened plantar flexors of the foot.

Inversion of the Foot.—The muscles concerned are: Tibialis anticus; tibialis posticus. When the anterior tibial is paralyzed, the extensor longus hallucis acts with some slight force to invert the foot.

EXAMINATION.—10. The patient lies on the affected side and while the leg is held firmly down on the table lifts the outer border of the foot away from the table with resistance from the hand on the inner border of the foot. To perform this movement both tibials must be very good and it is important to look for and identify the tendon of each when this move-



FIG. 421.—Test for tibialis posticus. (Lovett.)



FIG. 422.—Test for tibialis anticus. (Lovett.)

FIGS. 421 and 422—Examination No. 11.

ment is attempted for even with very weak muscles the tendons may be seen to contract. The peroneals must be relaxed before the movement is attempted as otherwise the rebound from their contraction might be taken for active movement. In case the extensor longus hallucis is acting to replace the tibialis anticus its tendon will be felt instead of the tibial tendon; normally both can be felt lying close together, the tibial tendon nearer the internal malleolus.

11. The patient sits with the foot hanging free, with the lower leg held firmly and turns the foot inward in an attempt to touch the surgeon's finger which is first held slightly above the great toe on the inner border of the foot (tibialis anticus) and then held slightly below the inner great toe joint (tibialis posticus) (see Figs. 421 and 422).

EXERCISES.—112. The patient attempts the movement described in 10, (*a*) with resistance on the inner border of the foot, (*b*) with help at the end of the movement (see Fig. 423).

113. The patient sits on the edge of the table with the legs hanging down and the leg steadied by the surgeon. He then attempts to turn the front of the foot inward and upward toward the other ankle, (*a*) with resistance against the inner border of the foot, (*b*) with the resistance of gravity alone.

114. The patient lies on his back, the surgeon holding the affected leg above the ankle to steady it and turns the foot inward toward the other ankle, (*a*) without help, (*b*) with help in accomplishing the movement.

Eversion of the Foot.—The muscles concerned in this are: peroneus longus; peroneus brevis; peroneus tertius.

The extensor longus digitorum in the weakness of tibial muscles acts as an evertor of the foot.

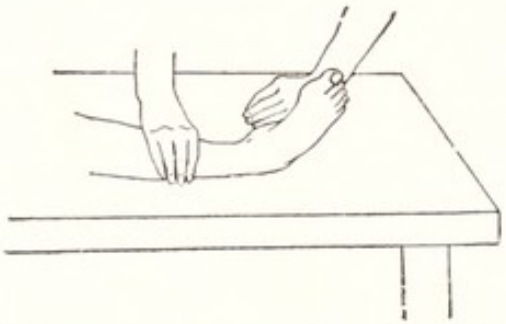


FIG. 423.—Exercise 112, inversion of foot. (Lovett.)

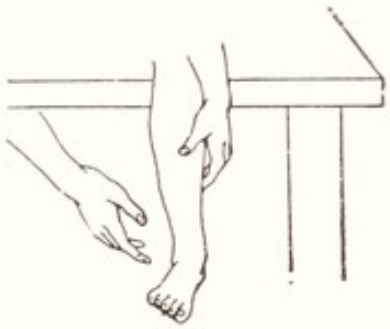


FIG 424.—Examination No. 12, eversion of foot. (Lovett.)

EXAMINATION.—12. The patient sits with the foot hanging free, the lower leg steadied by the hand, and turns the foot outward to touch the surgeon's finger (see Fig. 424).

EXERCISES.—115. The patient sits as in 12 and everts the foot, (*a*) against manual resistance, (*b*) with the resistance of gravity alone.

116. The patient lies on his back with the affected leg held and turns the sole of the affected foot outward away from the other foot.

KNEE

Flexion.—The muscles performing this movement are: biceps; semitendinosus; semimembranosus; gastrocnemius; popliteus; sartorius; gracilis (Cunningham).

EXAMINATION.—The hamstrings, which are the principal knee flexors are also, it must be remembered, extensors of the hip and for this reason are more powerful than would be the case if their sole function were to lift the weight of the leg in flexing the knee in walking.

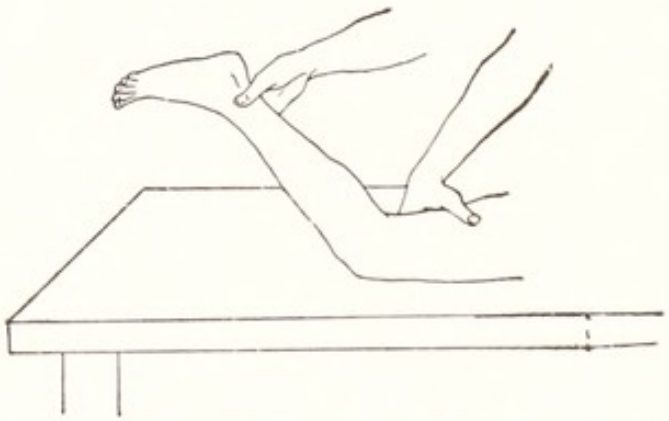


FIG. 425.—Examination No. 13, knee flexion. (Lovett.)

13. The patient lies face downward and flexes the knee from the straight position until the heel touches the buttock, while the surgeon offers resistance over the back of the ankle. Considerable resistance can be overcome if the muscle is normal. If it cannot raise the weight of the leg, it is poor and gravity must be eliminated as in the next exercise (see Fig. 425).

14. The patient lies on the affected side with the hip flexed and the knee extended while

the thigh is held firmly and attempts to flex the knee. If the muscles show no power in this position they must be classed as paralyzed and much information may be gained by feeling their tendons during attempted movement. Paralysis of the gastrocnemius weakens the force of knee flexion even with normal hamstrings. The inner or outer hamstring may be paralyzed while the other will contract (see Fig. 426).

EXERCISES.—117. 13 describes this exercise. It should be done, (*a*) with resistance at the back of the ankle, (*b*) with the resistance of gravity.

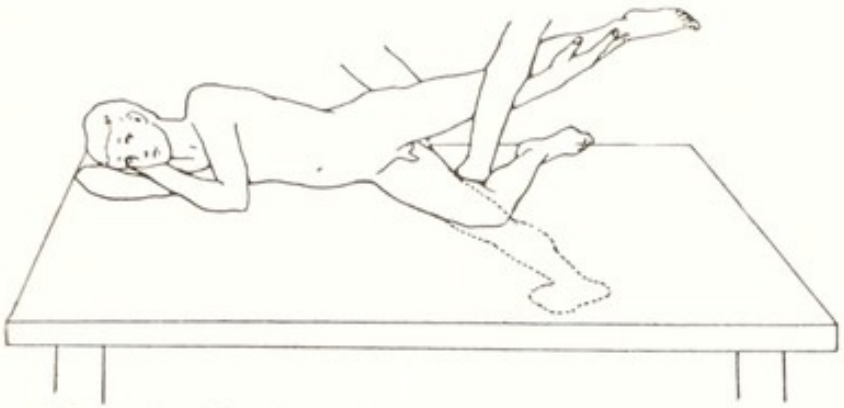


FIG. 426.—Examination No. 14, knee flexion. (Lovett.)

118. The exercise is the same as the examination in 14, (*a*) with resistance from the surgeon's hand on the back of the ankle, (*b*) by unaided muscular contraction (*c*) with assistance on the front of the ankle.

110. The patient lies on the back while the surgeon holds up the affected leg steadying the thigh in the vertical position and offers resistance on the back of the leg as the patient flexes the knee. In this exercise gravity assists the movement and it is possible to add just the amount of resistance necessary to overcome gravity and as much more as can be overcome by the weakest muscles.

Extension of the Knee.—The extensor of the knee is the quadriceps extensor.



FIG. 427.—Examination No. 15, knee extension. (Lovett.)

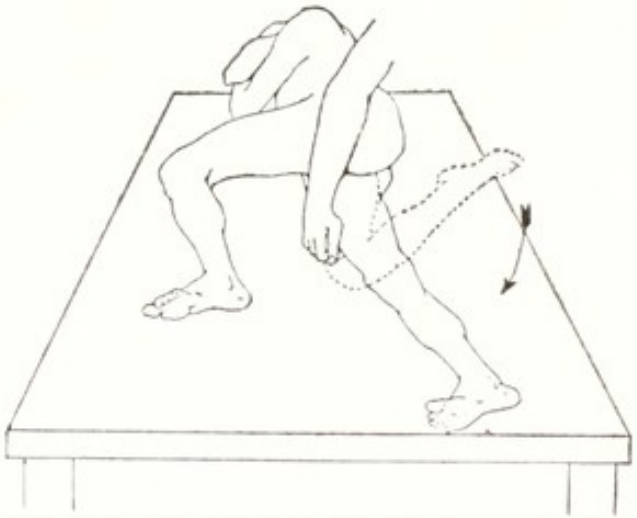


FIG. 428.—Examination No. 17, knee extension. (Lovett.)

EXAMINATION.—15. The patient sits on the heels, shifts all the weight onto the leg to be tested and comes up to the erect position on that leg, steadying himself by holding the surgeon's hands. The muscle is normal if this movement can be performed with slight assistance (see Fig. 427).

16. The patient sits on a table with the knees flexed and the legs hanging over the table, attempts to extend the knee against resistance on the front of the ankle. The amount of resistance required to stop the movement will enable the surgeon to judge its power especially if the muscle on the other side is normal and can serve as a comparison. If the quadriceps cannot raise the weight of the leg, it is poor.

17. The patient lies on the affected side with the hip fully extended and the knee flexed and attempts to straighten the knee. If no contraction is found in this position the muscle must be classed as wholly paralyzed (see Fig. 428).

EXERCISES.—120. The patient performs movement 16, (*a*) with resistance from the surgeon on the front of the ankle, (*b*) with the resistance of gravity alone.

121. The patient performs 17, (*a*) with resistance on the front of the ankle, (*b*) unaided, or (*c*) with assistance.

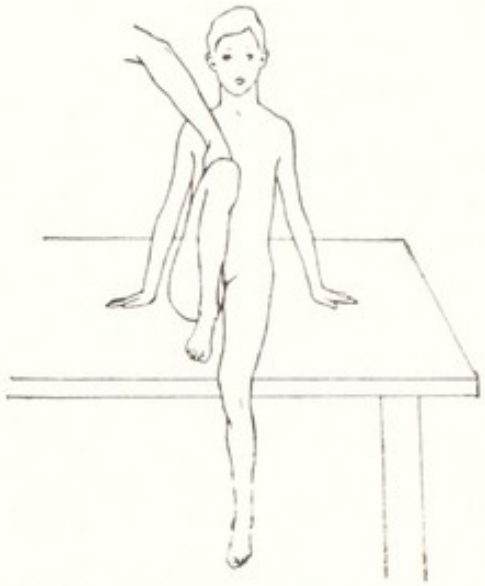


FIG. 429.—Examination No. 18, flexion of hip. (Lovett.)

122. The patient lies on the face with the knee flexed to a right angle and extends the knee against resistance.

123. The patient lies face down on a table with the hips flexed and legs hanging over the edge of the table. The surgeon steadies the affected thigh with his hand and with his other hand flexes the knee and holds it in front of the ankle while the patient attempts to extend the knee with the help of gravity.

HIP

Flexion.—The muscles performing this movement are: sartorius; psoas major and iliacus; rectus femoris; pectineus; adductor longus; gracilis; obturator externus (Piersol); adductor brevis (Cunningham).

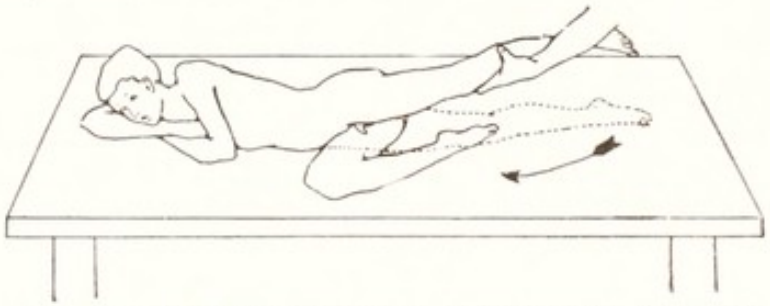


FIG. 430.—Examination No. 19, flexion of hip. (Lovett.)

EXAMINATION.—18. The patient sits with the lower legs hanging over the edge of a table and raises the knee to the chest with resistance at the front of the thigh just above the knee. Normal muscles should overcome much resistance (see Fig. 429).

19. The patient lies on the affected side, the surgeon supporting the other leg and attempts to draw the knee up to the chest. Muscles which show no power in the position must be counted as paralyzed (see Fig. 430).

During this movement it may be possible to distinguish between the contraction of the sartorius and rectus femoris by placing one finger on the anterior-superior spine and one on the inferior and feeling from which of them the contracting muscle originates.

EXERCISES.—124. The patient performs 18, (*a*) with resistance, (*b*) without resistance.

125. The patient lies on his back and brings his knee up to his chest, (*a*) with resistance, (*b*) without other resistance than the weight of the leg.

126. The patient performs 10, (*a*) with resistance against the front of the thigh, (*b*) without resistance, (*c*) with assistance.

127. The patient lies face down on a table with the legs hanging over the edge, being flexed at the hip-joints. The affected leg is then raised to the horizontal by the surgeon and from this position the patient flexes the hip with the surgeon supporting as much of the weight of the leg as may be required (Exercise, see Fig. 431).

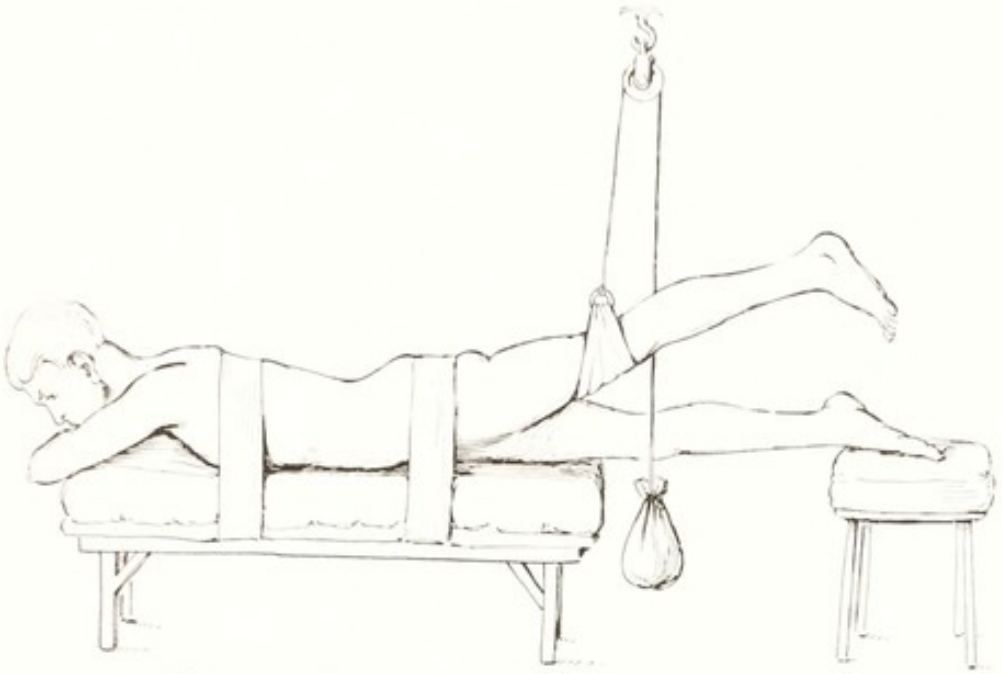


FIG. 431.—Exercise for weakened flexors of thigh.

Extension of Hip.—The muscles performing this movement are: gluteus maximus; hamstrings; gluteus medius (Cunningham); gluteus minimus (Cunningham); adductor magnus (Cunningham).

EXAMINATION.—20. The patient lies on the face and hyperextends the hip with the knee straight, raising the leg from the table. Considerable resistance can be overcome by normal muscles (see Fig. 432).

21. The patient lies on the affected side with the hip fully flexed and moves the thigh back into the line of the body. If there is no movement in this position the muscles must

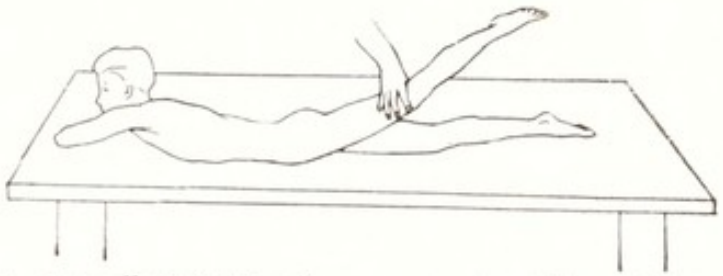


FIG. 432.—Examination No. 20, extension of hip. (Lovett.)

be considered paralyzed. Slight power to extend the hip may be found where the gluteals are paralyzed and only the hamstrings acting (see Fig. 433).

EXERCISES.—128. The patient performs 20, (*a*) with resistance, (*b*) without resistance, without twisting the body.

129. The patient lies face downward on a table with the hips flexed over the edge and the legs hanging down. In this position he raises the leg to the horizontal, (*a*) with the resistance of gravity alone, (*b*) with resistance on the back of the thigh.

130. The patient performs 21, (*a*) with resistance, (*b*) unaided, (*c*) with assistance.

131. The patient lies on the back and the affected leg with the knee straight is lifted as high as possible by the surgeon and the patient brings the leg back to the table with the surgeon making as much resistance as can be overcome.

Abduction of the Hip.—The muscles concerned are as follows: gluteus medius; gluteus minimus; tensor fasciæ femoris (Cunningham); obturator externus (Cunningham); during flexion, pyriformis, obturator internus, gemelli; sartorius, gluteus maximus (upper fibers) (Cunningham).

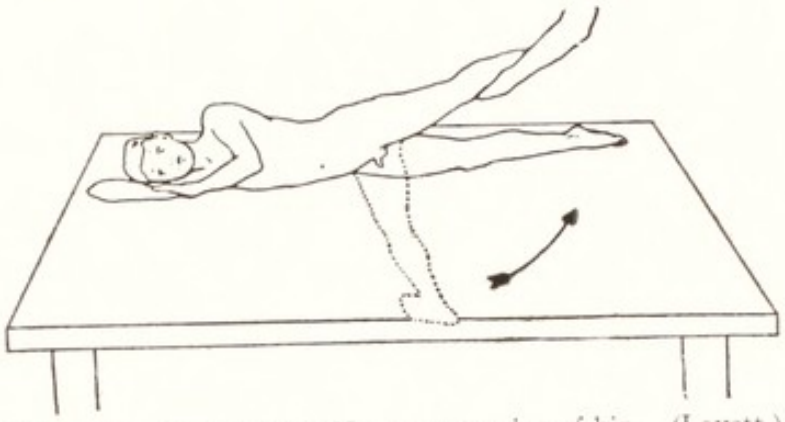


FIG. 433.—Examination No. 21, extension of hip. (Lovett.)

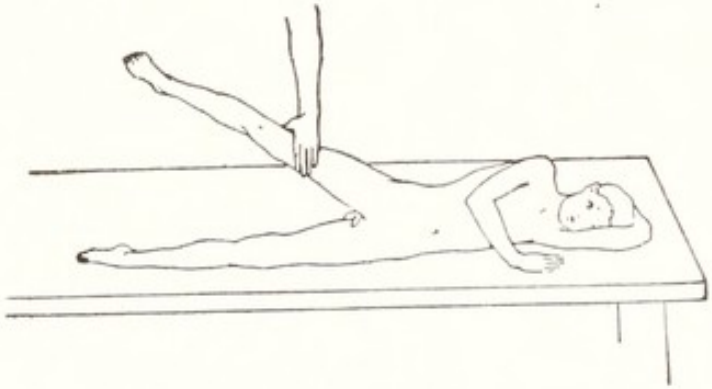


FIG. 434.—Examination No. 22, abduction of hip. (Lovett.)



FIG. 435.—Exercise for weakened abductors of the hip.

EXAMINATION.—22. The patient lies on the sound side and raises the affected leg with the knee straight and in line with the body. The normal muscle overcomes considerable resistance (see Fig. 434).

23. The patient lies on the back with the pelvis firmly held to prevent throwing of the body and abducts the affected leg. Outward rotation of the foot must be checked or flexors will be substituted for abductors.

24. In order to eliminate the possibility that friction of the heel on the table may overcome weak muscles the leg may be slung by a bandage under the ankle, the upper end being held by the surgeon, and the same movement attempted. If no motion occurs, the abductor muscles are paralyzed.

EXERCISES.—132. The patient performs 22, (*a*) with resistance, (*b*) without resistance (Fig. 435).

133. The patient performs 23, (*a*) with resistance, (*b*) without resistance, (*c*) by aid of a sling (see Examination 24).

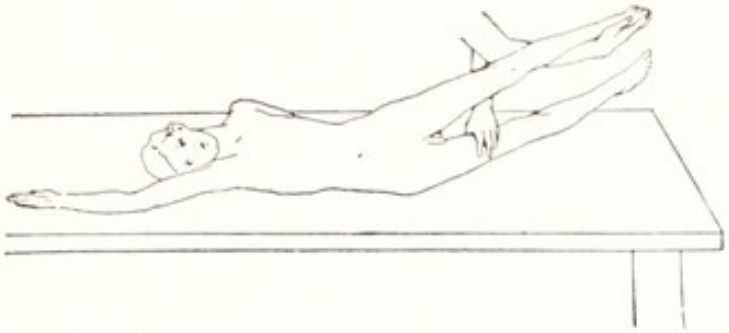


FIG. 436.—Examination No. 25, adduction of hip. (Lovett.)

Adduction of the Hip.—The muscles performing this are: adductors longus, magnus brevis; gracilis; pectineus; quadratus femoris (Cunningham); gluteus maximus (lower fibers) (Cunningham).

EXAMINATION.—25. The patient lies on the affected side with the sound leg held by the surgeon in a position of abduction. He then raises the affected leg from the table in line with the body with the knee straight and without rotating it. Considerable resistance can be overcome (see Fig. 436).

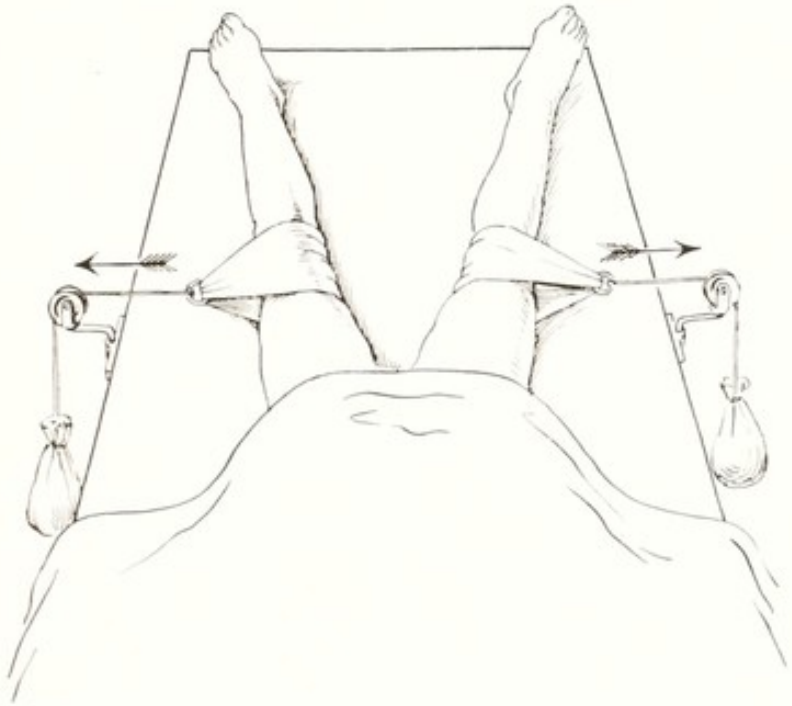


FIG. 437.—Exercise for weakened adductors of the thighs.

26. The patient lies on the back with the affected leg in extreme abduction and brings it in to the other leg.

27. To eliminate friction a sling may be used and the movement of adduction attempted (see Examination 24).

EXERCISES (Fig. 436).—134. The patient attempts the movement described in 25, (*a*) with resistance, (*b*) without resistance.

135. The patient lies on the back with the knees and hips flexed, with the soles resting on the table and the knees apart and attempts to bring the knees together, (*a*) with resistance against the inner side of the knees, (*b*) with only the resistance of gravity.

136. As in 26, (*a*) with resistance, (*b*) unaided, (*c*) by the use of a sling.

Inward Rotation of the Hip.—The muscles are: tensor fasciæ latæ; gluteus medius (anterior fibers); gluteus minimus (anterior fibers); semitendinosus (Piersol); semimembranosus (Piersol); gracilis (Piersol); iliopsoas (Piersol).

These muscles are all concerned also with other functions which have been mentioned in earlier sections.

EXAMINATION.—28. The patient sits with the knees flexed and the lower legs hanging over the edge of a table; keeping the knees together he moves the affected foot away from the other foot, thus rotating the thigh inward. Resistance is offered on the outer side of the ankle (see Fig. 438).

29. The patient lies on the back and rotates the whole leg inward. The feet should be somewhat separated and rotated outward at the start.

EXERCISES.—137. The movement described in 28 is performed, (*a*) with resistance, (*b*) with the resistance of gravity alone.

138. As in 29, (*a*) with resistance, (*b*) without resistance.

Outward Rotation of the Hip.—This is performed by the following muscles: gluteus maximus (lower fibers); gluteus medius (posterior fibers) (Cunningham); gluteus minimus (posterior fibers) (Cunningham); quadratus femoris; during extension, obturator externus,



FIG. 438.—Examination No. 28, inward rotation of hip. (Lovett.)

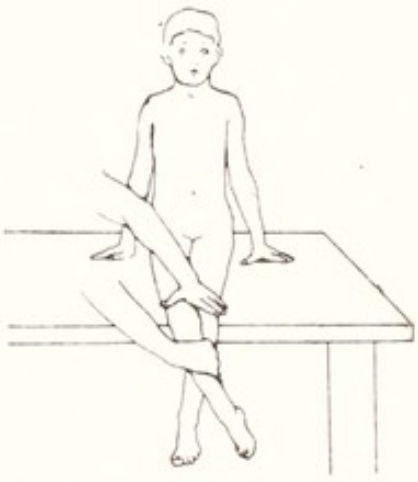


FIG. 439.—Examination No. 31, outward rotation of hip. (Lovett.)

pyriformis, gemelli; sartorius; iliopsoas (Cunningham); pectineus; adductors magnus, longus, brevis (Cunningham); biceps femoris; obturator internus.

The action of the iliopsoas is given by Piersol as an inward rotator and by Cunningham as an outward rotator.

EXAMINATION.—30. The patient lies on the face with the knees flexed, the lower legs upright and the knees touching, and the feet are allowed to fall apart. The legs are then rotated so as to bring the feet together.

31. The patient sits at the edge of the table with the knees flexed and the feet hanging down. The foot of the affected leg is then moved inward across the other leg twisting the thigh outward (see Fig. 439).

EXERCISES.—139. 31 is performed, (*a*) with resistance, (*b*) without resistance.

140. The patient lies on the back with the knees straight and legs slightly separated, the toes pointed up and the pelvis held to prevent rolling and turns the whole leg outward, (*a*) with resistance, (*b*) by unaided muscular contraction, (*c*) with assistance.

SPINAL COLUMN

Flexion of the Spine (Forward Bending).—The muscles concerned are: rectus abdominis; pyramidalis (Cunningham); obliquus externus; obliquus internus; transversus abdominis (Cunningham); psoas major and minor.

EXAMINATION.—32. The patient lies on the back with the arms folded, the thighs being held down by the surgeon and attempts to assume the sitting position.

If the muscles are normal, the ensiform cartilage is drawn toward the symphysis by the recti, assisted by the other abdominal muscles, thus flexing the lumbar spine; then the

psoas and iliacus and other hip flexors flex the pelvis on the thighs. If the hip flexors are paralyzed, normal abdominal muscles cannot raise the patient to a sitting position, but by placing the hand over them as they contract it is possible to feel them hard and to judge by their tone and by the ease with which the lumbar spine is flexed whether or not they are normal. If, on the other hand, the recti are paralyzed and the hip flexors normal, the patient will first fix the lumbar spine by contracting the erector spinæ muscles and then flex the pelvis on the thighs with the back hollowed and the abdomen prominent and soft. The abdominal muscles of one side may be affected more than those of the other, a fact which may be ascertained by feeling the muscles of either side as they attempt to contract and by watching to see whether the umbilicus is drawn to one side or the other.

EXERCISES.—141. The patient sits in a semireclining position with the back against a slanting support, with arms folded and knees held down and tries to assume a sitting position. The resistance is offered by the weight of the body and the exercise may be made more difficult by starting from a position of the trunk nearer the horizontal.

142. The patient lies on the back and flexes the knees onto the chest, if necessary with assistance under the knees.

143. The patient lies on the side with the arms folded on the chest and the hips firmly held and flexes the spine by bending the body forward. Resistance is offered by the friction of the body on the table. This exercise should be done with the patient lying first on one side and then on the other.

Extension of the Spine.—Produced by the contraction of the *erector spinæ*, a name used here to describe the whole group of posterior spinal muscles instead of the complicated more modern nomenclature given by Piersol and Cunningham. These muscles cannot be exercised without at the same time exercising the extensors of the hips.

EXAMINATION.—33. The patient lies on the face with the legs held down by the surgeon, and tries to raise the head and trunk from the table.

If the erector spinæ muscles are normal they can bend the spine backward and raise the head, shoulders and whole body clear of the table and can be felt as two prominent columns on each side of the spine. When they are not strong enough to lift the weight of the body, they may be still felt to contract by placing the fingers on each side of the spine. It is not easy to eliminate gravity in testing these muscles, so that their presence or absence must be judged by whether or not they can be felt contracting when the patient attempts to lift the body. Frequently the muscles of one side are good, while those of the other are paralyzed or very weak. In such a case the patient always sits or stands, and sometimes even lies with the spine curved laterally, although a lateral curvature may occur also as a result of asymmetrical abdominal weakness.

EXERCISES.—144. The patient performs the movement described in 33. Resistance is furnished by the weight of the trunk.

145. The patient sits with the trunk bent forward, the hips flexed and raises the trunk to the erect position, (*a*) with the hands behind the neck and the elbows squared (the stronger exercise), and (*b*) with the hands on the hips (the weaker exercise).

Lateral Flexion of the Spine (side bending).—The most important muscles taking part in this movement, which is not to be clearly separated from the following movement of rotation, are as follows: rectus abdominis; obliquus externus and internus; transversus abdominis; erector spinæ; psoas major and minor; quadratus lumborum.

EXAMINATION.—34. The patient lies on the unaffected side, the legs in line with the body and held down by the surgeon with the arms folded and attempts to lift the body up from the table. This is easily accomplished if the muscles are normal. If they are very weak, the muscles on the other side will contract and the affected side of the body will be arched up from the table between the hip and shoulder.

35. The patient lies on the back with the arms folded, the hips being held firmly by the surgeon and attempts to bend the body toward the side to be tested.

EXERCISES.—146. The patient performs 34.

147. The patient performs 35.

148. The patient stands and raises the foot of the affected side from the floor without bending the knee, or the patient lies on the face and draws the affected side of the pelvis up toward the shoulder of the same side keeping the knee straight and dragging the leg up along the table, (*a*) with resistance on the ankle, (*b*) without resistance.

Rotation of the Spine.—It has been mentioned that this movement is not clearly to be separated from lateral flexion. The muscles chiefly concerned are: erector spinæ; obliquus externus and internus.

EXAMINATION.—36. The patient sits with arms folded, the hips held firmly, and twists the body to one side, (*a*) with resistance, (*b*) without resistance.

EXERCISES.—149. See 36.

In formulating the movements of the arm Beevor's[1] Croonian lectures on muscular

[1] Chas. E. Beevor, M. D., London, F. R. C. P.: "The Croonian Lectures on Muscular Movements and Their Representation in the Central Nervous System," London, Adlard and Sons, 1904.

movements have been used as the basis of the analysis and have proved of the greatest use.

UPPER EXTREMITY

THE HAND

Fingers.—The examination of the fingers and exercises for weakened muscles will be dealt with only in general for the sake of brevity and because the examination of the different motions is perfectly obvious and the exercises similarly simple. An attempt should be made to perform the various movements with slight resistance offered by the surgeon and the exercises are similarly given. The opposing and adducting muscles of the thumb should be examined with care in every case whether the hand appears involved or not as involvement of these muscles is extremely common.

The function of the different groups is given by Cunningham[1] as follows:

Flexion.—Flexor digitorum sublimis; flexor digitorum profundus; lumbricales; interossei (acting on the metacarpophalangeal articulations); flexor digiti quinti brevis.

Extension.—Extensor digitorum communis; extensor indicis proprius; extensor digiti quinti proprius; lumbricales; interossei (acting on the interphalangeal articulations).



FIG. 440.—Test for thumb adduction. (Lovett.)

Abduction.—Lumbricales; flexor brevis and opponens digiti quinti (from the medial side of the hand); dorsal interossei (from middle line of middle finger).

Adduction.—Palmar interossei (to the middle line of the middle finger).

Thumb.—*Flexion.*—Opponens pollicis (carpometacarpal joint); flexor brevis adductor, abductor brevis (carpometacarpal and metacarpophalangeal joint); flexor pollicis longus (all joints).

Extension.—Abductor pollicis (carpometacarpal joint); extensor pollicis brevis (carpometacarpal and metacarpophalangeal joint); extensor pollicis longus (all joints).

Adduction.—Adductor of the thumb; flexor pollicis brevis; opponens pollicis; first dorsal interosseous.

Abduction.—Abductor pollicis brevis; extensors of the thumb.

Circumduction.—A combination of the above muscles.

Wrist.—*Flexion.*—This motion is performed by the following muscles: flexor carpi radialis; flexor carpi ulnaris; palmaris longus; long flexors of thumb and fingers.

EXAMINATION.—37. The patient sits with the forearm supported on the table and the hand extending over the edge with the palm up. The wrist is flexed against the surgeon's resistance. The finger flexors will assist the wrist flexors proper if the fingers are flexed in the palm of the hand.

38. The forearm and hand are supported, ulnar side down, on a table with the wrist hyperextended and an attempt is made to flex the wrist.

EXERCISES.—These are the same as the Examination.

Extension of the Wrist.—The muscles are: extensor carpi radialis; extensor carpi ulnaris; extensors of the thumb and fingers.

EXAMINATION is the reverse of that described in 37 and 38 and the Exercises are the same movements as described in 37 and 38 reversed.

Abduction of the Wrist.—Muscles: flexor carpi radialis; extensors of wrist and thumb. Extensor carpi radialis longior (Piersol).

Adduction.—Flexor carpi ulnaris; extensor carpi ulnaris.

EXAMINATION.—39. The patient sits with the arm resting on a table, ulnar side down, and the movements of adduction and abduction are tested by the surgeon who resists each attempted movement.

40. If the muscles are too weak to give satisfactory information in this position the forearm should rest on the table, palm up, and adduction and abduction be tested, (*a*) with resistance, (*b*) unaided.

EXERCISES.—These are described under Examination.

Pronation of the Forearm and Hand.—The muscles concerned are: pronator radii teres; pronator quadratus; flexor carpi radialis.

The brachioradialis (supinator longus) is given as a pronator from extreme supination

[1] Cunningham's "Text-book of Anatomy," Robinson, N. Y., Wm. Wood & Co.

by Cunningham but is regarded purely as a flexor by Beevor and is considered to have also slight supinator power by Piersol. (The view of Beevor will be followed here.)

EXAMINATION.—41. The patient sits with the forearm resting on the lap, palm up. The surgeon grasps the hand and resists pronation. The exercise is given without resistance when the muscles are very weak. The Exercises are the same.

Supination of the Forearm and Hand.—Supinator (supinator radii brevis); biceps; brachioradialis (Cunningham).

EXAMINATION.—42. The patient sits with the forearm resting on the lap, palm down. The surgeon grasps the hand and resists attempted supination. The test is given without resistance when the muscles are very weak (see Fig. 442).



FIG. 441.—Test for finger flexion. (Lovett.)



FIG. 442.—Examination Nos. 41 and 42 for pronation and supination. (Lovett.)

As the biceps is a powerful flexor as well as supinator, when it is weakened, strong supination will be accompanied by extension at the elbow and when the triceps is weakened and the biceps intact, by flexion of the elbow.

EXERCISES.—These have been described in 42.

ELBOW

Flexion.—The muscles are: biceps; brachialis; brachioradialis; pronator teres; flexors of wrist and fingers; extensors of wrist and fingers (in pronation).

(The biceps should be regarded as a flexor supinator and the pronator teres as a flexor pronator. If there is weakness of the biceps it is extremely difficult to flex the elbow without pronating the hand, although normally the elbow can be flexed with the forearm either in pronation or supination.)

EXAMINATION.—43. The patient sits and bends the elbow until the hand touches the shoulder, while the surgeon offers resistance against the wrist. This movement should be done first with the hand in complete pronation, then with the hand in complete supination, in order to try out the different muscles taking part in it. If the weight of the arm cannot be raised gravity must be eliminated.

44. The patient lies on the affected side, with the arm straight, and flexes the elbow until the hand touches the shoulder, first in pronation, then in supination. No response in this position must be set down to complete paralysis of all the muscles involved.

It is important to find out what proportion of elbow flexor power is due to the biceps, as a favorable prognosis depends on the hope of getting back power in that muscle. The other elbow flexors can lift the weight of the arm when the biceps is completely paralyzed, but can do very little more. Biceps paralysis is usually accompanied by pronation contracture.

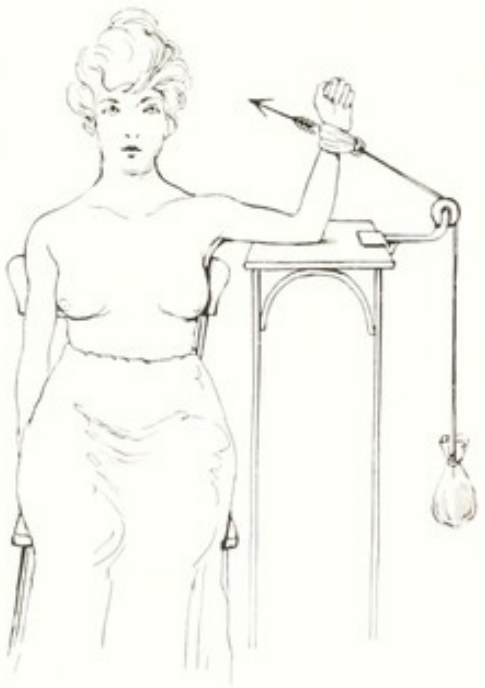


FIG. 443.—Exercise for weakened flexors of the forearm.

EXERCISES (Fig. 443).—150. As described in 43, (*a*) with resistance, (*b*) unaided.

151. As described in 44, (*a*) with resistance, (*b*) unaided, (*c*) with assistance. (To exercise the biceps the forearm must be supinated.)

152. The patient lies on his back, the upper arm supported vertically and flexes the elbow while the surgeon resists the movement.

Extension of the Elbow.—Triceps; anconeus; extensors of wrist and fingers (in supination) (Cunningham, not Piersol or Beevor).

EXAMINATION.—45. The patient sits with the upper arm raised forward as far above the shoulder height as possible and supported in that position, the elbow is completely flexed so that the hand touches the shoulder. He then extends the forearm against resistance on the wrist (see Fig. 444).

If the muscles cannot raise the weight of the arm, gravity must be thrown out of play.

46. The patient lies on the affected side, with the elbow flexed and the hand touching the shoulder, and tries to extend the forearm.

If this movement cannot be performed, the muscles are paralyzed.

EXERCISES.—153. The patient lies on his back with the upper arm vertical and the elbow flexed and attempts to extend the elbow, (*a*) with resistance, (*b*) unaided against the weight of the arm above.

154 (Fig. 445). The patient sits with the forearm held up in flexion by the surgeon and attempts to extend the elbow. The surgeon makes such resistance at the wrist as may be necessary to neutralize the weight of the forearm and offering weak resistance if it can be overcome.

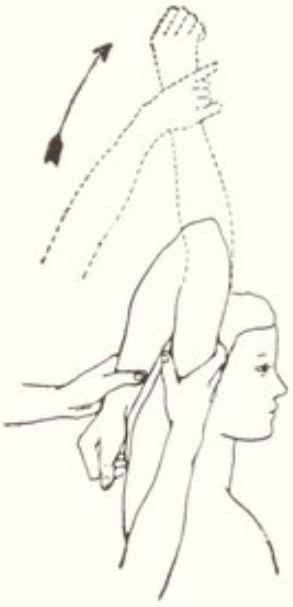


FIG. 444.—Examination No. 45, extension of the elbow. (Lovett.)



FIG. 445.—Exercise for weakened extensors of the elbow.

SHOULDER

In the analysis of movements of the upper extremity so far given Cunningham, Piersol and Beevor have been consulted as the authorities and their divergent views given when they were different. In analyzing the extremely complicated movements of the shoulder Beevor's very complete study of this region will be followed, and his terminology of muscles and movements will in this section be adopted, and the others quoted only occasionally. In practice the method founded on Beevor's views has proved most satisfactory.

Movements of the Shoulder-joint.—*Advancing or flexion of the humerus to the horizontal line*, anteroposterior plane (raising the arm forward): deltoid (anterior); pectoralis major (clavicular); biceps; coracobrachialis

Advancing or flexion of the humerus above the horizontal line; serratus magnus; trapezius (acromial); trapezius (inferior).

The first set of muscles contract and carry the humerus forward nearly to the horizontal line, an action which would rotate the scapula downward and push the inferior angle toward the spinal column if the trapezius did not immediately contract to fix the scapula. The serratus magnus probably does not contract at the beginning of the movement, but comes to the aid of the other muscles as the humerus approaches the horizontal line. If the trapezius is paralyzed, the inferior angle of the scapula will first be drawn toward the spine as the arm is raised, but when the humerus has passed through about 45

degrees, the serratus will start contracting and rotate the scapula upward. There is apparently a definite order in which the separate muscles taking part in any given movement enter into action.

EXAMINATION.—47. The patient lies on the face, with the arms stretched forward above the head, and raises the arms from the table without raising the body. If all the muscles enumerated above are normal the patient will be able to raise the arms somewhat above the line of the body while the shoulders are kept in contact with the table, and will be able at the same time to overcome some resistance. If the arms cannot be brought up to a line with the body, there is either some muscular weakness or joint contracture or both.

48. The patient stands or sits, and raises the arm forward and upward against resistance on the front of the elbow.

49. The patient raises the arm forward while the surgeon fixes the shoulder girdle by pressing firmly down between the patient's neck and the point of his shoulder (see Fig. 446).

In test 48 all the muscles concerned in this movement act. In 49 the serratus magnus and trapezius are thrown out of action and only those muscles act which advance the shoulder to the horizontal. By comparison of the two tests the relative weakening of the two sets of muscles is shown.

All the tests of this movement are to be used primarily to ascertain the condition of the trapezius and serratus magnus.

Abduction of the humerus to the horizontal line, laterovertical plane; deltoid (middle); supraspinatus; biceps.

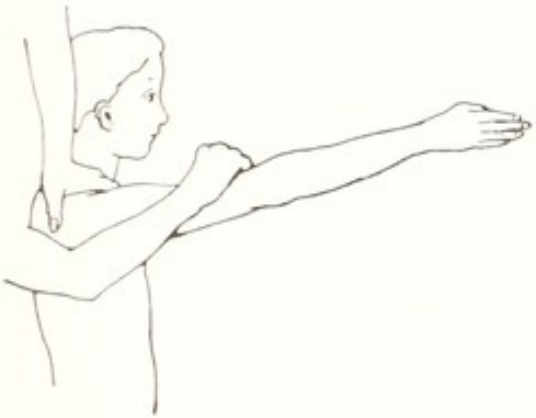


FIG. 446.—Examination No. 49, advancing or flexion of the humerus. (Lovett.)

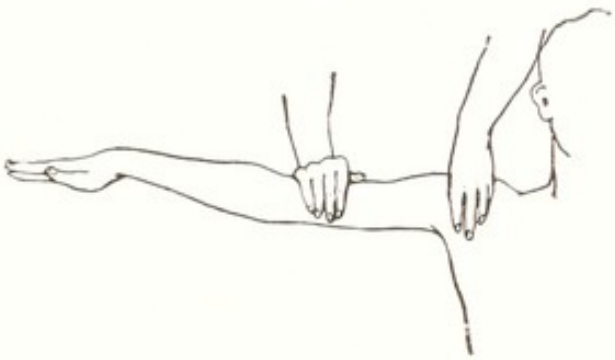


FIG. 447.—Examination No. 50, abduction of humerus. (Lovett.)

Abduction of the humerus above the horizontal line (raising the arm from the side): serratus magnus; trapezius (acromial); trapezius (inferior).

If the deltoid is paralyzed the trapezius and serratus will begin to act at once when the patient attempts to raise the arm sideways, and the inferior angle of the scapula will be seen to move outward, but the arm will be carried no more than 45 degrees from the side. To eliminate the action of the trapezius and serratus magnus the surgeon should fix the patient's shoulder girdle by downward pressure so that movement cannot take place above the horizontal.

EXAMINATION.—50. The patient stands or sits, and raises the arm sideways to shoulder height, against resistance. The arm should not be allowed to rotate outward, and the palm should be directed downward, as in this position the action of the biceps is excluded as much as possible from the movement. A normal deltoid can overcome considerable resistance besides the weight of the arm (see Fig. 447).

51. The patient lies on the back or on the face, and moves the arm out from the side to shoulder height. The same care is to be taken as in the previous test for position of the hand and fixation of the shoulder girdle. If the test is given with the patient lying on his back the greater part of the work is done by the anterior fibers of the deltoid; if on his face, by the posterior. It may well be that either half may show power while the other is totally paralyzed.[1] If the muscle does not functionate at all in this position it may not be totally paralyzed, on account of friction, but is certainly extremely weak.

A more delicate test can be made by slinging the arm under the elbow with a piece of bandage held far enough above so that the patient's movement is not assisted by it, but the friction of the arm on the table surface is removed.

[1] R. W. Lovett: Jour. A. M. A., Mar. 4, 1916.

EXERCISES.—155. The patient sits erect and with the arm at the side and raises the arm sideways until it is vertically above the head with the precautions described in 50, (*a*) with resistance, (*b*) raising the weight of the arm without resistance.

156. As described in 51, (*a*) with resistance, (*b*) unaided, (*c*) by means of a sling.

Extension of the humerus, anteroposterior plane (bringing the arm downward and forward): pectoralis major (sternal); latissimus dorsi; teres major and minor; infraspinatus; triceps (long head); subscapularis.

Hyperextension of the humerus (carrying the arm back of the body): latissimus dorsi; teres major and minor; infraspinatus; deltoid (posterior half).

During both parts of this movement the scapula is fixed by the rhomboids, the lowest fibers of the trapezius, and the pectoralis minor.

EXAMINATION.—52. The patient stands or sits with the arm in a vertical position above the head and brings the arm forcibly forward and downward until it is in line with the body, while the surgeon offers resistance against the back of the arm just above the elbow. He must judge by the amount of resistance they can overcome whether or not the muscles are normal. Beevor is of the opinion that the clavicular portion of the pectoralis major, which is properly a flexor of the humerus, does not act in this movement, although it is in an anatomical position to do so.

53. The patient stands or sits with the arm hanging at the side and raises it backward as far as possible, while the surgeon resists on the back of the arm as before. The pectoralis major no longer acts, but the pectoralis minor may be felt contracting beneath it. This test is a means of distinguishing between their action.

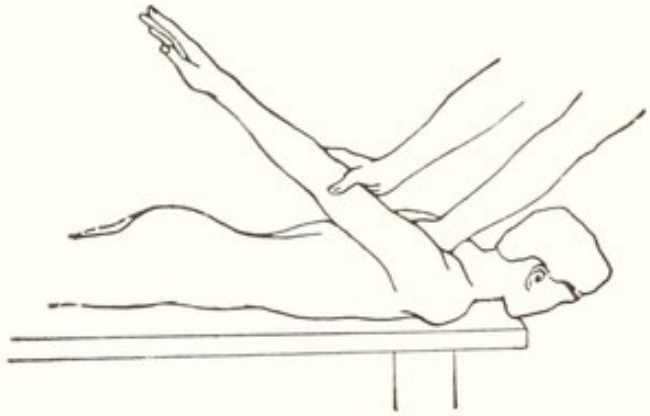


FIG. 448.—Examination No. 54, hyperextension of humerus. (Lovett.)

54. The patient lies on the face with the arm at the side and raises it backward with resistance. This is an even more powerful test for the latissimus dorsi and posterior half of the deltoid. It is impossible to isolate the action of the latissimus dorsi, but some idea of its relative share in this movement may be obtained by feeling the muscle during the effort to contract (see Fig. 448).

EXERCISES.—The Exercises are the same as the Examination.

Adduction of the humerus, laterovertical plane (bringing the arm to the side): pectoralis major (all); latissimus dorsi; teres major and minor; infraspinatus; subscapularis; deltoid (posterior third).

As in the previous movement the rhomboids and the lowest fibers of the trapezius fix the scapula. When they are paralyzed and the arm is forcibly brought down to the side, the inferior angle of the scapula is drawn outward away from the spine. When they are normal and the adductors are paralyzed an attempt to adduct brings the inferior angle of the scapula toward the spine.

EXAMINATION.—55. The patient stands or sits and pulls the arm down to the side against resistance under the elbow.

Whether or not the muscles are normal must be judged by the amount of resistance they can overcome and by the hardening of the tendons, which are easily felt at the anterior and posterior muscles of the axilla.

56. The patient lies on the back or on the face, with the arm stretched sideways at right angles to the body, and draws the arm in to the side.

The position on the back shows up the pectoralis best, that on the face, the latissimus. If the muscles are too weak to overcome the resistance of the arm on the table the arm may be slung as in the deltoid test. If there is then no sign of function the muscles must be classed as totally paralyzed.

EXERCISES (Fig. 440).—157. The patient performs 55.

158. The patient lies on the back with the arm stretched above the head and brings it to the side, (*a*) with resistance, (*b*) unaided, (*c*) with the aid of a sling to remove friction.

Horizontal adduction of the humerus (bringing the arm toward the middle line of the body at shoulder level): coracobrachialis; pectoralis major; deltoid (anterior half).

EXAMINATION.—57. The patient lies on the back with arms stretched out sideways at shoulder height, elbows straight, palms up, and raises the arms toward the middle line of the body until they are vertical and the palms meet above against resistance.

The deltoid does not take part in this movement to any considerable extent, so that it is as pure a test as can be found for the pectoralis major.

58. The patient sits with the affected side toward the table, upon which the arm is supported at shoulder height, and tries to slide the arm forward along the table.



FIG. 449.—Exercise for weakened adductors of the upper arm.

EXERCISES.—159. See 57, (*a*) with and (*b*) without resistance.

160. See 58, (*a*) with resistance, (*b*) unaided, (*c*) with a sling.

Horizontal abduction of the humerus (carrying the arm back at shoulder level); deltoid (middle); deltoid (posterior); latissimus dorsi; teres major and minor; infraspinatus; subscapularis.

In this movement, the middle fibers of the trapezius fix the scapula.

EXAMINATION.—59. The patient lies on the face with the arm stretched sideways at right angles to the body and raises the arm straight up from the table, with resistance from the surgeon (see Fig. 450).

If the deltoid is normal and the trapezius paralyzed the arm will be raised from the table, but the point of the shoulder will be pushed forcibly against the table and used for a pivot. If the condition is reversed the scapula will be drawn toward the spine and the point of the shoulder raised from the table with the arm dragging down.

60. The patient sits facing the table with the arm resting on it in a position of extreme adduction, that is, crossed over to the other side, and tries to abduct the arm.

EXERCISES.—161. The same as 59, (*a*) with resistance, (*b*) without.

162. See 60, (*a*) with resistance, (*b*) unaided, (*c*) with a sling.

Inward rotation of the humerus (twisting the arm in): pectoralis major; deltoid (anterior); teres major; latissimus dorsi; subscapularis.

Outward rotation of the humerus (twisting the arm out): teres minor; infraspinatus; deltoid (posterior).

EXAMINATION.—61. The patient lies on the face with the arm stretched out sideways at shoulder height, the forearm and hand hanging down over the edge of the table, so that the elbow is bent at a right angle. The surgeon steadies the upper arm and offers resistance against the ulnar side of the wrist while the patient raises the hand backward and upward, thus rotating the humerus *inward;* the surgeon then offers resistance against the radial side of the wrist while the patient raises the hand forward and upward, thus rotating the humerus *outward* (see Fig. 451).

The outward rotators, teres minor and infraspinatus, can easily be felt to contract by placing the fingers just below the spine of the scapula. They are assisted by the posterior fibers of the deltoid, the condition of which must be taken into account. Even normal muscles can overcome only very slight resistance in these movements, as the leverage is very great.

62. The patient lies on the back, the arm close to the side, the elbow bent at a right angle and the forearm resting across the body. He turns the arm outward, pivoting it on the elbow, which is kept at a right angle and then turns it in again. The first movement is a test for weak *outward* rotators, the second a test for weak *inward* rotators.

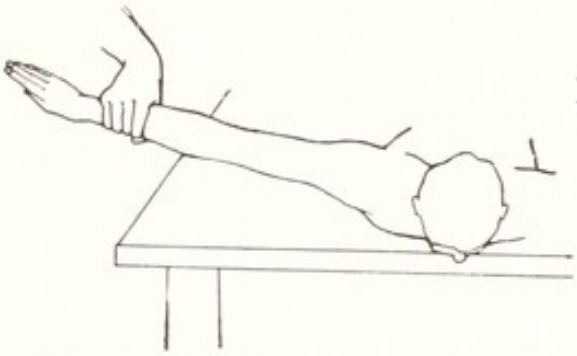


FIG. 450.—Examination No. 59, horizontal abduction of humerus. (Lovett.)



FIG. 451.—Examination No. 61, outward rotation of humerus. (Lovett.)

EXERCISES.—The Exercises are the same as the tests described (61 and 62).

Elevation of the Shoulder.—The muscles are: trapezius; levator anguli scapulæ; rhomboids.

EXAMINATION.—63. The patient sits and shrugs the shoulder while the surgeon offers resistance by pressing down from above.

NECK[1]

Flexion of Head.—Sternomastoids (Piersol); omohyoids; sternohyoids; sternothyroids; mylohyoids; recti capitis antici, longus colli, other smaller muscles.

EXAMINATION.—64. The patient lies on the back, with the shoulders held down, and attempts to raise the head from the table.

The sternomastoids are important muscles concerned in this movement. When they are seriously weakened the other muscles are apparently not strong enough to lift the head.

65. The patient sits with the head hanging over backward and raises it to the vertical. This can probably be done without the sternomastoids. The Exercises are the same as the tests, (*a*) with resistance, (*b*) without.

Extension of Head.—Trapezii (clavicular) (Piersol); splenii capitis; recti capitis postici; obliqui inferiores and others.

EXAMINATION.—66. The patient lies on the face, shoulders held down, and raises the head against resistance on the back of the head.

The Exercise is the same as the Examination.

Lateral Flexion of the Head.—EXAMINATION.—Many muscles take part in the movement, the sternomastoid being perhaps the most important.

[1] In the neck movements many muscles are involved and there is only partial agreement among anatomists as to their particular function. The list of muscles, therefore, given in this connection is of little value.

67. The patient lies on the unaffected side and attempts to raise the head laterally, (*a*) with resistance, (*b*) without.

The Exercise is the same as the Examination.

Rotation of the Head.—EXAMINATION.—A very complicated movement shared by many muscles.

68. The patient sits with the face turned to one side and rotates the head to the opposite side against resistance.

The Exercise is the same as the Examination.

THE SPRING-BALANCE MUSCLE TEST

An elaborate system of muscle tests by means of the spring balance has been developed by Professor E. G. Martin, of Harvard University. Lack of space forbids a detailed statement of these tests, for a description of which the reader is referred to the clear, concise statement of the technic by Lovett (*loc. cit.*, pp. 150–160).

TREATMENT OF THE CHRONIC STAGE

The treatment of the chronic stage is very largely operative, although it is advisable in most cases to supplement operative procedures by appropriate braces and by continuation of the massage and muscle training employed in the convalescent stage. It is again emphasized that it is unwise to undertake any corrective operation until two or three years after the onset of the disease. If shortening of a limb amounts to more than one-quarter to one-half an inch, it should be corrected by elevating the sole of the foot to avoid lateral curvature of the spine from obliquity of the pelvis and from derangement of the muscles of locomotion and particularly of those about the hip-joint.

Operative treatment is designed to meet two conditions, viz.: (A) Correction of fixed deformity, and (B) Improvement of function. Although the correction and the improvement of function are frequently undertaken by the author at the same operation, it occasionally happens that the deformity is sufficiently serious to warrant its entire correction before any operation for the improvement of function is performed. Therefore the procedures, operative and otherwise, for relieving these deformities will be considered separately.

A. CORRECTION OF DEFORMITY

Fixed deformity of a joint may be defined as a condition in which full movement through its normal arc of motion cannot be passively accomplished. As an illustration of very marked deformity, a recent case in the author's practice is instructive:

The patient had extreme equinus from shortening of the tendo Achillis and allied muscles, whereby the dorsal flexors of the foot became so stretched that no power of contraction could be detected in them. In any case where such a marked equinus as this has existed for any length of time operation for correction should be conducted in two stages, viz.: (1) lengthen the tendo Achillis and put the foot up in plaster-of-Paris at right angles for the purpose of determining how much muscular function will return to these overstretched muscles; in many cases in which the muscles were apparently completely paralyzed, full function has returned in a few months' time under the above treatment. (2) If contractile power has failed to return, operative procedure should then be undertaken along the usual lines, *i.e.*, to meet individual conditions (arthrodesis, tendon transplantation, or both).

At the outset, emphasis is laid upon the rule that *no treatment of any sort aiming at restoration of function should be undertaken until fixed deformity has been relieved*. Every deformity resulting from a weakened or a paralyzed muscle always produces a mechanical condition which is unfavorable to the transplantation of muscles; therefore every deformity should be thoroughly corrected and its correction permanently maintained by some bone or joint plastic procedure, *e.g.*, arthrodesis, implantation of bone-grafts, the formation of fascial or tendinous ligaments, etc., for stabilizing purposes. The author has seen many cases in which failures have resulted because the surgeon had planned for the transplanted muscle not only to functionate in place of a much stronger muscle but also expected it to overcome deformity. A muscle is at best not only weakened but its direction of pull is less advantageous in its transplanted than in its normal position. Before considering in detail the various procedures for the relief of deformity of specific joints, a few words must be said relative to tendon-stretching. Tendon-stretching is ineffective and is contra-indicated in long-standing cases, for the following reasons:

1. Nervous irritation and local pain.
2. Traumatization of other tissues besides the contracted parts.
3. Interference with circulation.

Although it is admitted that non-operative correction in the early stages of a deformity is sometimes feasible or justifiable, and even that a certain small percentage of cases of longer standing will yield to stretching, nevertheless time is lost and some injury done by non-operative procedures when the contracture is of long duration and there is permanent and structural shortening of the involved tissues (tendons, fasciæ, etc.). We believe, furthermore, that in the majority of cases there is less injury of tissues in the correction of a deformity by open incision than there is in correcting the same deformity by extreme force as applied manually or by means of the Thomas' wrench, for example. The ultraconservative surgeon is deluded by the belief that he is spilling less blood by his non-operative manipulations than by an operation, while, as a matter of fact, he is spilling more. The hematoma, laceration of tissues, etc., which he produces by his misapplied "bloodless" methods, invite the growth of connective tissue which finds a convenient scaffolding in these hemorrhagic exudates and thus promotes adhesion about the capsule and other peri-articular structures.

But in condemning tendon stretching as a routine procedure in the correction of deformity, we do not wish to go on record as advocates of radical or reckless surgery. We are in favor of conservative tendon stretchings in most cases of deformity of short duration. The author wishes again to emphasize the rule *not to operate unless there is a clear indication for it; and whenever operating, to employ the simplest procedure possible under the circumstances*.

1. **Deformities of the Ankle and Foot.**—(*a*) *Talipes Equinus.*—This is the commonest of all the deformities of infantile paralysis, because paralysis of the anterior muscles of the leg and rolling of the foot are the most frequent lesions of the disease and also because malpositions of the foot are so common, *e.g.*, pressure of the bed-clothes and a paralyzed foot lying in plantar flexion, and foot-drop from sitting with the foot hanging down. In these cases the posterior muscles are relaxed and shortened while the anterior muscles are stretched.

Stretching the tendo Achillis for the relief of equinus is absolutely unreliable, for reasons already stated. Although there is some slight danger that after a plastic tenotomy on the tendo Achillis the foot may become flail-like, this danger is obviated by the transplantation of other muscles

(usually the peroneals) to functionate for the paralyzed anterior tibial. The author prefers to lengthen the tendo Achillis by plastic tenotomy, thereby avoiding solution of its continuity, rather than to practise subcutaneous or other tenotomy, although this is perfectly permissible.

Technic of Plastic Tenotomy.—The method of plastic tenotomy about to be described obviates the danger of nonunion of the tendon, and at the same time allows any degree of lengthening desired. A vertical incision is made, about 2 inches in length, through the skin overlying the tendon. Two overlapping L-shaped cuts are made in the tendon at right angles to its long diameter, one on the right side and one on the left, and about 2 inches apart, and extending through two-thirds the width of the tendon. From the terminus of each of these cross-cuts, a vertical incision is made in the direction of the cross-cut from the opposite side and ending about $\frac{1}{2}$ inch from the cross-cut of the latter (Fig. 452). On sharp dorsiflexion of the foot, the tendinous tissue intermediate between these incisions unfolds itself, allowing a range of lengthening from 2 to 4 inches, without severing the tendon. The leg is then put up in plaster-of-Paris bandages, with the foot at right angles, for a period of six weeks.



FIG. 452.—Subcutaneous tenotomy of the tendo Achilles. Two incisions are made in the tendon at right angles to its long diameter, from the external and internal aspects respectively and extending through two-thirds the width of the tendon. The distance of the two cuts from one another varies with the amount of lengthening desired, but is usually $1\frac{1}{2}$ to $2\frac{1}{2}$ inches. Forcible dorsiflexion of the foot to a right angle accomplishes the lengthening.

(*b*) *Talipes Varus, and* (*c*) *Talipes Valgus.*—Since mere correction of the inverted and everted positions of the foot is valueless without transplanting muscles and stabilizing the foot, discussion of these two deformities will be deferred to the section on tendon transplantation in this chapter (*q.v.*).

(*d*) *Talipes Calcaneus and Calcaneocavus.*—Here, again, treatment is futile with the exception of preliminary tenotomy to be followed by some other plastic procedure, more detailed description of which will be found in the section of this chapter devoted to stabilizing procedures. It may be said in passing that calcaneocavus of severe type in a patient over four years of age requires correction by Whitman's astragalectomy (*q.v.*).

A foot that is in the position of calcaneus is always accompanied by the cavus deformity, for the reason that the os calcis is a two-armed lever. Relief of the posterior arm of this lever from the tension normally exerted by the gastrocnemius tendon causes the posterior arm to drop and the anterior

arm to rise toward the tibia, producing an angular concavity in the plantar surface of the foot, which is most marked in the mediotarsal joint.



FIG. 453.—Tenotome.

2. **Deformities of the Knee.**—Three varieties of deformity of the knee are encountered in infantile paralysis, viz.: (*a*) flexion deformity; (*b*) knock-knee; and (*c*) hyperextension.



FIG. 454.—Jones's tenotome. (Binnie.)

(*a*) *Flexion deformity* is caused by paralysis of the quadriceps extensor cruris. It may be accompanied by talipes equinus and flexion of the hip.

Treatment consists of division of the hamstrings by open incision. Tendon stretching by any method is unreliable and prone to relapse. Forcible straightening of the knee under anesthesia is dangerous on account of the fact that in long-standing cases there is more or less subluxation of the tibia on the femur and when the knee is straightened this subluxation may persist. If the distortion is of several years' standing, with much bony deformity, supracondylar osteotomy of the femur may be performed, but this operation should be avoided, if possible, before puberty because of the danger of injuring the epiphysis.

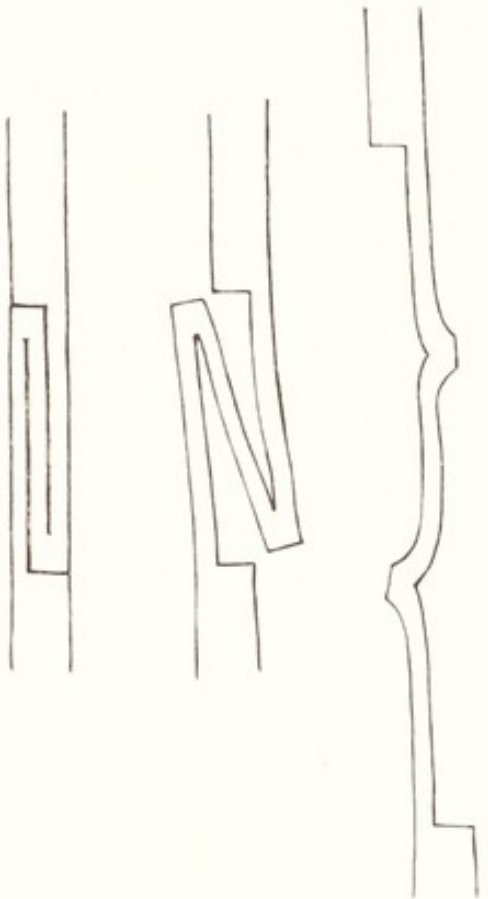


FIG. 455.—Plastic tenotomy by overlapping L-shaped incisions. By this method any degree of lengthening may be secured without solution of continuity of the tendon.

(*b*) *Knock-knee.*—In very young children, this deformity may be corrected by a splint pressing outward on the inner condyle. In adolescents after puberty, supracondylar osteotomy should be performed (see Chapter XIX on the Deformities of Rickets).

(*c*) *Genu Recurvatum.*—A slight degree of hyperextension of the knees may be overcome by a brace with a posterior strap at the knee. Persistent cases with great relaxation, pain and disability call for arthrodesis of the joint with reinforcement by bone-graft (see author's operation of arthrodesis of the knee in Chapter VII). Another method of procedure is supracondylar osteotomy of the femur, followed by rotation of the lower segment to overcome the deformity, performed synchronously with tendon transplantation (*q.v.*).

3. **Deformity of the Hip.**—One of the most troublesome distortions complicating infantile paralysis is flexion deformity of the hip. It is caused by

contracture of the tensor fasciæ femoris. With this deformity there may co-exist flexion deformity of the knee and talipes equinus. The hip distortion is a contracture in abduction and flexion. Standing is possible only with great inclination of the pelvis and severe lordosis to permit the foot of the affected limb to touch the ground.

All methods of stretching the contracted tissues are ineffective. A very satisfactory and, at the same time, simple procedure is an operation devised by Soutter (ref. Boston M. and S. Jour., clxx, No. 2, Mar. 2, 1914). The technic of the operation as modified and practised by the author is as follows:

A longitudinal incision 2 or 3 inches in length is made with the anterior-superior iliac spine as its center. With an osteotome, the tip of the cartilaginous spine with the periosteum and the underlying superficial portion of cancellous bone is chiselled away for three-quarters of an inch to 1 inch beyond the anterior-superior spine, and below it as far down as the anterior-inferior spine, and stripped down. Upon hyperextension of the femur the tensor fasciæ femoris is put upon the stretch, its detached point of origin coming away from the ilium, leaving an interval of 1 or 2 inches. If the anterior edge of the fascia lata is shortened, it should be severed through the same wound by scissors or scalpel. The skin is closed with a continuous suture of plain catgut No. 1, and the limb is put up in a long plaster-of-Paris spica from toes to costal border, with the hip in hyperextension. Recumbency is maintained for eight weeks.

4. **Paralytic Scoliosis.**—This is not only one of the most troublesome deformities of infantile paralysis, but is probably also one of the most frequently overlooked, inasmuch as it may develop while the child is confined to bed. Since its etiological factor—unilateral paralysis of the dorsal muscles—almost invariably persists, spontaneous improvement or recovery are entirely out of the question. Prophylaxis is the watchword in just such cases. The orthopedic surgeon, above all others, is the one best fitted to detect an unbalancing paralysis of the erector spinæ muscle and to institute preventive measures against structural deformity of the bony spine.

The spine should be supported from the time the deformity first appears, even before the patient is able to walk, in order to prevent adaptive structural changes in the vertebræ and the bony deformity consequent thereto, and to obviate stretching of the paralyzed muscles. A canvas corset reinforced by steel stays or the Knight brace is best for this purpose.

After the deformity is established, mild forcible correction on the author's frame, as shown in Fig. 190, page 417 (see Chapter XIII on Static Deformities of the Spine), should be begun, followed in some cases by a corrective plaster jacket (Abbottis or Forbes' method) with a window cut over the concave side and pressure exerted by pads on the convex side of the curvature. When good correction has thus been secured, it may be made permanent in many cases by the author's operation of inserting a bone-graft in the spinous processes (or lateral masses) of several vertebræ in the most pronounced portion of the curve (see Chapter XIII), the technic being precisely that followed in his spinal inlay-graft for Pott's disease.

Other Deformities.—*Deformities* of the *upper extremities* are due to gravity and vary in type. Limitation of abduction and extension at the shoulder from deltoid paralysis will be considered later. *Ulnar deviation* and *extreme hyperextension* of the *hand*, with contracture in these malpositions, are largely due to gravity (see Section on Tendon Transplantation, this Chapter).

B. IMPROVEMENT OF FUNCTION

To improve the function of an extremity thrown into disuse by infantile paralysis, two distinct classes of operation are employed, viz.: (1) for the improvement of muscle balance, and (2) to secure stability. Although the author very frequently combines the two procedures at a single operation, and almost invariably in the various distortions of the foot, the two classes of operation will, for purposes of clarity, be described separately.

1. OPERATIONS FOR IMPROVING MUSCLE BALANCE

1. **Tendon Transplantation** (Figs. 457 to 502).—Transplantation of tendons for the relief of infantile paralysis was first performed by Nicoladoni in 1880 (ref.: Wien. Med. Press, 1881, s. 46). The procedure consists of the substitution of a healthy, non-paralyzed muscle for one which has been weakened or paralyzed.

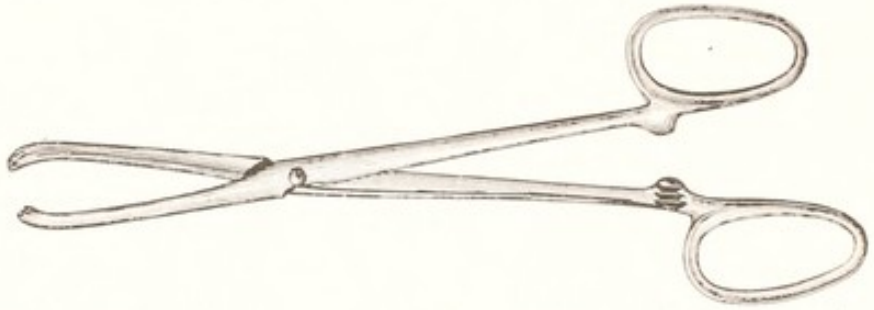


FIG. 456.—Clamp used to grasp the tip of the tendon during the operative manipulations. It enables the operator to hold the tendon firmly with a minimal degree of traumatization. (From Biesalski and Mayer: "Physiological Method of Tendon Transplantation.")

The methods of tendon transplantation may be divided into four different types, depending upon the manner of attaching the transplanted tendon to its new point of insertion. In order of merit, they are as follows:

(*a*) Portion of the bony insertion is transferred with the tendon as a bone-graft, when possible, and anchored in an osseous bed at its new point of insertion where it unites with its host bone by bony union. This method is, as far as is known, original with the author, and should *always* be used when possible, as it affords a firmer point of anchorage than any other method.

(*b*) The tendon is *sutured into a slit* in the *periosteum* at the new point of insertion.

(*c*) The transplanted tendon is *sutured into another tendon* (Vulpius). This method should never be used except under very favorable conditions, and where bony or subperiosteal insertion cannot be practised.

(*d*) Silk extension of the tendon.

In recent years an attempt has been made further to rationalize the method of tendon transplantation. This attempt was inaugurated by an article of Biesalski's (Deut. Med. Woch., 1910, No. 35) in which he suggested utilizing the tendon sheath of the paralyzed muscle as a physiological path for the transplanted tendon; thus, in case the tibialis anticus were paralyzed and the extensor hallucis proprius were to be used as the substituting muscle, the sheath of the tibialis would be used as the pathway through which the tendon of the extensor hallucis would be drawn to its new point of insertion. Henze and Mayer confirmed the rationality of this method by animal experiments (see Surg., Gyn. and Obst., 1914, No. 10). Their experiments

proved that a tendon transplanted by this technic glided in its new bed with the same freedom as a tendon normally does, in other words, that the post-operative adhesions which so frequently resulted in the older methods of transplantation were entirely avoided by this new procedure. The success in utilizing this one physiologic principle suggested the advisability of conforming each step of the operation with the exact physiology of the tendons. To do this, extensive research into the mode of action of tendons was necessary, since such fundamental questions as their mode of gliding, their tension, the function of the vascular membranes of the tendon (the mesotenon) had not as yet been investigated by physiologist or surgeon. Important anatomical facts related to tendons, such as their blood supply, the nature of the

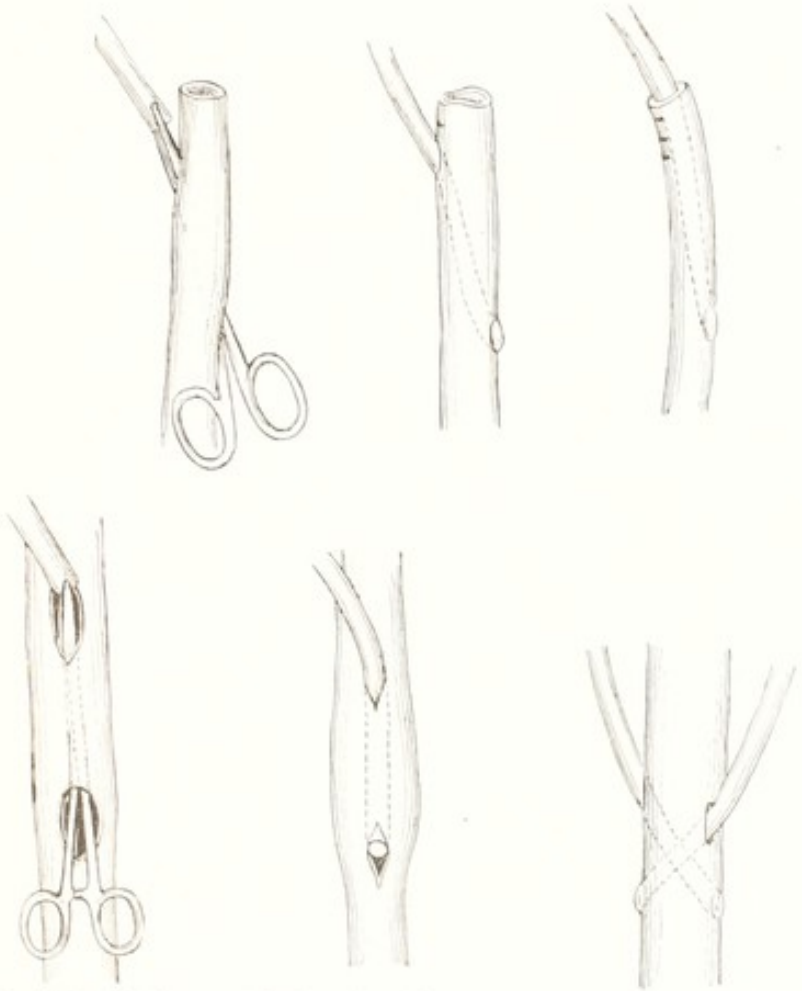


FIG. 457.—Various methods of tendon anastomosis. (After Jones.)

membranes and tissues surrounding the tendons, their exact length, their mode of insertion, had not been studied with sufficient accuracy. The results of this research and the system of operations based upon them were published by Biesalski and Mayer in 1916 under the title: "Die Physiologische Sehnen Transplantation" (the Physiological Method of Tendon Transplantation) (see also, Mayer, Surg., Gyn. and Obst., Feb., March, and April, 1916).

Rules in Technic of the Transplantation.—(*a*) In general, it is unwise to transfer a slender, delicate muscle to take the place and do the work of a large robust muscle, *e.g.*, the peronei for the gastrocnemius, except when mechanical conditions can be rendered very favorable. The author feels very strongly on this point, viz.: that mechanical conditions should be made as favorable as possible for a transplanted muscle, both in stabilizing the foot

(the commonest point of disability) and in increasing the leverage under which the muscle acts. When these conditions are fulfilled, the author differs with those who hold that it is unwise to substitute a delicate muscle for a heavy, robust one. Although the transplanted muscle may be much weaker than the one whose place it takes, nevertheless, in the case of the foot, by displacing that member backward by means of astragalectomy, the posterior lever arm of the foot is greatly lengthened and consequently the

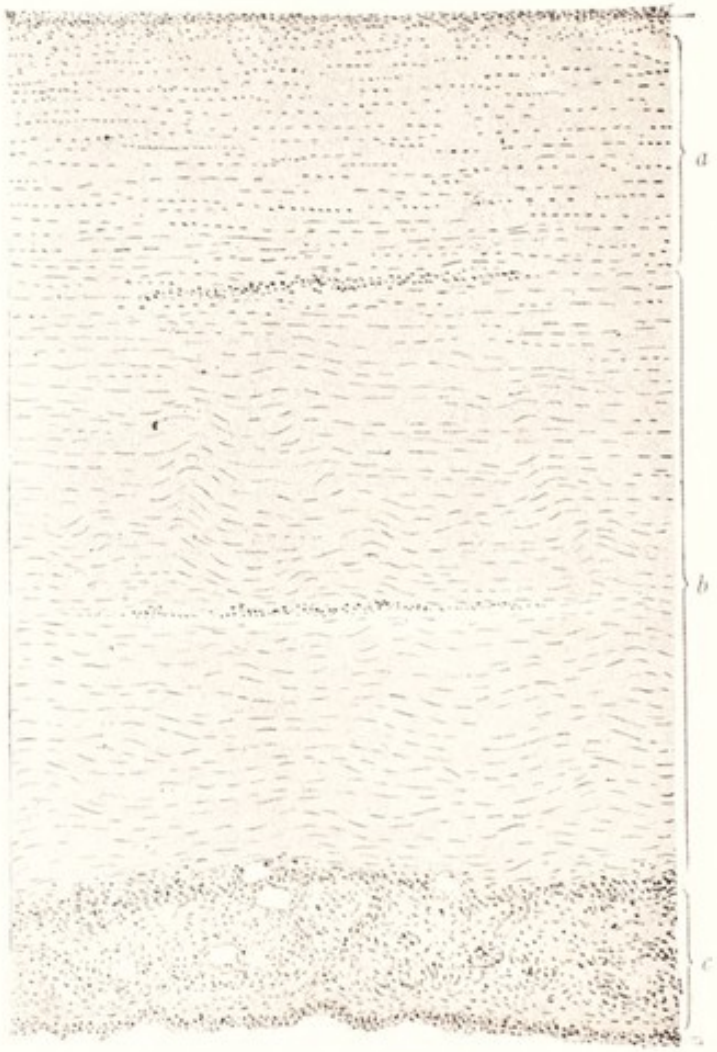


FIG. 458.—Microscopical longitudinal section through the tendon of the flexor longus hallucis. Leitz Obj. 3 Oc. 1 T 140. The section shows the different layers of the tendon at the point where it lies in the groove of the astragalus. The surface exposed to friction, against the bone, shows numerous round nuclei similar to those found in fibrocartilage. The main body of the tendon is composed of typical tendon cells with elongated nuclei. On the deep surface of the tendon, where it is protected from friction, is a layer of connective tissue in which the main blood-vessels of the tendon run. *a*, The portion of the tendon resembling fibrocartilage; *b*, typical tendon; *c*, connective tissue containing blood-vessels. (Biesalski and Mayer.)

work required of the peronei is much less than that normally performed by the intact gastrocnemius.

(*b*) Always correct an existing fixed deformity before transplanting a tendon.

(*c*) Always anchor a transplanted tendon to bone or periosteum—*not* to soft tissues—if possible.

(*d*) Always make a roomy, subcutaneous tunnel between the origin and the new insertion of the transplanted muscle.

(*e*) The direction of muscle-pull should be the shortest distance between the points of origin and insertion. Angles and roundabout routes of the tendon must be sedulously avoided. As regards passing the tendon of the

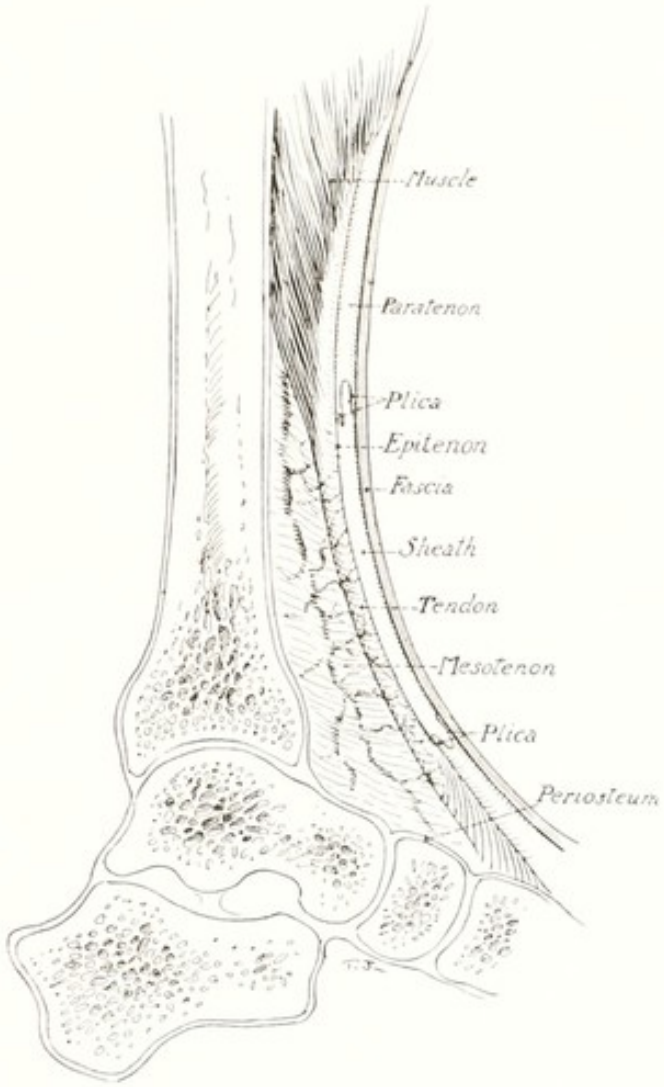


FIG. 459.—Schematic longitudinal sectional through the tendon of the tibialis anticus, showing the structures associated with the tendon. At the point where the tendon is bound down by the crucial ligament, the sheath is inserted to act as a fluid buffer and thereby diminish friction. Above the sheath between the tendon and fascia lies a loose, areolar tissue known as paratenon which permits the tendon to glide to and fro beneath the rigid fascial plane. This paratenon is continuous above with the perimysium and is extended below into the sheath as tongue-like prolongation known as the plica. On the deep surface of the tendon, it is continuous with a membrane, the mesotenon, through which the blood-vessels of the tendon run. Within the sheath the tendon is coated on its deep surface with a very thin layer of connective tissue, termed epitenon. Paratenon, epitenon and mesotenon form together the esotenon as opposed to the connective tissue within the tendon known as endotenon. (Mayer.)

transplanted muscle through the sheath of the paralyzed tendon (Biesalski-Mayer) (ref. Deutsch. Med. Wochsft., 1910, No. 35), this procedure appears to the author to be an advantage whenever possible of execution.

(*f*) A moderate amount of tension should be put upon the transferred tendon when the limb is in overcorrection, *i.e.*, with the origin and insertion

of the transplanted muscle approximated, its tension is zero. The part should be kept three months or more in the overcorrected position, followed by fixation in a brace which allows as much motion as possible and still affords support until six months after operation, to obviate strain on the transferred

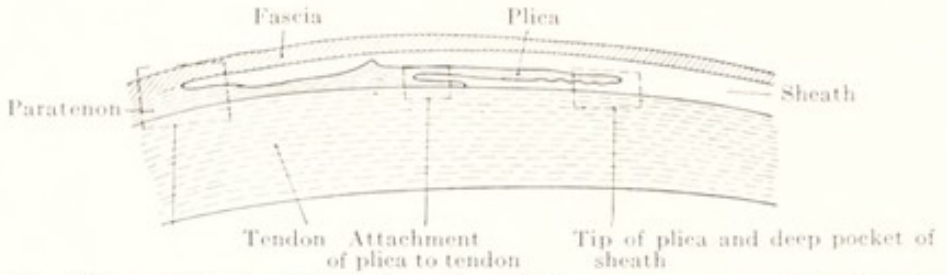


FIG. 460.—Diagramatic longitudinal section of the extensor proprius hallucis tendon to correlate the four preceding cross-sections. Note that the paratenon situated between fascia and tendon is prolonged downward as a tongue-like structure (the plica), which divides the upper pole of the sheath into two pockets: (1) a superficial, between fascia and plica, and (2) a deep, between plica and tendon. (Mayer.)

tendon. At the end of this period, massage and muscle training must be systematically administered.

(*g*) The two chief causes of failure in tendon transplantation are: (1) insufficient correction and (2) overcorrection. The former is the more

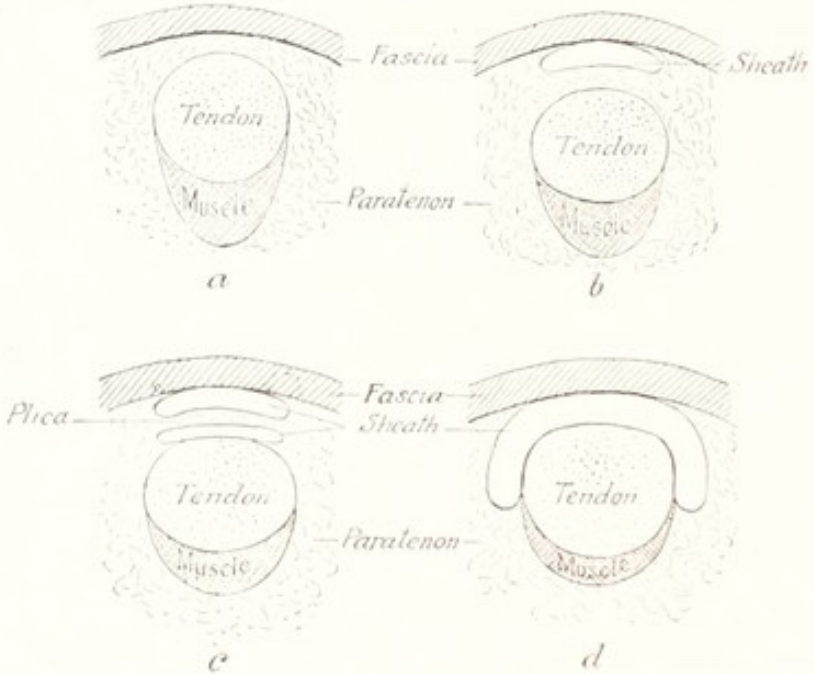


FIG. 461.—Diagrams representing the relations of the tendon to the paratenon and to the upper pole of the tendon sheath. *a*, Cross-section above the upper pole of the sheath corresponding to Fig. 460; note that the paratenon intervenes between the tendon and the fascia. *b*, Cross-section through the upper pole of the sheath corresponding to Fig. 460; note that the sheath is separated from the tendon by the paratenon. *c*, Cross-section ¼ inch distal to the preceding, corresponding to Fig. 460; note that the sheath is divided into a superficial and a deep portion by a band of paratenon, termed the plica. *d*, Cross-section ½ inch distal to *c*, note that the sheath now intervenes between fascia and tendon. (Mayer.)

frequent mistake. Overcorrection is most often seen in an unexpected valgus resulting from transference of the tibialis anticus tendon from the inner to the outer border of the foot, and increase of varus in transference of both peronei from the outer to the inner border of the foot, unless proper attention

is paid to the location of the site of transplantation with reference to the mechanical center of the forefoot (see Treatment of Varus and Valgus, respectively). This is another argument for stabilization procedures for the foot, to avoid relapse to former deformity or overcorrection.

(*h*) *Kangaroo tendon* (or some other strong and slowly absorbable material) should invariably be used, and this applies to every other surgical procedure

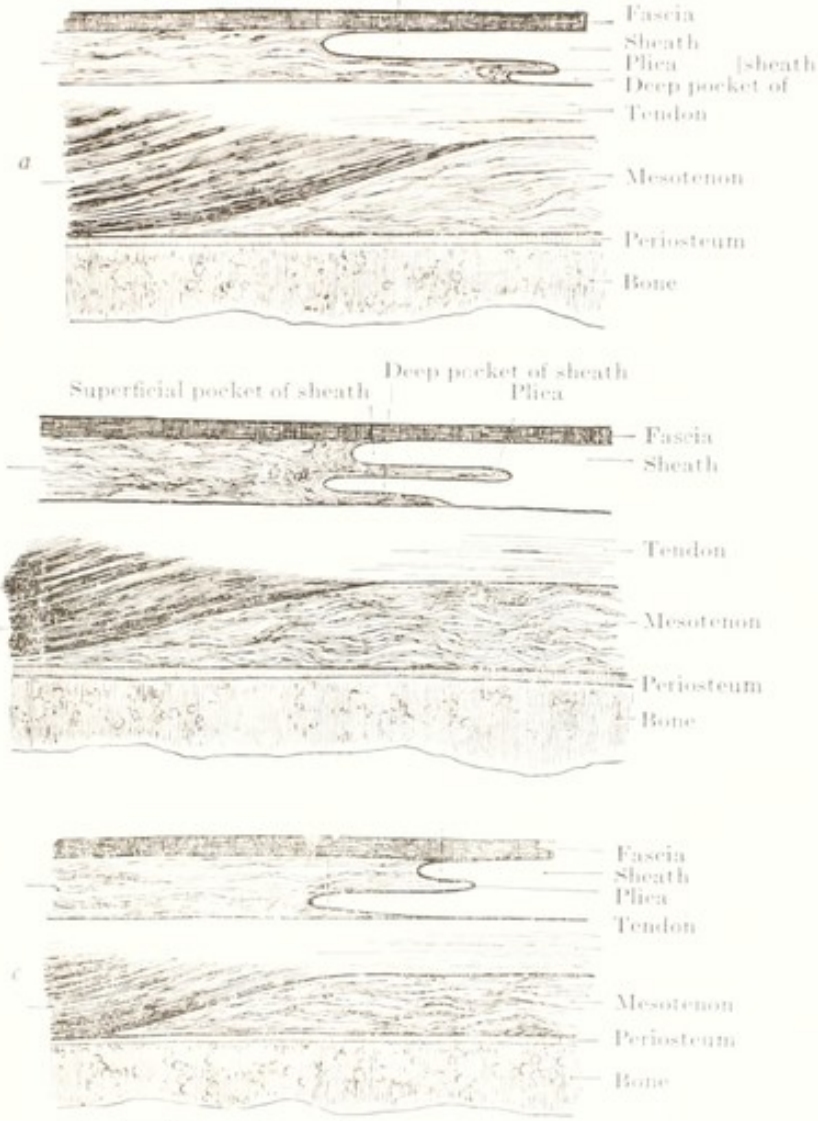


FIG. 462.—Diagramatic drawings of a tendon at its entrance into its sheath—showing the changes in the form of the sheath during the contraction of the muscle. *a*, Note that the pocket of the sheath lying between the fascia and the plica is deeper than that lying between the plica and the tendon. *b*, shows the relations when the muscle has reached the midpoint of its contraction. Then the two pockets of the sheath are of almost equal depth. When the muscle has reached the maximum contraction, the pocket between the plica and tendon is much deeper than that between the plica and fascia, in other words an invagination has occurred. This mechanism allows free motion of the tendon without rupturing the wall of the tendon sheath. (Biesalski and Mayer.)

on the extremities where suture material is to remain buried (see Introductory Chapter).

(*i*) An *Esmarch's bandage or tourniquet* should always be used, when it is possible to apply it, to control hemorrhage, and should be left in place until the dressings and plaster-of-Paris bandages have been applied.

In no other branch of surgery is the selection and preparation of cases for operation of more vital importance to the end-result than in tendon

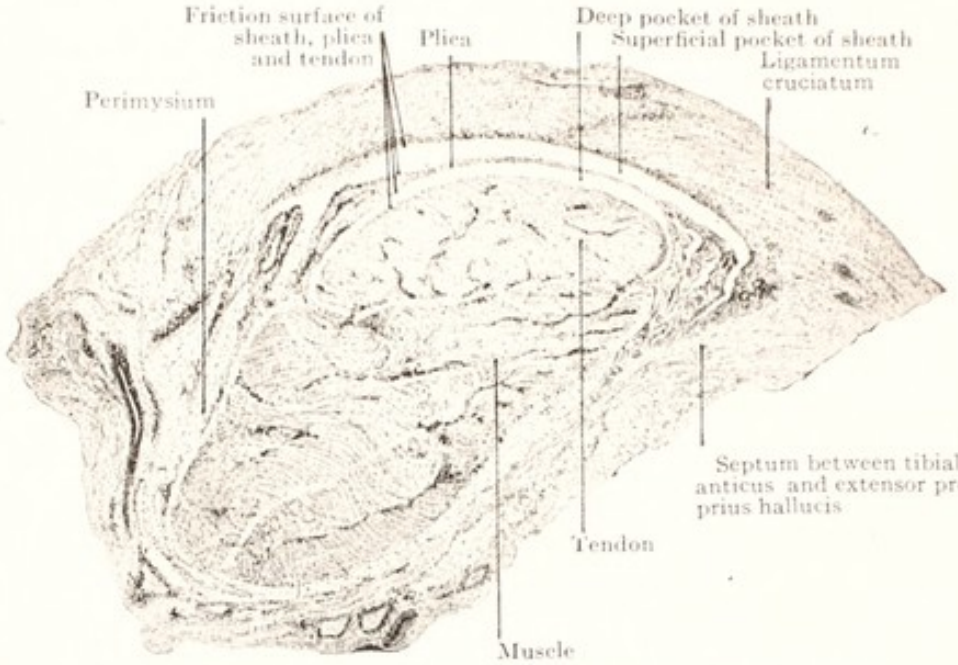


FIG. 463.—Cross-section through the extensor proprius hallucis tendon of a six months old child, about ½ cm. above the line joining the malleolæ. Leitz Obj. 1., Oc. 1 T 160. The section shows the tendon sheath divided into two portions by a connective tissue fold—the plica which on either side is continuous with the connective tissue enveloping tendon and muscles (Biesalski and Mayer.)

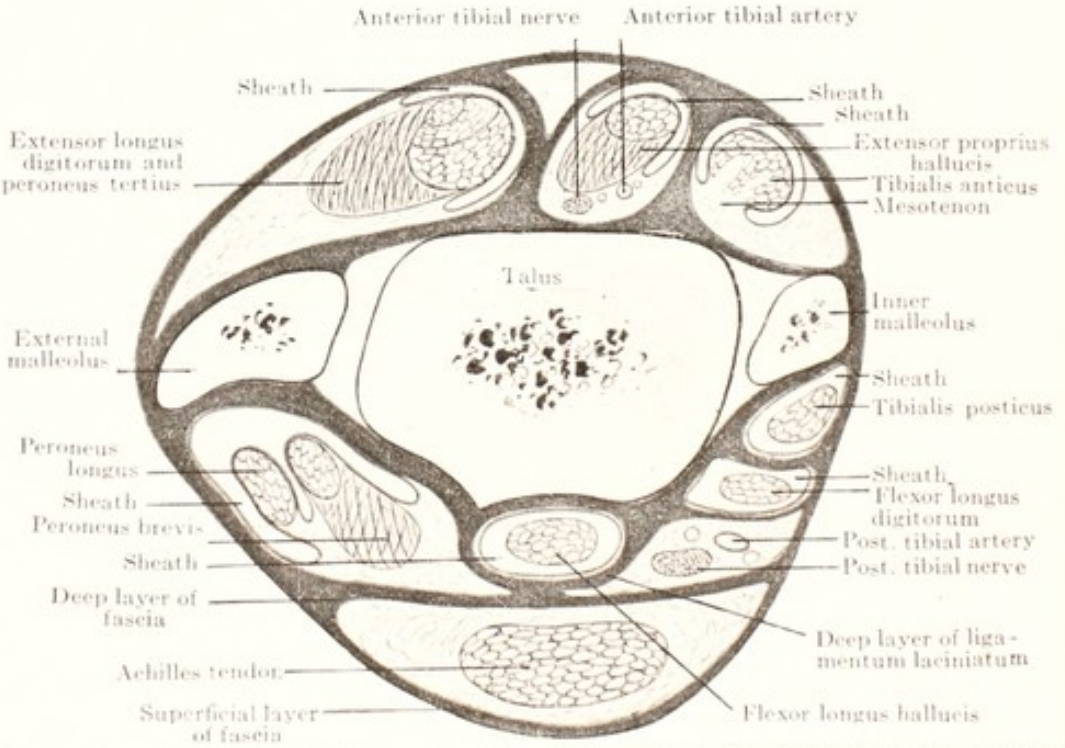


FIG. 464.—Semidiagramatic cross-section of the calf at the level of the line joining the malleolæ. The section is particularly important as showing the relation of the tendons to one another and to the fascial planes separating them. (Biesalski and Mayer.)

transplantation. That the success obtained by operation may become a *permanent* success depends upon fixed rules established by more or less universal experience. Out of the chaos of ingenious but misapplied operative procedures, there has come to us a certain standardization of tendon transplantations no less successful in practice than ingenious in conception. In carefully selected cases, tendon transplantations may be relied upon to give satisfactory results. Each case is an individual mechanical study, and in every instance the operative procedure should be especially devised.

General Considerations in Operative Work.—No transplantation should be attempted until at least two years after the attack of anterior poliomyelitis, and not until at least six months more of appropriate orthopedic treatment. During this time, attempts should be made to obtain a return of power in the unparalyzed or overstretched muscle fibers. We have, of course, no means of restoring a muscle actually paralyzed. With Robert Jones, we believe that many muscles are regarded as paralyzed when they are simply paretic from being overstretched. In the meantime, any existing deformity is to be corrected and the correction maintained by apparatus. Lovett,

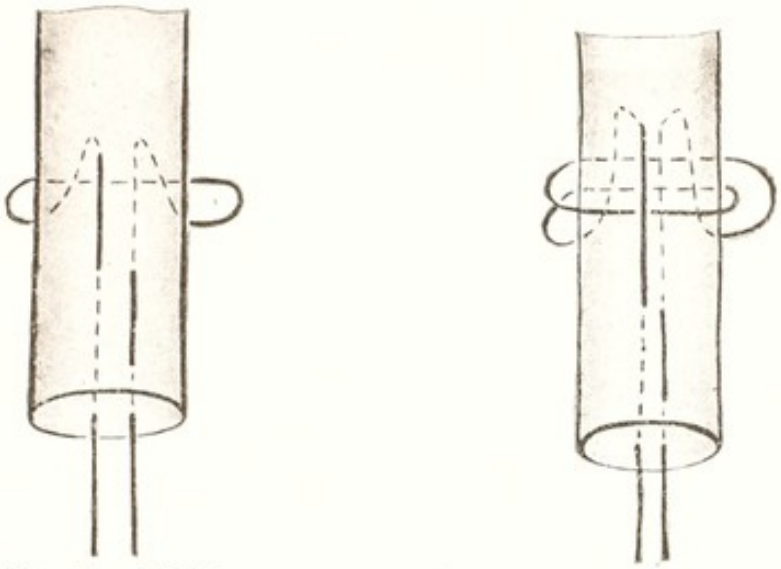


FIG. 465.—The Biesalski-Mayer suture used in anchoring the transplanted tendon to the new point of insertion. For a thin tendon the single stitch is used, for a larger tendon the double stitch shown on the right. (Biesalski and Mayer.)

with most commendable conservatism, postpones operative procedure until the maximum muscular effort of individual muscle groups is obtained by patient, persistent muscle training. No transplantation should be attempted in a patient under three years of age. The co-operation of the patient in the development of his voluntary muscle power by appropriate exercises is of prime importance, and is not easily obtained in a younger child. It cannot be too strongly emphasized that the development of the latent but existing muscle power is the all-important consideration on which the success of operative procedure may entirely depend. With the transplantation accomplished, this same development of muscle power must be continued.

Thus, pre-operative muscle training attempts to develop the individual power of the muscle; postoperative muscle training seeks to educate the brain to control the new arrangement of the musculature obtained by the transplantation.

An ideal technic demands the total transplantation of a muscle, or muscles, analogous in function, in a longitudinal and descending direction under physiological tension. Whenever possible, it is, of course, ideal to introduce the transferred tendon into the canal or tendon-sheath and attach

it to the same insertion as that occupied by the muscle whose function it is to assume.

Failure permanently to overcome existing deformity, sepsis, imperfect fixation, injury to tendons or sheaths, negligent or unintelligent after-treat-

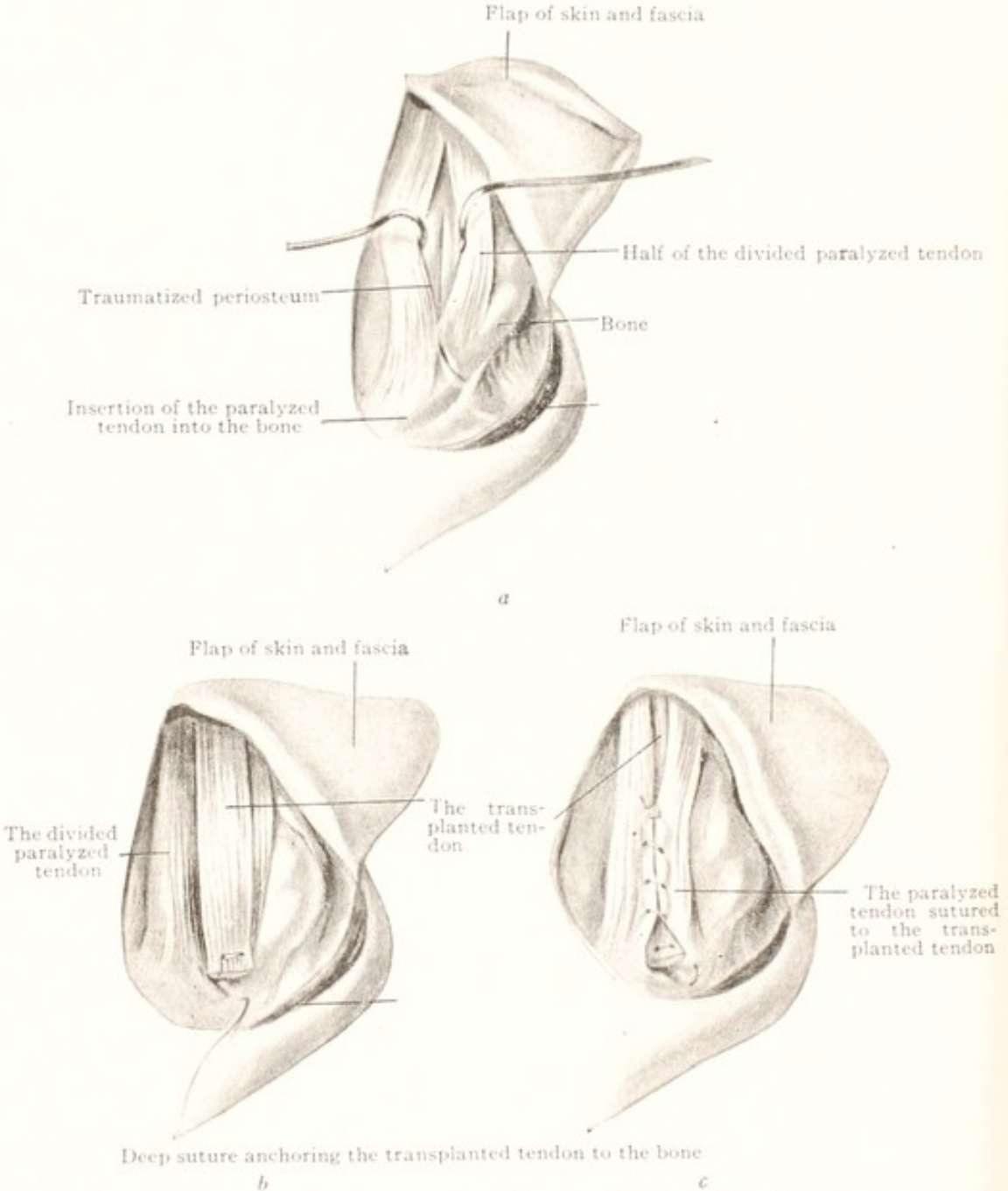


FIG. 466.—A physiological method of implanting the transplanted tendon. *a*, Shows the paralyzed tendon slit for about 1 cm. at its point of insertion and the periosteum of the bone traumatized to encourage the formation of adhesion between it and the transplanted tendon. *b*, The transplanted tendon has been drawn into place and is anchored firmly to the bone by a stout chromic catgut suture threaded as in Fig. 465. This suture gives sufficient mechanical security to prevent the tendon from tearing away. In *c* the paralyzed tendon is united to the active tendon by several fine sutures thus insuring union between them. Firm union between tendon and the bone results by this method within ten to fourteen days after operation. (Biesalski and Mayer.)

ment, selection of muscles for transplantation without regard to their physiological or anatomical function, these are the common causes of failure.

And failures do occur. Much unjustified and severe criticism has been applied to tendon transplantation when the fault has too often been with the criticising surgeon himself, in the improper selection of his cases for a particular type of procedure, or in his failure to correct deformity by some other measure than by the tendon transplantation. Much healthy criticism is still in order as regards the multiplicity of methods of transplantation; but, on the other hand, it is extremely deplorable that several members of the profession choose to resort to arthrodesis and other stabilizing operations (directed to destroy active muscle function) in place of tendon transplantation, rather than to utilize some other stabilizing procedure in conjunction

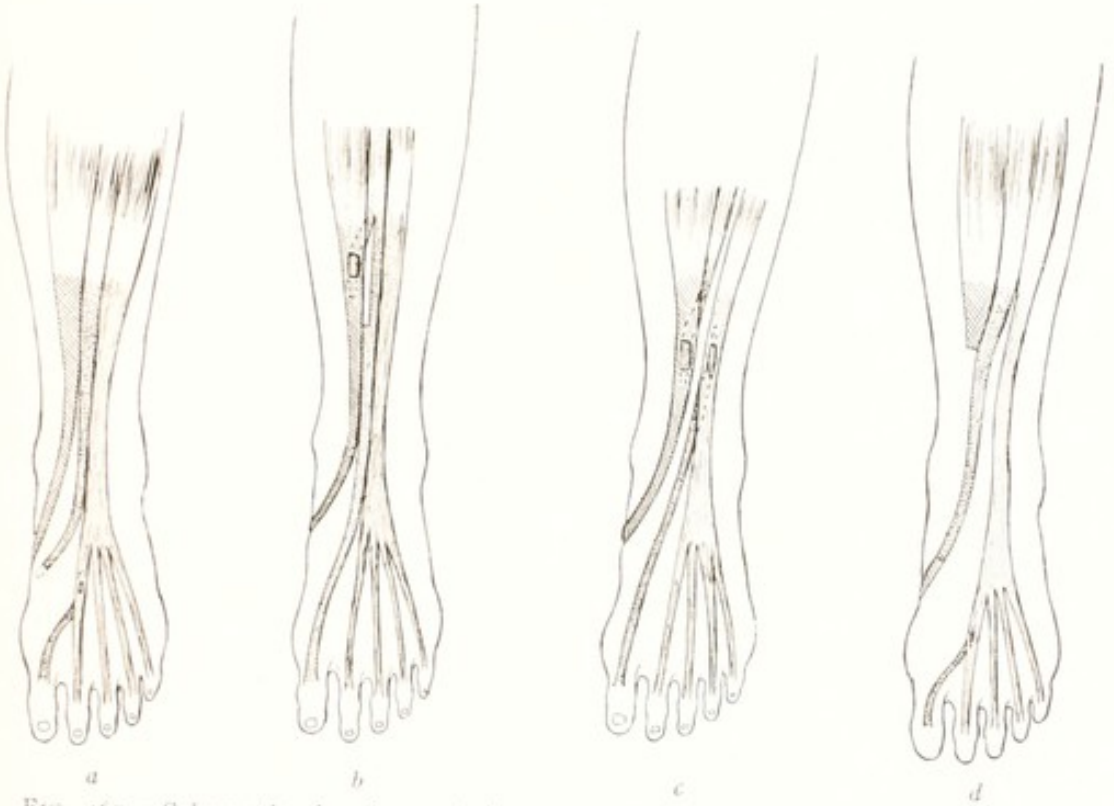


FIG. 467.—Schematic drawings of the various methods of tendon transplantation for paralysis of the tibialis anticus muscle. (Tibialis anticus indicated by checkered lines; extensor hallucis by dots; extensor communis digitorum by shading). *a*, Periosteal method. (Lange.) *b*, The partial descending and *c* the total ascending and descending tendinous methods. (Vulpius.) *d*, Biesalski's method.

with transplantation procedures whenever possible, *i.e.*, the *intelligent* use of arthrodesis of the *smaller* joints in favorable cases (as a stabilizing procedure enhancing the function of transplanted muscle) rather than to produce *complete ankylosis* by arthrodesis of the larger joints. Instead of an *end* in itself, arthrodesis in these cases is merely the *means* to an end.

General Plan of Operation.—No one plan of operation is of value without a careful study of the needs of the individual case. It is necessary to plan a careful re-adjustment of available muscle power, so to distribute the muscle power at our disposal that the forces will balance each other. For example, a gain in extension power, as in the case of a transplanted biceps, involves the loss of flexion power; but this gain in extension creates a joint balance by which active joint motion is possible, although both flexion and extension are weaker than normal. In many instances, even if a transplanted muscle is not capable of fully functioning for the muscle whose place it takes, its transplantation relieves the limb of a deforming force, *e.g.*, the

transplanted peroneals even if unable to equal the tibialis anticus in power, nevertheless, their transplantation so changes their line of pull that valgus deformity is no longer produced; moreover, every bit that they pull in their new position and alignment is so much gained. In other words they (peroneals) have been transformed from a deforming force to a functioning force, and the old adage "two birds with one stone, etc.," is exemplified.

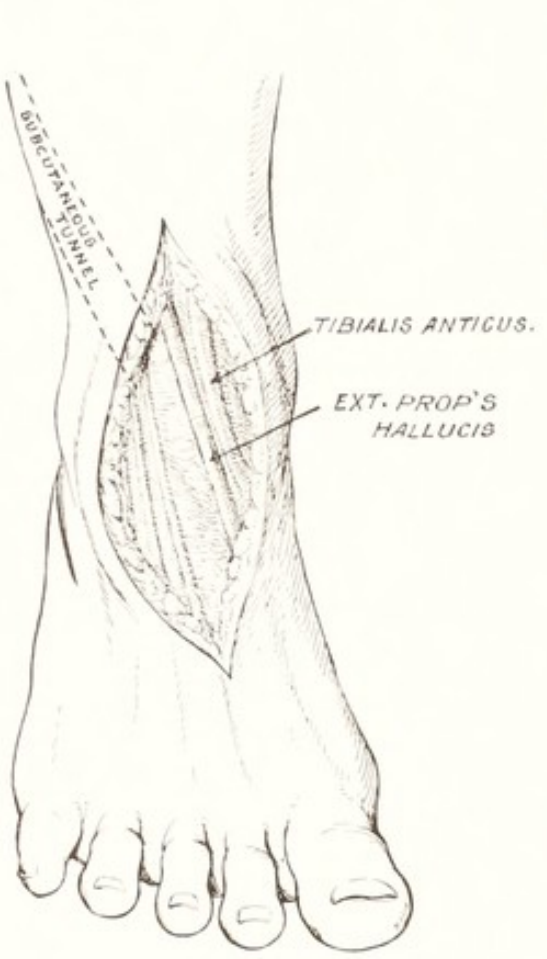


FIG. 468.

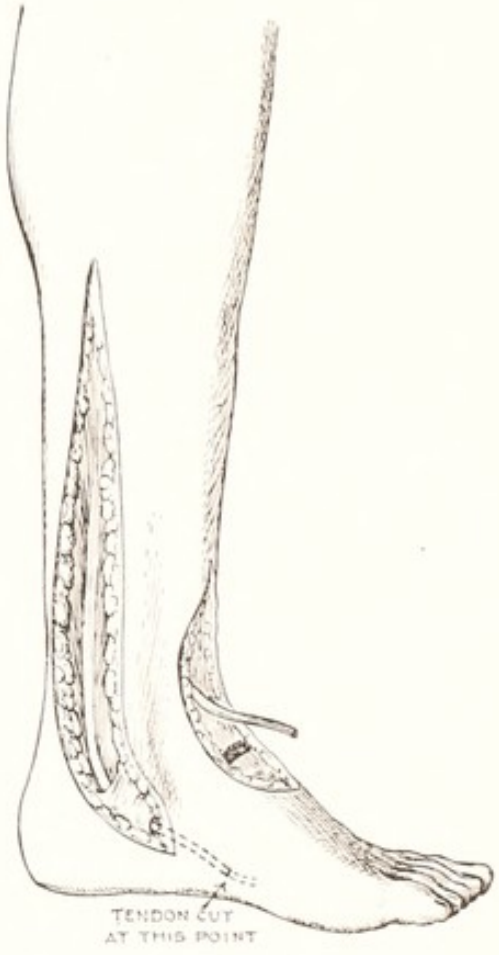


FIG. 469.

FIG. 468.—Transplantation of extensor proprius hallucis and peroneus longus tendons (for a weakened or paralyzed tibialis anticus).

Step 1: Exposure of tendons by median, vertical incision over anterior surface of ankle-joint. Direction of subcutaneous tunnel for passage of peroneus longus tendon indicated by dotted lines.

FIG. 469.—Transplantation of extensor proprius hallucis and peroneus longus tendons (for a weakened or paralyzed tibialis anticus).

Step 2: The tendon of the extensor proprius hallucis having been severed at the lower angle of the anterior incision and arthrodesis of the astragaloscaphoid joint performed, a long incision is made from the center of the fibula downward, and from the tip of the external malleolus downward and forward. The peroneus longus tendon is severed well forward on the external border of the foot.

Before operation, it is essential to decide as accurately as possible which muscles are paralyzed, which are normally active, and how much actual strength each muscle group possesses. Since the patient should have been under exercise-treatment for at least six months before operation, the orthopedic surgeon should be entirely conversant with the mechanical problems present in each case. We believe, as previously stated, that electricity is of negligible therapeutic value, and that direct clinical observations should be made in every case before operation.

Technic.—An Esmarch's band is applied to the extremity and removed only after the dressing and the plaster have been applied. We employ the iodin preparation. Our skin incisions are longitudinal, and long skin flaps are avoided. We prefer long incisions, after the technic developed by Mayer, in order that we can expose, examine, and therefore preserve the blood supply of the muscle itself, and treat the sheath with proper respect.

The incision may be made, according to Jones, through a white sterile stocking, and the cut edges carefully clamped to the subcutaneous tissues. This refinement of technic has not been found necessary by the author

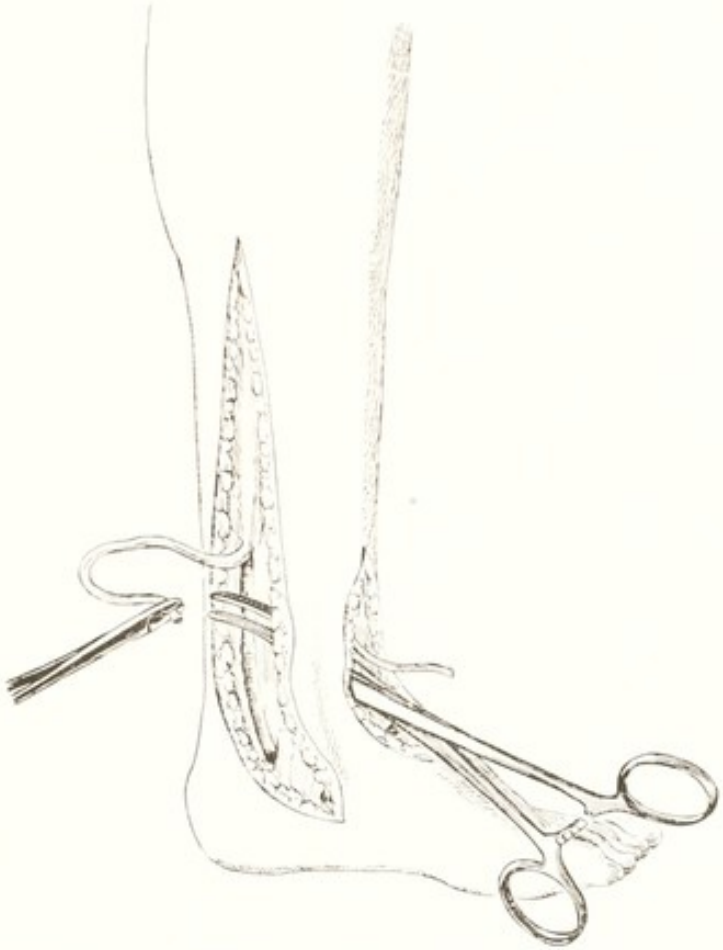


FIG. 470.—Transplantation of extensor proprius hallucis and peroneus longus tendons (for a weakened or paralyzed tibialis anticus).

Step 3: The peroneus longus is freed from its attachment to the fibula for a sufficient distance to give its direction of full marked obliquity, when it is carried down through the subcutaneous tunnel and together with the extensor proprius hallucis tendon sutured to the internal cuneiform bone anterior to the astragaloscaphoid joint. The site of transplantation should be beneath osteoperiosteal flaps and small-sized kangaroo-tendon employed for suture material.

when the iodin preparation is used. Before a tendon is divided, the bed for its insertion having already been prepared, its peripheral end is clamped with forceps or a loop of suture, and the tendon is freed sufficiently to allow it to be displaced easily to its new insertion. It is carefully wrapped in gauze wet with normal salt solution, if for any reason its new insertion has not been previously prepared. Whenever possible, this insertion should be either actually through a drill hole in the bone or under well-developed lips of periosteum which are turned up to receive the end of the tendon, like hinged doors. The latter insertion is easily obtained in most adult cases, while both insertions are possible in children.

Biesalski and Mayer avoid drying of the tendon by preparing the new site of insertion and the path before the tendon is exposed to the air.



FIG. 471.—Valgus deformity from weakness or paralysis of the tibialis anticus and over-activity of the extensor proprius hallucis, producing hammer-toe.

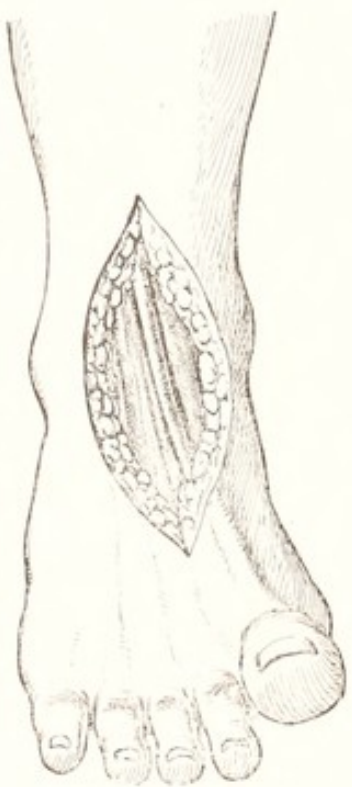


FIG. 472.

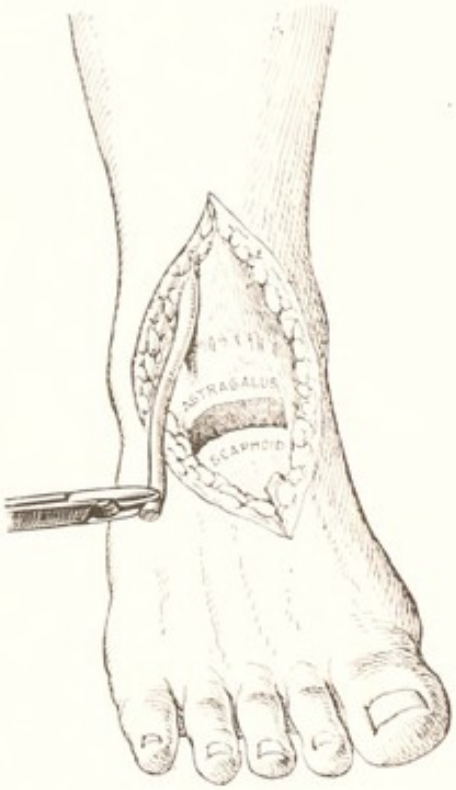


FIG. 473.

FIG. 472.—Valgus deformity and hammer-toe from weakness or paralysis of tibialis anticus. Exposure of tendons by median vertical incision over anterior surface of ankle-joints.

FIG. 473.—Valgus deformity and hammer-toe from weakness or paralysis of tibialis anticus. Tendon of the extensor proprius hallucis severed at lower angle of incision and its proximal end transplanted into the internal cuneiform bone anterior to the astragalo-scaphoid joint (after arthrodesis of the latter has been performed for securing greater mechanical advantage).

The actual fastening of the tendon in place must be done securely and under a physiological amount of tension, the exact amount of which can be learned only by experience. Stoffel and Mayer, working independently, in-

vestigated the normal tension of tendons and came to the same conclusion, namely, that where a muscle is at rest and its points of origin and insertion are approximated (for instance the tibialis anticus when the foot is held in

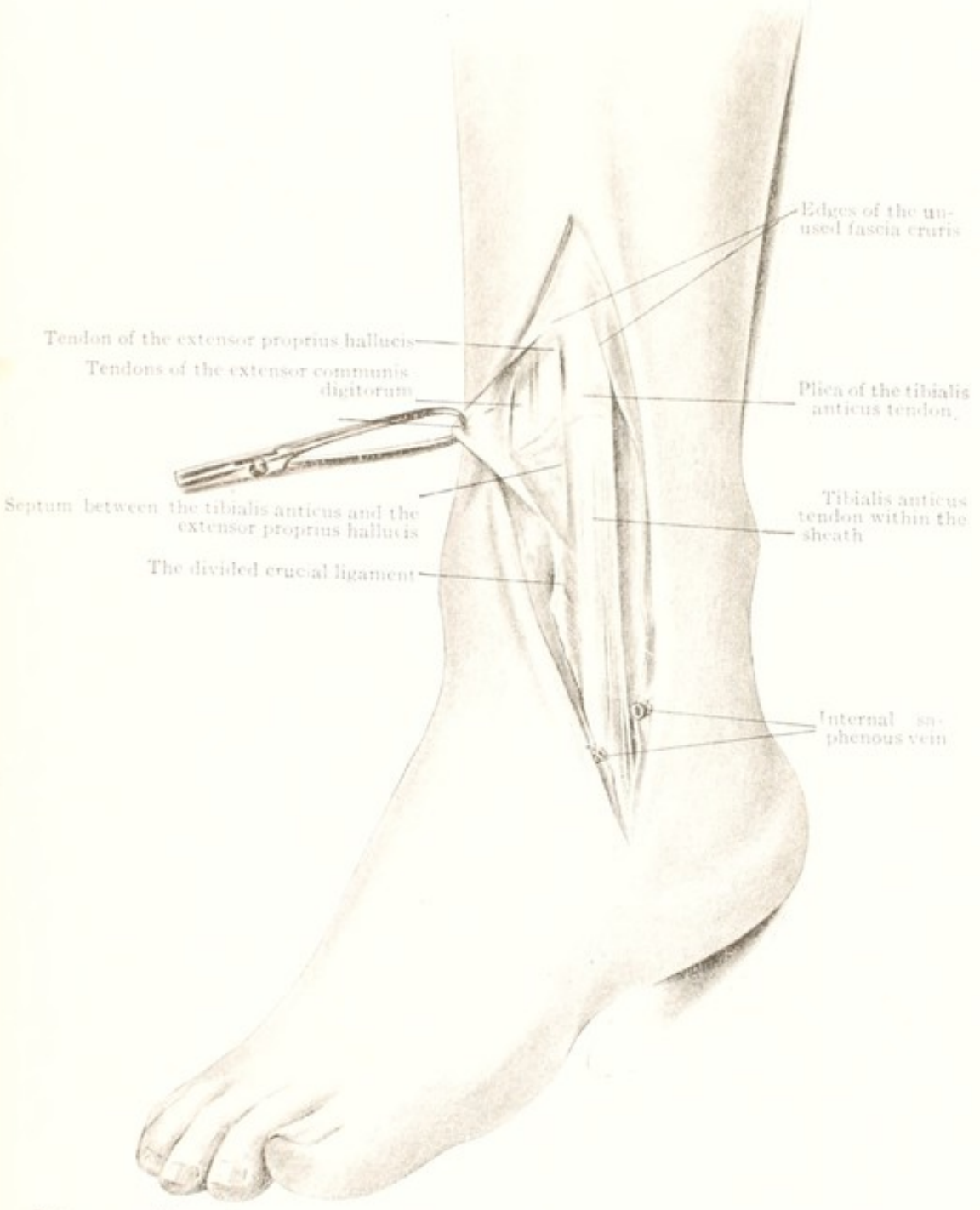


FIG. 474.—Transplantation of tibialis anticus for paralysis of the pronators of the foot. A long incision in the course of the anticus tendon exposes it from the upper boundary of the sheath to its point of insertion. The fascia of the calf is drawn laterally until the tendons of the extensor longus digitorum are brought into view. A probe is passed along the tendons through the sheath of the extensor longus digitorum and made to emerge over the insertion of the peroneus tertius shown in Fig. 475. (Biesalski and Mayer.)

calcaneovarus) the tension of the tendon is zero. By utilizing this principle, the operator can suture the tendon under the normal physiological tension and thus avoid undue strain on the muscle. The transplantation completed,

the skin is best closed with plain catgut No. 1, which may be left undisturbed for six weeks. A plaster cast is applied and the Esmarch's band is removed.

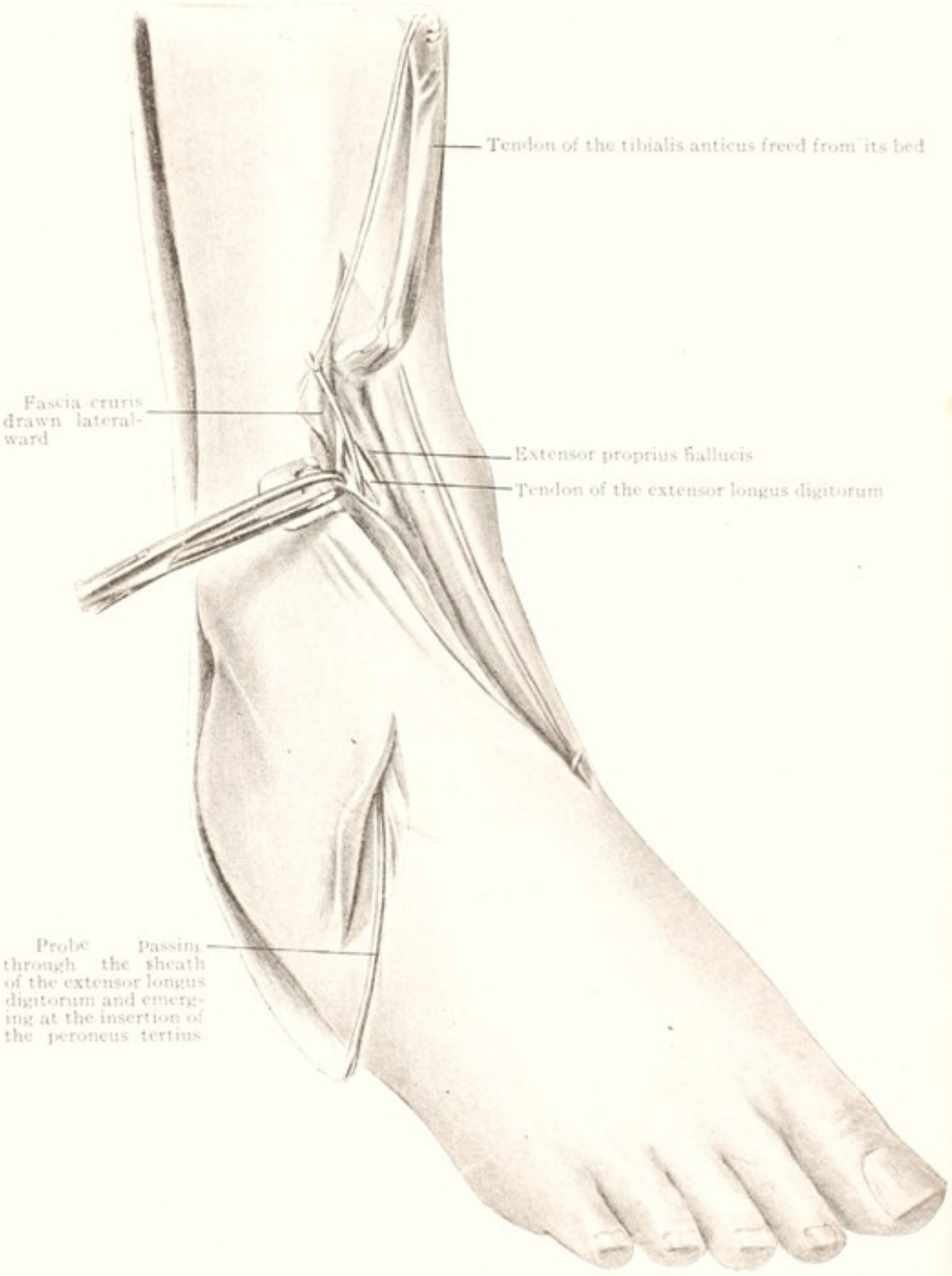


FIG. 475.—Second step in transplanting the tibialis anticus for the paralyzed pronators of the foot. The tibialis anticus is divided just at its insertion threaded with the fixation suture shown in Fig. 465, and by means of a probe is drawn through the sheath of the extensor longus digitorum down to the insertion of the peroneus tertius where it is firmly anchored to the bone. (Biesalski and Mayer.)

At the end of four to eight weeks, the cast is removed, and a light brace to protect the transplanted tendon is applied. Muscle training and massage should

be begun immediately. Some authors advocate a briefer period of immobilization. Putti advocates exercises after one week; Biesalski and Mayer, after two weeks. The latter authors have shown by animal experiments and by secondary operations that, provided the tendon is sutured by their method, it is sufficiently firm in its attachment to permit gentle exercising. It is hardly necessary to urge the importance of the after-treatment being carried out by one especially trained in this work. Rigid, persistent, and patient adherence to a routine of muscle development and training is of prime importance.



FIG. 476.—Step 1: Transplantation of the peroneus longus tendon for paralysis of the tibialis anticus.

Tendon Transplantation in Conjunction with Arthrodesis.—In the foot, tendon transplantation of itself may not be sufficient to prevent deformity. While dorsal and plantar motion may be restored, yet lateral foot deviation may persist, as when a patient is deprived of the power of the anterior and posterior tibial muscles. The peroneals and common extensors pull the foot into valgus and pronation. The ligaments, bearing an increased strain, yield and stretch, with a resulting laxity of the joints which, if allowed to persist, results in a change of the plane of the articulating surfaces and a gradual bone deformity is superimposed on an already existing muscular one. A muscle transference will only correct the muscle balance, but will not control the hyperrelaxation of the joints. It has been pointed out that this hyper-

relaxation exists chiefly at the astragaloscaphoid joint, and the resulting faulty alignment is corrected by arthrodesis of this joint. This technic, therefore, is applicable in conjunction with all transplantations where such deformities exist. With the opposite deformity, the same principle holds true. With loss of power in the peroneals, the foot takes the position of varus and supination. A certain amount of correction can be obtained by astragaloscaphoid arthrodesis, but the author has found that a tibial bone-graft mortised into an arthrodesed joint offers a means of correcting, or

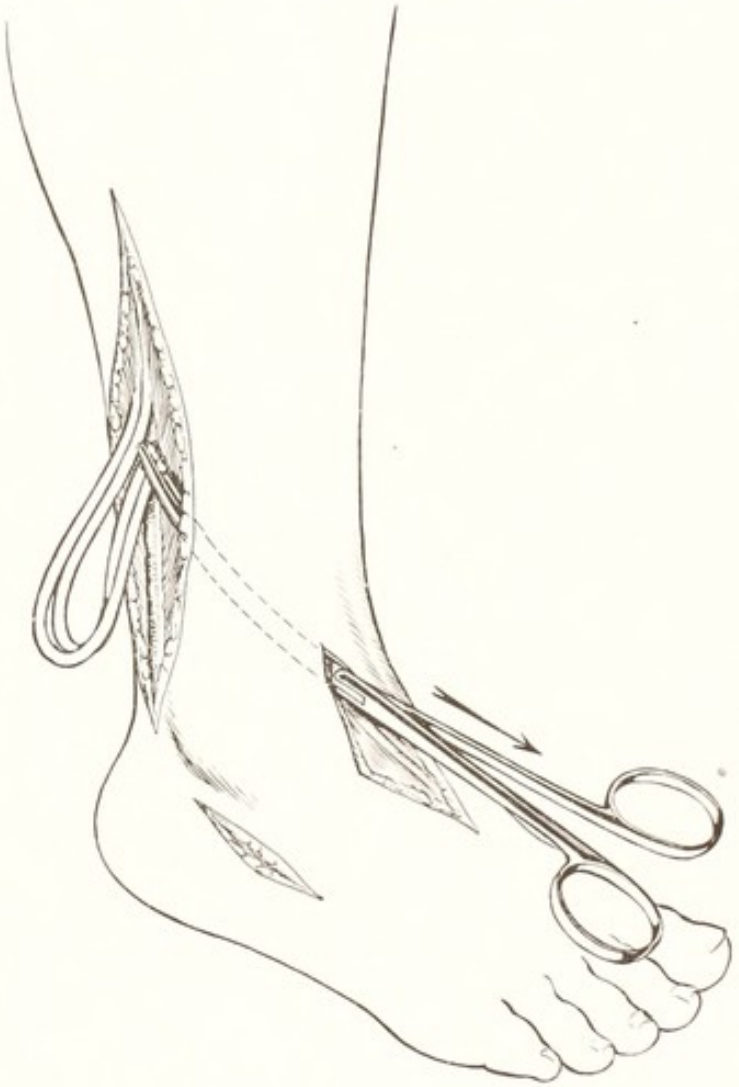


FIG. 477.—Step 2: Formation of subcutaneous tunnel and drawing through the peroneus tendon with a broad ligament clamp. The tendon is severed through the small incision over the cuboid bone. This drawing shows both peroneus longus and brevis tendons being transplanted; this is rarely advisable because of the danger of over-correction. The peroneus longus is the only one transplanted as a rule. (These drawings indicate the transference of both tendons which is not as a rule done.)

overcorrecting, this varus deformity by separating the scaphoid and astragalus. The degree of this overcorrection should vary in accordance with the amount of muscle force existing in the transplanted muscles; or, in other words, modification of the bone-graft can be used in all deformities for the purpose of aiding muscle readjustment in restoring balance.

Regional Application of Tendon Transplantation.—Foot.—(*a*) *Talipes equinus* ("dropped foot"), from paralysis of the anterior tibial and larger extensors of the toes, with integrity of the extensor proprius hallucis. Trans-

plantation of the tendon of the latter may be performed from its insertion in the terminal phalanx of the great toe to the middle cuneiform, implanting it by bony insertion (Figs. 468, 469, 470). Although relatively slender, this muscle will aid in balancing the foot, and to a greater or less extent assist in its dorsiflexion. The distance of the point of tendon implantation from the

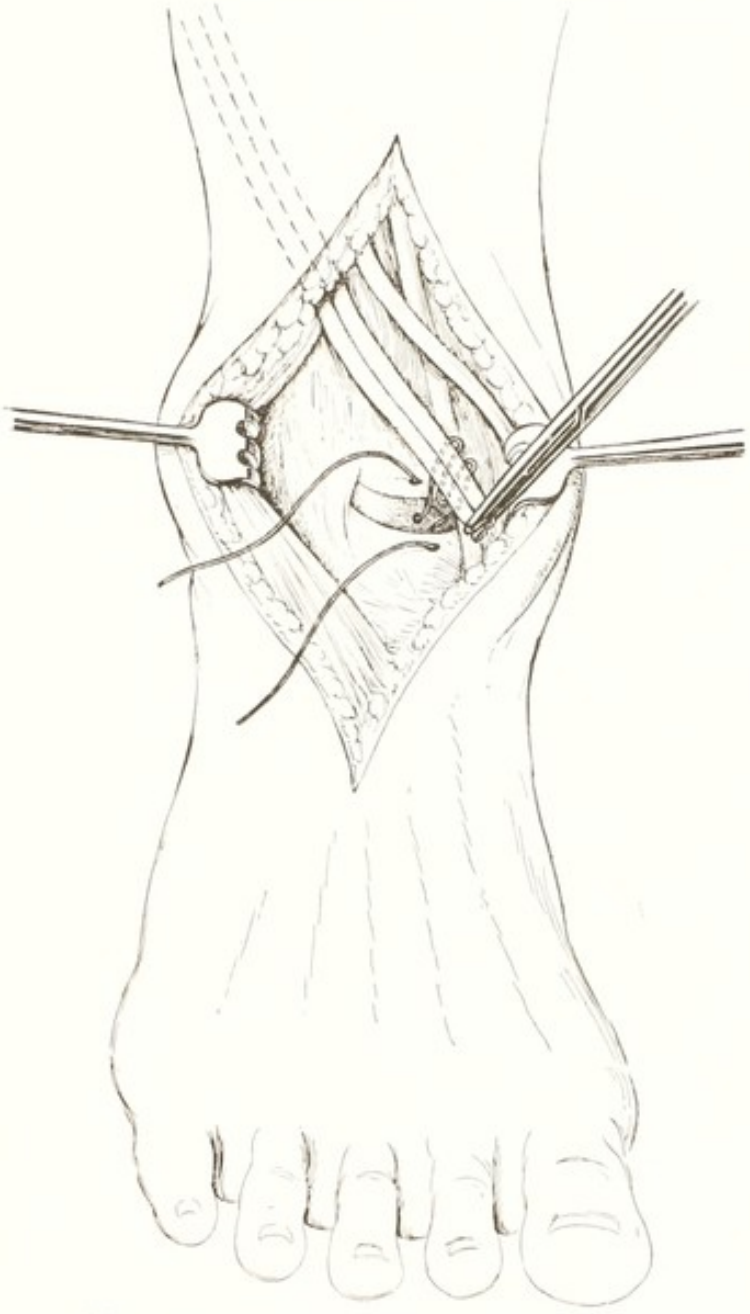


FIG. 478.—Step 3: After arthrodesis of the astragaloscaphoid joint has been performed, holes are made with the motor drill in the contiguous margins of astragalus and scaphoid, and by means of kangaroo-tendon sutures the peroneal tendons are lashed to the superior-internal aspect of this joint; care is taken, however, that the tendons are not included in the joint for fear of preventing the arthrodesis.

middle cuneiform, either internally or externally, will vary with the degree of varus or valgus.

The extensor proprius hallucis is a muscle which comes directly down the center of the leg and hence is unusually well adapted to transplantation either to the outer or the inner side of the mechanical center. Another advantage is that this muscle so frequently escapes paralysis. It is therefore extremely

useful for correcting a simple equinus combined with varus or valgus (see also Figs. 471, 472, 473).

(*b*) *Talipes Equinovarus with Moderate Cavus and Dropping of the Head of the First Metatarsal.*—Transplantation of the extensor proprius hallucis to the head of the first metatarsal gives uniformly good results. This operation, devised by Sir Robert Jones, is accompanied by tenotomy of the plantar

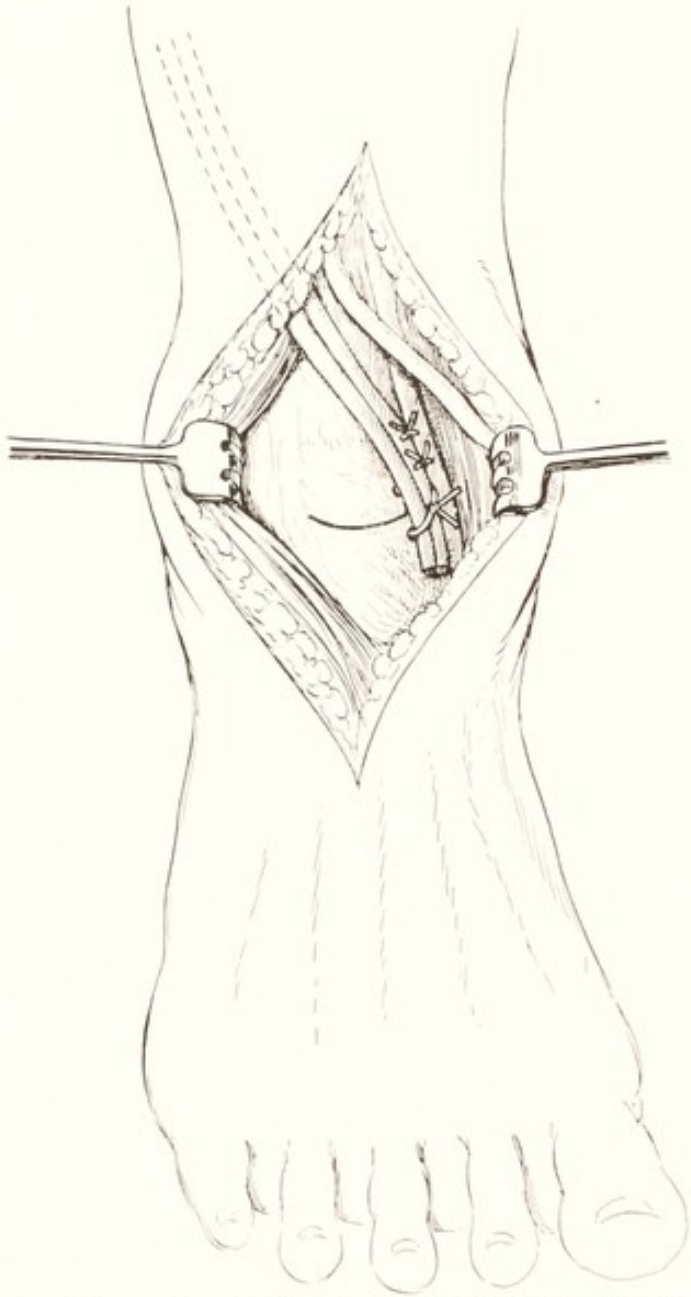


FIG. 479.—Step 4: The arthrodesed astragaloscaphoid joint is closed and the fresh bone surfaces brought firmly together by dorsal flexion. The peroneal tendon is drawn down on to the dorsal surface of the scaphoid bone by tying the kangaroo fixation sutures. Additional sutures are placed fixing this tendon firmly to the paralyzed tibialis anticus tendon.

fascia and a thorough wrenching. The extensor tendon is transplanted through a drill hole in the head of the metatarsal and sutured into the periosteum both at its entrance into the canal and at its exit. The deformity, the so-called "claw-foot," is not an infrequent one in adults and is often present with an occult spina bifida.

(c) *Talipes Varus and Equinovarus from Paralysis of the Peroneals.*—Substitution of the anterior tibial is the best procedure. The tendon, with its bony attachment on the inner surface of the internal cuneiform and

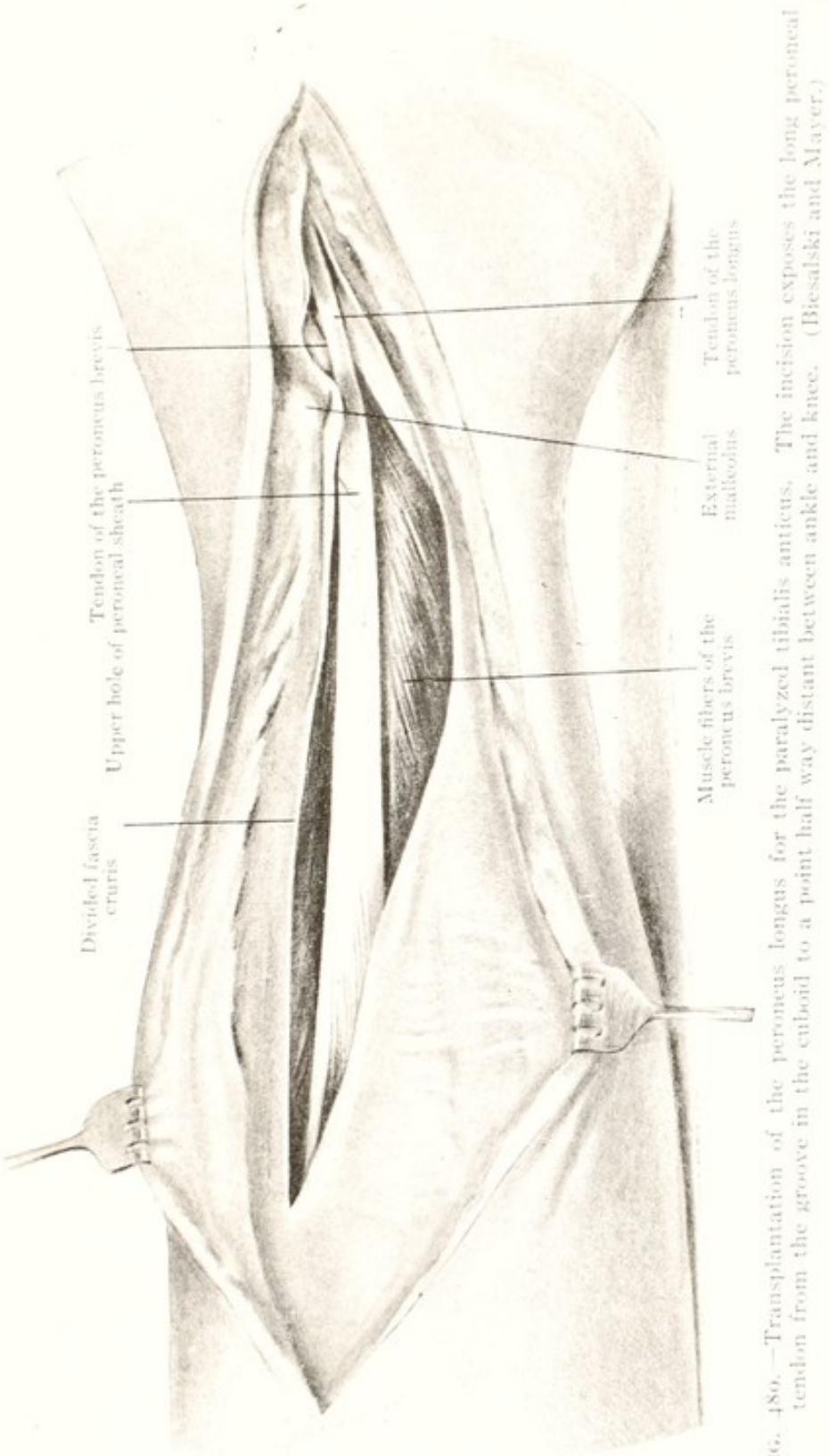


FIG. 480.—Transplantation of the peroneus longus for the paralyzed tibialis anticus. The incision exposes the long peroneal tendon from the groove in the cuboid to a point half way distant between ankle and knee. (Biesalski and Mayer.)

proximal end of the first metatarsal, is cut away and freed to its muscular origin (at the junction of the middle and lower thirds of the outer surface of the tibia), passed through a subcutaneous tunnel and inserted in the tarsus

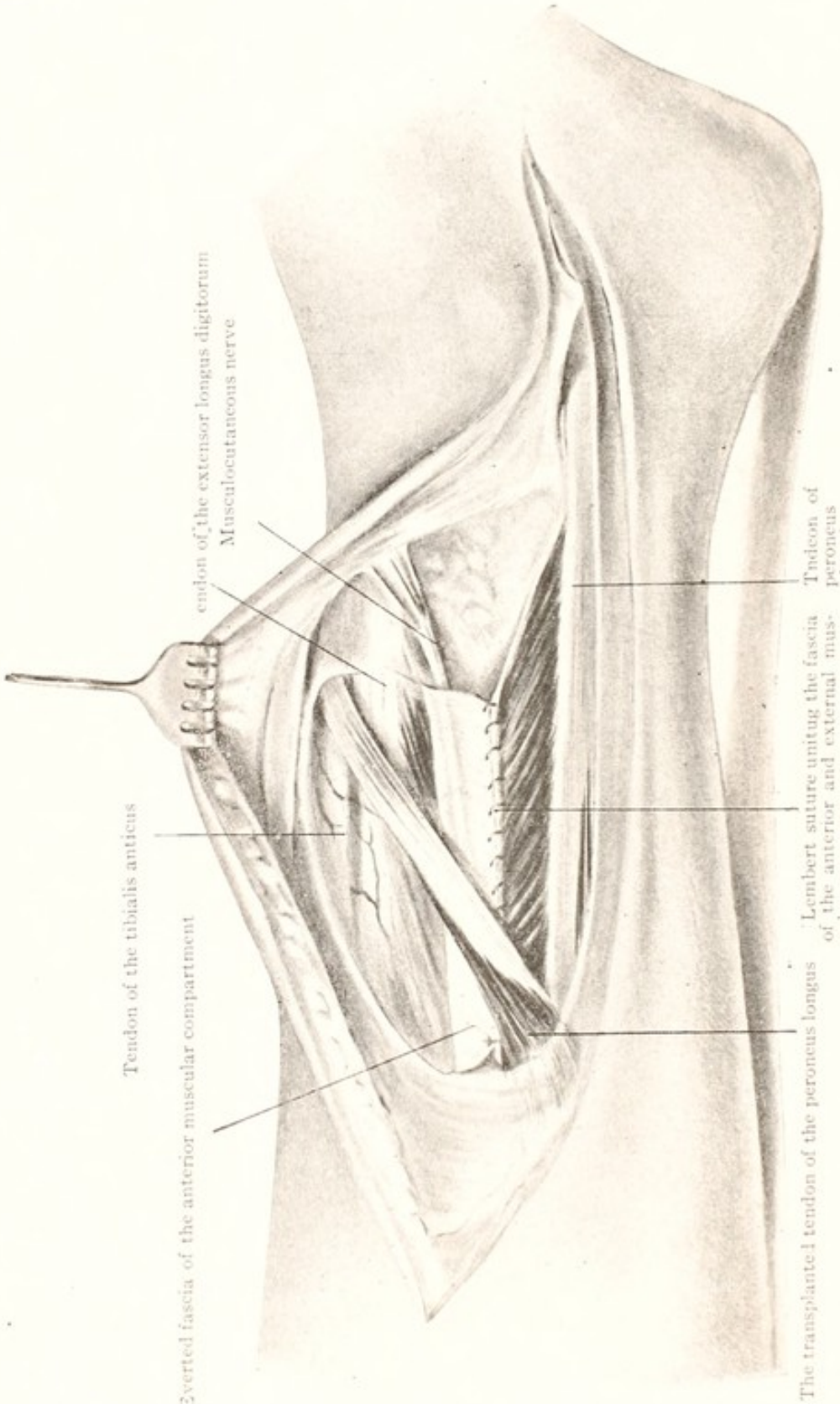


FIG. 481.—Transplantation of the peroneus longus for the paralyzed tibialis anticus, second step. In drawing the tendon from its original site to the sheath of the tibialis anticus, particular care must be taken to avoid adhesions to the fascial septum separating the peroneal muscles from the anterior extensor group. A fascial flap over the anterior extensor muscles is deflected outward in such a way as to expose the smooth deep surface, and then sutured to the everted fascia covering the peroneal muscles. A fascial bridge is thus constructed whose surface coated with a tissue particularly adapted to the gliding of the tendon, allows its passage from its original site to the sheath of the tibialis anticus. (Biesalski and Mayer.)

just *external* to the mechanical center of the foot, *i.e.*, into the external cuneiform, which will avoid overbalancing the foot, where it is inserted under double trap-doors of periosteum with a slice of underlying bone clinging to them.

The Biesalski-Mayer technic is as follows (Figs. 474 and 475): The incision over the tibialis anticus is carried up to a point 2 inches above the annular ligament. The fascia is strongly retracted toward the outer side of the foot, enabling the operator to pass an eye-probe along the tendons of the extensor communis digitorum into the sheath common to this muscle and to the peroneus tertius, and out of the lower end of the sheath in a line with the peroneus tertius tendon. A second small incision is made over the insertion of this tendon and the site of implantation is prepared by raising a trap-door of periosteum and bone. Through this second incision the probe is made to emerge, and by means of a catgut guide suture passed through the eye of the probe the anterior tibial tendon is drawn through the sheath of the peroneus tertius and anchored to its point of insertion.

(*d*) *Talipes Valgus from Paralysis of the Anterior Tibial with Integrity of the Peroneals.*—The peroneus longus or brevis, or both, are transplanted from their normal positions external to the mechanical center to a point *internal* to the mechanical center of the foot. If properly done, especially in simultaneous combination with arthrodesis of the astragaloscaphoid joint, this is one of the most brilliant of all the tendon transplantations in its results.

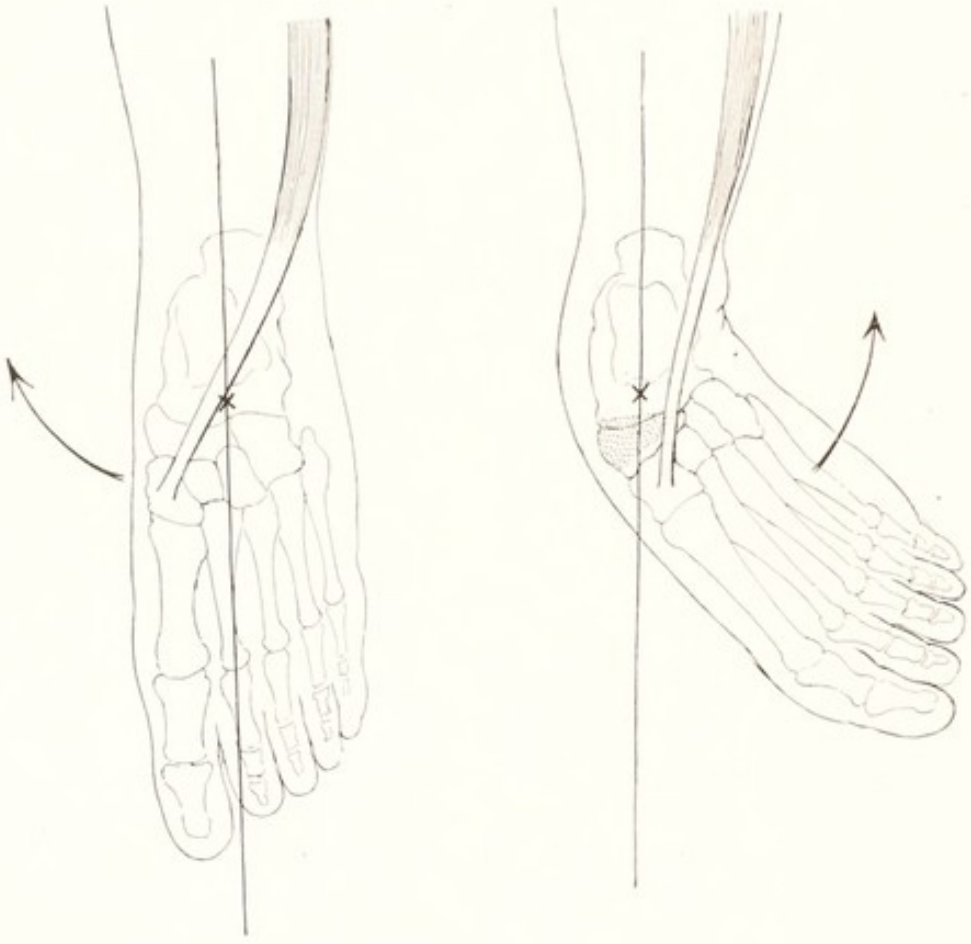


FIG. 482.—A pronounced varus and overcorrection resulting from the transplantation of both peronei to the inner side of the foot in paralysis of the anterior tibial and valgus. An arthrodesis of the astragaloscaphoid joint might have aided in preventing the occurrence of this deformity; also only one muscle should have been transplanted.

Technic of Operation.—Three incisions are necessary (Fig. 476) viz.: (1) A short incision with its central point over the outer side of the cuboid, to sever the tendons of the peroneus longus and brevis; (2) a long incision from a point just above the tip of the external malleolus upward for 6 to 8 inches along the outer surface of the fibula, through which the peroneal tendons are freed and the muscles themselves separated from their attachment to the fibula to a point near the middle of the bone; (3) a vertical incision on the dorsum of the foot, about 3 inches in length, between the outer edge of the tibialis anticus and extensor proprius hallucis tendons, the central point of the incision overlying the astragaloscaphoid joint.

(The operation is sometimes done with two incisions, the long and short incisions along the course of the peronei being made continuous and the external lateral ligament of the ankle being divided, but the author believes that this division of the lateral ligament should be avoided as it weakens the foot at this point.)

The peroneal tendons having been severed and freed, together with a considerable portion of their muscle bellies, to a point about the middle of the fibula, a subcutaneous tunnel is formed, connecting the lower angle of the long fibular incision with that over the astragaloscaphoid joint, by inserting and opening a pair of hemostatic forceps from the latter to the former incisions (Fig. 477). Great care should be taken that this tunnel is of sufficient size not to constrict the tendons or bellies of these muscles; also that it



a *b*

FIG. 483.—*a*. Illustrates the transplantation of the peroneus longus for the anterior tibial muscle when the foot is not markedly deformed. The transplanted tendon is on the inner side of the × which represents the mechanical center of the tarsus and therefore the arch is elevated by the transferred muscle in the same direction as the anterior tibial muscle normally pulls it. *b*. Represents the foot in sufficient pronation to bring the transplanted peroneus tendon on the outer or wrong side of × the mechanical center of the foot. Under these conditions the pull of the transplanted tendon increases the pronation instead of correcting it as was intended by the muscle transference. An arthrodesis of the astragaloscaphoid joint with removal of sufficiently large bone wedge as indicated by the shaded area and correction of the pronation obviates the above difficulty. The transplanted tendon then pulls on the inner side of the mechanical center and the arch is raised by it as it would be by the anterior tibial muscle were it not paralyzed.

be in as nearly straight a line as possible from origin to proposed insertion of the transplanted muscle, so as not to cause the muscle to pull around a corner. (These remarks apply with equal force to subcutaneous tunneling for the passage of a transplanted tendon in any locality.) The jaws of the hemostat are left open and made to grasp the tips of the severed tendons which have been pulled up along the fibula. These tendons are now drawn down through the subcutaneous tunnel or, if we follow Mayer's

technic, the lower ends of the peroneal tendons are slipped through the sheath of the anterior tibial tendon, a procedure which simulates the normal

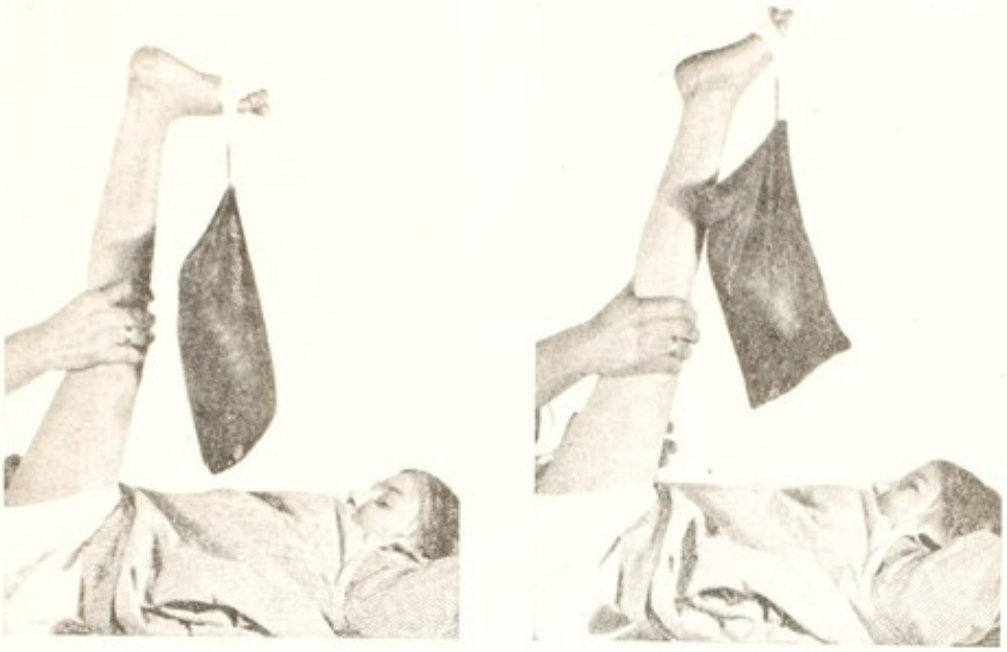


FIG. 484.—Effect of transplanting the flexor hallucis longus and the peroneus longus for the completely paralyzed gastrocnemius and soleus muscles. (Case of Dr. Mayer.) The patient is able to bring the foot into the equinus against the pull of a ten-pound sand bag. (Biesalski and Mayer.)

state of a tendon gliding in the sheath of its muscle. The ends of the tendons are brought down to the region of the astragaloscaphoid joint *where they are anchored into the inner side of the superior surface of the internal cuneiform*



a *b* *c*

FIG. 485.—Severe spastic flatfoot treated by transplanting the peroneus longus muscle. (Case of Dr. Mayer.) *a*, Before operation; *b*, two months after operation standing; *c*, after operation showing voluntary power of adduction and supination. (Biesalski and Mayer.)

(Figs. 478 and 479), a periosteo-osseous flap-door having been prepared for their reception. Note that the point of anchorage is located well to the *inner* half of the median plane of the astragaloscaphoid joint. The surgeon is

cautioned, however, *not* to insert the tendons *into* the astragaloscaphoid joint because of the danger of producing a pseudarthrosis of that joint, thereby defeating the entire object of the arthrodesis. As a matter of fact, the author invariably performs arthrodesis of the astragaloscaphoid joint (*q.v.*, page 741) previous to transplanting the tendons, in order further to stabilize the foot. Medium-sized kangaroo tendon is used to secure the tendons in place. The skin is closed with a continuous suture of No. 1 plain catgut. The foot is put up in the corrected position (inverted and at right angles) in plaster-of-Paris bandages from toes to groin. The original dressing is left on for four weeks. A supporting brace with free motion at the ankle, is worn thereafter until six months from the date of operation.

Biesalski and Mayer have devised an operation by means of which the sheath of the tibialis anticus can be used as a path for the long peroneal tendon (Figs. 480 and 481). A long incision on the outer side of the foot, extending half way up to the knee, lays bare the peroneal tendons and fascial septum which separates the peroneal muscles from the extensor group of muscles. To avoid boring a hole through this septum, a flap is cut out of the



FIG. 486.—Effect of transplanting the peroneus longus for complete paralysis of the dorsal flexors of the foot. (Case of Biesalski and Mayer.) The illustration shows the voluntary power of dorsal flexion four weeks after the operation. (Biesalski and Mayer.)

fascia covering the anterior muscles and is deflected outward so as to expose its deep surface, which is coated with a fatty tissue well adapted to the gliding of a tendon. Small incisions over the point of insertion of the tibialis anticus and over the upper end of its sheath enable the operator to pass an eye-probe through the sheath of the tibialis and thus transfer a guide suture from the fascial flap to the point of insertion of the anterior tibial tendon. This guide suture draws the peroneal tendon over the fascial flap beneath the fascia of the anterior muscles into the sheath of the anterior tibial and thence to its insertion.

A small but important point in the technic of tendon transplantation must be added. Irritation from knots and the danger of their untying may be avoided by employing an over-and-over continuous suture of fine kangaroo tendon.

Mechanical Center of the Foot.—The mechanics following the above operative procedure are a very forcible illustration of the adaptation of the mechanics favorable to transplanting muscles in the foot (Figs. 482 and 483).

In certain mechanical combinations a transplanted muscle may act in a way exactly opposite to that which was intended, if due regard is not paid to the location of the point of attachment of the transplanted tendon with respect to the mechanical center of the foot. As an example of this may be cited the markedly pronated foot due to paralysis of the tibialis anticus muscle. In this condition, the forefoot is rotated outward around the astragaloscaphoid joint to its extreme external limits, carrying with it the scaphoid bone which then articulates with the extreme outer surface of the head of the astragalus. In the presence of these mechanical conditions, if the peroneus longus tendon is transplanted into the scaphoid the mechanical center may be to the *inner* side of their direction of pull instead of to the *outer* side, the desired position (see illustrative diagrams). In this instance, instead of these

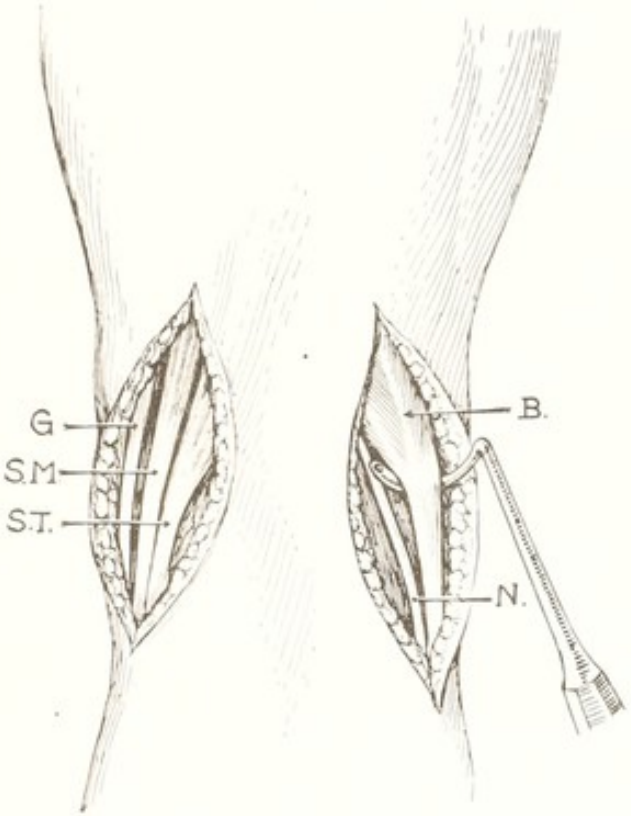


FIG. 487.—Relationship of hamstring tendons when doing an open tenotomy. *B*, Biceps femoris; *N*, external popliteal nerve in close relationship and just posterior to the tendon; *G*, gracilis; *S.M.*, semimembranosis; *S.T.*, semitendinosis.

muscles pulling the foot into the desired position of varus and elevating the arch, they will rotate the scaphoid and the forefoot still further outward on the head of the astragalus into the position of valgus, thus increasing instead of correcting the pronation.

(*e*) *Talipes Valgus from Paralysis of the Tibialis Posticus Alone.*—Two methods of procedure may be followed, viz.:

1. The flexor longus hallucis may be substituted, transplanting its tendon to the inner surface of the internal cuneiform; or

2. The tendon of the peroneus longus may be carried around under the tendo Achillis and sutured to the inner border of the internal cuneiform.

(*f*) *Talipes Calcaneus from Paralysis of "Triceps Suræ"* (gastrocnemius and soleus).—The peronei or the tibialis posticus may be transplanted, but astragalectomy or Jones' operation should usually be performed as an auxiliary measure and the foot dislocated backward, thus lengthening the posterior

lever arm of the os calcis, the object being to minimize the work required of the transplanted muscles (see Astragalectomy, p. 776).

Leg.—*Transplantation of Hamstrings in Paralysis of Quadriceps Extensor Cruris.*—An operation which has given very satisfactory results in the hands of the author is transplantation of the biceps flexor cruris (outer hamstring) to replace a paralyzed quadriceps extensor cruris.



FIG. 488.

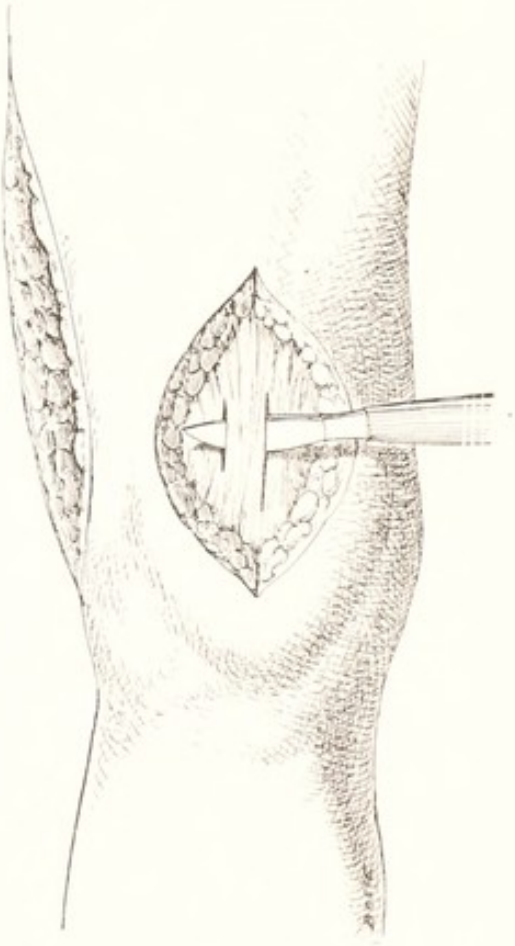


FIG. 489.

FIG. 488.—Transplantation of biceps femoris. *A*, *B* indicates incision through which to expose the tendon and lower portion of the biceps femoris muscle; *C*, *D*, incision to expose patella for the purpose of implanting the biceps tendon and part of its bony insertion.

FIG. 489.—Step 1: Transplantation of biceps femoris into patella. Incision over upper portion of the patella. The quadriceps tendon is split so that the end of the tendon can be drawn through before it is inserted into the patella. The site for inserting the tendon should be prepared before the tendon is dissected so as to avoid drying of tendon and muscle.

Author's Technic (Figs. 487 to 496).—Two incisions are necessary, one to expose the upper border of the patella, and another, longer incision, to develop the outer hamstring and the head of the fibula.

The patella and its tendon are exposed by a vertical incision about 2 inches in length. With a narrow-bladed osteotome, two flapdoors about 1 inch in length are turned up from the upper portion, outer side, of its anterior surface.

A long incision, 6 to 10 inches in length, is made with its lower extremity over the insertion of the biceps flexor cruris into the head of the fibula, and a portion of the latter is cut off with an osteotome, carrying with it the tendinous portion of the biceps. The short head of the latter is then almost entirely removed from its origin on the outer lip of the linea aspera and upper two-thirds of the outer supracondylar ridge of the femur. A subcutaneous tunnel is then produced by inserting and opening a pair of large forceps introduced through the upper angle of the patellar incision and emerging from the lateral incision. The jaws of the forceps are now made to grasp the tip of the biceps tendon with the portion of the head of the fibula attached to it.

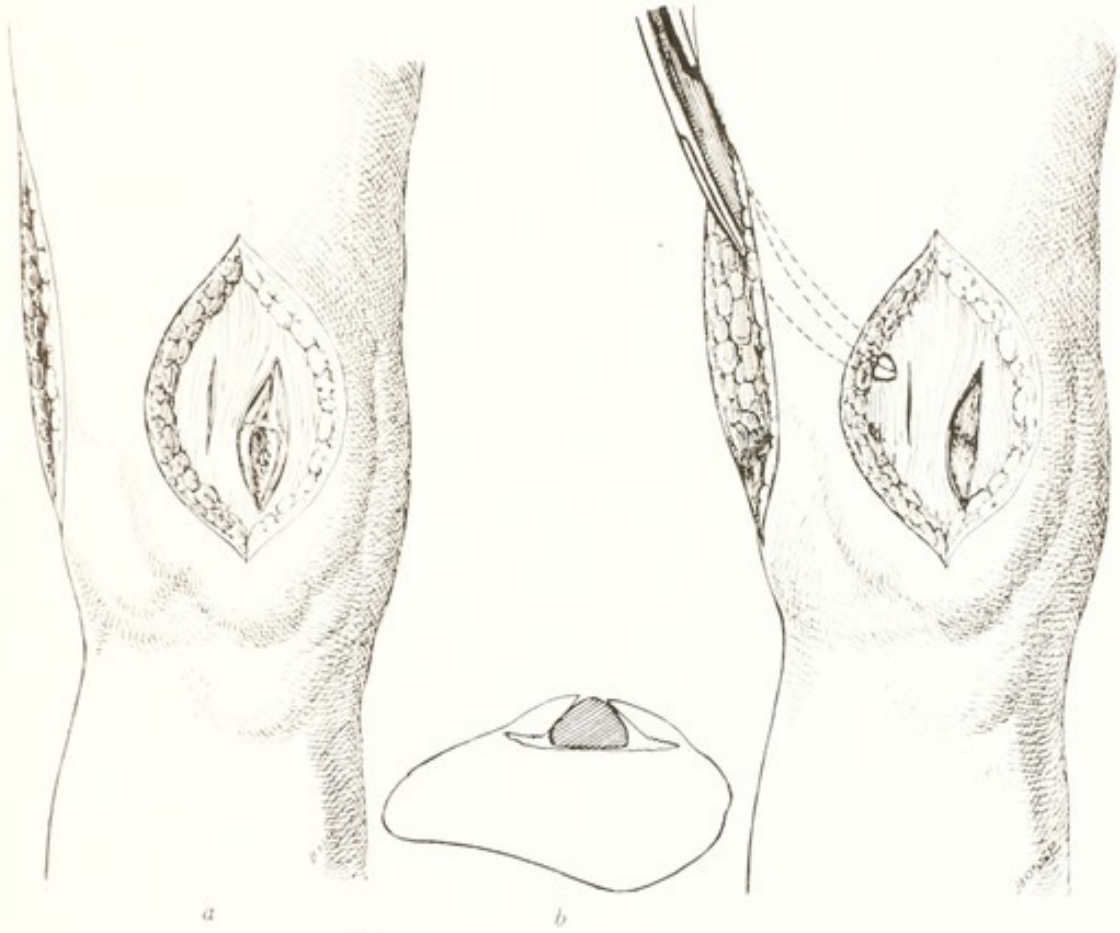


FIG. 490. FIG. 491.

FIG. 490.—Step 2: *a*, Same as Fig. 489. The site for receiving the tendon with its bony insertion is prepared by turning up hinged doors of bone (see *b*), with osteotome.

FIG. 491.—Step 3: The subcutaneous tunnel for the tendon is formed by pushing through a broad ligament clamp and opening the same. Care should be taken that the tunnel is sufficiently large.

As the belly of the biceps flexor cruris is large, care must be taken to have the subcutaneous tunnel large, straight, and of proper direction to allow of the most direct pull when the muscle is in action. The tip of the tendon and its attached osseous insertion are then drawn down under the periosteo-osseous flap-doors in the patella and anchored there by medium-sized kangaroo-tendon sutures passed through the dense periosseous patellar tissues and by over-and-over sutures. The transplanted portion of the head of the fibula makes firm bony union with the patella, and the results are often brilliant. Rigid muscle training should be employed to supplement the operative correc-

tion. The leg is put in extension in a plaster-of-Paris dressing from toes to costal border, and kept immobilized for five to eight weeks.

Transplantation of Sartorius in Paralysis of Quadriceps Extensor Cruris.—Goldthwaite, in 1897, advocated the transplantation of the sartorius to take

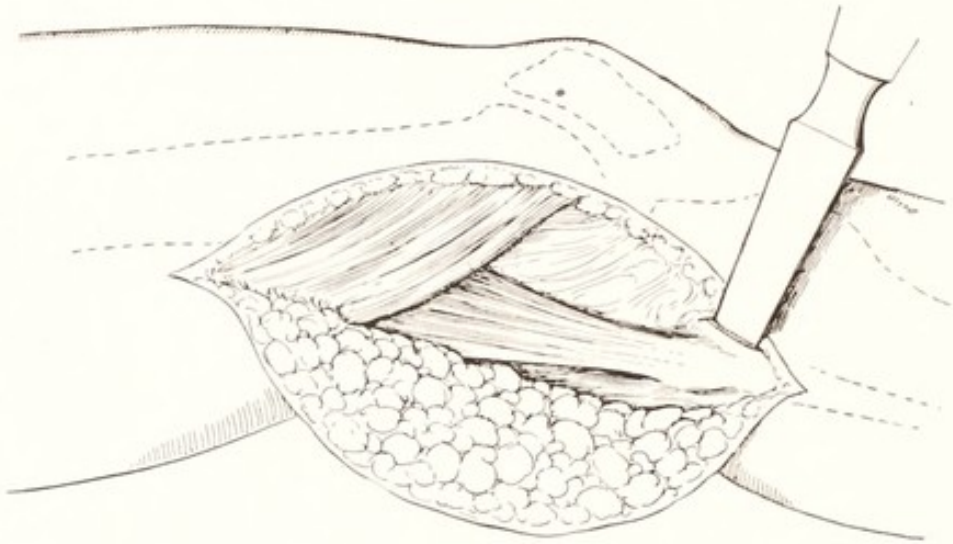


FIG. 492.—Step 4: Detaching the tendon with its bony attachment from the head of the fibula, with an osteotome.

the place of the paralyzed quadriceps (ref. Boston M. and S. Jour., 1897, No. 20). The author has found this to be a very satisfactory operation, since the direction of the sartorius is ideal and its small size is no contra-indication, as it will readily hypertrophy under systematic exercise.

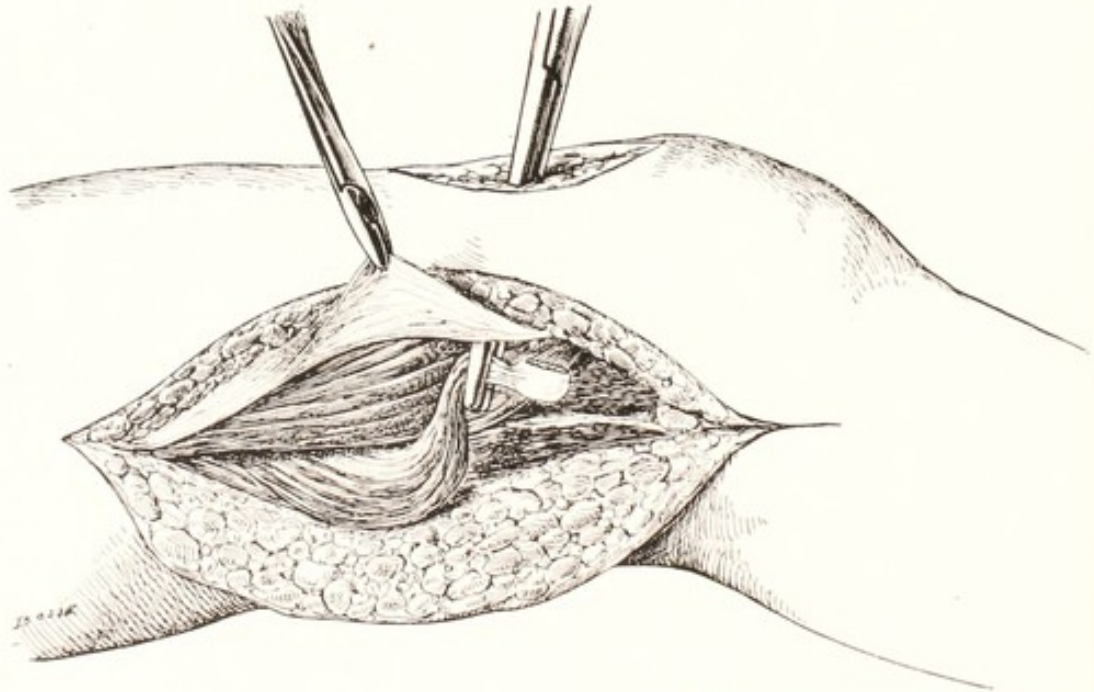


FIG. 493.—Step 5: Drawing the tendon through the subcutaneous tunnel. Care should be taken that the muscle is separated from the femur high enough so that it pulls in as straight a line as possible; also that the tendon is not twisted in pulling it through.

Hip.—*Paralysis of Gluteus Medius and Minimus.*—Lange (ref. Am. Jour. Orth. Surg., Aug., 1910, p. 19) advocates transplantation of the *vastus externus* for the paralyzed glutei. He detaches the origin of the vastus ex-

ternus from the base of the great trochanter and by a series of sutures anchors it to the crest of the ilium to assist abduction of the thigh.

The author has adopted the same procedure except that, in place of silk, he uses fine kangaroo tendon and over-and-over suturing.

If there is recurrent dislocation of the hip, recourse must be had to the author's operation of arthrodesis of the hip-joint (*q.v.*).

Shoulder.—*Deltoid Paralysis.*—Attempts have been made to make the transplanted trapezius functionate for the paralyzed deltoid, but they have met with little success.

Transplantation of Pectoralis Major in Paralysis of Deltoid (Legg).—This operation is of very little practical benefit to the patient, even when technically well performed. The only procedure affording complete relief of the "shoulder-drop" is arthrodesis of the shoulder-joint, described on page 767.

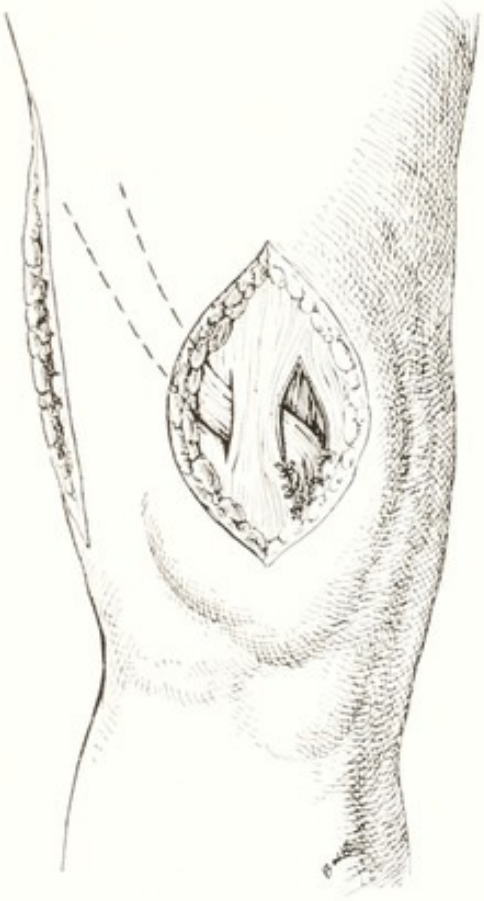


FIG. 494.



FIG. 495.

FIG. 494.—Step 6: The tendon and its bony attachment are buried beneath the hinged doors in the patella and held with over and over sutures of fine kangaroo-tendon. The author prefers the continuous suture so as to avoid not only knots in the tissues but their propensity to untie.

FIG. 495.—Posterior view to demonstrate close relationship of the external popliteal nerve to the tendon of the biceps posteriorly.

Hand.—(*a*) *Transplantation of Flexor Carpi Radialis in Paralysis of Extensors of Digits and Hand with Finger-drop and Wrist-drop.*—Murphy (ref. Murphy's Clinics, vol. iv, No. 4, Aug., 1915, p. 679) performed this operation for musculospiral paralysis from fracture of the external condyle of the humerus, and it is especially applicable to cases of infantile paralysis of similar

nature. A short incision is made on the flexor surface of the wrist over the insertion of the flexor carpi radialis, through which the latter is detached and released dorsally by tunnelling through a button-hole incision and then passed subcutaneously downward again to the level of

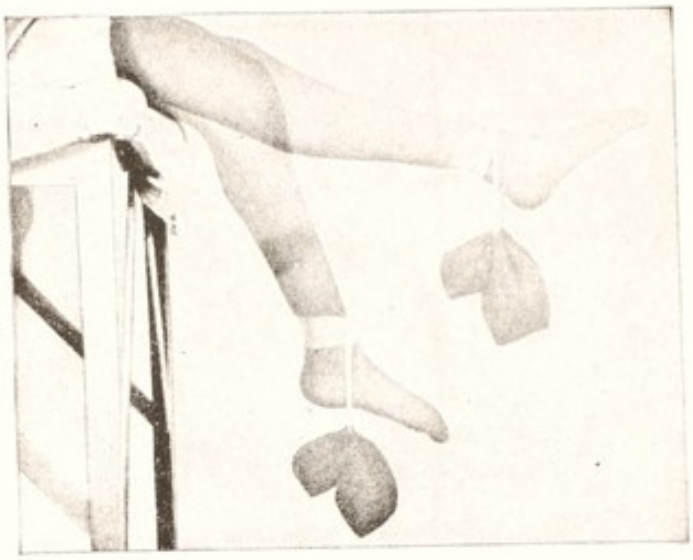


FIG. 496.—Result of quadriceps plastic, seven months after operation. (Case of Dr Biesalski.) By means of the transplanted biceps and sartorius, the patient is able to extend the leg with a weight of three pounds attached to it. (Biesalski and Mayer.)

the upper margin of the posterior annular ligament. The extensor tendons are then located and identified. Each one of the latter is pierced by the scalpel and the tendon of the flexor carpi radialis is threaded through the slits

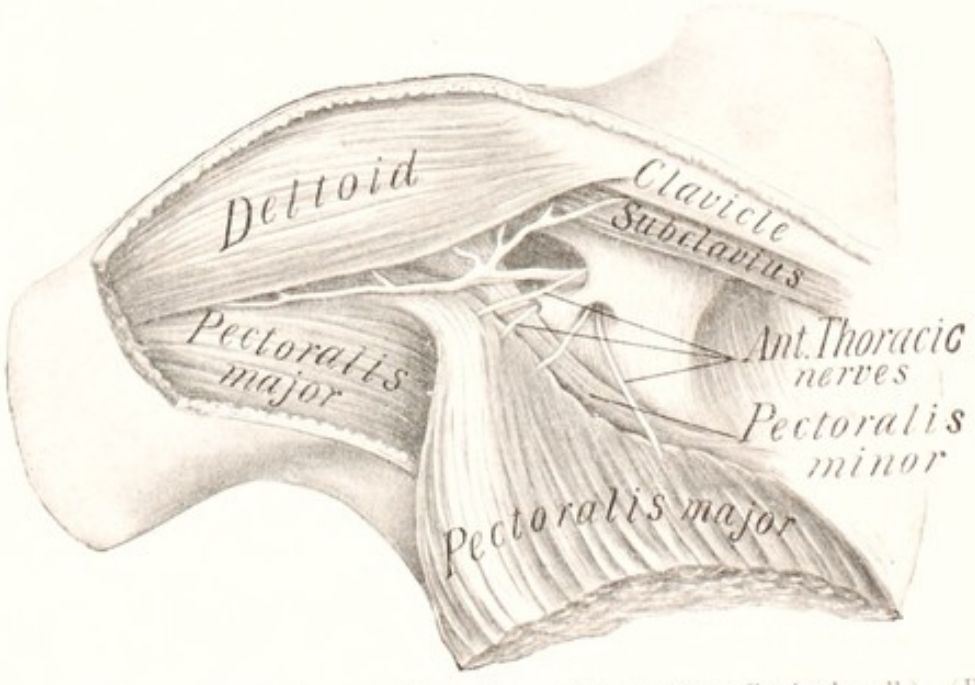


FIG. 497.—Transplantation of pectoralis major. (Adapted from Zuckerkandl.) (Binnie.)

and attached in the following manner: Transfix the extensor tendons of the thumb and then of each finger, two for the index and two for the little finger. The tendon transplants for the thumb and for the index-finger are attached in almost a direct line and then the remaining tendons arranged obliquely

from above and without, downward and inward, so that extension will not bring into play the inner three fingers ahead of the thumb and index-finger, *i.e.*, so that the thumb and index-finger will extend independently of the other three. After completing this step, the superficial fascia and fat are united to prevent union of the tendons with the skin. The skin is closed with interrupted sutures of No. 1 plain catgut. With the hand in hyperextension and the elbow extended, the arm is kept immobilized in a plaster-of-Paris dressing for four to eight weeks.

(*b*) *Transplantation of* (1) *Extensor Carpi Radialis Brevis*, (2) *Extensor Carpi Radialis Longus, and* (3) *Brachioradialis, in Paralysis of Flexors of Hand and Fingers from Paralysis of Ulnar amd Median Nerves.*—In paralysis of the flexors of the hand and fingers from lesions of the ulnar and median nerves, we have a combination of muscles which can be converted into flexors, viz.: (1) extensor carpi radialis longus and (2) brevis, and (3) the brachioradialis.

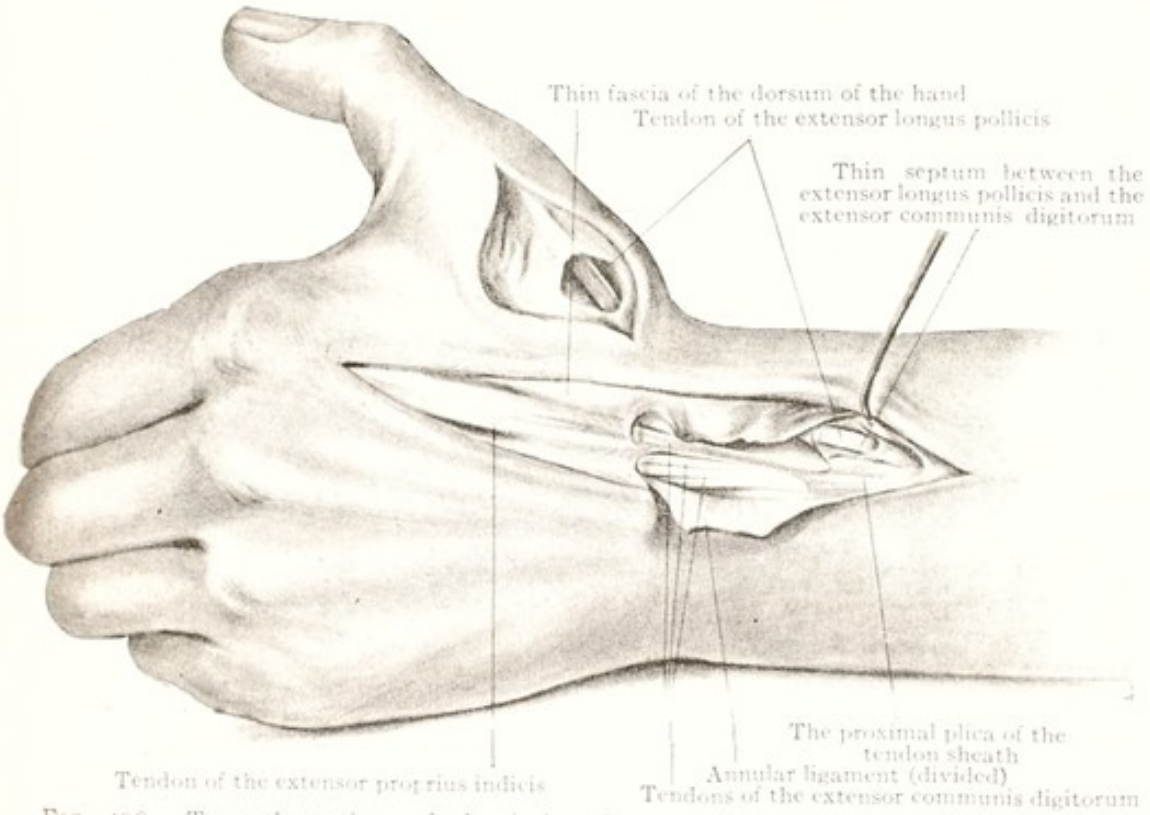


FIG. 498.—Transplantation of the index finger tendon of the extensor communis digitorum for the paralyzed extensor pollicis longus. The skin incisions expose the index finger tendon from the wrist to the metacarpophalangeal joint, and the tendon of the extensor pollicis at the wrist and in its course over the metacarpal bone of the thumb. (Biesalski and Mayer.)

In making the transplantation the chief desideratum is to obtain a good flexor for the thumb, the most important member of the hand. The second desideratum is the attainment of good flexors for the index and middle fingers. Paralysis of the flexor carpi radialis can be disregarded, inasmuch as flexion of the fingers flexes the hand secondarily.

The extensor carpi radialis longus and brevis are attached to the bases of the second and third metacarpal bones after running beneath the extensor of the thumb. Murphy (*loc. cit.*, p. 693) advocates the following procedure: A linear incision is made on the dorsum of the hand, exposing the styloid process of the radius from which the attachment of the brachioradialis is separated. The tendons of the extensor longus brevis lie in close proximity

to that of the brachioradialis. They are separated near their attachments to the bases of the second and third metacarpals (behind) and allowed to slip out from beneath the thumb extensors.

Now expose the flexor tendons by going to the ulnar side of the radial artery and nerve. Next, isolate the flexors profundis and sublimis. All the tendons of the superficial group are now developed. Before beginning the transplantation, the extensor tendons, which have become contractured from lack of opposition, should be lengthened about three-quarters of an inch by some plastic procedure (see Plastic Tenotomy, page 723) and the posterior joint capsule stretched to admit of complete passive flexion of the wrist and fingers.

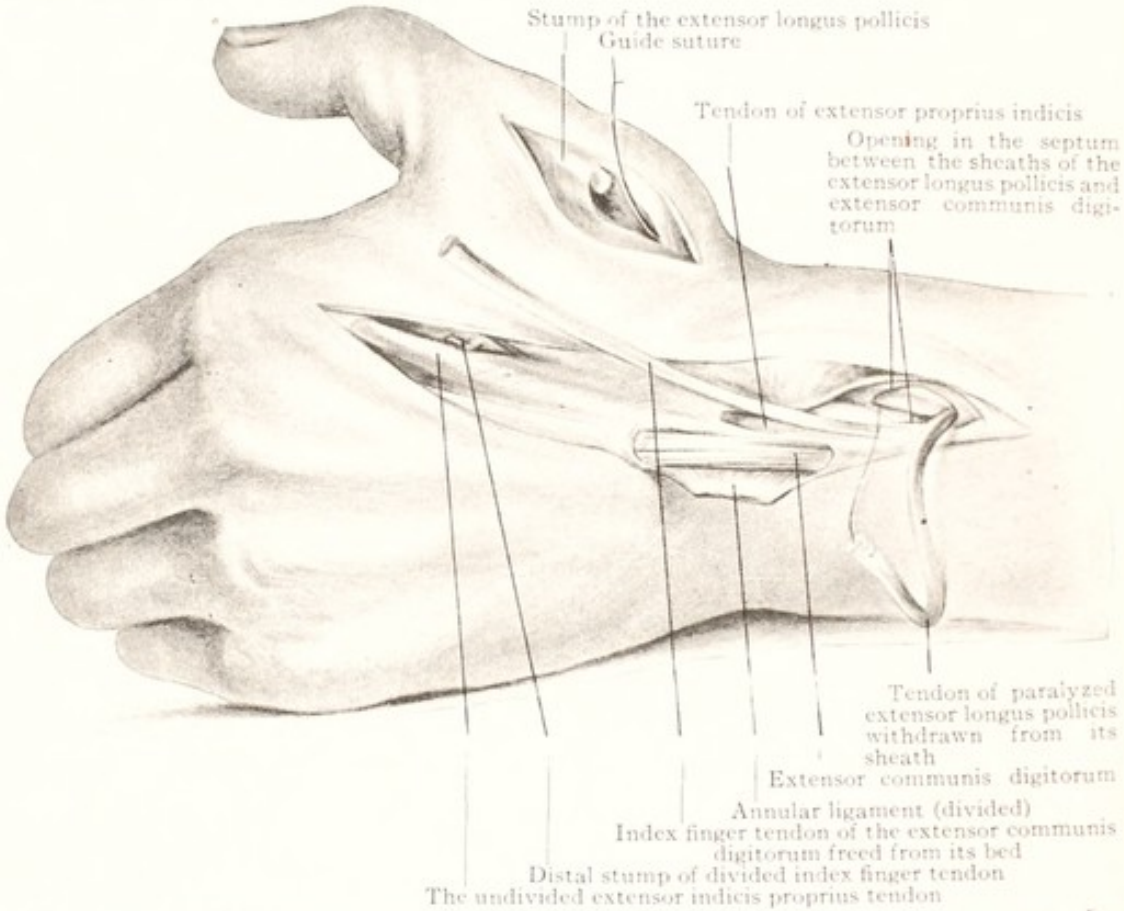


FIG. 499.—In the second step of the operation the index finger tendon is freed from its bed and by means of a guide suture passing through the sheath of the paralyzed extensor pollicis tendon, it is drawn downward and sutured to the distal stump of the thumb tendon. In the illustration, the extensor longus pollicis is shown withdrawn from its sheath. Later investigation has shown that this procedure is not necessary since the sheath is sufficiently large to accommodate two tendons. (Biesalski and Mayer.)

The detached extensor tendons are passed forward under the skin and brought out again 3 inches higher up than where they had passed beneath the extensors of the thumb. Next, the extensor carpi radialis brevis (or brachioradialis) is attached to the long flexor tendon of the thumb to insure full flexion of that member. Then the extensor carpi radialis longus is passed through perforations in all the tendons of both the deep and superficial flexors, and each is fixed in succession to the longus tendon.

(*c*) *Transplantation of the Index-finger Tendon of the Extensor Communis Digitorum for the Paralyzed Extensor Pollicis Longus.*—The technic is amply explained by the accompanying illustrations (see Figs. 498, 499, 500, 501 and 502).

2. **Nerve Transplantation.**—Anastomosis, or transplantation of a normal nerve to one whose function is impaired, has been successfully performed experimentally and in a limited series of actual operations by various surgeons. A healthy peripheral nerve may be transplanted into a functionless nerve either peripherally or distally; its insertion may be central or peripheral, and the whole or a part of the nerve used. It is essential that the transplantation be made before degeneration has proceeded very far in the nerve endings of the affected muscle. When the transplantation is successful, power begins to return in about three weeks after the operation. The percentage of success, even in the hands of those of large experience with the operation, is relatively small, *e.g.*, Spitzy (quoted by Lovett, *loc. cit.*, p. 106) in 1911 claiming only 20

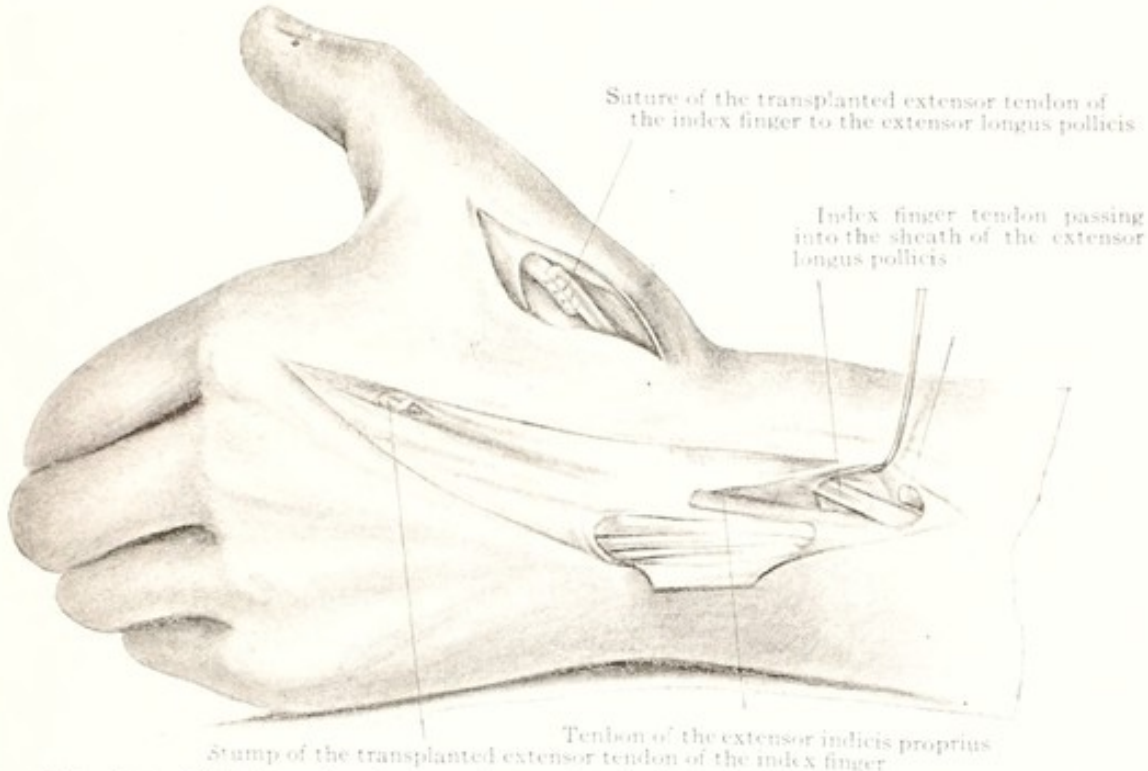


FIG. 500.—Third step in the transplantation of the index finger tendon of the extensor communis digitorum for the paralyzed extensor pollicis longus. The drawing shows the index finger tendon passing into the sheath of the extensor pollicis longus and sutured to the distal stump of that tendon. (Biesalski and Mayer.)

per cent. of good results in 61 operations, while 40 per cent. were not entirely satisfactory and 40 per cent. gave bad results.

3. **Neurotization of Muscle.**—A promising field for research is the possibility—as shown by Heinecke, Erlacher, and Steindler—of implanting the end of a healthy nerve into a paralyzed muscle, with subsequent transmission of electrical nerve impulses along the transplanted nerve, causing contraction of the muscle. The work, however, is still in the experimental stage.

II. STABILIZING PROCEDURES

Having considered in detail the operations for improving muscle balance, chiefly by tendon transplantation, we will now take up the other means of improving function, namely, the various stabilizing procedures. Although there are many methods for securing greater stability of a paralyzed limb, we shall consider in detail only the most important, and in their order of merit:

1. **Arthrodesis.**—Arthrodesis is one of the most useful operative procedures in surgery, if properly performed; this qualification is made advisedly because many surgeons half-perform the operation, use poor judgment in the selection of cases, get repeated failures, and therefore unjustly condemn the procedure. It is well to begin our discussion by a definition of arthrodesis, which is "the surgical fixation of a joint; artificial ankylosis." It must be borne in mind that *true bony ankylosis cannot be absolutely produced so long as any appreciable amount of hyaline cartilage remains in the joint.* Hence it is well to remember that the chief cause of failure in performing arthrodesis is the insufficient removal of joint cartilage. To insure success, in every arthrodesis one should put back fragmented grafts (bone-seed) into the joint,



FIG. 501.—The degree of flexion secured by transferring the flexor sublimis tendon of the index finger for the severed flexor tendons of the middle finger: above, fingers extended; below, fingers flexed. (Mayer.)

and in unfavorable cases should use bone-pegs. The work should be done thoroughly and all cartilage should be painstakingly removed. As a rule, arthrodesis should not be performed in a patient under six years of age, because it is untrustworthy. As an adjunct to tendon transplantation, arthrodesis is particularly useful and, in the case of the foot, is often indispensable.

Regional Application of Arthrodesis.—(*a*) *Foot.*—To stabilize the foot, the author practises various methods of arthrodesis. In order of preference, these are:

1. Arthrodesis of astragaloscaphoid joint.
2. The same, with fixation by bone-graft peg (Soule).
3. Arthrodesis of astragaloscaphoid joint with tibial bone-graft wedge in tarsus, for paralytic equinovarus.
4. The astragalus used as a bone transplant.

5. Arthrodesis of the joint between cuboid and os calcis, in marked adduction of the foot.

6. Arthrodesis of subastragular joint (between astragalus and os calcis) (Davis's Operation, see page 781).

7. Interphalangeal arthrodesis, for bad hammer-toe with sensitive corns.

Technic.—1. *Arthrodesis of Astragaloscaphoid Joint for Paralytic Flat-foot.*—Persistently relapsing, painful, and relaxed pronated flat-foot, after thorough treatment by conservative means has failed, can be restored by arthrodesing the astragaloscaphoid joint, and where the scaphoid presents prominently the fixation and corrected position of the foot is fortified by drilling through this prominent scaphoid into the head of the astragalus, as advocated by Soule.

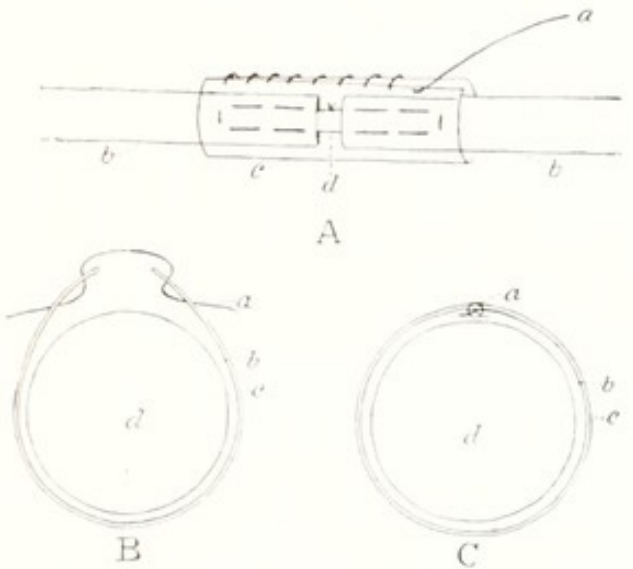


FIG. 502.—Suture of tendon to tendon, when overlapping is impossible. The suture is reinforced by a free transplantation of fascia from the calf. A, longitudinal diagramatic sketch showing the Lembert suture in process of application which closes the tube of fascia overlapping the tendons; *a*, Lembert suture; *b*, tendon; *c*, transplanted fascia; *d*, Lange suture. B, Diagramatic cross-section of the tendon and transplanted fascia indicating the manner of inserting the Lembert suture; *a*, suture; *b*, fascia (superficial surface turned toward the tendon); *c*, fascia (deep surface turned outward); *d*, tendon. C, Diagramatic cross-section of the tendon and transplanted fascia after the Lembert stitch has been drawn taut. Note that the smooth deep surface of the fascia adapted to the gliding function is turned outward: *a*, suture; *b*, fascia (superficial surface); *c*, fascia (deep surface); *d*, tendon. (Mayer.)

The foot and leg having been prepared and a tourniquet tightly applied above the knee, the foot, if rigid, is thoroughly loosened up, after the manner of correcting rigid flatfoot; first, by forcing the foot into equinus, and then by strongly adducting and dorsiflexing the foot. This causes the scaphoid to rotate about the head of the astragalus into a more normal position. The foot is thoroughly loosened up by wrenching. The arthrodesis of the astragaloscaphoid joint is done with a curved gouge through a skin incision, about 2 inches long, beginning just in front of the internal malleolus and extending along the course of the anterior tibial tendon, which is then retracted and the joint is exposed along its dorsal aspect by freeing the overlying joint ligaments and making strong flexion of the foot. The joint ligaments are thoroughly freed of articular cartilage, but care is taken to preserve the ovoid shape of the head of the astragalus and the convexity of the scaphoid, so that when the forefoot is adducted to its proper corrected position, the convexity of the scaphoid rotates about and remains in contact with the denuded head of the astragalus.

With the foot held in its corrected position by an assistant, a hole is drilled through the prominent inner portion of the scaphoid obliquely into the head of the astragalus, large enough to admit a sufficiently strong autogenous bone dowel. The drill is left in position while the bone-graft is being removed from the crest of the tibia at about its middle third where the cortex is thick, either with a mallet or chisel or (preferably) by the motor-saw. This bone is next passed through the author's motor dowel-shaper, forming a bone nail to fit the drilled hole in the scaphoid. This bone nail can be shaped with cutting forceps and a rasp or file, if the dowel-shaper and motor outfit are not available.



FIG. 503.—Correction of varus deformity and an arthrodesis of the astragaloscaphoid joint accomplished by the insertion of a mortised tibial bone-graft for relief of paralytic equinovarus. This procedure is usually supplemented by tendon transplantation.

The foot being held securely by the assistant, the drill is withdrawn and the bone dowel is driven into its place. The superfluous end of the dowel protruding from the scaphoid is cut off with the small motor-saw, and the skin is closed over with plain catgut sutures, without drainage. The foot is put up in a plaster-of-Paris case extending above the flexed knee. This case is worn for the same length of time as advocated for the bone-wedge cases of club-foot, and is removed in the same sequence, namely, the portion enclosing the knee is removed after six weeks, and the remainder four weeks later.

As in the case of other bone-grafting procedures, it is well in some instances to protect the part from undue strain by having the patient wear a metal flatfoot plate for a few months, until the proliferation changes and adjustment of the grafted parts are complete. The plate should be accurately made over a plaster-of-Paris model of the corrected foot, as in the case of all flatfoot plates, the Whitman plate being preferred.

2. *Mortise-graft for Paralytic Equinovarus* (Figs. 503, 504, 505 and 506).—This type of club-foot is caused by either partial or complete paralysis of the peroneal muscles, producing an unbalanced condition of muscle control of the foot. The result is a deformity similar to that of congenital club-foot. The outer border of the foot drops, the forefoot adducts, and the patient walks on the outer aspect of the foot, causing it to adduct further by weight-bearing. An undue laxity of the astragaloscaphoid articulation results and the unopposed muscle action of the anterior and posterior tibial muscles pulls the foot further into varus and adduction. The pull of the anterior tibial muscle, when the foot is in full adduction, forces the foot into further varus and adduction on the leg, and cases have been seen where the forefoot is so markedly adducted and inverted upon the leg that the patient walked wholly upon the outer side of the os calcis and cuboid bones. In the more

severe cases the forefoot is limp and hardly touches the ground, and there is sharp angulation at the mediotarsal joint.

This type of club-foot presents four principal defects, namely: (1) Equinus resulting from the shortened calf muscles; (2) lack of support of

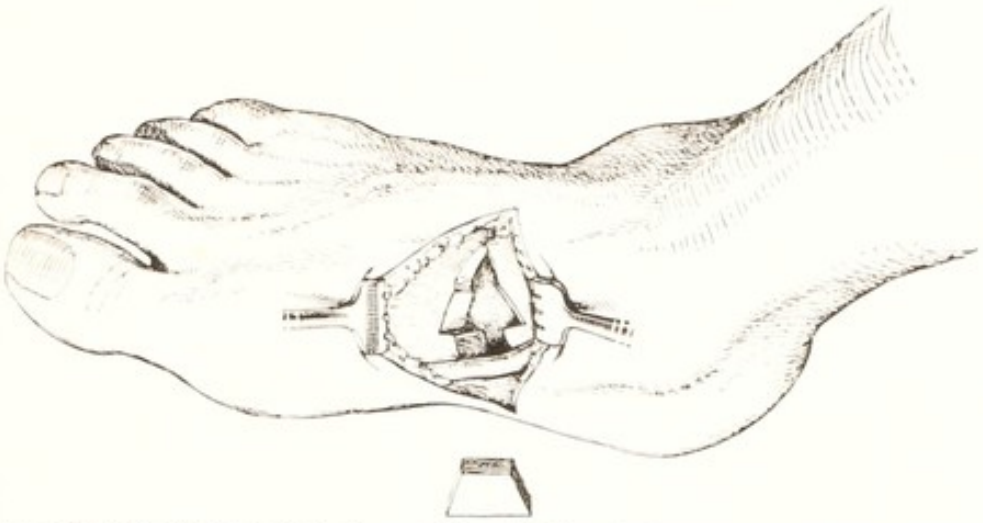


FIG. 504.—To illustrate method of mortising tibial graft for paralytic talipes equinovarus (club-foot).

the outer border of the foot; (3) abnormal laxity of the astragaloscaphoid articulation; and (4) misplaced center of weight-bearing in the foot, due to its faulty adducted varus position.

These faulty mechanical conditions are best met by the following measures: The leg and foot having been prepared for operation, and a tourni-

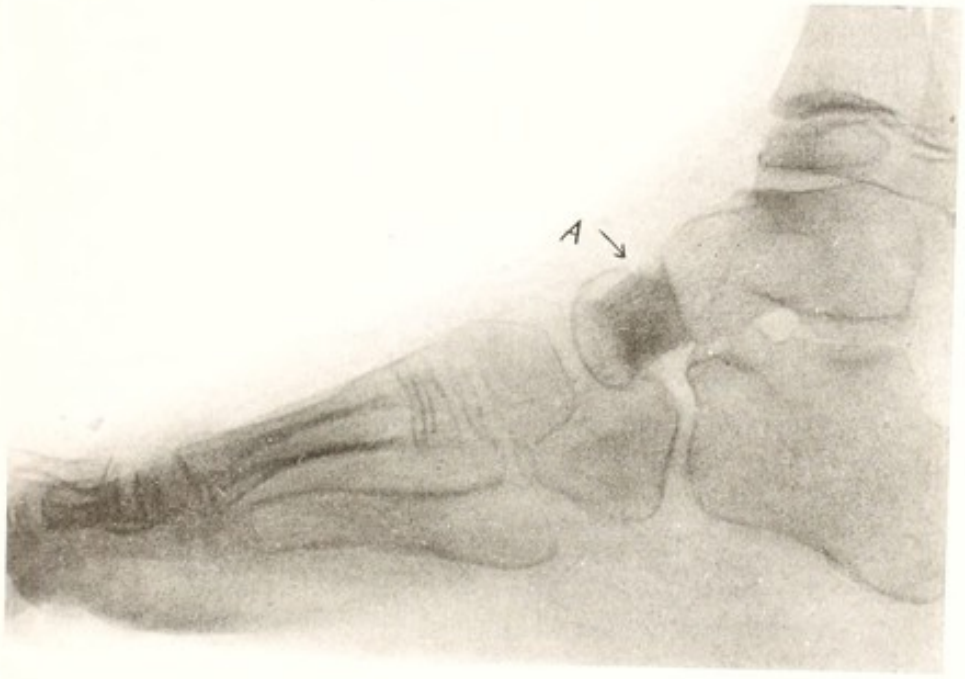


FIG. 505.—A indicates tibial graft mortised into head of astragalus and scaphoid six months before.

quet applied above the knee, the equinus is overcome by subcutaneous tenotomy of the tendo Achillis, and the heel is brought down by forcible manipulation.

The astragaloscaphoid joint is reached by a U-shaped incision, precisely as described for congenital club-foot. The curved part of this skin incision should be well forward so as to afford an ample flap to cover in the grafted field. If preferred, the joint may be exposed by a straight incision parallel with the anterior tibial tendon on the dorsum of the foot.

The articulating surfaces of the head of the astragalus and scaphoid are removed with a narrow osteotome and mallet, following the contour of the joint or forming plane surfaces, as may appear better adapted to the individual case at the time of operation, the idea being to secure the maximum amount of bone surface for contact with the graft. If overcorrection of the foot is resisted by the soft structures, they are subcutaneously severed.

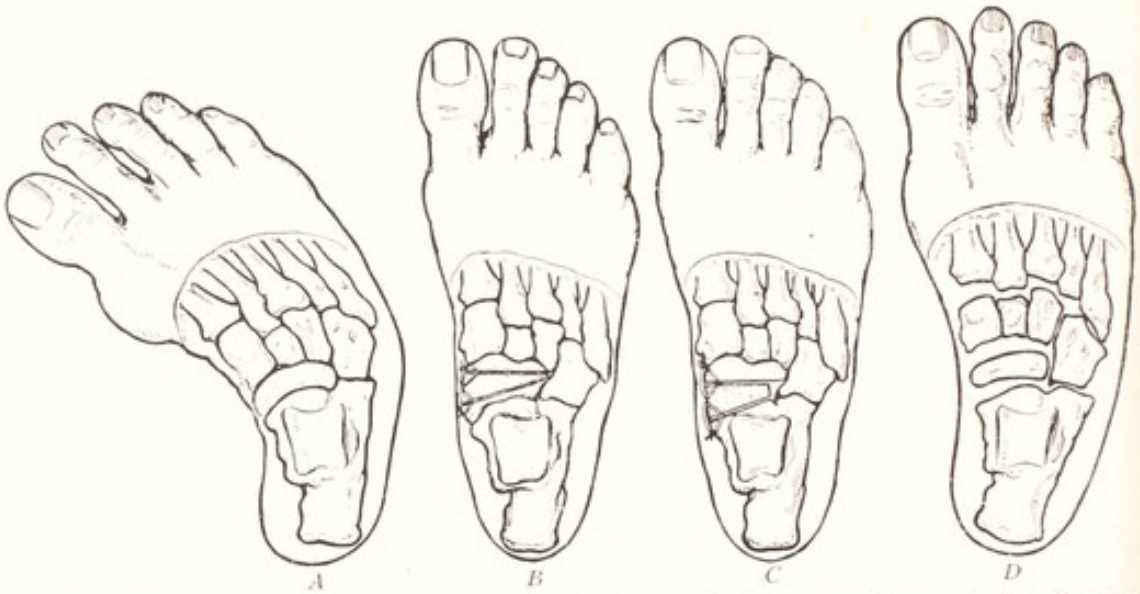


FIG. 506.—Paralytic clubfoot—the deformity and the correction. *A* in diagram representing adduction deformity in congenital or paralytic club-foot, the scaphoid bone is split into interior and posterior halves. *B*, shows the foot after osteotomy of the scaphoid and correction of adduction and varus deformity by the separation of the scaphoidal halves. A wedge cuboidal or tibial graft fixed with kangaroo-tendon is represented in place. *C* indicates the cartilage removed from the posterior surface of scaphoid and the head of the astragalus in paralytic club-foot. A wedge tibial graft is represented in place. This increases the stability of the foot, at the same time it corrects the club-foot deformity. *D* represents the correction of a club-foot in an older child after the Phelps operation or any other purely soft tissue operation. The foot has been corrected by separating the tarsal bones on the inside of the foot at their joints. The danger of the subsequent closing up of these joints and a relapse of the deformity is obvious. (Albee, in Johnson, "Operative Therapeusis.")

The overcorrection of the foot produces a wedge-shaped cavity between the separated cut surfaces of the head of the astragalus and scaphoid. This wound is packed with a hot saline compress.

To overcome the dropping of the outer border of the foot, due to paralysis of the peroneal muscles, the tendons of these muscles are made to serve as ligaments (Codivilla, Gallie). The external malleolus and tendons are exposed by a curved skin incision, encircling the lower end of the malleolus. An osteoperiosteal flap with its overlying peri-osseous tissues is lifted from the external malleolus and turned posteriorly on the peri-osseous tissues as a hinge. The osseous incisions for forming this trap-door are easily and quickly made with the author's small motor-saw, and further freeing of the flap is accomplished by a sharp osteotome. The peroneal tendon sheaths are split, and the tendons are freed and placed under the osteoperiosteal trap-door.

The foot is then forced into pronation and the peroneal tendons are drawn taut by reefing or suturing them securely to the peri-osseous tissues above this bone flap. The edges of this osseous flap, as well as those of the adjacent cortex, are drilled, the tendons fitted into the grooves, and the trap-door is closed over and held firmly in place by kangaroo-tendon sutures, passed through the drill holes and tied. The skin wound is closed by a continuous catgut suture, without drainage. The outer border of the foot is thus held firmly elevated in an overcorrected position.

The saline compress is removed from the wound on the inner border of the foot, and while the foot is held by an assistant in a well-adducted position, an accurate measure is obtained of the resulting cavity between the head of the astragalus and the scaphoid. A saline compress is again placed in this wound and a graft corresponding to the measurements obtained is removed from the central portion of the tibia where the cortex is of sufficient thickness. As in the case of the graft obtained for the correction of congenital club-foot, it is drilled before it is dislodged from the tibia. If the bone of the head of the astragalus and scaphoid is too dense to permit the passage of a strong curved needle, the necessary holes are drilled with the motor-drill. Ordinarily in children, the softness of the bones permits puncture by a strong cervix needle, and the technic is carried out as follows in either case:

The kangaroo tendon is threaded through the drill holes of the graft wedge, by virtue of its own stiffness. A cervix needle is then threaded to each end of this tendon. These needles are thrust through the head of the astragalus and the scaphoid at their inner borders from their cut surfaces.

The bone-graft wedge is then forced into place and the tendon suture is drawn taut and tied over the graft.

Soule's modification of the author's technic, which is simple in that it does not require drilling of bone or fixation suture, is recommended whenever it is found feasible. The astragaloscaphoid joint is approached from its superior aspect and all the articular cartilage is removed from both bones, preserving the original contour of the joint. A mortise is formed in the inner portion of the cut surface of each bone, as shown by the diagrams. The graft is so shaped in its removal from the tibia that it fits accurately into these mortises when the foot is overcorrected. These mortises lock the graft in position and the foot is wedged securely into full correction. By this method the foot is insured against relapse and at the same time the abnormal laxity of the mediotarsal joint is permanently overcome by the ankylosis of this joint. Weight-bearing is placed further toward the inner border of the foot, and the anterior tibial muscle which was barely able to functionate before the operation is now made to do more than its normal amount of work. A stable foot is furnished, capable of weight-bearing, usually without the additional support from a brace.

3. *Astragalus Used to Arthrodese Ankle* (Figs. 507 to 511).—Wrede's arthrodesis of the ankle-joint is a trustworthy operation, since it establishes a somewhat elastic joint instead of a complete ankylosis; at the same time, the ankle-joint does not become flail-like. It is indicated in cases where the transplantation of tendons is either contra-indicated or has not given satisfactory results. The ankle-joint having been exposed by a Kocher incision, the astragalus is removed without being fractured. The cartilaginous surfaces of the astragalus, as well as those surfaces articulating with the astragalus, are removed. The author does this with the electric rotary saw and burrs. The astragalus denuded of its periosteum is then replaced into its normal site. The wound is closed, and a plaster-of-Paris dressing is applied for twelve weeks. The astragalus is thus used as an autogenous free graft.

Bone ankylosis is not the usual result unless the cartilage is removed too deeply. Fibrous union is the usual result.

Knee.—(See Chapter VII, Tuberculosis of Knee.)



FIG. 507.—The heavy line indicates incision for removal of the astragalus.

Hip.—(See Chapter VI, Tuberculosis of Hip.)

Shoulder.—In cases of flail-shoulder from complete paralysis and where muscle transplantation is inadvisable, arthrodesis may be indicated. It is

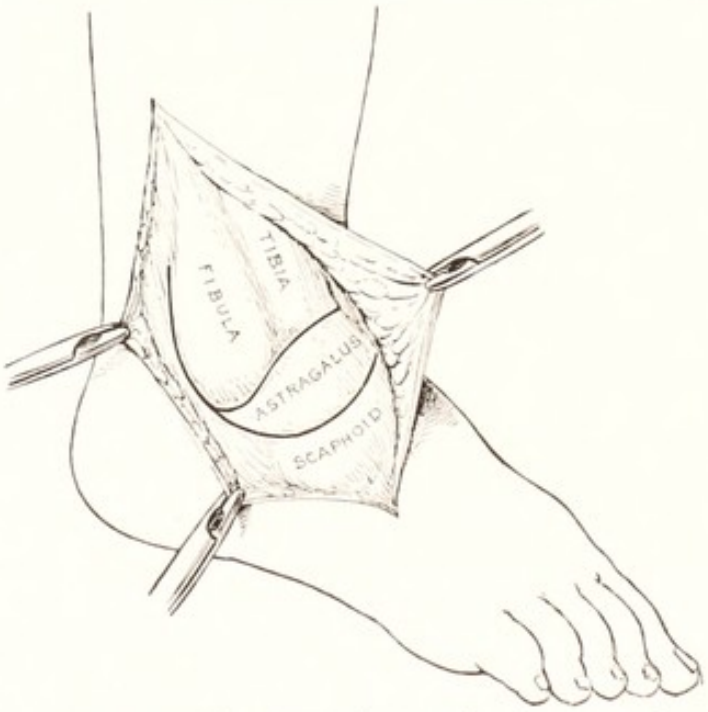


FIG. 508.—Exposure of astragalus for removal.

particularly useful if the muscles of the hand, elbow, and those uniting the scapula to the trunk are still active. If the muscles controlling the elbow are

also paralyzed, arthrodesis of both the shoulder and the elbow may, in rare cases, be advisable at one sitting.

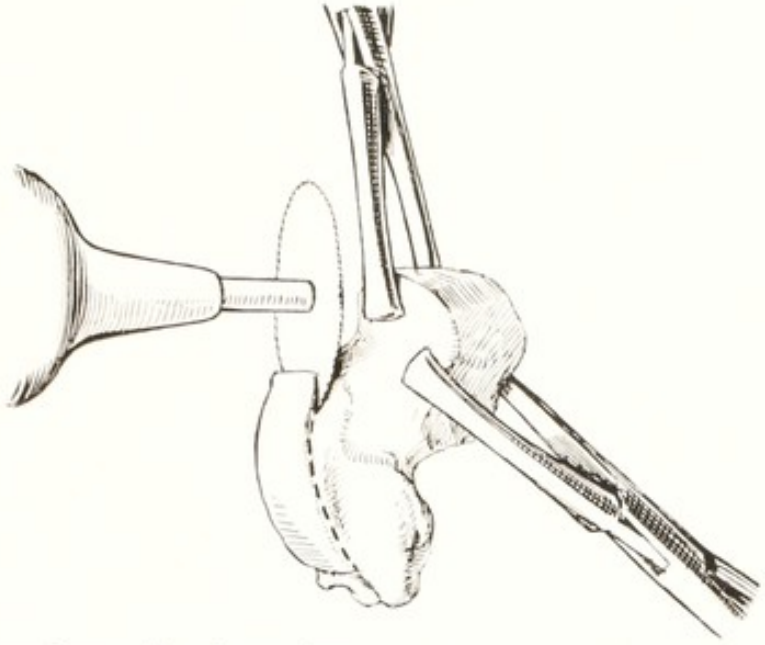


FIG. 509.—Removing cartilage from the astragalus before placing it back in the foot as a graft.

Technic (Fig. 512).—Beginning just internal to the acromioclavicular joint, a vertical incision is made downward to the outer side of the pectorodeltoid groove. The capsule is incised along the bicipital groove, and the

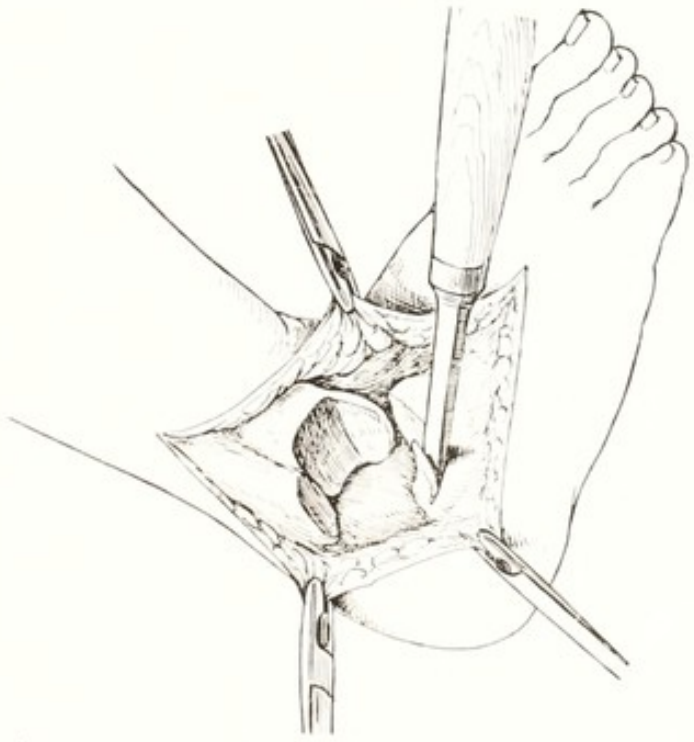


FIG. 510.—Removing cartilage from surface of scaphoid, os calcis, ibia and fibula, which articulate with the astragalus.

synovia excised as thoroughly as possible, and any remaining is cureted away. Dislocate the head from the glenoid by sharp external rotation of the humerus. All cartilage is removed from the head and glenoid by osteotome

or gouge, and from the approximating surface of the acromion process. While the scapula is held in good position by an assistant, return the head to the glenoid cavity and close up to the acromion process. With the arm held in slight internal rotation, elevated anteriorly at right angles to the body, and slight flexion at the shoulder (*i.e.*, in such a position that by flexing the forearm the patient can touch mouth, head, and neck), a bone-graft peg is driven into the head of the humerus, through the acromion process. This latter procedure retains the position, increases fixation, and hastens bony union. The capsule is reefed to take up the slack, and the

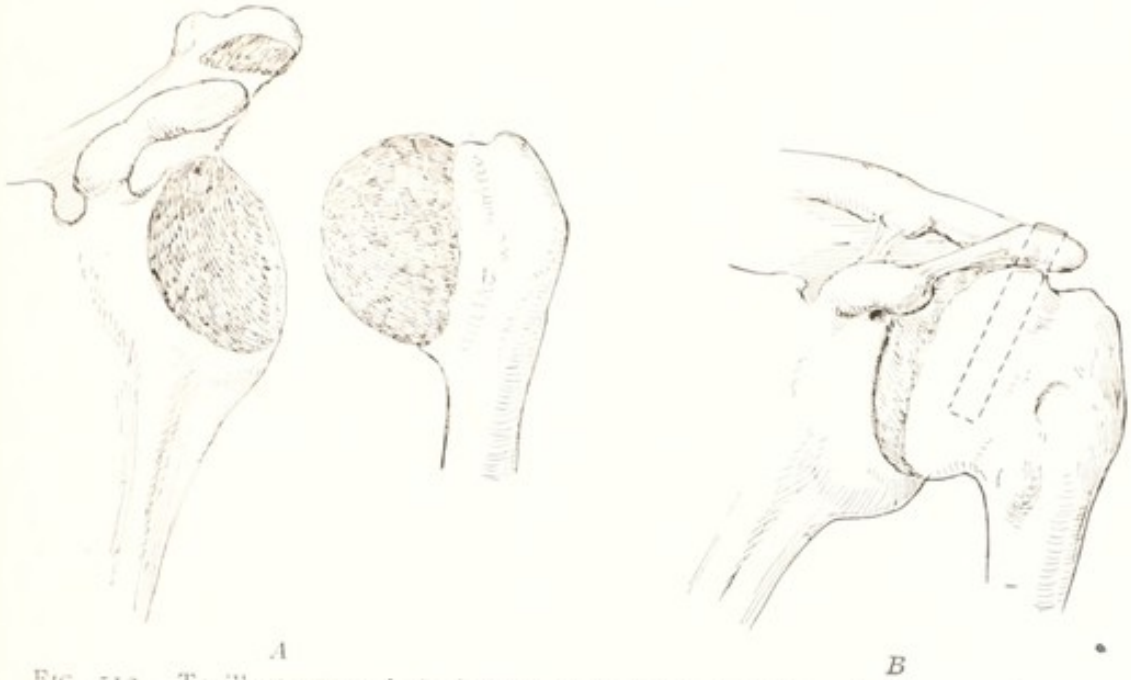


FIG. 511.—Complete paralysis of all the muscles controlling the foot from infantile paralysis. The astragalus was removed and all its articular cartilage peeled off with motor saw. Also the cartilage from the bones articulating with it was removed. The denuded astragalus was then put back for the purpose of making a stable ankle and foot.

arm and shoulder are fixed in the desired position in plaster-of-Paris in which immobilization is maintained for at least ten weeks. It is essential that the arm be elevated anteriorly and so rotated that the hand can best reach the mouth, neck and hair under the control of the scapulo-thoracic muscles.

Elbow.—The only indication for arthrodesis of the elbow in infantile paralysis is flail-joint, and arthrodesis should never be done if there is hope of getting a useful joint by tendon transplantation. The joint is approached by one or two lateral incisions, 5 to 6 inches long, on either side of the

olecranon; or the olecranon may be cut off and turned up from behind. The cartilage is removed by osteotome or gouge from the articulating surfaces of ulna, radius, and humerus. The bone is fixed with sufficient flexion at the



A B

FIG. 512.—To illustrate technic for ankylosing the shoulder. *A*, The cartilage from the glenoid fossa and acromion process, and contiguous surface of the head of the humerus, is removed. *B*, the humeral head is placed in the glenoid fossa and a bone-graft peg inserted into it through the acromion process.

elbow to enable the hand to reach the mouth and the hand is placed in a position midway between pronation and supination. If the shoulder and elbow are both flail, arthrodesis of each may be performed.

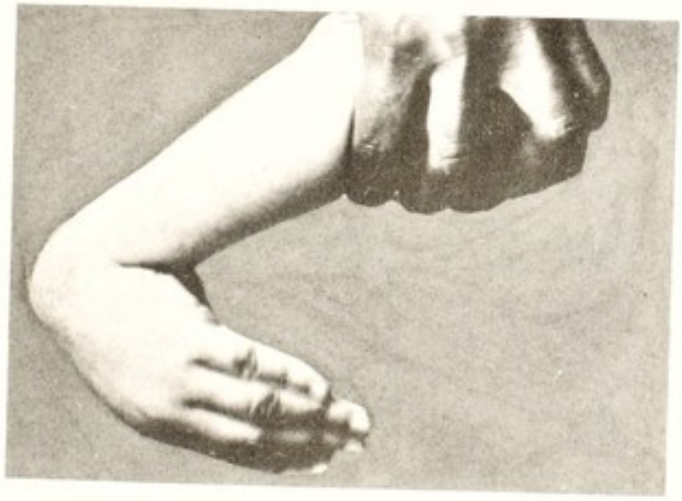


FIG. 513.—A case of drop wrist from anterior poliomyelitis and complete paralysis of the extensor muscles of the forearm. Any attempt to use the hand caused the unapposed muscles of the anterior forearm to acutely flex the hand, and therefore a complete loss of power to flex the fingers. (See Figs. 514 and 515.)

A substitute for arthrodesis of the elbow, in cases where the shoulder has to be arthrodesed, has been offered by Sir Robert Jones. This consists of excision of a diamond-shaped area of skin from the flexor surface of the elbow. The apices of the diamond above and below the joint are sutured

together, which obliterates the excised space, producing more or less flexion at the elbow. This procedure is not so reliable as arthrodesis because of the well-known tendency of skin to stretch and cause relapse of the deformity.

Wrist.—A linear incision is made, on either the ulnar or radial side, and cartilage removed from the cartilaginous surfaces of ulna, radius, and carpus. The hand is put up in dorsiflexion, the most useful position for the flexors of the fingers. Additional assurance of bony ankylosis is attained if a bone-graft is inlaid from the carpus to the radius or ulna, or bone pegs driven into carpus, ulna and radius. Figs. 513, 514 and 515 show a case of wrist-drop and complete paralysis of the extensor muscles of the forearm, and the shape and position of the bone-graft inserted into radius and onto posterior surface of os magnum, the grasp of the hand being almost completely restored by this procedure.

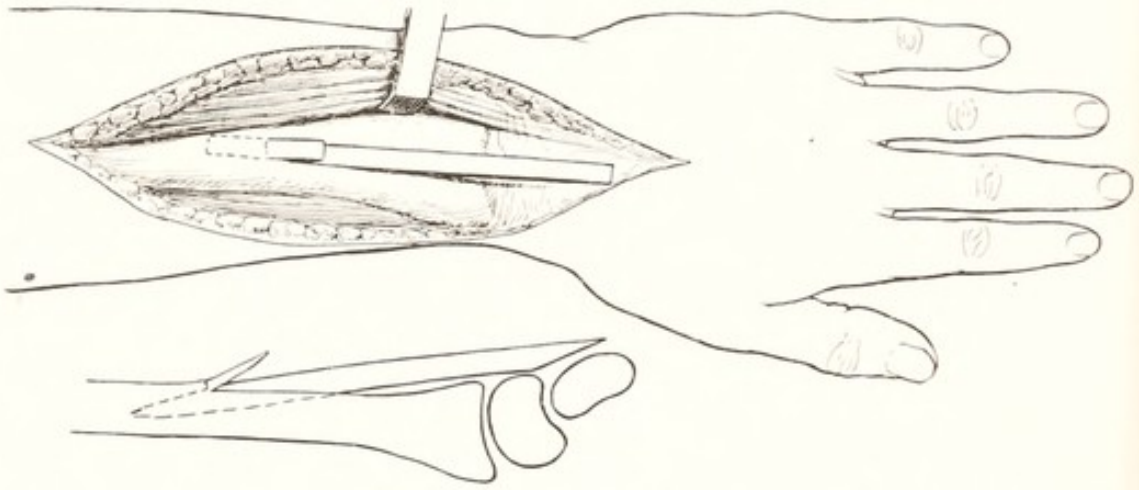


FIG. 514.—The illustration indicates the shape and position of the bone-graft in its application to support a paralytic drop wrist in extension to restore the grasp of the flexors of the fingers. (Author's technic.)

2. **Tendon Fixation (Tenodesis).**—*Foot.*—It is noteworthy that while tendon transplantation in itself may suffice to maintain correction of a deformity by the conversion of a vicious pull into a corrective functional one, yet it is in conjunction with other procedures that tendon transplantation is of greatest value. The most commonly employed tendon transplantations are transference of a portion of the tibialis anticus tendon to the cuboid for correction of a simple varus, and the transference of the peroneus longus and brevis to the scaphoid for a simple valgus correction. We have already indicated the value of supplementary arthrodesis to correct lateral deviation and stabilize the part. A very useful adjunct to tendon transplantation has been recently developed by the author in various uses of the bone-graft. This agent enables the surgeon to almost entirely change the mechanism of the foot by changing its shape and relationship to the leg, and in this way a transplanted muscle which would otherwise pull over a dead center, or at a mechanical disadvantage, may be enabled by changing the mechanical leverage action of the foot and limb, to pull at a mechanical advantage even greater than the normal. Thus, a weaker muscle transferred to take the place of a stronger one may do the work required of it because it can be so arranged that it will pull on a greater lever arm at a greater mechanical advantage, or have less work to do. The latter may be accomplished by so overbalancing the foot that an increased amount of work will be transferred to a strong uninvolved muscle. Example: Paralysis of peroneals with valgus

deformity; graft into astragaloscaphoid joint so that strong intact anterior tibial can do more than its normal share of work.

Gallie has demonstrated that a tendon of a paralyzed muscle may be drawn taut and buried in a bony groove, with resulting union that prevents the part from returning to its former position of deformity. He has shown that the tendon will not stretch and also that in a child the tendon will grow at the same rate as the rest of the limb, therefore maintaining permanent correction.

Talipes Varus.—The simplest type of deformity to which this method is applicable is that of *varus* resulting from *paralysis* of the *peronei*. After the application of a tourniquet, a curved incision is made over the external malleolus, exposing the peronei tendons. The tendon sheaths are split and the tendons are freed of all attachments to the sheath. A vertical incision is then made through the periosteum on the outer aspect of the lower end of the fibula toward the anterior border, extending upward about $2\frac{1}{2}$ inches from the extreme tip of the bone. With the author's small saw and an osteotome, a hinged door of bone and periosteum is raised for an eighth of an inch or more on either side of the incision (Figs. 516 and 517). With a gouge of suitable size, a trough is then cut in the bone and cartilage, extending the full length of the periosteal and perichondrial incisions, and of sufficient depth to allow one of the tendons to be completely buried in it. The varus deformity having been corrected and forcible manipulation having been employed if necessary, the tendon of the peroneus longus is laid in the trough and drawn taut by an assistant, who holds the foot in a correct position with one hand and tightens the tendon, with the assistance of a pair of Kocher clamps, with the other (Fig. 518). The surgeon then passes a fine-sized kangaroo-tendon suture twice through the tendon and through the cartilage on either side of the groove at the lower end of the incision, and by tying the suture over the tendon firmly fastens the latter in position. Emphasis is laid upon the use of kangaroo tendon, or other absorbable material, for the fixation of tendons as well as for all bone work, instead of silk, metal, or other non-absorbable material. The hinged door of bone and periosteum is then turned down over the tendon and held in place by means of a suture of medium kangaroo tendon placed through the edge of the bony door, edge of tendon, and edge of aperture, by means of a strong curved



FIG. 515.—Rontgenogram of case (Fig. 513) after tibial bone-graft had been inserted into radius and onto posterior surface of the os magnum. For diagramatic drawing of author's technic, see Fig. 514. The grasp of the hand was almost completely restored by the mechanical support of hand in extension.

needle in small children or through drill holes (motor) in older individuals (Fig. 519). When this suture has been tied, the surgeon's assistant should gently let go his grip on the foot and thus test the solidity of the fixation. If the position is not correct, the suture should be readjusted.

A similar groove is prepared for the peroneus brevis tendon on the posterior surface of the fibula, exactly subjacent to the normal position of the tendon, and a similar operation is performed. The reason for making one groove anteriorly and the other posteriorly in this operation is that by this means the two tendons balance each other. If both peronei were drawn taut in their normal position behind the malleolus, the result would be plantar flexion or equinus, in addition to abduction, but, by placing one tendon in front and one behind, equinus deformity is prevented. The skin incision is closed with catgut, and a plaster bandage is applied extending from the toes to the knee. After ten weeks the patient is allowed to walk, and two weeks later the plaster is removed.

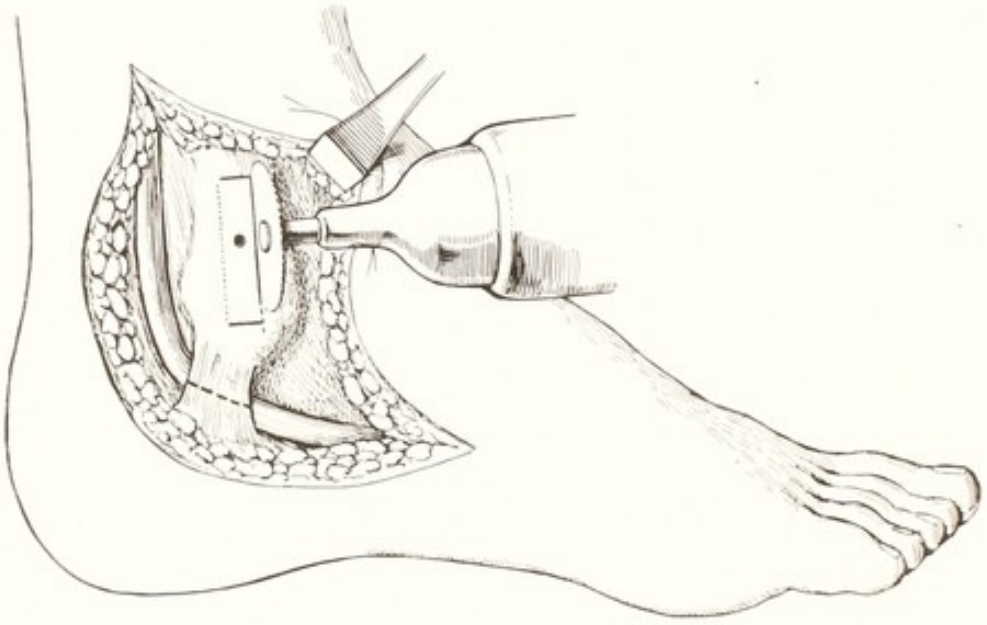


FIG. 516.—Gallie's tenodesis.

Step 1: Lower end of fibula and peroneus longus tendon exposed by Kocher incision passing behind and below the external malleolus. Trap-door, previously outlined with scalpel, is cut in lower end of fibula with author's small motor saw. Hole made in trap-door with motor-drill and another in adjoining portion of fibula for subsequent closure of the door with kangaroo-tendon. Dotted line indicates location of incision in calcaneo-fibular ligament.

The results of this operation have been most gratifying. The patient is able to walk without splints of any kind and, if the peronei are the only muscles in the limb which are affected, he walks without limp. Fortunately, the elimination of the possibility of adducting the foot is of no disadvantage to the patient in walking and running, and consequently many of these patients are practically cured.

Talipes Calcaneus (Fig. 520).—Another simple deformity to which this method of treatment is applicable is that of *calcaneus*, which results from paralysis of the triceps suræ muscle. With the patient lying face downward, an incision is made along the whole length of the outer side of the tendo Achillis. The sheath is split throughout the length of the incision and the tendon exposed. It is thoroughly freed from its attachments to the sheath and retracted inward so as to expose the fibrous covering of the deep muscles of the leg. A vertical incision is made through this sheath (which is the

intermuscular septum between the deep and superficial layers of the flexor muscles of the leg), and the *flexor longus hallucis* comes into view. This muscle is then retracted inward, exposing the posterior surface of shaft and lower extremity of the tibia. It may be necessary to divide a few of its fibers of origin from the fibula and interosseous membrane in order that sufficient length of the tibia may be exposed. A vertical incision is then made through periosteum in the middle line of the posterior surface of the tibia and a trap-door of cortex and periosteum raised with the author's small motor-saw and osteotome, as in the peroneal operation.

With a small gouge, a trough is cut in the tibia, from 2 to 2½ inches long, extending into the medullary cavity. This trough usually extends across the epiphyseal cartilage and slightly into the epiphysis. The tendo Achillis is then buried in the trough and the bony trap-door fixed over it, in exactly the same way as in the peroneal operation.

If the patient has a short leg, the tendon may be fastened in such a way as to produce a slight fixed equinus; and if not, the range of dorsiflexion is locked at about a right angle. The incision is closed with plain No. 1 catgut, and a plaster bandage applied. Up to the present time the results of this operation have been excellent.

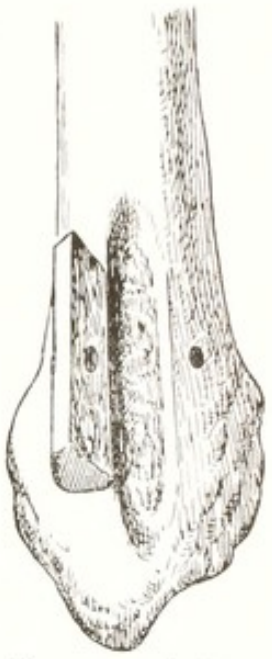


FIG. 517.—Gallie's tenodesis.

Step 2: Trap-door, having been cut with author's motor saw, is pried open with osteotome and is reflected on its osteoperiosteal hinge.

Paralytic Triceps Suræ and Tibialis Posticus.—In addition to the simple operations described for varus and calcaneus, the method is equally applicable to the various deformities that result from *paralysis* of the *triceps suræ* and of the *tibialis posticus* muscles. Here, in addition to fixation of the tendo Achillis, one does a fixation of the tibialis posticus tendon into that portion of the tibia adjacent to its own groove. It has been our custom to give these patients the additional support of either a single-bar brace (ext.) fastened to the shoe and extending to the tubercle of the tibia with internal Y-strap, or a flatfoot plate.

Paralytic Equinus; Equinovarus; Valgus; Equinovalgus.—Similarly, paralytic *equinus* is treated by fixation of the tibialis anticus; *equinovarus*, by fixation of the tibialis anticus and of the peronei; *valgus*, by fixation of the tibialis posticus; and *equinovalgus*, by fixation of the tibialis anticus and tibialis posticus.

Modifications of Technic of Tendon Fixation.—There are, however, some important modifications of the technic which deserve consideration. Cases occasionally present themselves in which deformities are present in spite of partial recovery of the muscle. Obviously it would not be wise to do a tendon fixation in such cases, and yet the deformity calls for treatment here as urgently as in the cases of complete paralysis. To combat such conditions, the experiment was tried of doing a fixation of half of the tendon and leaving the other half free to carry out the function of the normal tendon. The preliminary details of the operation for calcaneus are the same as those already described. When the tendon has been exposed, it is split longitudinally into an anterior and a posterior half, and at the upper end of the incision in the tendon the anterior half is cut free from the muscle. This piece of tendon is then threaded through a small hole in the anterior wall of the sheath and fixed in a groove in the bone, as above described, locking the foot

at a right angle. Finally, the sheath of the tendo Achillis is sewed over the other half of the tendon with fine catgut and the wound closed as usual.

Not only do the patients have permanent locking of the foot at a right angle when the foot is dorsiflexed, but they are able to plantar-flex the foot

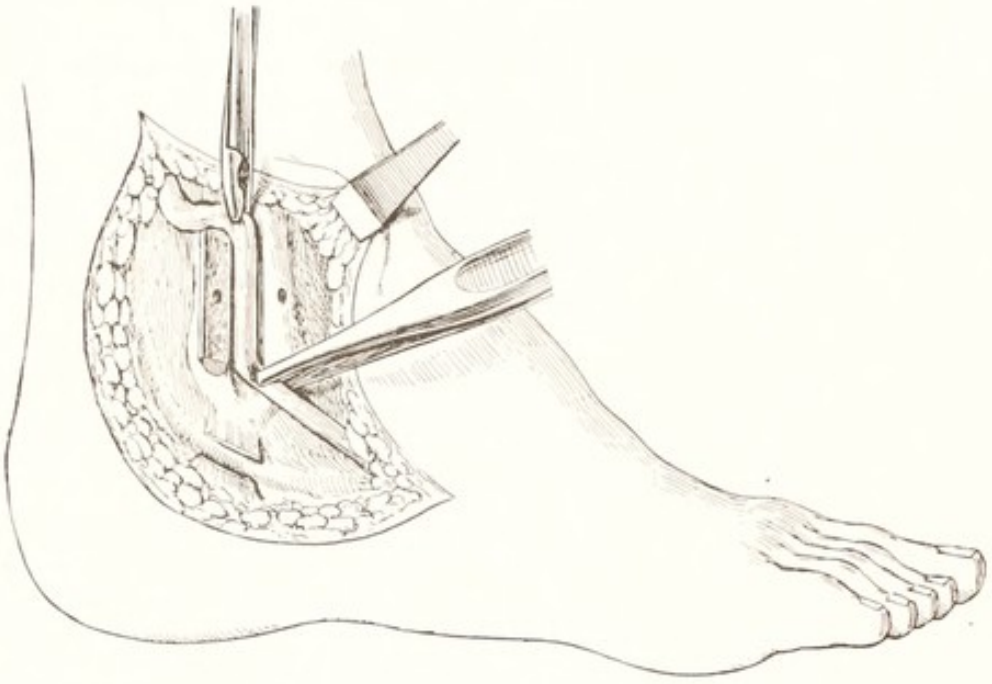


FIG. 518.—Gallie's tenodesis.

Step 3: The calcaneo-fibular ligament is cut, releasing the peroneus longus tendon which is now carried forward by forceps and laid in the gutter in the fibula after being put in sufficient tension to correct the deformity caused by its paralysis.

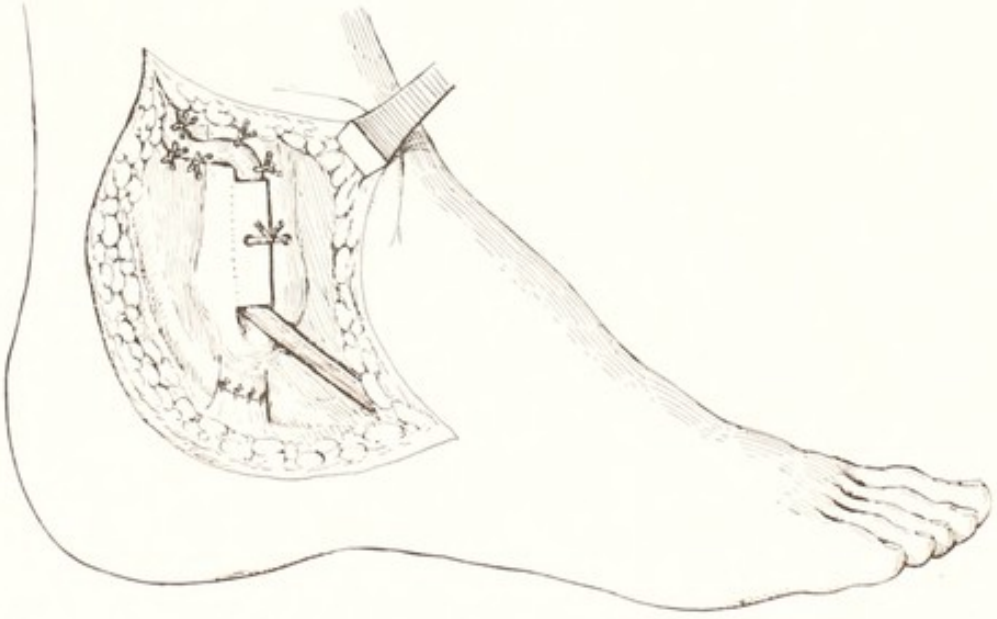


FIG. 519.—Gallie's tenodesis.

Step 4: The trap-door is closed over the tendon and secured by a strand of medium-sized kangaroo-tendon passed through holes in the door and adjoining portion of the fibula. The portion of the tendon immediately above the trap-door is firmly fixed to the periosteum of the fibula and to the neighboring fascia by sutures of kangaroo-tendon, while the calcaneo-fibular ligament is repaired with smaller-sized sutures of the same material.

voluntarily to the normal range. This enables them to walk with a certain amount of spring to the gait as the weight leaves the ball of the foot. The

half of the tendon which was left attached to the muscle increases to the normal thickness. This principle has also been employed in cases of varus in which there is partial power in the peronei muscles, and the results are equally gratifying.

In relation to these cases of partial paralysis, an interesting observation has been made. After the patient begins to walk again there is rapid improvement in the power of the partially paralyzed muscles, and in a few weeks the power will be much greater than before the operation. This is probably accounted for by the elimination of the constant overstretching of the weak muscle. It now gets plenty of exercise without ever being



FIG. 520.—The tendo Achillis is fixed in the posterior surface of the tibia to prevent calcaneus and the peroneal tendons have been transplanted into the os calcis. (Lovett after Gallie.)



FIG. 521.—Marked equinovalgus of right foot and equinovarus of left foot following double astragalectomy, and undoubtedly due to faulty technic, the surgeon having failed to prepare adequate sulci for the malleoli.

overstretched, and consequently increases in size and power. This explanation is based on Sir Robert Jones' observation that the paralyzed muscles recover more rapidly and more fully if overstretching is prevented.

Combination of Other Stabilizing Procedures with Tendon Fixation.—Frequently other operations may be combined advantageously with "tendon fixation." (*a*) Thus in *calcaneovalgus* a favorite operation is that described by Nicoladoni, namely, transplantation of the peronei tendons, when these muscles are active, into the os calcis. This has been combined with fixation of the tendo Achillis on many occasions, and works satisfactorily. (*b*) Similarly, fixation of the tibialis anticus for *equinus* has been combined with transplantation of the extensor longus hallucis into the first metatarsal. (*c*) On several occasions, also, in cases of severe *equinovarus*, fixation of the peronei has been combined with excision of a wedge of bone from the outer

side of the foot and arthrodesis of the midtarsal joint. This combination seems to be successful. We are always careful to scarify the tendons before burying them.

The chief points in favor of Gallie's method are:

1. Its efficacy in preventing recurrence of the deformity.

2. It is superior to arthrodesis in that mobility is preserved except in the direction of deformity.

3. It is applicable to patients of four years as well as to adults.

4. Using one-half of a tendon for fixation (for paralytic deformities where partial recovery has occurred), allows the other half of the tendon to recover from overstretching and the muscles to more fully develop by being relieved from overstretching.

5. In moderate cases of calcaneovalgus and dangle-foot it preserves the length of the limb, which is decreased by an astragalectomy.

6. Since the tendon does not stretch or pull away from its mooring, it is infinitely superior to silk ligaments.

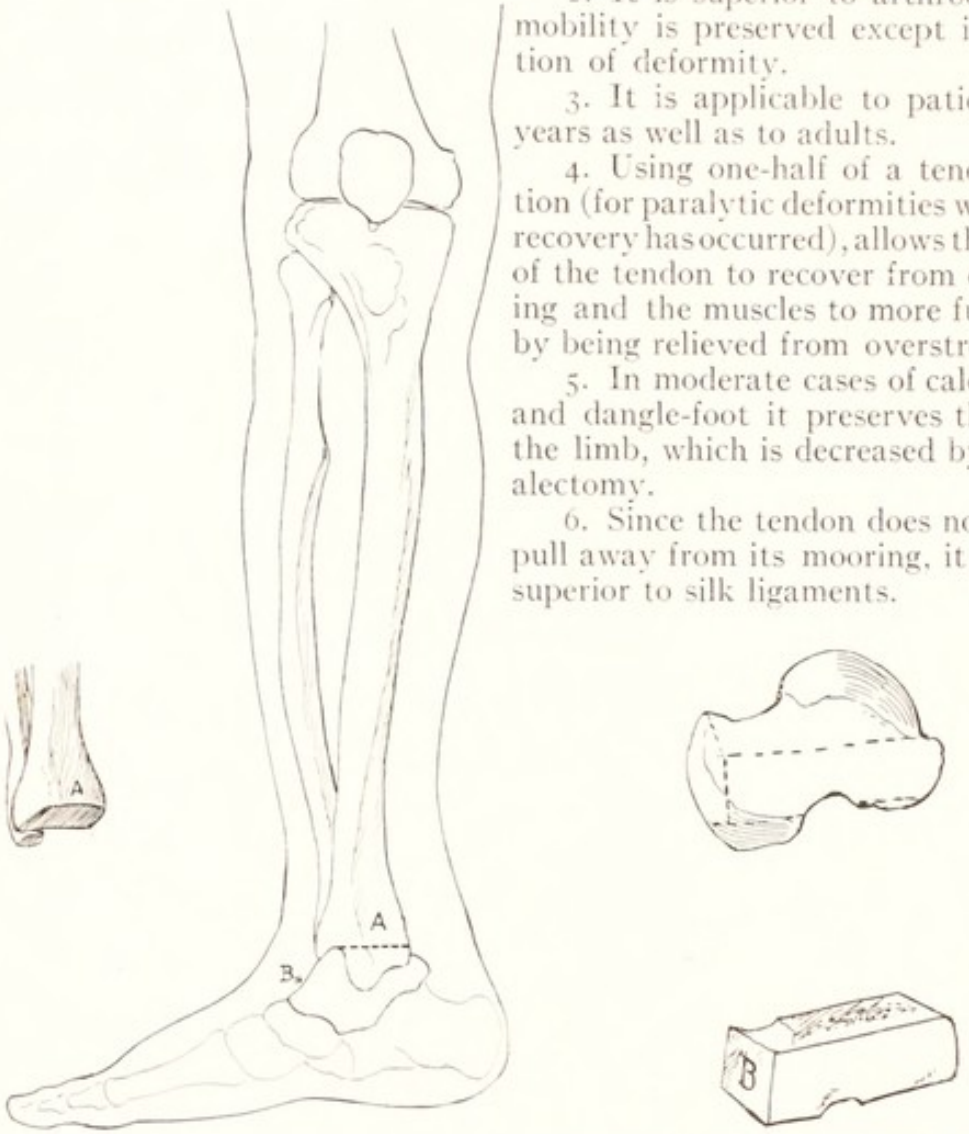


FIG. 522.—Drawing made to illustrate the treatment of an extreme case of paralytic equinovarus with the lower end of tibia and foot twisted outward at right angles from their normal plane. Note that the patella and the internal malleolus (*A*) are both directed forward. To correct both the rigid varus and the right angle eversion of the foot, an astragalectomy was done (through Kocher incision) and both malleoli were removed with osteotome (*A*) and the astragalus was made into a rectangular block of bone (*B*) with large motor saw. The articular surface of the os calcis was also denuded of its cartilage and made a flat surface. The bone block (*B*) was then put back as a graft.

In many cases of calcaneovalgus and dangle-foot, however, the Whitman operation is much superior.

3. **Astragalectomy.**—The Whitman operation for calcaneovalgus consists of removing the astragalus and displacing the foot backward. This operation is most ingenious and definitely fulfills the mechanical requirements in calcaneovalgus, for correction of which it was originally planned. Recently this operation has been recommended for cases of paralytic equinus or equinovarus in which the mechanical conditions are entirely different from calcaneo-

valgus. While arthrodesis may successfully correct, its permanence is uncertain; and, even if successful, the resulting stiff joint produces an awkward gait. Astragalectomy gives stability and yet preserves good function at the ankle.

This operation should not be done until at least two years after the original paralysis, and not until seven years of age.

Technic.—A curved incision is made around the external malleolus forward over the head of the astragalus. The tendons of the peronei longus and brevis are exposed, dissected free, and severed at the tip of the fibula. The tendon ends are clamped and retracted. An incision is made through the external ligaments around the astragalus. The foot is strongly inverted, and the astragalus removed with knife and curved scissors. The internal lateral ligament is dissected upward from the internal malleolus; and, if necessary, the cartilage is shaved from the internal surfaces of the malleoli and small pockets are gouged from the scaphoid and cuboid, into which the malleoli are fitted (Fig. 525). The foot is then displaced backward. The peronei are sutured to the Achilles tendon. The skin is closed with plain catgut No. 1, and a plaster is applied from the toes to the thigh, with the knee flexed and the foot in equinovalgus. The leg is kept elevated for ten days.

The first cast is changed in four weeks for a walking cast, which is continued for five or six months. This is then replaced by a shoe with a $\frac{1}{4}$ inch lift on the outer side of the sole, and $\frac{1}{2}$ or $\frac{3}{4}$ inch total lift to the heel to compensate for the shortening. The valgus position is maintained throughout the treatment. In cases of quadriceps paralysis, the second cast is applied with the equinus corrected to a right angle. When the quadriceps is active, a moderate equinus is maintained.

4. **Robert Jones' Operation for Paralytic Calcaneocavus.**—Jones advises against performing this operation on children under eight years of age. The operation varies somewhat in cases where calf paralysis is complete and in those in which some power remains in the calf muscles.

(a) Calcaneocavus with Complete Paralysis of the Calf Muscles.—The operation is done in two stages with an interval of four weeks.

Stage I (Figs. 526 and 527).—Divide the plantar fascia if it is contracted and apply manual force or the wrench to correct the distortion. An incision is made down to the bone, about 3 inches in length, on the inner side of the foot, the center of the incision being opposite the angle of greatest concavity of the foot. With a periosteal elevator, separate the soft structures from the tarsus above and below, from the inner to the outer



FIG. 523.—Same case as Fig. 525. The eversion and varus have been corrected. The reduction in size of the astragalus allowed this to be done readily. *C* is the scaphoid bone. *B* is the flat surfaced astragalus back of *C* in place between the flat surface of the tibia above and that of the os calcis below. The muscles controlling the foot were entirely paralyzed and therefore were not suitable for an astragalectomy.

side. Remove a transtarsal V-shaped section of bone from the dorsal aspect of the tarsus. If valgus deformity is present, this section is made wider on the inner than on the outer side. Suture the wound and obliterate the cavus deformity by extending the foot, now bandaged to the tibia, which apparently much increases the calcaneus deformity.

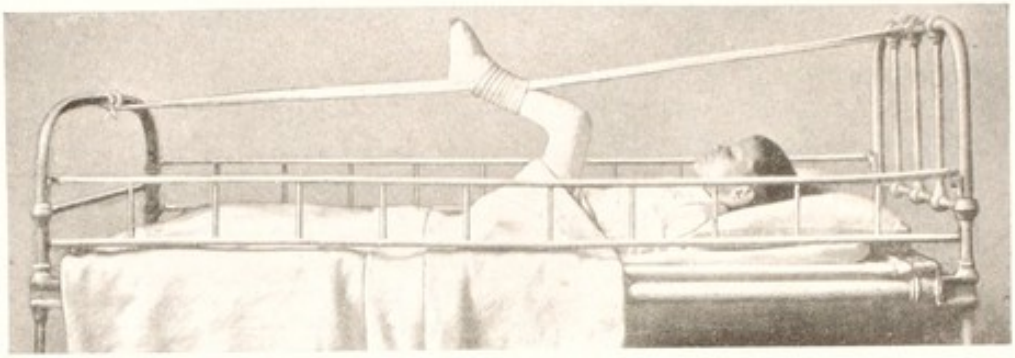


FIG. 524.—The plaster bandage and the attitude after the operation. (Whitman.)

Stage II (Four weeks later) (Figs. 528 and 529).—A longitudinal incision is made at the back of the heel, its center being opposite the ankle-joint. Open the joint and take a wedge from the astragalus large enough to be accurately obliterated when the foot is brought to a right angle. Denude the tibia and



FIG. 525.—The foot after Whitman's operation for calcaneovalgus, showing the restoration of symmetry. Also a simple brace to be worn temporarily within the shoe. Whitman.)

fibula of their cartilage. The foot is brought to a right angle with the leg and immobilized until union is complete.

(*b*) *Calcaneocavus with Some Power Remaining in the Calf Muscles.*—*Stage I.*—As above.

Stage II.—Through a longitudinal incision with its center opposite the ankle-joint, shorten the tendo Achillis and the posterior portion of the capsule

of the ankle-joint, close the incisions and put the foot up in a plaster case for three weeks in its normal position, at the end of which time massage is begun. No bone is removed.

In older subjects, Jones states that it may be necessary when removing the wedge to incise the outside as well as the inside of the foot.

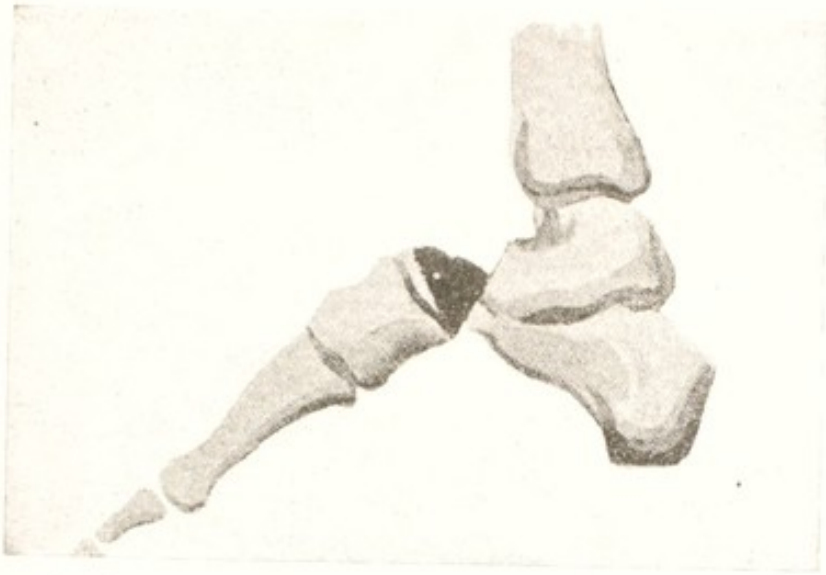


FIG. 526.—Jones' operation for talipes calcaneocavus. (Jones.) Stage I.

After both these operations protect the foot from strain during walking, by the use of a brace for several weeks.

5. **Jones' Operation in Paralytic Equinovalgus.**—A wedge of bone is removed from the inner surface of the shaft of the tibia, extending three-

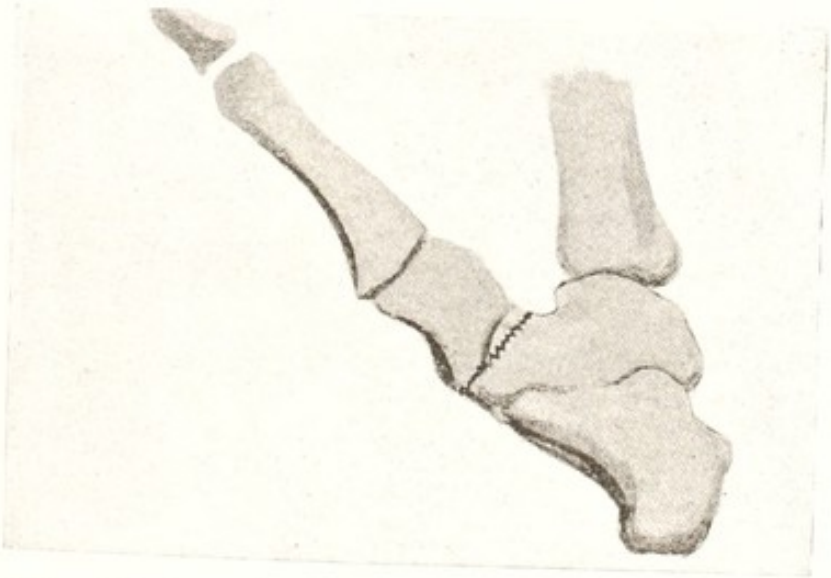


FIG. 527.—Jones' operation for talipes calcaneocavus. (Jones.) Stage I.

fourths of the distance through its shaft. The fibula is simultaneously divided. The foot is then put up in eversion for two weeks, when the bones are fractured at the site of previous osteotomy and the foot again immobilized in proper position with relation to the leg.

Other substitutes for arthrodesis are numerous, but lack of space prevents more than brief mention of these procedures.

6. **Hooking up the extensors of the foot** *en masse*, and shortening them by a loop has been recommended by Hoffa, but the procedure is ineffective, relapse occurring from stretching of the tendons.

7. **Periosteal flap** over the anterior surface of the joint (Cramer).

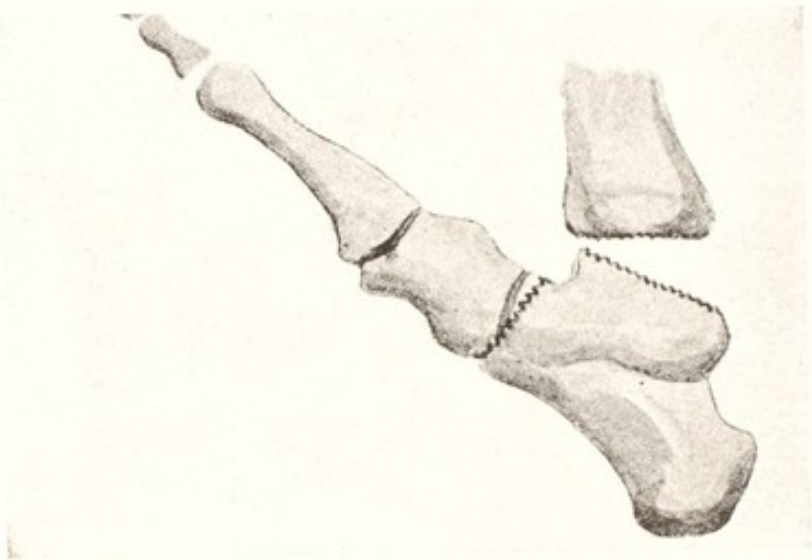


FIG. 528.—Jones' operation for talipes calcaneocavus. (Jones.) Stage II.

8. Codivilla advised the following procedure: (*a*) arthrodesis of the ankle; (*b*) anchoring a portion of the tendo Achillis to the dorsum of the foot; (*c*) suturing the tendon of the peroneus brevis to the bones of the leg, after drawing the tendon up from the plantar region; (*d*) shortening the anterior tendons.

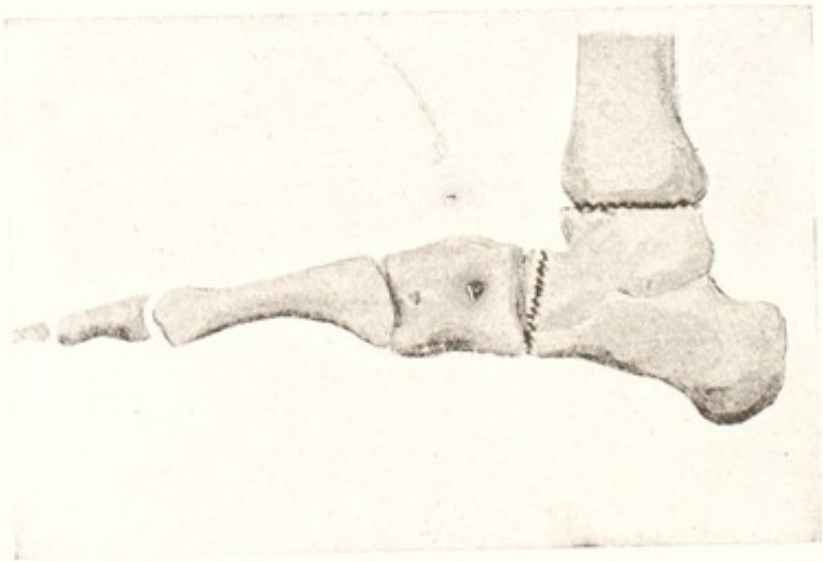


FIG. 529.—Jones' operation for talipes calcaneocavus. (Jones.) Stage II.

9. A **bone-peg** driven from the sole through the anterior end of the os calcis and body of the astragalus into the lower end of the tibia (Lexer). This operation cannot be too severely condemned. It does not produce arthrodesis because the joint cartilages are left intact. It is here repeated for

the sake of emphasis that because in the presence of cartilage osteoclasis is more pronounced than osteoblasis, healthy cartilage must never be left in the neighborhood of a bone-graft if one expects successful ankylosis to occur.

10. **Transverse Section of the Foot for Calcaneocavus** (G. G. Davis, Am. Jour. Orth. Surg., 1913, xi, No. 2, 231–42).—Good functional results are reported from Davis' operation, the technic of which is as follows:

On the outer side of the foot an incision about 2 inches long is made immediately below the tip of the malleolus and extending from the posterior edge of the malleolus forward. The long and short peroneal tendons then come into view and if it is desired to transplant them into the os calcis they are cut long and turned out of the way. If it is desired to preserve them intact, they can be loosened from their sheaths and held aside. Through this incision, with a chisel and periosteal elevator, the soft structures are raised from the bones anteriorly and posteriorly. Then a transverse horizontal section of the bone is made in the line of the skin incision, but passing entirely through the tarsus from the junction of the os calcis and astragalus posteriorly and emerging on the anterior surface of the cuneiform bones. In making this bone section, no attention is to be paid to the joints. It passes through the subastragaloid joint, cutting off parts of the upper portion of the os calcis and lower portion of the astragalus; it may clip off a piece of the upper portion of the cuboid, the scaphoid, and the upper portion of the cuneiform bones. These pieces may or may not be removed. As it is too difficult to loosen the foot sufficiently through this incision, another, about an inch long, is made on the inner side of the foot below the internal malleolus and over the sustentaculum tali. The tendon of the tibialis posterior is exposed and loosened from its sheath and held out of the way. The soft parts having been loosened from the bones anteriorly and posteriorly, the bone section is completed from the inner side. An effort is then made to push the foot back and the leg forward. If this cannot be done, then, with a chisel or other instrument, the soft parts are loosened still more until the foot can be displaced as far backward as is desired. Any loose pieces of cartilage or bone that may be present in the incision can be removed. If desired, the peroneal tendons can now be implanted into the os calcis, the external incision being prolonged backward or a posterior incision added if necessary. To hold the foot in its new position, chromic gut sutures may be passed from the tibia and fibula above to the tarsal bones below. The wounds are to be closed without drainage and the foot put up in plaster-of-Paris. A wooden sole plate is to be incorporated with the plaster and the foot is to be placed in a position of slight varus and equinus. While the plaster is setting, the foot is to be pressed firmly back and the leg bones forward as much as possible. If desired, at the end of a week or so, a window may be cut in the plaster and the wound inspected, or the plaster and dressing may be entirely renewed and this left on until eight weeks have elapsed. The plaster cast is then removed and a simple ankle brace substituted to keep the foot from everting under pressure. This may be worn for a few months until bony consolidation is complete and is to be followed by a suitable shoe (ref. Am. Jour. Orth. Surg., Oct., 1913, p. 240).

11. **Arthrodesis of the ankle and mediotarsal joints** with passage of the divided extensor and tibial tendons through a hole bored in the tibia, and fixation of the tendons to the fascia and periosteum of the tibia (Biesalski).

12. **Silk Ligaments.**—Silk has been used to extend tendons and to reinforce joints by forming artificial ligaments. The silk gradually becomes

surrounded by fibrous tissue. The disadvantages of the maneuver are that the silk gives way under tension, and there is difficulty in getting silk tendons to glide in the tissues.

In the use of silk ligaments in the ankle, there are three methods of procedure, viz.:

(*a*) *Periosteal Insertion.*—The crest of the tibia is incised, a flap of periosteum elevated, and the silk quilted up one side and down the other. Strands are passed down under the annular ligament by a flat probe with large eyelet and quilted into the periosteum at the desired point in the tarsus at the inner or outer side of the foot, or both, or at its middle point.

(*b*) *Bony Insertion.*—By means of the motor-drill, holes are bored transversely in the tibia and at the point of desired insertion in the foot. Strands of silk are passed between the two points and tied.

(*c*) *Subcutaneous Bony Insertion.*—Same as (*b*) without open incision.

The best of these three methods is incision and bony insertion of the silk through drill holes. Recumbency must be enjoined for two to three weeks following operation, and quiet maintained for two months or more. A plaster case is worn for a period of four to six months after operation, and a brace for an additional six months, and no weight-bearing is permitted until the end of that period.

Bartow and Plummer have advocated the use of internal articular silk ligaments for greater stability and to modify malposition, and they have developed a very ingenious technic and instruments for these operations. For further information the reader is referred to their writings.

13. **Tendon Shortening.**—The operative shortening of stretched or elongated tendons is unsatisfactory, because the condition recurs unless the abnormal mechanical factors which caused the stretching are relieved. Hence tendon shortening is rarely performed by the author and then only as an adjunct to some other procedure for stabilizing purposes or the improvement of muscle balance.

Robert Jones' Technic in Talipes Calcaneus.—The tendo Achillis is split longitudinally and the two halves are pulled apart with retractors, exposing the posterior capsule of the ankle-joint. With the foot in strong plantar flexion, the posterior capsule is reefed by over-and-over silk sutures. To shorten the tendo Achillis, the longitudinal cleft is so sutured as to render it transverse, thus taking up several inches of slack in the tendon, after which the foot is put in a plaster case in the equinus position. (Tendon transplantation or Jones' osteoplastic operation for calcaneocavus, *q.v.*, page 777, should be added to make this effective in stabilizing the foot.)

SUMMARY OF THE VARIOUS PROCEDURES FOR THE VARIOUS DEFORMITIES AND PARALYSES

I **Foot.**—1. *Talipes equinus:* Plastic tenotomy to lengthen tendo Achillis, with transplantation of extensor proprius hallucis to middle cuneiform or head of first metatarsal bone, with or without tenotomy, tenodesis, or arthrodesis.

2. *Talipes calcaneus* and *calcaneocavus:*
   (*a*) Astragalectomy (Whitman).
   (*b*) Jones' osteoplasty, two stages.

3. *Talipes varus:* Transplantation of anterior tibial or of extensor proprius hallucis to internal cuneiform (with or without astragalectomy, tenodesis, or arthrodesis).

4. *Talipes valgus:* Transplantation of peronei longus and brevis to inner side of superior surface of internal cuneiform, arthrodesis of astragaloscaphoid joint *always* done in conjunction.

II. **Knee.**—1. *Flexion deformity:* Open division of hamstrings.
2. *Knock-knee:* supracondylar osteotomy.
3. *Quadriceps paralysis:*
   (*a*) Transplantation of hamstrings (preferably biceps cruris with portion of head of fibula) to upper external edge of anterior surface of patella.
   (*b*) Sartorius transplanted for quadriceps.
4. *Genu recurvatum:* May do supracondylar osteotomy and rotate condyles of femur in extreme cases where tendon transplantation is not practicable.
5. *Flail knee:* Author's arthrodesis with implantation of inlay bone-graft.

III. **Hip.**—1. *Flexion deformity:*
   (*a*) Soutter's operation to lower anterior iliac spine with its attached muscles.
   (*b*) Vastus externus transplanted from great trochanter to crest of ilium.
2. *Recurring dislocation.*
   (*a*) Deepening acetabulum by bone-graft wedge (Albee).
   (*b*) Albee's arthrodesis.

IV. **Spine.**—*Paralytic scoliosis:* Correction by frame and plaster jacket, followed by bone-graft inlaid into spinous processes (Albee).

V. **Shoulder.**—*Recurring dislocation from deltoid paralysis:*
   (*a*) Reefing capsule of shoulder-joint.
   (*b*) Arthrodesis, with bone-graft through acromion into head of humerus (Albee).

VI. **Hand.**—1. *Paralysis of extensors of digit and hand:* Flexor carpi radialis attached to extensor tendons of digits and hand (Murphy).
2. *Paralysis of flexors of hand and fingers:* Extensor carpi radialis longus, extensor carpi radialis brevis, and brachioradialis, all these passed through perforations in both deep and superficial flexor tendons.

VII. **Wrist.**—*Flail-wrist:* Arthrodesis between ulna, radius and carpus, with bone-graft to increase fixation.

VIII. **Elbow.**—*Flail-elbow:*
   (*a*) Arthrodesis of elbow-joint.
   (*b*) Robert Jones' plastic operation on skin of flexor surface of elbow.

REFERENCES

Wilson, H. A.: "The Surgery of Anterior Poliomyelitis." Therapeutic Gazette, April, 1912.
Williams, T. A.: Jour. Am. Med. Ass'n, Jan. 21, 1911, p. 192.
Lange, F.: Am. Jour. Orthop. Surg., August, 1910, p. 8.
Lange, F.: Medical News, Jan. 9, 1892.
Rhoads, J. N.: Medical News, Nov. 28, 1891.
Anderson: London Lancet, July 2, 1891.
Keen, W. W.: London Lancet, Nov. 21, 1891, p. 1195.
Wilson, H. A.: Internat. Med. Mag., August, 1893.
Wilson, H. A.: Am. Medicine, ix, No. 18, May 6, 1905, p. 725.
Willetts: Brit. Med. Jour., May 31 and June 14, 1884.
Esmarch: Roberts' Surgery, p. 140.
Le Fort: Jour. Am. Med. Ass'n, Oct. 14, 1893.
Wolfler: Jour. Am. Med. Ass'n, Oct. 14, 1893.

LeDentu: Jour. Am. Med. Ass'n, Oct. 14, 1893.
Trnka: Jour. Am. Med. Ass'n, Oct. 14, 1893.
Czerny: Jour. Am. Med. Ass'n, Oct. 14, 1893.
Schwartz: Jour. Am. Med. Ass'n, Oct. 14, 1893.
Tillaux and Duplay: Jour. Am. Med. Ass'n, Oct. 14, 1893.
Elting, A. W.: Albany Medical Annals, April, 1902.
Duplay: Bull. de la Soc. de Chir., Paris, xi, 788, 1876.
Parrish: New York Med. Jour., 1892.
Drobnik: Zeit. f. Chir., xliii, 470.
Goldthwait: Trans. Am. Orthop. Ass'n, viii, 20.
Eve, F. S.: Brit. Med. Jour., Oct. 15, 1898.
Vulpius: Münch. med. Wochenschr., Apr. 25, 1899.
Lange: Münch. med. Wochenschr., Jan. 7, 1902.
Gluck: Practitioner, lxix, 360.
Kümmell: Practitioner, lxix, 360.
Müller, E.: Cent. f. Chir., Jan. 10, 1903, p. 40.
Tubby and Jones: "Surgery of Paralysis," 1903, p. 120.
Vulpius: Wiener Med. Presse, 1900, xli, p 1811.
Hoffa: Berliner klin. Woch., 1899, No. 30.
Hoffa: Am. Jour. Orthop. Surg., January, 1904, p. 48.
Goldthwait: Am. Jour. Orthop. Surg., January 1908, p. 271.
Osgood, R. B.: Boston Med. and Surg. Jour., June 30, 1910, p. 893.
"The Early History of Infantile Poliomyelitis." Jour. Am. Med. Ass'n, lxii, No. 6, Feb. 7, 1914.
Gibney and Wallace: "The Recent Epidemic of Poliomyelitis." Jour. Am. Med. Ass'n xlix, No. 25, Dec. 21, 1907.
Starr: "Epidemic Infantile Paralysis." Jour. Am. Med. Ass'n, li, No. 2, July 11, 1908.
Leegaard: Norsk. Mag. for laegevidensk, lxviii, 1241, 1907.
Colmar: Am. Jour. Med. Sci., 1843, p. 248.
Bergenholtz: Reported by Medin in Verhandl. des x. internat. med. Cong., Berlin, 1980.
Cordier: Lyon Med., Jan. 1, 1888.
Oxholm: Reported by Leegaard in Neurologisch. Zentralbl., 1890, p. 760.
Medin: Nordsk' med. Archiv, No. 1, 1896.
Putnam: Boston Med. and Surg. Jour., Nov. 23, 1893.
André: Compt.-rend. du Cong. de Méd. de Bordeaux, 1895, p. 352.
Caverly: New York Med. Rec., Dec. 1, 1894; also MacPhail, Brit. Med. Jour., 1895.
Sever, J. W: "Anterior Poliomyelitis." Interstate Med. Jour., xxi, serial, Nos. 5, 6, 7, 8, 1914.
Pieraccini: Lo Sperimentale, Sept. 21, 1895.
Bucelli: Il Policlinico, June 15, 1895.
Medin: Nordsk. Med. Archiv, No. 1, 1896.
Altman: Australasian Med. Gaz., 1897; Lancet, July 3, 1897.
Pasteur: Trans. Clinic Soc., 1897, p. 143.
Taylor: Phila. Med. Jour., Jan. 29, 1898.
Bondurant: Phila. Med. News, Aug. 18, 1901.
Buzzard: Lancet, Mar. 26, 1898.
Taylor: New York Med. Jour., 1897, p. 192.
Pleuss: Inaug. Dissert., Kiel, 1898.
Newmark: Philadelphia Med. News, Jan. 28, 1899.
Packard: Jour. Nerv. and Ment. Diseases, 1899, p. 210.
Auerbach: Jahrbuch fuer Kinderheilk., 1899; Neurologische Zentralbl., 1900, p. 466.
Zappert: Jahrbuch fuer Kinderheilk., p. 126.
Wickman: Heine-Medinischer Krankheit, Berlin, 1907, p. 148.
Leegaard: Norsk. Mag. for Laegevidensk., p. 377, 1901.
Chapin: Archiv Ped., 1900, p. 807.
McKenzie: New York Med. Rec., lxii, 528, 1902.
Painter: Trans. Amer. Orthop. Ass'n, p. 414, 1902.
Woods: Occidental Med. Times, xvii, 77.
Wickman: *Loc. cit.*, p. 149.
Lorenzelli: La Pediatria, 1904, 428.
Blackhall: Australasian Med. Gaz., 1904, p. 347.
Ham: Australasian Med. Gaz., xxiv, p. 193.
Nannestad: Norsk. Mag. for Laegevidensk., lxvii, 409, 1906.
Platon: Tidsskr. for den norske Laegeforening, 1905, p. 601.
Giersvold: Norsk. Mag. for Laegevidensk., 1905, p. 1280; Jahrbuch fuer Kinderheilk. lxiv, 235, 1906.
Wickman: *Loc. cit.*, p. 150.

WICKMAN: *Loc. cit.*, p. 262.
LUNDGREN: Hygiea, 1906, p. 1089.
TERRIBERRY: Long Island Med. Jour., December, 1907.
GRIFFIN: Jour. Mich. State Med. Ass'n, Feb., 1908, p. 142.
FREE: Jour. Nerv. and Ment. Dis., p. 250, April, 1908.
"Minnesota State Medical Ass'n Symposium." Jour. Am. Med. Ass'n, liii, No. 21, Nov. 20, 1909.
COLLINS AND ROMEISER: "An Analysis of 500 cases of Spinal Infantile Paralysis." Jour. Am. Med. Ass'n, vol. L., No. 22, May 30, 1908.
LOVETT: "The Occurrence of Infantile Paralysis in Massachusetts in 1909." Month. Bull. Mass. State Board of Health, June, 1910.
"Epidemic in Westphalia." Jour. Am. Med. Ass'n, liii, No. 19, p. 1575, Nov. 6, 1909.
SHIDLER: "The Epidemic of Spinal Disease in Nebraska." Jour. Am. Med. Ass'n, liv, No. 4, Jan. 22, 1910.
MCCLANAHAN: "A Brief Report of the Nebraska Epidemic of Poliomyelitis." Jour. Am. Med. Ass'n, lv, No. 14, Oct. 1, 1910.
MANNING: "A Partial Report of the Epidemic of Acute Anterior Poliomyelitis in the State of Wisconsin during 1907–1908." Wisconsin Med. Jour., April, 1909.
LOVETT: "The Occurrence of Infantile Paralysis in Massachusetts in 1908." Boston Med. and Surg. Jour., July 22, 1909.
EMERSON: "An Epidemic of Infantile Paralysis in Massachusetts in 1908." Boston Med. and Surg. Jour., July 22, 1909.
KRAMER: "Epidemic Poliomyelitis." Med. Klin., Dec. 26, 1909.
KOPLIK: "Anterior Poliomyelitis." An Epidemic. Archiv. Ped., p. 321, May, 1909.
KERR: "Acute Anterior Poliomyelitis." Long Island Med. Jour., November, 1909.
WOLLENWEBER: "Observations on the Occurrence of Epidemic Infantile Paralysis." Dortmund Zeitschr. fuer Medizinalbeamt, No. 21, 1909.
"The Increase of Acute Epidemic Infantile Paralysis in the Vicinity of Giessen." Berl. klin. Wochenschr., Dec. 27, 1909.
RECKZEH: "Acute Spinal Infantile Paralysis in the Rhenish-Westphalian Industrial District." Med. klin., No. 45, 1909.
TREVES: "An Epidemic of Acute Poliomyelitis." Brain, 1909.
EICHELBERG: "Spinal Paralysis in Children." Deutsch. med., xxxvi, No. 3, 1910.
PEIPER: "Appearance of Spinal Paralysis in Vorpommern." Deutsch. med. Wochenschr., xxxvi, No. 9, 1910.
LORD: "The 1909 Epidemic of Acute Anterior Poliomyelitis (Epidemic Spinal Paralysis) in Nebraska, 1909." Jour. Am. Orthop. Ass'n, viii, No. 3, February, 1911.
NETTER: "Epidemic of Poliomyelitis in France and Elsewhere." Bull. Academy of Med., lxiii, No. 21, May 31, 1910.
"Studies in Infantile Paralysis during 1910." By the Washington (State) Board of Health. Published by the State.
"Infantile Paralysis in Massachusetts during 1910." (Reprint from the monthly Bulletins of the Mass. State Board of Health for 1911.)
COLLINS: "The Epidemiology of Poliomyelitis." Jour. Am. Med. Ass'n, liv, No. 24, June 11, 1910.
O'REILLY: "A Report of the Prevalence of Infantile Paralysis in Missouri." Jour. Mo. State Med. Ass'n, November, 1911.
GUNDRUM: "Acute Poliomyelitis in California." Jour. Am. Med. Ass'n., lviii, No. 4, Jan. 27, 1912.
SHERMAN: Occid. Med. Times, p. 445, August, 1897.
NEWMARK: Med. News, lxxiv, p. 101, 1899.
WOODS: Occid. Med. Times, p. 77, March, 1903.
FLEISCHNER: Calif. State Jour. Med., September, 1911.
LOVETT: "The Work of the Massachusetts State Board of Health in the Investigation of Infantile Paralysis." Boston Med. and Surg. Jour., clxviii, No. 4, Jan. 23, 1913.
BRUNO: "Domestic Animals and Epidemic Poliomyelitis." Münch med. Wochenschr., vol. lx, No. 36, Sept. 9, 1913.
ROTH: "Epidemics of Poliomyelitis." Lancet, Nov. 15, 1913.
Monthly Bulletin Ohio State Board of Health, vol. iv, No. 1, p. 23, January, 1914.
HARBITZ AND SCHEEL: "Epidemic Acute Poliomyelitis in Norway in the Years 1903 to 1906." Jour. Am. Med. Ass'n, xlix, No. 17, October 26, 1907.
HOUSE: "Acute Anterior Poliomyelitis." Northwest. Med., September, 1910.
Bulletin of the Kansas State Board of Health, vi, No. 7, July, 1910.
MAY: "An Investigation as to the Occurrence in Massachusetts of Paralysis in the Lower Animals and Fowls." Monthly Bull. State Board of Health, Mass., vol. 0, No. 0, June, 1911.
LOVETT: "The Occurrence of Infantile Paralysis in the United States and Canada in 1910." Amer. Jour. Dis. of Children, vol. 2, August, 1911.

FERREIRA: "Epidemic Poliomyelitis in Brazil." Bull. de la Soc. de Ped., No. 7, October, 1913.
DIXON AND KARSNER: "Epidemiologic and Etiologic Studies of Acute Poliomyelitis in Pennsylvania." Am. Jour. Dis. of Children, vol. 2, October, 1911.
EDITORIAL: "Infantile Paralysis in 1910–1911." Jour. Am. Med. Ass'n, lviii, No. 18, p. 1379, May 4, 1912.
BRUES AND SHEPPARD: "The Possible Etiological Relation of Certain Biting Insects to the Spread of Infantile Paralysis." Jour. of Economic Entomology, vol. 5, No. 4, August, 1912.
LUST AND ROSENBERG: "Etiology of Epidemic Poliomyelitis." Münch. med. Wochenschr., lxi, No. 3, Jan. 20, 1914.
PIERSON: "Epidemic Poliomyelitis and Distemper of Dogs." Jour. Am. Med. Ass'n, lxii, No. 9, Feb. 28, 1914.
HARBITZ AND SCHEEL: "The Microbe of Poliomyelitis." Jour. Am. Med. Ass'n, vol. l, No. 4, Jan. 25, 1908.
EDITORIAL: Journal Am. Med. Ass'n, lii, No. 25, June 19, 1909.
FLEXNER AND LEWIS: "The Transmission of Acute Poliomyelitis to Monkeys." Jour. Am. Med. Ass'n, liii, No. 20, 1909.
FLEXNER AND LEWIS: "The Nature of the Virus of Epidemic Poliomyelitis." Jour. Am. Med. Ass'n, liii, No. 25, 2095, 1909.
FLEXNER AND LEWIS: "Experimental Epidemic Poliomyelitis in Monkeys." Jour. Am. Med. Ass'n, liv, No. 14, April 2, 1910.
FLEXNER AND LEWIS: "Experimental Poliomyelitis in Monkeys." Jour. Am. Med. Ass'n, May 18, 1910, p. 1780.
MEINICKE: "Experimental Investigations of Acute Epidemic Paralysis in Children." Deutsch. med. Wochenschr., xxxvi, No. 15, 1909.
KRAMER AND MEINICKE: "Etiology of Acute Epidemic Paralysis in Children." Deutsch med. Wochenschr., xxxvi, No. 14, 1910.
BONHOFF: "Etiology of Acute Poliomyelitis." Deutsch. med. Wochenschr., xxxvi, No. 12, 1910.
LEVADITI: "Attempts to Cultivate the Micro-organisms of Infantile Paralysis." La Presse Méd., No. 6, 1910.
LANDSTEINER AND LEVADITI: "An Experimental Study of Acute Poliomyelitis." Annales de l'Institut Pasteur, xxiv, No. 11, November, 1910.
STRAUSS: "Inoculations of Nasal Secretion from Patients with Acute Poliomyelitis." Jour. Am. Med. Ass'n, Apr. 22, 1911.
KNOPFELMACHER: "Transmission of Acute Anterior Poliomyelitis to Monkeys." Med. klin., xliv, Oct. 31, 1909.
LEINER AND WEISNER: "Experimental Research on Acute Anterior Poliomyelitis." Wein. klin. Wochenschr., xxiii, No. 7, Dec. 9, 1909.
DUVAL: "Anterior Poliomyelitis; Etiology and Pathology." New Orleans Med. and Surg. Jour., March, 1910.
STRAUS AND HUNTOON: "Experimental Studies on the Etiology of Acute Poliomyelitis." New York Med. Jour., Jan. 8, 1910.
KRAUSE AND MEINICKE: "The Etiology of Acute Epidemic Infantile Paralysis." Deutsch. med. Wochenschr., Oct. 21, 1909.
RUSSEL: "Acute Anterior Poliomyelitis, with Autopsy." Montreal Med. Jour., December, 1909.
FLEXNER AND LEWIS: "Epidemic Poliomyelitis in Monkeys." Jour. Am. Med. Ass'n, liv, No. 1, Jan. 1, 1910.
LUCAS: "The Diagnosis of Infantile Paralysis in the Prodromal and Early Acute Stage, as Found in the Experimental Study of Acute Poliomyelitis in Monkeys." Trans. Mass. Med. Soc., June, 1910.
GAY AND LUCAS: "Anterior Poliomyelitis Methods of Diagnosis from Spinal Fluid and Blood in Monkeys and in Human Beings." Archiv Int. Med., vol. 6, September, 1910.
PROESCHER: "Etiology of Poliomyelitis." New York Med. Jour., Dec. 17, 1910.
FLEXNER AND LEWIS: "Epidemic Poliomyelitis in Monkeys." Jour. Am. Med. Ass'n, liv, No. 7, Feb. 12, 1910.
SKOOG: "Acute Poliomyelitis." Weekly Bull. Jackson County, Mo., Med. Soc., vol. 5, No. 1, Jan. 6, 1911.
OSGOOD AND LUCAS: "Transmission Experiments with the Virus of Poliomyelitis." Jour. Am. Med. Ass'n, lvi, Feb. 18, 1911.
ANDERSON AND FROST: "Abortive Cases of Poliomyelitis." Jour. Am. Med. Ass'n, lvi, No. 9, Mar. 4, 1911.
NEUSTAEDER AND THRO: "Experimental Poliomyelitis." New York Med. Jour., Sept. 23, 1911.

"Report of Committee on Methods for the Control of Epidemic Poliomyelitis." Jour. Am. Med. Ass'n, lvii, No. 10, Oct. 14, 1911.

FLEXNER AND CLARK: "Epidemic Poliomyelitis." Jour. Am. Med. Ass'n, lvii, No. 21, Nov. 18, 1911.

LUCAS AND OSGOOD: "Experiments as to the Protective Value of Certain Specific Sera and Vaccines against the Virus of Poliomyelitis." Mass. State Board of Health, 1911.

PETTERSSON: "Transmission of Poliomyelitis." Jour. Am. Med. Ass'n, lix, No. 14, Oct. 5, 1912.

FLEXNER, CLARK, AND DOCHEZ: "Experimental Poliomyelitis in Monkeys. The Survival of the Poliomyelitis Virus in the Stomach and Intestine." Jour. Am. Med. Ass'n, vol. lix, No. 4, July 27, 1912.

ROSENAU AND BRUES: "Some Experimental Observations upon Monkeys Concerning the Transmission of Poliomyelitis through the Agency of Stomoxys Calcitrans." Monthly Bull. Mass. State Board of Health, vol. 7, No. 9, September, 1912.

FLEXNER: "The Mode of Infection in Epidemic Poliomyelitis." Jour. Am. Med. Ass'n, lix, No. 15, Oct. 12, 1912.

"Transmission of Poliomyelitis by Means of the Stable Fly (Stomoxys Calcitrans)." . . . Public Health Reports, Oct. 25, 1912, p. 1733.

LANGHORST: "Possible Transmission of Poliomyelitis through the Dog." Jour. Am. Med. Ass'n, lix, No. 26, Dec. 28, 1912.

HOWARD AND CLARK: "Experiments on Insect Transmission of the Virus of Poliomyelitis." Jour. Exper. Med., xvi, No. 6, December, 1912.

FLEXNER, CLARK, AND FRASER: "Epidemic Poliomyelitis. Passive Human Carriage of the Virus of Poliomyelitis." Jour. Am. Med. Ass'n, lx, No. 3, Jan. 18, 1913.

FLEXNER AND NOGUCHI: "Experiments on the Cultivation of the Virus of Poliomyelitis." Jour. Am. Med. Ass'n, lx, No. 5, Feb. 1, 1913.

MCINTOSH AND TURNBULL: "Transmission to Monkeys of Virus Obtained from English Cases of Poliomyelitis." Lancet, Feb. 22, 1913.

LUCAS AND OSGOOD: "Transmission Experiments with the Virus of Poliomyelitis." Jour. Am. Med. Ass'n, lx, May 24, 1913.

PROESCHER: "Poliomyelitis and Variola." New York Med. Jour., xcvii, No. 15, Apr. 12, 1913.

ROSENAU: "The Mode of Transmission of Poliomyelitis." Trans. Mass. Med. Soc., 1913, p. 53.

KLING, WERNSTEDT, AND PETTERSSON: "Duration of Infectiousness of Secretions in Epidemic Poliomyelitis." Zeitsch. f. Immunitætsfors., xvi, No. 17, 1913.

SAWYER AND HERMS: "Attempts to Transmit Poliomyelitis by Means of the Stable Fly (Stomoxys Calcitrans)." Jour. Am. Med. Ass'n, lxi, No. 7, Aug. 16, 1913.

EDITORIAL: "The Hypothesis of the Self-limitation of Poliomyelitis." Jour. Am. Med. Ass'n, lxi, No. 21, Nov. 22, 1913.

DUBOIS, NEAL, AND ZINGHER: "Experimental Studies in Poliomyelitis." Jour. Am. Med. Ass'n, lxii, No. 1, Jan. 3, 1914.

FLEXNER: "Some Problems in Infection and Its Control." Science, Nov. 22, 1912.

PASTEUR, FOULERTTON, AND MACCORMAC: "Case of Acute Poliomyelitis Associated with Diplococcal Infection of the Spinal Sac." Lancet, Feb. 15, 1908.

LANGER: "School as a Factor in Acute Poliomyelitis." Jahrbuch f. Kinderkeilk, vol. lxxvi, No. 2, August, 1912.

KLING: "Epidemic Poliomyelitis." Wien. klin. Wochenschr., xxvi, No. 2, Jan. 10, 1913.

HAYWOOD: "Acute Anterior Poliomyelitis Following Bite of Dog Infected with Rabies." New York Med. Jour., Apr. 12, 1913.

FLEXNER, CLARK, AND AMOSS: "A Contribution to the Epidemiology of Poliomyelitis." Jour. Exper. Med., xix, No. 2, Feb. 1, 1914.

FLEXNER, CLARK, AND AMOSS: "A Contribution to the Pathology of Epidemic Poliomyelitis." Jour. Exper. Med., xix, No. 2, Feb. 1, 1914.

AMOSS: "A Note on the Etiology of Epidemic Poliomyelitis." Jour. Exper. Med., vol. xix, No. 2, Feb. 1, 1914.

CLARK AND AMOSS: "Intraspinous Infection in Experimental Poliomyelitis." Jour. Exper. Med., xix, No. 2, Feb. 1, 1914.

WALTON: "Anterior Poliomyelitis in the Adult, with Illustrative Cases." Boston Med. and Surg. Jour., Nov. 28, 1907.

"Symposium on Poliomyelitis." Med. Soc. of the State of Pennsylvania, September, 1908. Jour. Am. Med. Ass'n, li, No. 19, Nov. 7, 1908.

CLIMENKO: "Clinical Study of the Etiology of Acute Anterior Poliomyelitis." Long Island Med., Jour., December, 1907.

AGER: "Symptoms in the Acute Stage of Anterior Poliomyelitis." Long Island Med. Jour., December, 1907.

BROWNING: "Sensory Elements in Anterior Poliomyelitis." Long Island Med. Jour. December, 1907.

LOVETT AND LUCAS: "A study of Six Hundred and Thirty-five Cases of Infantile Paralysis." Jour. Am. Med. Ass'n, li, Nov. 14, 1908.
LHERMITTE: "Multiplicity of Symptoms and Lesions of So-called Epidemic Anterior Poliomyelitis." Semaine Med., Nov. 24, 1909.
BALL: "The New Disease—Epidemic Paralysis." St. Paul Med. Jour., December, 1909.
MORSE: "Infantile Paralysis—Spinal Form." Am. Jour. Dis. Children, Vol. 2, August, 1911.
Anterior Poliomyelitis—Infantile Paralysis." Jour. Am. Med. Ass'n, lvii, No. 9, Aug. 26, 1911.
FRISSELL: "Report of a Case of Anterior Poliomyelitis." Jour. Am. Med. Ass'n, lvi, No. 9, March, 1911.
KOPLIK: "Cerebral Forms of Poliomyelitis and Their Diagnosis from Forms of Meningitis." Am. Jour. Med. Sci., June, 1911.
MORSE: "Acute Poliomyelo-encephalitis (Infantile Paralysis)." Boston Med. and Surg. Jour., clxiv, No. 4, Jan. 12, 1911.
MUELLER: "Epidemic Poliomyelitis with Bulbar Symptoms." Münch. med. Wochenschr., lix, No. 4, Jan. 23, 1912.
COLLIVER: "A New Preparalytic Symptom of Poliomyelitis." Jour. Am. Med. Ass'n, lx, No. 11, March 15, 1913.
SHARP: "The Differential Diagnosis Between Acute Epidemic Poliomyelitis and Affections Having Poliomyelitis Syndromes." Interstate Med. Jour., 1913, p. 824.
WACHENHEIM: "Atypical Infantile Paralysis." New York Med. Jour., Nov. 8, 1913.
MONRAD: "Diagnosis of Epidemic Poliomyelitis and Treament in Acute Stage." Ugeskrift for Laeger, lxxvi, No. 2, Jan. 8, 1914.
CLARK: "Treatment of the Acute Stage of Anterior Poliomyelitis." Long Island Med. Jour., December, 1907.
MACKENZIE: "Treatment of Infantile Paralysis of the Upper Limb." Intercolonial Med. Jour. of Australia," May, 1909.
TAYLOR: "Practical Points in the Management of Poliomyelitis and its Sequelæ." Med. Rec., Oct. 15, 1910.
LANGE: "The Orthopedic Treatment of Spinal Paralysis." Am. Jour. Orthop. Surg., August, 1910.
MYERS: "Some General Considerations in the Treatment of Infantile Paralysis." St. Luke's Hospital Report, 1910.
FEISS: "Address on Infantile Paralysis." Cleveland Med. Jour., x, February, 1911.
O'REILLY: "Treatment of Anterior Poliomyelitis." Jour. Missouri State Med. Ass'n, April, 1913.
LOVETT: "Principles of the Treatment of Infantile Paralysis." Jour. Am. Med. Ass'n, lxii, Jan. 24, 1914.
EDITORIAL: "Hexamethylenamin." Jour. Am. Med. Ass'n, lxii, No. 1, Jan. 3, 1914.
BERRY AND VAN DENBERGH: "Anterior Poliomyelitis and its Treatment by Muscle Training." Albany Med. Annals, April, 1910.
WRIGHT: "Muscle Training in the Treatment of Infantile Paralysis." Boston Med. and Surg. Jour., clxvii, No. 7, October, 1912.
FRAUENTHAL: "The Treatment of Paralysis of Anterior Poliomyelitis." Jour. Am. Med. Ass'n, lxi, No. 25, Dec. 20, 1913.
SACHS: "Muscle Transplantation in the Treatment of Infantile Paralysis." Deutsche. med. Wochenschr., No. 37, Sept. 13, 1906.
LONGFELLNER AND FROHSE: "Operative Treatment of Deltoid Paralysis." Med. klin., No. 34, Aug. 22, 1909.
BRADFORD: "The Operative Treatment of Paralysis of the Shoulder Following Anterior Poliomyelitis." Amer. Jour. Orthop. Surg., viii, No. 1, August, 1910.
MCCURDY: "Tendon Transplantation and Grafting for Paralytic Deformities." New York Med. Jour., July 21, 1906.
KILIANI: "An Operation for Paralytic Shoulder-joint Due to Infantile Paralysis." Annals Surg., January, 1910.
STRUNSKY: "Treatment of Chronic Infantile Paralysis." Am. Jour. Dis. Children, April, 1911.
LEWIS AND DAVIS: "Experimental Direct Transplantation of Tendon and Fascia." Jour. Am. Med. Ass'n, lvii, No. 7, Aug. 12, 1911.
DAVIS: "Treatment of Poliomyelitis by Operative Measures." N. Y. Med. Jour., Jan. 3, 1914.
BARTOW AND PLUMMER: "The Use of Intra-Articular Silk Ligaments for Fixation of Loose Joints in the Residual Paralysis of Anterior Poliomyelitis." Buffalo Med. Jour., January, 1912.
WILSON: "The Surgery of Anterior Poliomyelitis." Therapeutic Gazette, April, 1912.
SEVER: "Tendon Transplantation and Silk Inserts." Jour. Am. Med. Ass'n, lviii, May, 1912.

BARTOW: "Shoulder and Arm Paralysis of Poliomyelitis." New York Med. Jour., May 3, 1913.
RICH: "Limitations of Lange's Silk Ligaments in Paralytic Surgery and Substitutions therefor." Jour. Am. Med. Ass'n, lxi, No. 18, Nov. 1, 1913.
SEVER: "The Causes and Treatment of Paralytic Dislocations and Subluxations of the Hip-joint." Boston Med. and Surg. Jour., clxv, No. 9, Aug. 31, 1911.
MAGRUDER: "Infantile Paralysis." New York Med. Jour., Nov. 8, 1913.
ALLISON AND SCHWAB: "Muscle Group Isolation and Nerve Anastomosis in the Treatment of the Paralysis of the Extremities." Surg., Gyn. and Obst., 1911, p. 240.
OSGOOD: "Review of the Evidence in Support of the Value of Nerve Grafting in Infantile Paralysis." Boston Med. and Surg. Jour., clxii, No. 26, June 30, 1910.
FEISS: "Recent Experimental Work on the 'Fusion' of Nerves and its Practical Bearing on Infantile Paralysis." Boston Med. and Surg. Jour., clxiv, No. 19, May 11, 1911.
DUROUX: "Clinical Results of Nerve Grafting." Lyon Chir., viii, No. 6, December, 1912.
JONES: "Arthrodesis and Tendon Transplantation." Brit. Med. Jour., March 28, 1908.
MACAUSLAND AND WOOD: "Arthrodesis and Its Application in Infantile Paralysis of the Foot." Boston Med. and Surg. Jour., clxii, No. 25, June 23, 1910.
SOULE: "Arthrodesis of Some of the Smaller Joints in the Treatment of Paralytic and Acquired Deformities." Jour. Am. Med. Ass'n, lviii, No. 19, May 11, 1912.
RYERSON: "The Surgery of Infantile Paralysis." Jour. Am. Med. Ass'n, lxi, No. 18 Nov. 1, 1913.
COMER AND BASHALL: "Amputation in Infantile Paralysis." Lancet, Sept. 28, 1912.
SCHWANDIN: "Ultimate Outcome of Arthrodesis for Paralyzed Ankle." Arch. f. klin. Chir., vol. ci, No. 4, July 26, 1913; Jour. Am. Med. Ass'n, lxi, No. 9, Aug. 30, 1913.
LAAN: "When Is Arthrodesis Required in Epidemic Poliomyelitis?" Nederl. Tijdschr. voor Geneeskunde, ii, No. 19; Abst. Jour. Am. Med. Ass'n, lxii, No. 8, Feb. 21, 1914.
FLEXNER, S.: "Epidemic Poliomyelitis—Mode of Infection and Etiology." Am. Jour. Dis. Children, May, 1915.
SHY, D. E.: "Poliomyelitis, with Cases." Jour. Missouri State Med. Ass'n, May, 1915.
LOVETT, R. W.: "Treatment of Infantile Paralysis; Based on a study of the Vermont Epidemic of 1914." Jour. Am. Med. Ass'n, June 26, 1915.
LANGERMANN: "Infantile Paralysis in Hesse, 1909–1914." Zeitschr. f. Hyg. u. Infect., lxxx, 1.
FLEXNER AND AMOSS: "Poliomyelitis Virus, Diffusion and Survival of." Jour. Exp. Med., May, 1915.
FLEXNER, S.: "Microbic Cause and Manner of Infection of Poliomyelitis." Bull. Johns Hopkins Hosp., May, 1915.
SYLVESTER, P.: "Anterior Poliomyelitis—Case with Multiple Paralyses." Boston Med. and Surg. Jour., Sept. 16, 1915.
ABRAMSON, H. L.: "Spinal Fluid in Poliomyelitis and Its Differentiation from Fluids of Other Diseases. Am. Jour. Dis. Children, November, 1915.
MARTIN AND LOVETT: "Method of Testing Muscular Strength in Infantile Paralysis." Jour. Am. Med. Ass'n, Oct. 30, 1915.
TRUSLOW, W.: "Prevention of Deformities in Poliomyelitis." Long Island Med. Jour., November, 1915.
HASSIN, LUKAS, AND BROWN: "Roentgenographic Bone Changes in Poliomyelitis." Jour. Am. Med. Ass'n, Oct. 23, 1915.
FRANCISCO, C. B.: "Early Management of Anterior Poliomyelitis." Jour. Missouri State Med. Ass'n, January, 1916.
TAYLOR, R. T.: "Infantile Paralysis." Practical Medicine, Jan. 29, 1916.
ORR, H. W.: "Character of Orthopedic Treatment Necessary During Period of Spontaneous Improvement after Infantile Paralysis." Lancet-Clinic, Feb. 26, 1916.
LOVETT AND MARTIN: "Aspects of Infantile Paralysis, with description of a Method of Muscle Testing." Jour. Am. Med. Ass'n, March 4, 1916.
HARRINGTON AND TEACHER: "Subacute Anterior Poliomyelitis." Glasgow Med. Jour., May, 1916.
BARBER, W. L.: "The Diagnosis and Treatment of Poliomyelitis." Med. Record, July 22, 1916.
FRASER, F. B.: "Epidemic Poliomyelitis. Symptomatology and Diagnosis in the Acute Stages." Boston Med. and Surg. Jour., July 20, 1916.
"Acute Anterior Poliomyelitis." Journal American Medical Ass'n, July 8, 1916.
"Acute Anterior Poliomyelitis"—Editorial. Medical Record, July 8, 1916.
SPINGARN, A.: "Poliomyelitis in Brooklyn." N. Y. Med. Record, July 8, 1916.
FLEXNER, S.: "The Nature, Manner of Conveyance, and Means of Prevention of Infantile Paralysis." Jour. Am. Med. Ass'n, July 22, 1916.
WILE, IRA S.: "The Communicability of Poliomyelitis." Am. Medicine, July, 1916.
EDITORIAL: "Poliomyelitis Epidemic." Am. Medicine, July, 1916.

CHAPTER XXII

SPASTIC PARALYSIS, NEUROPATHIES AND MYOPATHIES, AND THEIR DEFORMITIES

(A) SPASTIC PARALYSIS OF INFANCY AND CHILDHOOD

Synonyms.—Cerebral paralysis of childhood; Little's disease.

Varieties.—Spastic paraplegia; infantile hemiplegia; monoplegia; cerebral diplegia.

The incidence of the lesion and its effects vary, viz.:



FIG. 530.—Two cases of severe spastic paralysis of different types. (Bradford and Lovett.)

(*a*)[1] *Cerebral diplegia*, a bilateral cerebral lesion; affects the corresponding parts of both sides of the body; (*b*) *hemiplegia*, affects one-half the body;

[1] "Little's disease" is a term applied only to bilateral (diplegic) and not to hemiplegic or monoplegic cases.

(*c*) *monoplegia*, involves one limb only; (*d*) *paraplegia*, paralysis of the lower part of the body, due to a lesion of the spinal cord and not of the brain (Fig. 530).

Spastic paralysis and its deformities are very commonly encountered in orthopedic practice and are second in importance only to anterior poliomyelitis. The disease is characterized by motor weakness and inco-ordination, stiffness and loss of control.

Clinical Types.—(*a*) In *cerebral diplegia*, although rigidity and paralysis co-exist, rigidity is the more marked feature; (*b*) *hemiplegia*, paralysis preponderates, rigidity is a secondary feature, and the arm is most seriously affected, (*c*) *congenital chorea* (bilateral athetosis) (choreic diplegia), rare; athetosis affects the tongue most seriously, but may be evident in the trunk and limbs; convulsions are usually insignificant, and the mentality is good.

Etiology.—The cerebral paralysis of childhood is either congenital or acquired. Tubby (Deformities, including Diseases of the Bones and Joints, Macmillan, 1912, vol. ii, 1912, p. 721) has classified these cases from the etiological standpoint, as follows:

1. Paralysis of intra-uterine origin:
   (*a*) Large cerebral defects, such as porencephaly and absence of the gray matter.
   (*b*) Hemorrhage and softening.
   (*c*) Microcephaly.
   (*d*) Syphilis.
   (*e*) Specific fevers.
   (*f*) Eclampsia and convulsions.
   (*g*) Injury.
   (*h*) Repeated pregnancies. There can be no doubt that cerebral paralysis more often affects the younger children of a large family than the older ones. Consanguinity of the parents has also been noticed.
2. Traumatism occurring during labor, *e.g.*, injuries to the head produced by forceps and by prolonged labor, leading to laceration of the vessels of the brain. The hemorrhage is very seldom intracerebral; it is either on the surface of the cortex or into the arachnoid cavity. It leads to meningo-encephalitis chronica, cysts, and porencephaly.
3. Paralysis acquired after birth:
   (*a*) Meningeal hemorrhage; embolism; thrombosis from syphilitic arteritis; and in association with marasmic conditions. As a result of them, vascular lesions, cysts, softening, atrophy, and sclerosis follow.
   (*b*) Chronic meningitis.
   (*c*) Hydrocephalus.
   (*d*) Primary encephalitis (Strümpell).

Clinical Features.—*Cardinal Signs.*—(*a*) Muscular rigidity increased on active and passive movement and disappearing under anesthesia; (*b*) paresis; (*c*) ataxic movement; (*d*) contractures; (*e*) increase of deep reflexes; (*f*) unequal growth of limbs; (*g*) occasionally amentia. Spasticity of the limbs results from exaggerated reflexes and impairment of inhibition of the higher cerebral centers; distortion of the limb follows spasticity and eventually results in fixed deformity, the result of tissue changes (Fig. 531); as a rule, the muscles are not atrophied and the circulation is very little impaired; shortening of the limb occasionally occurs, but never to the degree observed in anterior poliomyelitis.

In the severest diplegic cases, rigidity is extreme, the patient being "stiff

as a board" throughout the body. In other cases, rigidity of the extensors of the thighs and legs may prevent the patient from sitting. In still other cases the hands and arms are in normal condition, while spasm of the legs prevents walking. Scoliosis occasionally occurs.

The patient presents a typical picture in walking. He walks on the toes, with the heels raised, the knees flexed and closely approximated, the femora rotated inward, the body flexed on the hips. Spastic contraction (with eventual structural shortening) affects the flexors of the hips, the abductors of the femora (finally producing "scissors deformity"), the flexors of the legs, and the plantar flexors of the feet.



FIG. 531.—Typical case of spastic paraplegia, with knees flexed because of the predominance of the constantly contracting flexors over the extensors.

The characteristic attitude of the upper extremity is flexion at the elbow, strong pronation of the forearm, complete flexion of the hand, adduction of the thumb which is contracted into the palm, and flexion of the fingers. The affected arm is atrophied, shortened, and its surface temperature lowered. Its movements are clumsy and may be associated with athetosis. Cutaneous sensation is usually unimpaired.

Mental Condition.—Some cerebral diplegics are hopeless idiots, while others display varying grades of defective mentality. Amentia is more marked in the paraplegics and diplegics than in the hemiplegics. These aments are of two types: placid and irritable, in both of which memory for abstract things (figures, dates, etc.) remains good. The irritable type usually improves upon relief of the physical deformity.

Attendant phenomena in the subjects of spastic paralysis are delayed speech until the fourth or fifth year, or absence of articulation. Speech gradually improves, but some defect frequently remains, such as a lisp or a hesitation. Convergent strabismus is present in a half to a third of the cases. More or less dysphagia is not uncommon. Convulsions are frequent in the severer cases.

Prognosis.—Cerebral diplegia of the severe form is rapidly or slowly fatal, especially if general rigidity is excessive. In paraplegia, or in the event of only slight general rigidity, the case may improve.

TREATMENT

A considerable proportion of the cases are benefited by treatment consisting of mechanical, operative, and re-educational measures. No relief can be expected from medication.

Indications for Operative Treatment.—Operation is indicated in a child or adolescent suffering from secondary contractures due to spasm of the flexors, in whom mental development is fair and who has been free from convulsions for three or four years and is amenable to the discipline and muscular re-education which must necessarily follow operation.

Contra-indications to Operative Treatment.—Idiocy, microcephaly, diplegia of violently irritable type, attended by convulsions and athetosis; patients with incontinent sphincters; and patients in whom paralysis is complete or in whom spastic contraction of the hands and arm is constant without remission.

Pre-operative Treatment.—It is important to maintain the nutrition of the muscles, particularly those antagonized by the spastic muscles. For this purpose, dry heat may be applied locally for a period of half an hour to an hour prior to massage, which is best performed in the morning, because at that time spasticity is less marked. The deformities are due primarily to overactivity of the spastic muscles and secondarily to contracture, gravity, and abnormal movement; therefore the use of some form of apparatus may be advisable to obtain overcorrection, *e.g.*, in spasm of the gastrocnemius with tendency to equinus, use steel uprights with a toe piece to keep the foot at right angles. Manipulation and stretching of the affected muscles should be performed daily.

The above-mentioned mechanical and manipulative treatment should be tried for twelve consecutive months. Many cases are greatly improved by this treatment, but if such is not the case, operation is advisable; or, if the case has not been seen until the contracture has become established, operation should be performed at once, without waiting for preliminary measures.

OPERATIVE TREATMENT

Robert Jones' Routine in Spastic Paraplegia.—(1) Resection of adductors of hip. (2) Tenotomy of hamstrings except biceps. (3) Sectioning and lengthening of tendo Achillis. (4) Resection of peronei if valgus is extreme.

This is followed by recumbency in extreme abduction on Thomas' frame or in a plaster spica from waist to toes for two months. At separate operations the biceps is transplanted into the patella.

Daily massage and muscle training must be persistently followed for at least one year. The superb results in Jones' clinic he ascribes very largely to the benefit of faithful after-treatment.

I. **Upper Extremity.**—The chief deformities are (1) flexion of the elbow; (2) pronation of the forearm; (3) flexion of the wrist and fingers. Rarely, in cerebral diplegia, is rigid extension observed in the upper extremity. The principal operative procedures are tenotomy, tendon transplantation, and tendon lengthening.

1. *Flexion Deformity at the Wrist.*—(*a*) A longitudinal incision is made on the flexor surface just above the wrist, the median nerve developed and retracted, and the radial and ulnar arteries and nerves are avoided. The flexor tendons are picked up over a grooved director, and each is lengthened by overlapping L-shaped incisions. The wound is closed and dressed, and the hand and fingers are put up in a plaster-of-Paris splint with the fingers and hand midway between flexion and extension. The splint is removed in six weeks and massage and manipulation are performed daily. (*b*) Transplantation of the flexor carpi radialis and flexor carpi ulnaris to the dorsal surface of the bases of the second and fifth metacarpal bones, respectively (R. Jones). If the flexor tendons are too short, they should be lengthened by plastic tenotomy by means of overlapping L-shaped incisions.

2. *Flexion Deformity at the Elbow with Excessive Pronation.*—Tubby has devised an operation whereby the excessive pronating power of the pronator radii teres and flexor carpi radialis cannot only be neutralized but

made to add to supination. His technic is as follows (Tubby, Deformities including Diseases of the Bones and Joints, vol. ii, p. 732):

"An incision about 6 inches long is made in the middle three-fifths of the forearm over the line of the radial artery. The inner margin of the supinator longus is then defined and this muscle separated from the flexor carpi radialis. The radial vessels and nerve are found and drawn well to the inner side. The pronator radii teres is then sought for, the direction of its fibers affording a guide. It is a broad muscle with a short flat tendon which rapidly merges with the periosteum of the radius. The upper and lower margins of the muscle are well cleared, and the tendon with some periosteum is detached from the bone. The flexor carpi radialis is then separated from its neighbors and its tendon divided about 1½ inches above the wrist. Both it and the pronator radii teres are placed on the stretch, and the latter is sutured firmly to the former. The next step is division of the interosseous membrane. We find the flexor longus pollicis and then completely sever the membrane with a tenotomy knife, taking care to avoid the anterior interosseous artery and nerve. Through the space so made, the conjoined tendon is brought round to the back of the radius. An aneurism needle is passed through the interosseous space and round the outer side of the bone. By working the aneurism needle rather vigorously in a vertical direction, the soft tissues are cleared away from its outer surface and the needle is withdrawn. A silk suture having been previously passed through the end of the conjoined tendon, one end of the silk is threaded through the eye of the aneurism needle, now passed from the outer side, and the tendon is drawn through behind the radius. The aneurism needle is now dispensed with. The next step is to refix the conjoined tendons, which is accomplished in the following way: A hole is drilled through the radius from front to back; one end of the silk ligature which has been passed through the tendon is threaded on a straight needle, and the needle and silk are passed from before backward through the hole in the radius, and through the tendon now lying at the back of it, care being taken that the latter is pulled upon vigorously. The ends of the silk ligatures are then knotted and the tendon fixed in its new position. The limb is put up with the forearm supinated and the elbow flexed for four weeks."

Postoperative treatment consists of passive movements which should be of limited extent for the first six weeks, after which they may be made more extensive and active movements begun, viz.: extension at the elbow and supination of the forearm synchronously, and in both arms simultaneously.

II. **Lower Extremities.**—Mild cases of slight contraction at the hips may be overcome in some cases by employing a double abduction frame, consisting of two steel uprights straight from the scapulæ to the hips, where they are bent outward at an angle of 30 to 40 degrees, prolonged to the mid-calf or ankle, where they are connected by a transverse bar. Bracelets at the hips and lower extremities of the apparatus, and three bands to half encircle the thorax, complete the outfit; or a double plaster-of-Paris spica serves the same purpose.

Severer cases of contracture of the hips require operative treatment. The contracted structures are chiefly the adductors of the thigh, the tensor vaginæ femoris, sartorius, and iliotibial band; also contracted hamstrings and tendo Achillis. Multiple contractures may be treated at one or at several sittings.

1. *Adductor Contraction.*—With the leg abducted to put the adductors on the stretch, a short incision, 1 or 2 inches in length, is made over the adductor longus tendon just below the inguinal fold. The tendon is exposed,

the finger hooked around it, and $\frac{3}{4}$ to 1 inch of it excised. The leg is further abducted, and equal amounts of the adductors brevis, gracilis, and magnus, and even the pectineus, are removed, as well as any other restraining bands of tissue. Some surgeons recommend division and excision of a portion of the obturator nerve at the same time. The limb is immobilized in strong abduction in a long plaster-of-Paris spica.

2. *Contraction of the Sartorius and Tensor Vaginæ Femoris, and Iliotibial Band.*—The most satisfactory treatment for this condition is Soutter's operation (lowering the anterior-superior spine of the ilium with the muscles and fasciæ attached to it, which is fully described in Chapter XXI, page 725).

3. *Contraction of the Hamstrings.*—Vertical incisions are made over the inner and outer tendons; tunnelling between the incisions permits section of the tense fascia. The hamstring tendons are treated by simple division or lengthening by plastic tenotomy, or by the excision of 1 or 2 inches of each tendon. Extension of the limb is maintained by a plaster-of-Paris splint from toes to groin for six weeks.

4. *Contraction of the Gastrocnemius.*—The tendo Achillis is lengthened by overlapping L-shaped incisions and the foot is immobilized at right angles in a plaster-of-Paris splint from toes to groin for a period of six weeks.

At the end of the period of immobilization, the plaster-of-Paris splint is cut down, and active and passive movements are practised daily; the two halves of the splint re-applied and strapped together at night, until there is no tendency for the contracture to recur. The manipulation should be made under the supervision of a nurse or other professional attendant. The most important movements at the hip are flexion, external rotation, abduction, then full extension of the hips and knees. These movements are to be performed first passively, then actively. When walking, splints may be necessary to prevent relapse, while at night the foot may be fastened to the bed-frame to maintain abduction. Twice daily, massage is administered to all the muscles of the lower extremity, particularly the abductors of the hips, the extensors of the knees, and the dorsi flexors of the feet.

Muscle grafting, tendon transplantation, nerve section, and nerve transplantation occasionally give satisfactory results, but are not uniformly practised in the case of spastic paralysis. (Clark and Taylor have advocated section of the posterior roots for spastic paralysis, N. Y. Med. J., Jan. 29, 1910; Apr. 13 and 20, 1912.) Through a unilateral laminectomy properly performed, the roots of both sides may readily be divided without in any way injuring the cord substance. In most of the lower extremity cases, a portion of all the roots involved was divided, instead of dividing two consecutive roots completely and then skipping one. There are no practical grounds for the objection that in dividing part of the root the remainder would be traumatized, because the posterior roots leave the cord in a series of little bundles and any proportion of these bundles may be cut without injury to those remaining.

(B) PARALYTIC DEFORMITIES FOLLOWING NERVE INJURIES

Causes.—1 *Wounds*, accidental or operative; (*a*) accidental wounds, chiefly of the wrist and lower forearm, and accompanied by severance of the tendons. The median nerve is usually, the ulnar nerve frequently, severed at the same time. (*b*) Operative wounds affect most commonly the spinal accessory, a branch of the cervical plexus, facial, nerves of the abdominal wall, and the posterior branches of the lumbar plexus.

2. *Pressure.*—(*a*) Dislocation, *e.g.*, subcoracoid dislocation of the shoulder with pressure on the cords of the brachial plexus; (*b*) heel in the axilla, in reducing dislocations of the humerus; (*c*) dislocation of the elbow, injury to the ulnar nerve; (*d*) dislocation of the hip, with damage to the great sciatic nerve; (*e*) "bloodless" reduction of a congenitally dislocated hip, with injury to the whole sciatic and the external popliteal nerves; (*f*) complicating fractures, chiefly of the upper extremities, in which paralysis may be immediate or remote; if immediate, it may be temporary or permanent. Temporary paralysis in these cases is due to the pressure of a displaced fragment (*e.g.*, musculo-spiral paralysis in fracture of the shaft of the humerus, paralysis of the popliteal nerve, and from separation of the lower epiphysis of the femur), pressure on vessels, hematomata, or tight bandages. Permanent paralysis in the case of fractures, is the result of rupture of a nerve or its crushing or prolonged pressure by fragments; in this connection there also should be mentioned "crutch palsy" from pressure on the brachial plexus by the crutch-head in the axilla, also inclusion of a nerve in the callus or adhesions. Other pressure causes are instanced by postanesthetic palsy, and the paralysis of sleep.

3. *Traction.*—The evil effects of traction are seen in birth palsy (brachial plexus), prolonged extension in apparatus, and "bloodless reduction" of the congenitally dislocated hip.

Symptoms.—The gross symptoms are usually very apparent, but a careful examination is necessary to ascertain whether there is complete or only partial division, irreparable or only temporary damage, and to determine the question of the propriety of surgical intervention. The cutaneous sensations, such as light touch, pin pricks, etc., and the deep sensations should both be examined, as well as the electrical reactions.

Treatment.—If rupture of a nerve can be definitely determined, primary suture should be practised. If the paralysis is incomplete and muscular power appears to be returning, it is best to wait until the amount of residual paralysis has been manifested before undertaking to operate, but prolonged delay should be avoided, since the nerve progressively degenerates. If the nerve injury is due to displaced fragments, these should be re-adjusted and retained in proper position. If the nerve is embedded in callus, it should be dissected free.

After any nerve operation, the affected part should be immobilized with the nerve and the muscles completely relaxed until voluntary movement has been re-established, after which daily massage, passive motion, friction, and stimulation by the constant current of electricity should be practised. The after-treatment usually consumes several months.

Primary Nerve Operation.—An electrical examination is essential to determine whether or not the nerve has been severed; if the question still remains in doubt, the suspected nerve should be developed by dissection; if it is found divided, it should be sutured with plain catgut No. 0, or No. 1, passed at right angles to the long axis of the nerve and tied just tight enough to approximate the cut ends. The ends of the nerve should be freshened if they are frayed; the point of repair should be protected by (*a*) a free fascia fat flap, or (*b*) chromicized cargile membrane.

Secondary suture (after subcutaneous injuries from pressure, traction, suppurating gunshot wounds, etc.).—Before the nerve operation is undertaken, any secondary deformity present should be reduced. The bulb on the proximal end of the nerve and the fibrous bridge between the two ends are removed and the nerve is freed from all adhesions and fibrous tissues. If the ends will not come together by gentle traction and by flexing

the joints, autotransplantation (the use of a portion of another nerve from the same patient) may be tried. For example, the upper two-thirds of the radial nerve can be removed without disturbing sensation, or the internal saphenous nerve of the leg may be employed.

If autotransplantation is impossible or has failed, nerve anastomosis or nerve crossing may be tried.

Prognosis.—If primary suture has been performed, the outlook is good, but in the event of secondary suture it is not so favorable. The shorter the interval between the accident and the time of suture, the better are the chances for recovery of function.

Deformities from Injuries to Special Nerves

1. PARALYSIS OF THE FACIAL NERVE

The causes are injury, pressure of obstetric forceps, otitis media, rupture of the nerve, and pressure from fracture of the petrous portion of the temporal bone. The clinical features are too well known to require description here. If the nerve has been divided outside the skull, it may be repaired by primary suture, or a faciohypoglossal or spinofacial anastomosis may be performed, for the technic of which works on neurological surgery should be consulted.

2. SPINAL ACCESSORY NERVE

This nerve may be injured or divided in removing the glands of the neck. If it is injured before it enters the sternomastoid muscle, paralysis of the latter and of the upper part of the trapezius occurs. In injuries to the spinal accessory in the posterior triangle of the neck, branches of the third and fourth cervical nerves may be simultaneously cut and paralysis of the whole trapezius may follow, with marked deformity, viz.: the shoulder is dropped, the scapula being rotated forward and so tilted that the glenoid cavity faces downward, while the patient is unable to raise the arm, after it has been abducted by the deltoid, above his head in an outward direction. Primary suture may be performed if the injury is discovered soon, otherwise secondary suture, or, if this is not feasible, anastomosis of the peripheral end with the anterior primary divisions of the third and fourth cervical nerves, or with the suprascapular nerve as suggested by Skillern, Annals of Surgery, 1917.

3. BRACHIAL PLEXUS

Traumatic disturbances of this plexus are common. The plexus may be injured above or below the clavicle.

Supraclavicular Lesions.—Injury during birth, a fall or blow upon the shoulder or head, or side of the neck, separating these two; postanesthetic paralysis, pressure of a cervical rib, penetrating wounds, injuries to the cervical spine.

Infraclavicular Lesions.—Pressure from a dislocated humeral head, fracture of the upper end of the humerus, fracture of the neck of the scapula, pressure of the heel in the axilla in reducing dislocations of the shoulder, penetrating and gunshot wounds.

Disturbances of the brachial plexus will be considered under the following headings: (*a*) obstetrical paralysis, and injuries to the brachial plexus from other causes; (*b*) from cervical rib or exostosis; and (*c*) infraclavicular lesions of the brachial plexus.

(*a*) **Obstetrical Paralysis** (Birth Paralysis).—Most of the cases are the result, not of compression, but of laceration from overstretching the nerves

and their sheaths incidental to manipulations attending delivery. The upper limbs are chiefly affected. Clarke, Taylor, and Prout (Am. Jour. Med. Sci., October, 1906) in this country have made valuable contributions to our knowledge of the subject.

Etiology.—Anatomical studies by the men quoted above have eliminated backward pressure on the nerve by the clavicle, hyperextension of the arm in breech delivery, and pressure of the forceps blades as causes of this paralysis, and have, to the author's mind, conclusively demonstrated that *damage to the nerve roots is produced by tension, i.e.*, forcible increase of the distance between the head and the shoulder at the time of delivery. In these difficult cases, the accident is encountered most frequently in vertex presentations, where traction has been exerted on the head while the shoulders were obstructed, and in breech presentations by traction on the after-coming head. The vulnerability of this plexus can be demonstrated in very young infants a few days to a few weeks old by traction on the shoulder which causes the upper nerves of the plexus to stand out like whipcords under the skin; whereas in any other position these nerves are relaxed. Tearing usually begins with the fifth nerve and affects the others in downward progression, the extent of laceration varying with the amount of tension applied.

Pathology.—The gross lesion is a *fraying out* of the nerve in a linear direction, exactly as in the case of a rope under excessive tension, and this manner of tearing explains the production of hematomata, fibrous tissue and nodules in the nerve cords. The lesion may affect the upper part of the plexus, the fifth and sixth nerves, either above or below their junction, or the roots themselves may be torn from the cord. Whether the lesion is mild or consists of laceration or fraying, the greatest damage is to the fifth root. The supraclavicular nerve is almost universally injured on account of its origin from the distal and external aspect of the junction of the fifth and sixth nerves.

Specific Lesions.—The perineurium yields to tension, and its vessels rupture with consequent hemorrhage into the perineural sheath, and between the bundles of nerve fibers. The surrounding fascia is thickened and in places adherent to the nerve. A well-marked nodular mass is palpable in the affected nerve. The ends of the ruptured fibers are globular and buried in hematomatous exudate.

Symptoms.—The symptoms are usually referred to the upper arm (Erb-Duchenne type); in other cases, to the lower arm (Klumpke type).

Erb-Duchenne symptom-complex: This affects the upper arm and is due to a lesion of the fifth and sixth anterior primary branches or their junction (Fig. 532). The position of the arm is typical, viz.: it hangs close to the side, the forearm being in extreme pronation while the entire arm is rotated inward. The muscles affected are the deltoid, the spinati, biceps, brachialis anticus, supinator longus, and occasionally the extensor carpi radialis longus. Sensation usually remains normal.

Laceration of the nerve roots is furthermore accompanied by traumatic neuritis and indicated by irritability, peevishness, and pain on manipulation of the affected arm. These symptoms are of bad prognostic omen, while on the other hand, their absence usually indicates more or less spontaneous recovery of function.

At a point about 2 cm. outside the sternomastoid and equidistant above the clavicle, Erb's point, electrical stimulation causes contraction of all the muscles involved by the Erb-Duchenne type of paralysis. The motor fibers of the affected muscle run in the junction of the anterior divisions of the fifth and sixth nerves.

A decision cannot be made immediately after birth relative to the extent or degree of the lesion. It is necessary to watch the progress of the symptoms and to test the electrical reactions under anesthesia. Thickening and induration of the nerve roots at Erb's point are often recognizable by palpation a few months after birth.

Prognosis.—Mild cases without severe laceration usually undergo recovery in three to nine months. If laceration is severe, the outlook is modified by the amount of contraction of scar tissue, and the degree to which the conductivity of the nerve fibers is impaired. Cases complicated from the outset by traumatic neuritis, present a relatively poor prognosis. The outlook improves with proper treatment.

Treatment.—Palliative.—The presence of traumatic neuritis demands absolute rest of the part for three to four months, with the limb in the most favorable position to obviate contractures of the muscles and ligaments. In the absence of neuritis, massage, friction, active and passive motion,

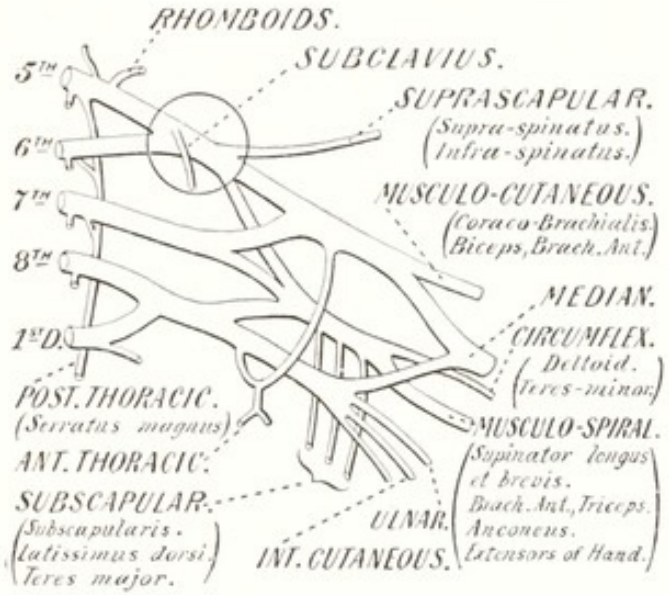


FIG. 532.—Duchenne-Erb paralysis. (Binnie.)

alternating douches of hot and cold water, and electrical stimulation of the muscles may improve the condition.

Operative Treatment.—A difference of opinion exists as to the time of election for operation, whether three, six, or twelve months. The later periods have an advantage in the increased size of the parts, more definite localization of the lesion, and the improved vital resistance of the patient.

The patient is placed in the dorsal position, with sand-bag under shoulders to allow hyperextension of the head. With the head and face inclined to the opposite side, an incision is made from the junction of the middle and lower thirds of the outer margin of the sternomastoid outward and downward to the junction of the outer and middle thirds of the clavicle. The deep fascia between the sternomastoid and the trapezius is divided, and the omohyoid is exposed below the lower edge of the wound. The scalenus anticus is next exposed above the omohyoid and the nerve trunks emerging from beneath the scalenus are developed. The upper two nerve trunks are dissected free, outward to their junction.

After the junction of the fifth and sixth nerves has been isolated, the various

branches of these nerves should be identified, and the main trunks and the branches freed from adhesions (Fig. 534). The isolated nerves should now be carefully examined; if the entire nerve appears to be cicatrized, the fifth and sixth nerves should be divided above the site of the lesion. Unless the cut surface has a healthy appearance, resection should be continued inward until normal nerve tissue is reached. The affected portion of the plexus is pulled inward and the three peripheral divisions of the nerve (the suprascapular, the branch to the outer, and that to the posterior cord of the plexus) are put on the stretch and severed through a healthy portion of their structure at points distant to the diseased area.

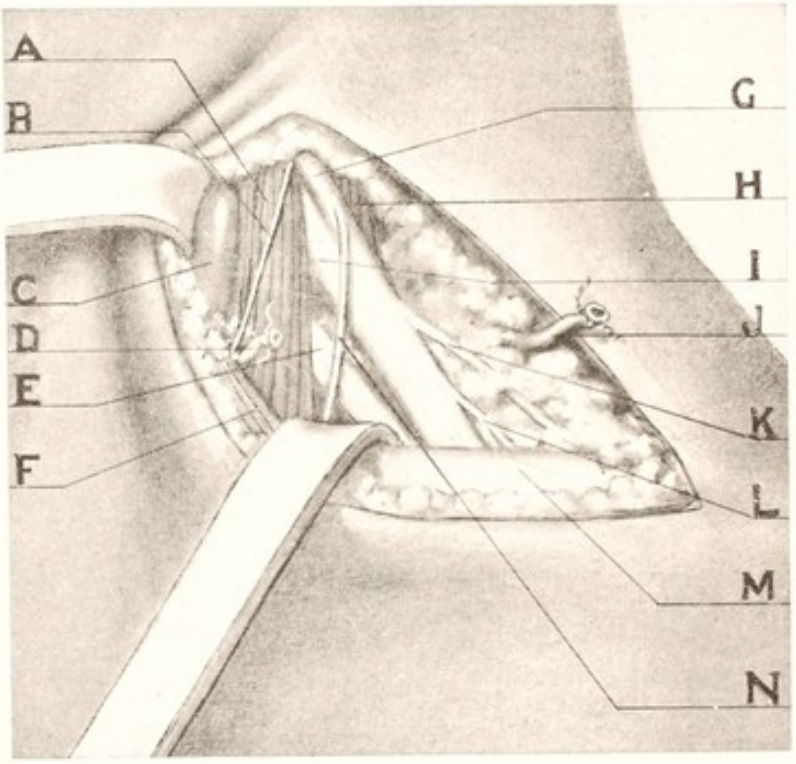


FIG. 533.—*Operation for Duchenne-Erb paralysis.* *A*, Scalenus anticus; *B*, phrenic n.; *C*, int. jugular; *D*, transversalis colli a; *E*, seventh root; *F*, omohyoid; *G*, fifth root; *H*, scalenus medius; *I*, sixth root; *K*, suprascapular n; *L*, ext. ant. thoracic n; *M*, clavicle; *N*, nerve to subclavius. (Taylor.)

The patient's shoulder is now pushed upward and the head inclined *toward* the affected side, in order to relieve the parts of tension and facilitate approximation of the severed nerves.

The three peripheral stumps are now sutured to the two proximal stumps with fine chromicized catgut. Adhesions about the site of anastomosis may be prevented by covering the line of suture with a free fascia fat graft, cargile membrane, etc. After closing and dressing the wound, the patient's head and shoulders are thoroughly immobilized in a plaster-of-Paris dressing, the shoulder is well elevated, the head inclined toward the side of the lesion, and great care exercised that no movement of the head on the shoulders is possible.

If the lesion extends further outward toward the periphery of the nerves, greater exposure will be necessary. The skin incision may be prolonged downward between the pectoralis major and deltoid, these muscles separated and the clavicle divided between them, together with the subclavius and

omohyoid muscles and suprascapular vessels. By pulling the outer half of the clavicle and the shoulder outward, the entire plexus to the upper margin of the pectoralis minor (which can also be divided if essential) lies exposed. Resection and anastomosis are performed as directed, and the divided muscles and clavicle are repaired. Fixation in plaster-of-Paris should be maintained for at least two weeks, after which electrical stimulation and massage may be instituted.

Injuries to the brachial plexus from causes other than those incident to parturition, are:

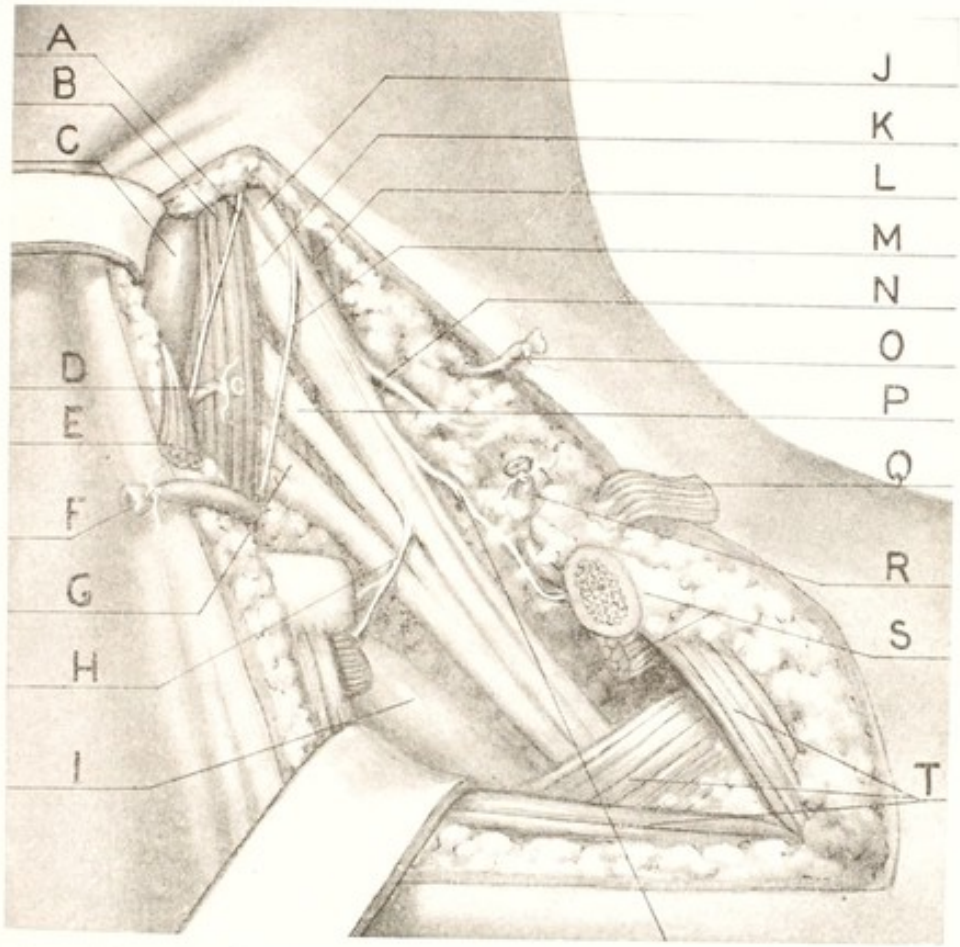


FIG. 534.—*Operation for Duchenne-Erb paralysis.* *A*, Phrenic n; *B*, scalanus ant.; *C*, Int. jugular; *D*, *O*, transversalis colli a; *E*, omohyoid; *F.R.* suprascapular a; *G*, VIII cervical and dorsal root; *H*, muscular branch; *I*, subclavian v; *J*, fifth root; *K*, sixth root; *L*, scalenus medius; *M*, nerve to subclavius; *N*, suprascapular n; *S*, clavicle and subclavius; *T*, pect. major; *U*, ant. thoracic n. (Taylor.)

(*b*) **Injuries from Cervical Ribs or Exostoses.**—Symptoms from pressure by cervical rib are commonest on the right side and are rare on the left. Tubby (*loc. cit.*, p. 758, vol. ii) estimates that 5 to 10 per cent. of patients with cervical ribs present nerve symptoms. The ulnar nerve is the first to be involved, then the flexors of the fingers. The symptoms are sharp pain along the inner surface of the arm, numbness of the ulnar side of the hand and little finger, and occasionally anesthesia, chilblains on the fifth finger, and generally atrophy of the intrinsic muscles of the hand. The treatment is operative removal of the offending cervical rib or exostosis (for technic, see Chapter XII, page 386).

(*c*) **Infraclavicular Lesions of the Brachial Plexus.**—The usual cause is dislocation of the head of the humerus, the direct cause being pressure by the humeral head, the heel in the axilla in attempting reduction, or fracture of the surgical neck of the humerus or scapula, or fracture dislocation of the upper end of the humerus. As a rule, the inner cord only is injured, rarely, the outer, while occasionally the whole plexus is affected.

Lesions of the whole plexus are more often due to direct than to indirect injury to the head or shoulder or attempts at reduction; they are less frequently due to indirect trauma. The symptoms depend upon the location of the injury. If above the clavicle, there is loss of sensation below the lesion, except an area of the shoulder innervated by the descending branch of the cervical plexus and a small area on the inner side of the arm innervated by the intercostohumeral nerve. For a detailed description of the paralytic phenomena, works on neurology should be consulted.

Prognosis after these injuries to the brachial plexus, is quite favorable, the outlook being modified by the nature and the extent of the injury. Total paralysis of the plexus requires years for recovery of function, even after operation. Spontaneous recovery is out of the question when there has been extensive laceration of nerve fibers with overgrowth of connective tissue, and recovery in these cases can only be expected by a thorough dissecting and freshening operation. Lesions above the clavicle present a poorer prognosis than those below; but, after all, most depends upon the skill of the surgeon, not only in accurate diagnosis of the extent and localization of the lesion, but in plastic repair of the injury.

Diagnosis.—In cases where there is the least doubt as to the diagnosis, the co-operation of a competent neurologist is of paramount importance. Cerebral lesions and hematomyelia may be confused with paralysis of the brachial plexus, although a discussion of the points of differentiation is beyond the scope of this work.

Treatment.—The immediate treatment following injury consists of rest and support of the part, to permit resolution of any blood-clot and to favor healing. An apparently complete lesion may be observed to be only an incomplete one, judging by the evanescent paralysis. Upon cessation of pain from traumatic neuritis, massage, friction, electricity, passive motion, and splinting should be employed to forestall deformity. The surgeon should be on the lookout by means of careful electrical tests, for the reaction of degeneration, which usually begins about fourteen days from the date of injury; its advent is an urgent indication for operation.

The operative technic has already been indicated (see Birth-palsy). If the hiatus remaining after resection is too great to permit end-to-end union, a portion of another nerve, *e.g.*, radial or internal saphenous, may be transplanted between the cut ends, or the portion of nerve distal to the lesion may be anastomosed into the neighboring nerve. If these neuroplastic procedures are ineffective, recourse may be had to tendon transplantations, muscle transplantation, etc.

Operative Treatment of Contractures following Injury of the Brachial Plexus.—The picture of an untreated or an unsuccessfully treated case of brachial plexus injury is that of an arm rotated strongly inward and contractured in that position; any attempt to execute flexion at the elbow causes the forearm to swing at the chest. Since the primary and essential movement to permit the hand to be brought to the mouth, face, or head, is external rotation, patients with this deformity are greatly disabled, and the only relief of the condition is surgical intervention to restore this function. Motion of the shoulder is considerable, with the exception of external rotation, but inas-

much as that is the essential movement to which all others are secondary in the execution of the acts noted above, the arm must be restored to such a position that with the upper arm held at the side, the forearm and elbow-joint can be swung into external rotation when flexion at the elbow readily permits the forearm to be carried to the face and head.

A plastic procedure on the shoulder to accomplish this result is difficult of execution and is not recommended. The desired result is very simply and effectively attained by performing osteotomy at the central segment of the humerus and rotating the lower half on the upper half sufficiently to allow satisfactory function. The amount of rotation necessary varies from one-third to one-half the circumference of the humerus.

Author's Technic for Osteotomy of the Humerus to Restore External Rotation.—The central portion of the humerus is approached by an incision in the outer aspect of the arm, carefully avoiding the musculospiral nerve. With the motor-saw, the humerus is split longitudinally, for a distance of 2 to 3 inches, into equal internal-external halves; the external half is cut completely off at the *upper* end of the longitudinal saw-cut by means of the small hand saw or an osteotome; the internal half is then severed in the same way at the *lower* extremity of the parallel saw-cut. Drill holes for kangaroo-tendon ligatures are then made in the anterior edges of each half; medium sized kangaroo-tendon ligatures are then inserted through these drill holes, and the inferior half of the humeral shaft is rotated externally on the superior half, sufficiently to allow the hand to be brought to the neck or hair when the elbow is at the side of the torso. The arm is then placed in a plaster-of-Paris shoulder spica extending from the fingers over the thorax, with the upper arm slightly abducted and the *lower half of the humeral shaft rotated strongly outward* on the upper half. The plaster-of-Paris splint is kept on for five weeks, when it is removed and massage and manipulation are begun, and the patient is encouraged to use the hand as frequently as possible.

(C) DEFORMITIES OF NEURO- AND MYOPATHIC ORIGIN

1. From Degeneration of the Spinal Cord

(*a*) **Tabes Dorsalis** (Locomotor Ataxia).—Its importance from a surgical point of view lies in the occurrence of spontaneous fracture and Charcot's disease. Spontaneous fracture occurs in any long bone and heals readily, but with the production of excessive callus.

Charcot's Arthropathy.—This condition usually affects the knee (Fig. 535) and then with diminishing frequency, in the order given, the hip, shoulder (Fig. 538), tarsus, elbow, ankle, wrist, jaw, and spine. It may also, rarely, affect the spine, producing extensive curvature or even fracture. "Tabetic flat-foot" is caused by changes in the tarsal bones and joints.

Pathology (Figs. 535 to 539).—The influence of injury in exciting this arthropathy is often marked. There may be acute and rapidly progressing inflammation, followed by swelling, disorganization of the joint, and frequently subluxation and dislocation. The essential lesion consists of erosion of the articular cartilages, rapidly progressive osteoporosis and absorption of the bony surfaces, laxity of the articular ligaments, and consequently a flail-like joint. The process somewhat resembles the degenerative type of arthritis deformans. In a small percentage of cases, however, the ends of the bones are enlarged, with thickening of the ligaments and enormous effusion into the peri-articular tissues, with great swelling of the joint.

Treatment.—In a case of either spontaneous fracture or arthropathy, immediate rest and immobilization, either total in plaster-of-Paris dressings, or partial, by a splint appropriate to the joint involved, are essential; in the case of the knee, a caliper splint or some other suitable apparatus is very serviceable. It is rare for a case of Charcot's arthropathy to heal or for function to be restored, but much disability, in the case of the knee at least, can be prevented by early recognition of the condition and the use of a splint, and, even if the joint is flail-like, a suitable splint will enable the patient to walk with cane or crutch. Surgical interference with a Charcot joint is very unsatisfactory.



FIG. 535.



FIG. 536.

FIG. 535.—Charcot's arthropathy of knee. Disintegration of condyles of femur and of head of tibia. Condition painless.

FIG. 536.—Typical Charcot's arthropathy of ankle. Spontaneous fracture and disintegration of lower end of tibia, with foot displaced toward tibial side. Although there is extreme disorganization of the joint, pain was absent as is usual in such cases.

Treatment of the ataxic condition itself consists of strengthening the muscles by gymnastic exercises in conjunction with apparatus, or else carefully regulated exercises without supporting apparatus.

(*b*) **Friedreich's Ataxia** (Hereditary Ataxia).—The disease is marked by muscular inco-ordination of the arms and legs, loss of knee jerks, unsteadiness of the neck and head, difficulty in speech, and nystagmus. Its interest to the surgeon lies in the deformities associated with it, viz.: scoliosis, talipes equinovarus, claw-foot, and occasionally flexion contracture of the knees.

The serious prognosis usually contra-indicates surgical interference, yet in mild cases without great inco-ordination rectification of the deformity should be attempted.

(*c*) **Syringomyelia.**—A disease of the cord, characterized by cystic degeneration of the glioma with the production of cavities. Clinically, there are loss of sensation, chiefly of pain and temperature sense, and muscular atrophy. If the disease affects the pyramidal tracts, it results in spastic paralysis. Atrophy of the trunk muscles is followed by scoliosis; thickening of the bone

results from trophic disturbance, and occasionally arthropathy, similar to Charcot's disease. No specific treatment of the disease is known. The spine should be supported to control curvature. The deformities are to be treated on their individual merits, but frequently the patient does not live long enough for surgical relief.

2. Deformities Resulting from Multiple Neuritis

The common causes are: Intoxication from chronic alcoholism, lead, arsenic, and other mineral poisons, diabetes, gout, rheumatism, syphilis,



Fig. 537.—Anteroposterior skiagram of a Charcot ankle. This was the case of a middle-aged man, who first noticed that he was walking on the outer side of the foot. There was no pain and the progress of the deformity was rapid. At the time this radiogram was taken, the lower end of the fibula was bent by the pull of the ankle ligament over the outer corner of the tibia. (Albee, Jour. of Med. Society of New Jersey.)

diphtheria, smallpox, typhus, and typhoid. In chronic alcoholism and plumbism, the dorsiflexors of the foot, the extensors of the toes, and the extensors of the fingers are first affected, and foot- and wrist-drop result. Other muscles may be affected later.

Treatment.—Prevention of malposition of the feet with subsequent contracture of the gastrocnemius, incident to the rest which is always indicated in treating the neuritis, is imperative. Passive dorsiflexion of the feet, morning and night, should be practised and followed by friction and massage of the affected muscles. In the intervals of treatment, the foot should be placed in a right-angled splint. Weakness of the extensors of the knees and

hip may cause flexion contracture which may be prevented by weight extension while the patient is in bed.

The hand is treated in a manner similar to that of the foot, and is to be splinted midway between flexion and extension to prevent flexion contraction. It is rarely necessary to do a tenotomy or tendon transplantation if the cause is removed and the neuritis vigorously treated.

3. Neuropathic Conditions of the Bones and Joints

These neuropathic conditions are encountered during tabes dorsalis, syringomyelia, Pott's disease, acute myelitis, injuries to the peripheral



Fig. 538.—Charcot's arthropathy of shoulder-joint. Spontaneous fracture of shaft of humerus; upper fragment abducted by the supraspinatus or deltoid. Arrows point to additional fragments.

nerves, cerebral hemorrhage, tumors of the cord, crushing injuries of the cord, and acute anterior poliomyelitis. The lesions are (*a*) osteopathies, (*b*) arthropathies, and (*c*) osteo-arthropathies. All these occur in locomotor ataxia in which the lesions are typical of these conditions.

(*a*) **Osteopathies.**—The spontaneous painless fractures of locomotor ataxia are due to malnutrition of the bones. Union is the rule, with extensive callus formation. The lower limbs are more often affected than the upper, and women more frequently than men. The changes in the bone consist of increase in the size of the medullary canal with decrease in thickness of the compact bone (osteoporosis), and diminution of lime-salts.

(*b*) **Arthropathies** (Charcot's Joints).—Two forms of arthropathies are recognized, the atrophic and the hypertrophic; the former affects chiefly the hip and shoulder; the latter, the knee and elbow. Charcot's joints are characterized by rapid onset without pain and fever, enormous distention (coming on in a few hours), and rapid disorganization of the joint. These changes extend to the peri-articular tissues. These progressive changes usually cease for a few days or weeks, when the joint may be left in one of three conditions: either completely disorganized, only slightly damaged, or in a state intermediary between these two. As has been previously stated, the joints are attacked in the following order of frequency: knee, hip, shoulder, tarsus, elbow, ankle, wrist, jaw, and spine. The hand is usually not involved. Although these arthropathies resemble arthritis deformans, the following points of difference distinguish Charcot's joints: absence of fever and pain, rapidity of joint destruction, monarticular character, infrequency of anky-



FIG. 539.—Skiagram of a very destructive arthropathy of the hip-joint. Large pieces of bone can be seen embedded in the surrounding soft tissues. The head and neck have become entirely disintegrated with a dislocation of the femur upward. (Albee, Jour. of Med. Society of New Jersey.)

losis, and the usual flail-like condition resulting from the lesion; furthermore, in some instances no osteophytes are formed. The pathological changes are as follows: the articular surfaces are altered, all semblance to a joint being frequently lost; in the hypertrophic type, the articular cartilage disappears, leaving bare the porous cancellous bone, with a few peripheral bony outgrowths in some cases. The ligaments and capsule are relaxed and distended with a clear fluid. The synovial membrane is either thickened or partially destroyed, together with the internal ligaments.

The arthropathy has been seen associated with infantile paralysis, and the identity of infantile paralysis with Charcot's disease has been suggested. In these cases, the ankle has been affected, with persistent effusion. The condition is usually monarticular and its onset synchronous with that of the poliomyelitis, or may be delayed for some weeks.

(*c*) **Osteo-arthropathies.**—The spine and feet are the parts usually affected. In the spine, kyphosis, scoliosis, and spontaneous fractures are the usual lesions. *Foot* may be flat, deviated outward or inward, or the arch raised.

The affection occurs in syringomyelia. The large joints of the upper extremity are affected in the following order of frequency: shoulder, elbow, wrist, hip, knee, and tarsus, a notably different order from the distribution of Charcot's joint. The pathological lesions correspond very closely with those of the two forms of arthritis deformans (the proliferative and the degenerative). The affection begins in a manner similar to a Charcot joint. There is absence of pain, redness, heat, while the joint becomes suddenly distended with fluid. Osteo-arthropathies have been described in leprosy, and are known to occur in general paralysis of the insane.

Treatment.—This consists mainly of protecting and supporting the joint with apparatus. There is no surgical procedure of any avail, with the exception of arthrodesis supplemented by a long bone-graft for additional support in selected cases.

4. Deformities Due to Muscular Dystrophies and Myopathies

In some paralyses, disturbance of the muscular and not of the nervous system is a primary cause. These affections occur chiefly in early life. The lesion, which is a progressive muscular atrophy, may be so extreme that the muscle is reduced to a strand of connective tissue. The pseudohypertrophy is the result of fat deposit.

On the basis of distribution of paralysis, cases are classified as:

(*a*) Duchenne or pseudohypertrophic type.

(*b*) Erb type, scapulæ and arms chiefly affected.

(*c*) Landouzy-Déjerin, begins in face and arms.

(*d*) Charcot-Marie-Tooth: begins in the legs, forearms and back (complicated by lesions of the peripheral nerves as well as of the muscles).

Etiology.—The conditions are often hereditary and, as Tubby puts it (*loc. cit.*, ii, 786): "There is in fact, a congenitally deficient power of evolution." The process is a simple muscle atrophy, the pseudohypertrophic varieties representing merely deposits of fat in the affected muscles.

(*a*) **Pseudohypertrophic Muscular Paralysis** (Duchenne Type).—There are wasting and loss of power of the affected muscles, preceded in some cases by great hypertrophy, in other cases by atrophy. It is an affection of childhood, most frequent in males. A peculiarity of the disorder is that it often afflicts several members of a family. It is transmitted through the females, themselves unaffected.

Symptoms.—The first abnormality noted is loss of power, manifested by a tendency to fall without ability to rise again. Also rapid increase in size of certain muscles, particularly those of the calf, quadriceps extensor cruris, glutei, and infraspinales, with synchronously rapid atrophy of the pectoralis major and teres minor. The gait is a peculiar waddle, closely resembling that of congenital hip dislocation, with which therefore it may be confused.

Deformities.—These are a very late sequel, and are due to shortening and contraction of muscles, viz.: flexion of the knees and elbows, the result partly of habitual posture, partly of survival of flexor muscular power; equinovarus from shortening of the gastrocnemius, which may be so extreme as to cause subluxation of the ankle; lordosis, from weakness of the hip extensors; kyphosis, supervening on lordosis as the spinal muscles become more weakened; scoliosis, following lordosis and kyphosis.

Prognosis.—The outlook is grave. A large percentage of the children do not reach adult life. The power of standing is generally lost between the tenth to the fourteenth years, as the result of weakening and contraction of the calf muscles. This loss of locomotion induces rapid progression of the muscular disease.

Treatment.—Scientifically planned exercises undoubtedly retard the muscular lesions. Massage and friction should supplement these but are of minor importance compared with the exercises. Tenotomy of the tendo Achillis should be performed in the case of equinus. The back must be suitably supported by apparatus as soon as there is indication of weakness of the spinal muscles.

(*b*) **Erb Type.**—Begins at twelve to sixteen. Muscles affected: pectorales, trapezii; rhomboidei, and deltoids, which are all hypertrophied and weakened. Atrophy affects the biceps and triceps. Characteristic deformity: stoop-shouldered, with protrusion of the scapulæ. Other deformities make their advent at a later period, as in the Duchenne type.

(*c*) **Landouzy-Déjerin Type.**—Atrophy begins in the muscles of the face, viz.: orbicularis oris, risorii, and levator menti; result, the lips are weak and everted, and the mouth stands open ("tapir mouth"). The atrophy gradually spreads, and the ultimate course resembles the Erb type.

(*d*) **Peroneal Type of Muscular Atrophy** (Charcot-Marie-Tooth Disease).—The affection first appears in the peronei, in the extensor proprius hallucis, or in the extensor communis digitorum. Although the primary lesion is a myopathy, neuritis and possibly a cord lesion may be combined with it. Males are affected twice as frequently as females. It is a disease of early childhood, and is sometimes hereditary. Aside from the muscles already enumerated, others are involved at a later period, viz.: the calf, then the thigh (particularly the vastus internus). Club-foot is a frequent complication, and is the result of unequal involvement of the leg muscles. At a later period, the thenar, hypothenar, and interossei are affected (claw-hand) with subsequent involvement of the forearms, but with integrity of the supinator longus. Impairment of the cutaneous sense occurs particularly where atrophy is the most marked. The pain is most pronounced in the muscles of the thighs. The reflexes are diminished or absent in the affected regions.

The electrical reactions are peculiar and of great diagnostic value. The true reaction of degeneration or absence of response to either the induced or the constant current may be present, while the muscles which are not atrophied or weakened respond with difficulty.

Etiology.—The affection is almost always hereditary or occurs in several members of the same family. In most cases, no exciting cause can be demonstrated, although there is sometimes a history of toxemia preceding the muscular wasting.

Pathology.—The central lesions are: fatty and degenerative changes in the muscles, extreme atrophy of the peripheral nerve fibers, increase of connective tissue between the fibers in the anterior cornua, the large gray cells being smaller than normal and having lost their processes; the cells of the posterior cornua are diminished in number and atrophied.

Deformities.—Those of the feet are the most marked: the feet are pointed, inverted, and in rigid equinovarus; active movement of the toes is limited; there is often more or less pes cavus. The treatment of this condition consists of plantar fasciotomy and tenotomy of the extensors of the toes, tibialis posticus, and tendo Achillis, *i.e.*, the treatment of talipes equinovarus. If the knees are deformed, they are usually benefited by massage and suitable exercises.

(D) HYSTERICAL AND NEUROMIMETIC AFFECTIONS OF THE JOINTS AND BONES

Although the subject of hysterical and neuromimetic affections belongs to the realm of abnormal psychology and cannot be discussed here, it is

incumbent upon us to emphasize the importance of a careful examination in every case of alleged hysteria, to eliminate the possibility of a true organic lesion of the bones and joints, supplementing the ordinary examination by one made under anesthesia, if necessary, and a radiographic examination made at the site of the disturbance.

Hysterical affections are commonly referred to the spine, hip, knee, and ankle, while hysterical club-foot is occasionally encountered.

(E) INJURIES AND DISEASES OF THE MUSCLES

Injuries

Spontaneous Rupture.—In the convulsions of tetanus and eclampsia, in mania or delirium, in the forcible contractions of the uterus and its complementary muscles in labor, in vomiting, and occasionally spontaneously if the muscle is weakened by toxemia (*e.g.*, typhoid fever), rupture may occur.

Traumatic Rupture.—(*a*) *Rupture by Contraction Alone.*—Some sudden unusual movement of the individual and of the muscle in question may cause abnormal inco-ordinated exaggerated contraction and produce rupture.

(*b*) *Rupture by Elongation of a Contracted Muscle.*—A person going upstairs rapidly, slips off the step, and in "an attempt to save himself" he suddenly contracts the plantar flexors of the foot, and may rupture the plantaris longus, elongated in contraction.

(*c*) *Contusion of a Contracted Muscle.*—The muscles most often ruptured are: In running or leaping, the extensor brevis of the toes, the gastrocnemius, and the tibialis posticus; in falling backward, the rectus femoris; in horseback riding, the adductors and biceps femoris; in climbing, the pectoralis major, biceps humeri, deltoid, and trapezius; in parturition, the abdominal muscles; in falling forward, the plantaris longus; the external oblique in reapers; the sternomastoid in swimmers.

The usual lesion is a tearing of the belly from the tendon, and retraction, although rupture may affect the body of the muscle. The characteristics of the rupture may be: (*a*) complete, but with integrity of the sheath; (*b*) partial, the muscle being torn half-way across, leaving a wedge-shaped gap; (*c*) fibrillar, in which a few fibers only are affected, with the production of a diffuse or circumscribed hematoma.

Clinical Features.—The leading clinical phenomena are: sudden sharp pain, with a sensation of "something giving way," accompanied in some instances by an audible snap; the patient often believes himself hit with a stone or kicked at the site of rupture, particularly in the case of the calf muscle. Disability and pain on movement may be extreme. A gap or a depression may be felt in the muscle, or a change in the contour of the limb may be noted. Ecchymosis may be extensive. A pathognomonic sign is swelling at the site of rupture on attempted contraction, disappearing on relaxation. The swelling is greatest in the case of complete rupture, when this is located near the tendon of insertion, *e.g.*, rupture of the adductor longus just below the os pubis.

Young vigorous males are the usual subjects. Rupture of the tendon is the commonest lesion, then partial, and, least frequently, complete rupture of the muscle itself. Union occurs by fibrous tissue, and there is very little muscle regeneration. If the peripheral portion has been separated from its motor and trophic nerves, degeneration and atrophy are inevitable.

Treatment.—Immediate suture is the desideratum. Interlocking sutures should be used, and hemorrhage arrested. The part should be immobilized in a plaster-of-Paris splint in such a position as to relax the involved muscle.

Upon removal of this splint, massage and electricity should be applied to the rest of the synergic group, to prevent their degeneration.

MYOSITIS

Inflammation of a muscle is caused by (*a*) direct infection; (*b*) bacterial toxemia; (*c*) pyemia.

Toxic Myositis.—Encountered in the course of typhoid fever, scarlet fever, syphilis, and rheumatic fever. In the so-called rheumatic states, the myositis is of the interstitial variety, at the expense of the muscle-tissue; the characteristic symptoms are intermittent and remittent pain, the muscle is tender, stiff, and painful on movement. The muscles most affected are the lower spinal and lumbar muscles, intercostals, trapezius, deltoid and occipitofrontal, causing respectively lumbago, pleurodynia, torticollis, etc. Purposeful contraction of the opposing muscle groups is often noted, *e.g.*, in rheumatic myositis of the deltoid, the pectoralis major, latissimus dorsi, and teres major; of the trapezius, the sternomastoid.

Syphilis.—The muscular lesions of this disease are myosalgia, syphilitic contractures, gummata, diffuse infiltration. Regarding syphilitic contracture, the biceps humeri is the usual seat, the onset slow and painless, with right-angled rigidity, while forcible extension is painful at the junction of muscle and tendon, with spontaneous disappearance in a few months to a year or so, and with no residual disturbance.

ISCHEMIC MYOSITIS (VON VOLKMANN)

Von Volkmann, in 1875, first described a contracture found chiefly in the forearm and hand, rarely in the leg, rapidly following too tight bandaging (Fig. 540).



FIG. 540.—Volkmann's paralysis (ischemic myositis) of forearm and hand.

Etiology.—Any lesion interfering with blood supply (*i.e.*, arrest of arterial inflow and venous outflow at the same time) may cause this phenomenon. Total interruption of the arterial inflow for a longer or shorter period, is followed by flaccid paralysis, while if both the arterial and venous circulations are obstructed at the same time, the characteristic degenerative tissue changes take place. In the vast majority of cases the arm is the site of disturbance. Common exciting causes are fractures, particularly of the humerus near the elbow-joint, or the forearm, with fixation of some sort. The disturbance does not always depend upon the bandage. In some cases, it is excited merely by a sling upon the arm, compressing the brachial artery, or the latter may be constricted by the pressure of fragments. Any prolonged obstruction of the arterial blood supply, *e.g.*, embolism, dysbasia, angiosclerotica, Raynaud's disease, syphilitic endarteritis, may cause the degenerative change in the muscle, but not necessarily the characteristic deformity. Severe contusion without fracture, and the prolonged use of an Esmarch bandage, are other well-known causes.

Pathology.—The lesion is a combination of myositis and neuritis, in the majority of cases.

Muscular Changes.—If the obstruction exceeds three to six hours in duration, there follow rigor mortis, and necrobiosis, with rapid degeneration and shortening of the muscle. There is great infusion with round-cell infiltration and, ultimately, replacement of the degenerated muscle-fibers by connective tissue, which increases in density and shortens. On section, the muscles are firmer and harder than normal, yellow in color, and often matted together; in other cases, the muscles are edematous and the veins full and distended, and characterized by round-cell infiltration. Microscopically, the muscle fibers are larger, edematous, homogeneous, irregular in outline, their transverse striation is absent, their nuclei diminished, and the fibers vacuolated.

Nerve Changes.—Gross appearance: The nerves are small, have a purplish hue, and may be surrounded and perhaps constricted by scar tissue. Occasionally the nerve may be nodular in places, or flattened and anemic. Constriction by scar tissue seems to be the cause of the nerve lesion and not of the primary affection.

Skin.—The skin frequently shows various trophic disturbances, *e.g.*, lowered surface temperature, cyanosis, glossy appearance, ulcers, vesicles, etc.

Clinical Features.—The signs and symptoms depend on the degree and duration of vascular obstruction. Pain is the earliest and commonest symptom, and ensues at once after the application of a too tight bandage or splint. If the pressure is not immediately relieved, the limb swells, becomes cyanotic, and covered with vesicles. In the case of the hand, a claw-like contraction may appear in twenty-four hours, further constriction resulting in necrosis of the skin and flexor muscles of the forearm just below the elbow. The flexor muscles, particularly on the ulnar side of the forearm, are chiefly affected because the ulnar artery lies in the anterior aspect of the forearm and is more readily compressed against the bone in the upper part of its course. On removing the constricting bandage or splint, the muscle is found to be hard, the forearm flexed at the elbow, pronated, the hand slightly flexed, and the fingers strongly flexed, like a claw. Attempts at extension of the fingers cause the flexor muscles to stand out prominently. Pressure on the nerves is indicated by more or less cutaneous anesthesia, and, as compression by scar tissue increases, trophic and sensory changes begin.

Diagnosis.—The simultaneous onset of loss of function, flexion contracture, and rigid resistance to extension forms a characteristic picture. In paralysis of nervous origin, on the other hand, the muscle is flaccid from the beginning, and passive movement is possible in all directions; furthermore, there is no discoloration, swelling of the arm and hand, or evidence of constriction. In hysteria, the faradic current elicits contraction.

It is important to determine whether or not the nerves have been involved in ischemic paralysis. If the muscle responds to both the faradic and galvanic currents, there is no nerve involvement; if to the galvanic but not to the faradic, there is no nerve involvement; if to neither galvanic nor faradic, complete injury to the muscle may be presumed, but the condition of the nerve remains problematical. When there is no response whatever to the faradic or the galvanic current, the condition of the nerves of the forearm may be ascertained by electrical examination of the intrinsic muscles of the hand, which are almost invariably intact in ischemic myositis.

Prognosis.—The outlook for restoration of function is very poor. A great deal depends on the promptness and thoroughness with which treat-

ment is executed. After the muscle has been completely replaced by scar tissue, its condition is hopeless, although lesser grades of fibrosis show varying degrees of restoration of function.

Treatment.—*Preventive Treatment.*—It has been demonstrated experimentally on animals that a very few hours of constriction are sufficient to produce ischemic myositis. We therefore cannot too strongly emphasize the eternal vigilance necessary on the part of the surgeon after a limb has been immobilized, whether in plaster-of-Paris, wooden, metal, or other splints, bandages, or even in a sling, to obviate the danger of this untoward event. In view of the fact that most cases of ischemic myositis occur in fracture of some part of the arm in children, especial care must be exercised not to allow constriction, particularly about the elbow. Inspection should be made of the patient every three to four hours during the first twenty-four, by the nurse or other attendant, and any evidence of swelling or discoloration should be reported to the surgeon, whereupon the dressings should be immediately removed, and, while the fracture is immobilized by the hands of an assistant, the limb is massaged and passive movements of the hands and fingers performed, using an anesthetic if necessary. This treatment should be repeated at frequent intervals (every two hours); when no further evidence of circulatory derangement exists, the immobilizing dressings may be replaced.

Curative Treatment.—Success depends upon the time which has elapsed between the onset of the contracture and the beginning of treatment. If the electrical reactions show the nerve to be injured, immediate operation should be performed and the nerves released from scar, callus, or pressure of fragments, etc. If the muscle alone is damaged, treatment is by mechanical means, massage, or operation.

In the case of the forearm, the author employs a malleable aluminum splint applied to the flexor surface with prolongations for the individual digits, extending from the elbow to the finger tips; the fingers and hand are brought gradually into intermittent extension.

The splint is bent and adapted to the flexion deformity both of the fingers and the wrist. The fingers are first slowly straightened (extended) by bending the malleable splint from day to day, and thus gradually overcoming the flexion deformity, the wrist meanwhile remaining in marked flexion. After several days, attempts to overcome the flexion deformity of the wrist are then begun by methods similar to those employed for the fingers, but are continued to the point of hyperextension, while the fingers are carried beyond physiological extension. The splint should be evenly padded with felt or other material; the process of extension may take weeks or months, but should be continued as long as any improvement is noted. If at the end of this trial period, no improvement has been noted, the question of operation should be considered, but the author believes that operation is inadvisable in these cases except as a last resort.

In addition to the above-described brace and manipulative treatments, other therapeutic measures should be employed, as follows: Once or twice a day, the affected limb is subjected to friction with hot water, massage, and stretching of the muscles by gentle manipulation, always beginning with the distal joints. The principle of mechanical treatment is gradually and gently to extend each contracted joint separately and in succession, the distal, then the middle interphalangeal joints, and the metacarpophalangeal joint; the wrist and elbow are flexed during manipulation of the hand and fingers, to relax the forearm muscles. The wrist is then extended with the elbow flexed, and finally extension of the elbow is practised. As has already been stated,

the treatment must be persistently prosecuted, often for many months, before improvement is noted. Tubby suggests that fibrolysin injections, as well as ionization with tincture of iodin, may be serviceable in these cases.

Operative Treatment.—Stretching under anesthesia, tenotomy, tendon lengthening, resection of the ulna and radius, etc., have all been tried, but without very satisfactory results.

Drehmann's Operation.—Through a long incision, the affected muscles are exposed, the main nerve trunks and muscles dissected free of scar tissue,

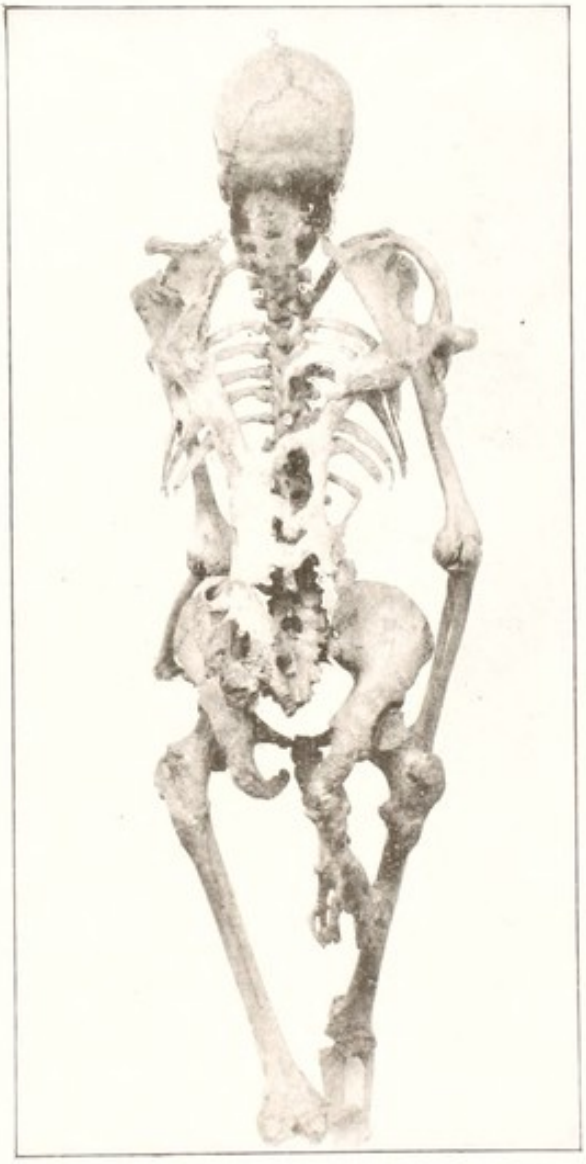


FIG. 541.—Myositis ossificans, diffuse form. (Royal College of Surgeons, London. Phelps.)

and the muscles separated from one another. The shortened muscles are then lengthened by slitting them alternately on opposite sides by short incisions, which procedure allows them to be lengthened until the fingers can be fully extended. The tendons of the lengthened muscles are divided and sutured to the healthy tendons of a synergic group. This operation must be followed by active and passive movements, massage, electrical stimulation of the muscles, etc.

The objection to this, as to all other tenoplastic procedures, is that the postoperative scar-tissue formation, by producing adhesions, interferes with

gliding, and it is suggested that a fascial flap, cargile membrane, or other organic material be interposed between the reconstructed muscle and tendon, and its healthy neighbors.

TUBERCULOSIS OF MUSCLE

The lesion is secondary to a primary focus, *e.g.*, lungs or intestine. The muscles of the forearm, the biceps and triceps in the arm, and the quadri-



FIG. 542.—Myositis ossificans, local form; man of forty-five. Blow on calf fifteen years before, followed by slowly progressing stiffness at ankle. (Hospital for the Ruptured and Crippled.)

ceps extensor cruris are those most extensively affected. The lesions consist of a solitary focus, multiple foci, or a diffuse tuberculous infiltration. Differential diagnosis from syphilis, lipoma, angioma, cysts, and sarcoma may be very difficult. Treatment consists of incision and thorough removal of the diseased tissue, to the point of excising the entire muscle; in the latter event, the tendon should be attached to one of its synergic group.

MYOSITIS OSSIFICANS

Three types can be distinguished:

I. Myositis ossificans progressiva.

II. Myositis ossificans circumscripta (limited to one muscle or group) (Fig. 542).

III. Traumatic myositis ossificans (osteoma of muscle and tendon).

I. **Myositis Ossificans Progressiva** (Fig. 541).—This type is rare, steadily progressive, and fatal in ten to twenty years. There is a deposit of bone in the muscles, usually in the back first. Boys and male adolescents are the usual victims.



FIG. 543.—Myositis ossificans following fracture of upper end of ulna. Motion of elbow almost entirely lost.

Pathology.—The bony deposit is interstitial in the muscles, but the fasciæ, ligaments, aponeuroses, and tendons are also affected.

Etiology.—The cause is unknown. Various theories have been advanced, viz.: (*a*) interstitial myositis as a basis; (*b*) trauma; (*c*) heredity; (*d*) syphilis; (*e*) trophic disturbance analogous to morphea, or Addison's keloid.

Symptoms.—The involved muscles give early evidence of tenderness and induration, while the patient suffers neuralgic or myalgic pains. The induration may entirely disappear, or recur at intervals, before ossification appears; the back is first to be affected, the trapezius and latissimus dorsi particularly. The patient presents a characteristic attitude, viz.: bowing

of the spine forward, the chin resting on the sternum; the abduction of the arms is limited and the jaws are fixed if the masseters are involved. Irregular bony masses may be visible and palpable, first in the scapular and interscapular regions, then in the erector spinæ muscles, while later other regions are affected. The ribs are locked by ankylosis and ossification of the muscles, necessitating diaphragmatic breathing; thus intercurrent pulmonary infection is common and is the usual terminal event. Rigidity of the jaws may necessitate artificial breathing.

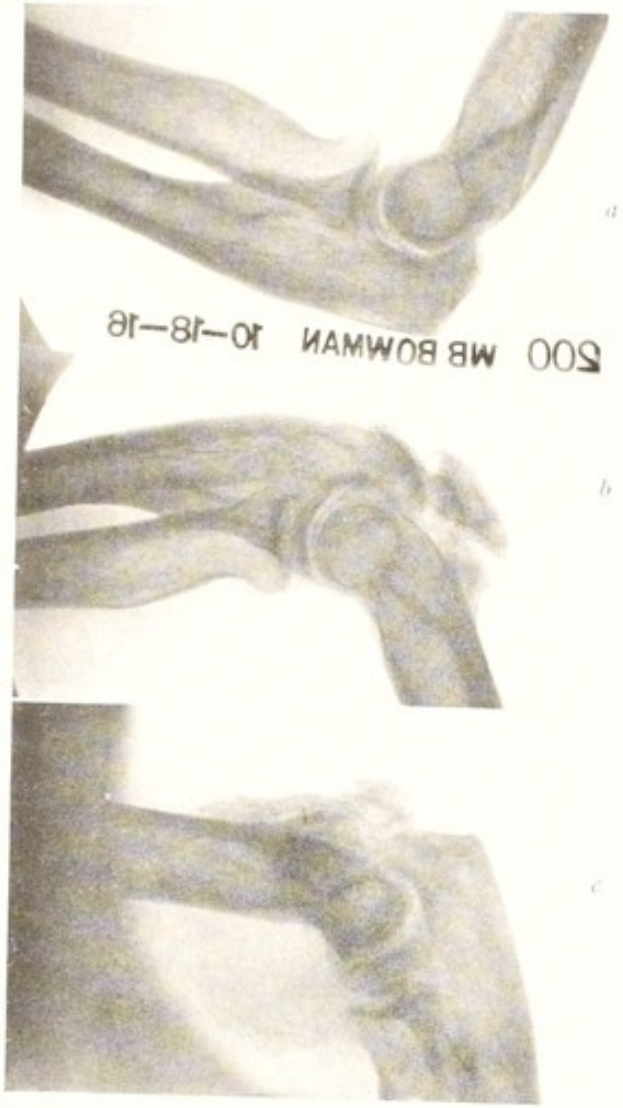


FIG. 544.—Myositis ossificans traumatica following old fracture of elbow. *a*, Normal elbow; *b*, and *c* stages in development of bony deposit in the insertion of the triceps muscle, almost entirely preventing motion.

Treatment.—No cure is known. Internal medication with mercury, potassium iodid, phosphoric acid, hydrochloric acid, etc., is futile.

II. and III. **Myositis Ossificans Circumscripta and Traumatic Myositis Ossificans.**—*Definition.*—An affection characterized by the development, within or in contact with muscle, of masses of osseous tissue.

Etiology.—The affection is found chiefly in males between twenty and thirty. The order of frequency of involvement is: Brachialis anticus, adductors of the thigh, quadriceps extensor cruris, other muscles rarely. There is usually a history of trauma, either single and severe, or of repeated slight traumatisms.

Pathology.—Traumatic Type.—Commonest near the elbow-joint and frequently follows dislocation (Figs. 543 and 544). It is caused by detachment of a fragment of periosteum which becomes implanted in the muscle and develops into bone. These bony masses, moreover, are attached to the bone from which they originated. The condition is also encountered in soldiers from excessive marching, and in their case is commonest at the posterior portion of the tibia, at the origin of the tibialis posticus.

Another type is characterized by true muscular osteomata, which may be multiple (four or five) and scattered through the body of the muscle. These masses are round or lamellar. Some are detached, others peduncu-



FIG. 545.—Myositis ossificans traumatica, extending from posterior surface of femur into and about ham-string muscles, thus preventing full extension of knee.

lated and attached to the bone. Their location may be tendinous, intermusculotendinous, aponeurotic, or intermusculo-aponeurotic. The arrangement is usually in flake-like masses on the surface, rounded or oval masses in the depth of the muscle. While the early growth is translucent to the *x*-ray, the later growth is impermeable to it (Fig. 544).

Theories of origin are numerous, viz.: (*a*) periosteal insemination, *i.e.*, escape of osteogenetic cells from torn periosteum; (*b*) ossified hematomata; (*c*) from muscular contusions and ruptures; (*d*) excessive strain on muscles, ligaments, and bones; (*e*) sesamoid bones.

Clinical Features.—In the circumscribed form, the onset is slow; in the traumatic cases, the muscles may rapidly undergo ossification. The following history suggests traumatic myositis ossificans: progressively increasing

limitation of motion, with thickening over the bone in the situation of a muscle, following injury, particularly a dislocation. Radiography gives confirmatory proof.

Treatment.—This is unsatisfactory. Massage increases the growth. It is best to defer operation until ossification of the affected muscle is complete, but if the mobility of a joint is threatened, early operation with the removal of *all* the affected muscle, its sheath and the new bone formation, together with removal of the attachment of any pedicle, including a ring of periosteum about it, is indicated.

HERNIA OF MUSCLE

Definition.—Protrusion of an intact healthy muscle through its sheath.

Etiology.—The accident affects adult males, usually as the result of trauma. The long fibered muscles, *e.g.*, tibialis anticus, the adductor longus, rectus femoris, biceps humeri, are those chiefly affected. The accident also occurs from syphilitic ulceration, and also following careless suturing after operation.

Pathology.—The protrusion always occurs through a buttonhole in the sheath or through a thinned out portion of the sheath. The hernia is apparent only at rest, disappearing when the muscle undergoes contraction.

Symptoms.—The swelling is usually small, soft, semi-fluctuating, reducible, and compressible. The margins of the aperture are palpable after reduction has been effected.

Treatment.—Open operation should be performed in a manner analogous to the radical cure of intestinal hernia, *i.e.*, reduce the protrusion, close the aperture after freshening its edges, overlap the margins, and suture. Recurrences are more or less common.

DISUSE ATROPHY

This is a simple atrophy from disuse rather than a trophoneurosis. The extent varies somewhat with the degree of immobilization used.

THOMSEN'S DISEASE

The affection is congenital and hereditary, and is characterized by marked hypertrophy of the muscle fibers and proliferation of their nuclei, associated with more or less paresis. The chief symptom is a peculiar rigidity of the muscle after rest, which becomes "unlimbered" after exercising.

REFERENCES

Auer, E. M.: "Spastic Paraplegia with the Cutaneous Reflex of Defense Occurring in Pott's Disease." Jour. Am. Med. Ass'n, jan. 25, 1913.

Babinski, J.: "Paraplégie flasque par compression de la moelle." Arch. de med. expér. 1891.

Babinski, J.: "Paraplégie spasmodique organique avec contracture en flexion et contractions musculaires involontaires." Rev. neurol., Paris, Jan. 12, 1911.

Babinski, J.: "Sur une farme de paraplégie spasmodique consécutive à une lésion organique et sans dégéneration du systéme pyramidal." Bull. et Mém. d. l. soc. hóp. d. Paris, 1899.

Baldwin, Henry C.: "Spastic Paraplegia of Extreme Degree, Great Improvement in Locomotion under Treatment." Boston Med. and Surg. Jour., Dec. 6, 1906.

Bungert, J.: "Ueber einen Fall von Spastischer Gliederstarre." Boun, C. Georgi, 1890.

Clark, L. S., and Taylor, A. S.: "The New Treatment of Spastic Paralysis by Resection of Posterior Spinal Nerve Roots." N. Y. Med. Jour., Jan. 29, 1910.

EDLAVITCH, B. M.: "Intraspinal Injections of Mercurialized Serum in a Case of Spastic Paraplegia." Jour. Am. Med. Ass'n, Jan. 29, 1916.
ERB, W.: "Ueber die Spastische Spinal-paralyse (tabes dorsal spasmodique, Charcot)." Virchow's Archiv, 1877.
FRANCOIS, M.: "Etude sur l'étiologie et la pathogénie de la sclérese en plaques." Paris, 1909.
HOFFMANN, J.: "Der Symptomencomplex der Sogen, Spastischen Spinal-paralyse als Theilerscheinung einer Hereditär Syphilitischen Affection des Centralnervensystems." Neurol. Cent., 1894, No. 13.
KNUTH, M. A.: "Ueber Spastische Spinal Paralyse und Dementia Paralytica." Kiel, Schmidt u. Klaunig, 1888.
LEYDEN, E. VON: "Ueber Spastische Spinallähmung." Berl. klin. Wchnschr., No. 48, 1878.
NATHAN, P. W.: "A Case of Cerebral Diplegia (so-called Spastic Spinal Paraplegia) with Pseudohypertrophy." N. Y. Med. Jour., Mar. 26, 1904.
PELIZAEUS, F.: "Ueber eine Eigenthümliche Farm Spastischer Lähmung mit Cerebralerscheinungen auf Hereditärer Grundlage (Multiple Sklerose)." Arch. f. Psychiatr., Berl., 1885, Bd. 16.
SCHOLTZ W.: "Zur Lehre von der Paralysis Spinalis Spastica." Breslau, P. Cohn, 1885.
SHARPE, W.: "The Results of Cranial Decompression in Selected Types of Cerebral Spastic Paralysis due to Hemorrhage." N. Y. State Jour. Med., October, 1916.
STRÜMPELL, A.: "Ueber das Tibialisphenomen und Verwandte Muskelsynergien bei Spastischen Paresen." Deut. Zeitsch. f. Nervenhlk., Bd. 20, Leipz., 1901.
WESTPHAL, C.: "Ein Fall von Spastischer Choreatischer Paraplegie." Charité ann., p. 4, 1879.

SPASTIC PARALYSIS IN CHILDREN

ADELINE, P.: "Contribution à l'étude de l'origine syphilitique de la Maladie de Little." Paris, A. Legrand, 1913.
AMIEUX, E. C.: "Etude clinique de quelques cas d'affections spasmo-paralytiques datant de l'enfance. Maladie de Little—Rigidité spasmodique—Tabes spasmodique hemiplégie cérébrale infantile double." Paris, Jauve et Boyer, 1899.
BABINSKI, J.: "Hemiplégie spasmodique infantile. (Paralysie post-spasmodique). Rev. neurol., Par., 1904.
BACARESSE, L.: "Consideration étiologiques sur le syndrome de Little." Paris, 1902.
BAUDON, A.: "Le syndrome de Little, valeur nosologiques." Forme clinique. Traitément, Paris, 1906.
CESTAN, R.: "Le syndrome de Little. Sa valeur nosologique. Sa pathogénie." Paris, g. Steinheil, 1899.
DE AMICIS, T.: "Die Little'sche Krankheit (Congenital Spastic Rigidity of Limbs) und die Hereditäre Syphilis." Wien u. Leipz., W. Braumüller, 1898.
DEJERINE, J. J.: "Sur la rigidité spasmodique congénitale d'origine médullaire. Syndrome de Little par lésion medullaire en fayer dévelloppeé pendant la vie intra-uterine." Rev. neurol., 1903.
GANGELE, K.: "Die Little'sche Krankheit und ihre Behandlung mit besonderer Berücksichtigung der Försterschen Operation." Jena, G. Fischer, 1913.
GUINOISEAU, L.: "La paralysie pseudo-bulbaire dans la maladie de Little." Paris, G. Steinheil, 1910.
KETCH, S.: "The Orthopedic Treatment of Spastic Paralysis in Children." Med. News, Mar. 27, 1897.
LITTLE, E. M.: "Infantile Spastic Paralysis and Its Treatment." Med. Rec., Nov. 30, 1907.
LONG, LANDRY, MME. M.: "La maladie de Little. Etude anatomique et pathologénique." Paris, H. Delarue, 1911.
NEUSTAEDTER, M.: "Two Cases of Little's Disease." N. Y. Med. Rec., Sept. 23, 1911.
RICH, E. A.: "The Atrophic Form of Little's Paralysis." Jour. Am. Med. Ass'n, July 20, 1912.
SHARPE, W., AND FARRELL, B. P.: "A New Operative Treatment for Selected Cases of Cerebral Spastic Paralysis." Jour. Am. Med. Ass'n, Feb. 6, 1913.
SPILLER, W. G.: "Fourteen Cases of Spastic Spinal Paralysis Occurring in one Family." Phila. Med. Jour., June 21, 1902.

CHAPTER XXIII

DEFORMITIES AND OTHER AFFECTIONS OF THE ANKLE AND FOOT

1. CONGENITAL AND ACQUIRED CLUB-FOOT

Synonyms.—Talipes (L.); Pied bot, Strephodie, Kyllopodie, Kyllose (F.); Klumpfuss (G.).

Definition.—A congenital or acquired deformity in which the anatomical relations of the foot to the leg or of one part of the foot to another are abnormal.

Varieties.—In the simple forms, the distortion is mainly "north, east, south, and west," viz.:

Simple forms:

1. Talipes equinus (plantar flexion) } Articulating center is ankle-joint.
2. Talipes calcaneus (dorsiflexion) }
3. Talipes varus { adduction and inversion, supinated foot } } Articulating centers: ankle and mediotarsal joints.
4. Talipes valgus (abduction and eversion) }
5. Pes cavus, increased convexity of longitudinal arch.
6. Pes planus, flattened longitudinal arch.
7. Talipes equinovarus, extension and inversion.
8. Talipes calcaneovalgus, flexion and eversion.
9. Talipes equinovalgus, extension and eversion.
10. Talipes calcaneovarus with cavus, flexion and inversion.

In spastic and paralytic cases, abnormal muscle-pull is the cause of the distortion of the foot; in the former class of cases, the deformed position of the foot corresponds to the action of the affected muscles; in the latter, the foot is pulled in a direction opposite to that of the affected muscles.

The majority of cases of club-foot are acquired. Males are more frequently affected than females, and the right foot is involved more often than the left. The distortion is unilateral in acquired cases, bilateral in congenital. Club-foot is occasionally a familial affection. When it is congenital other anomalies are frequently present, *e.g.*, polydactylism, club-hand, hare-lip, spina bifida. In the production of the ultimate deformity, Wolff's law plays an important part, *i.e.*, that the external shapes of the bones are the result of functional adaptation.

1. Congenital Club-foot

Whitman (Orthopedic Surgery, 1910 edition, p. 794) has found that talipes equinovarus forms 77.4 per cent. of his series of congenital club-foot. The experience of other authors conforms to these figures and makes talipes equinovarus the commonest variety of congenital club-foot.

CONGENITAL TALIPES EQUINOVARUS (Fig. 546)

Nature of Deformity.—The deformity is compound, with its elements at two points: (*a*) Foot, chiefly at the mediotarsal joint; (*b*) at the ankle,

viz.: (1) The heel is raised and the foot is in plantar flexion; (2) the sole is adducted, brought toward the middle line, and inverted; (3) the internal border is elevated, shortened, and bent upon itself, the great toe markedly adducted and flexed ("pigeon-toe"), and the small toes extended; (4) the outer border of the foot is convex and supports the body-weight.

The deformity varies according to the age and according to the degree to which it can be manually corrected. The plantar fascia, tibial tendons, and tendo Achillis are firmly contracted. The skin on the external border and dorsum of the foot is thickened, covered with callosities or with tender, painful corns; the bursæ between the skin and bones are inflamed; the foot is shorter and smaller than the other; shortening of the leg occurs, and its muscles are smaller than on the normal side. Distortion of the head and

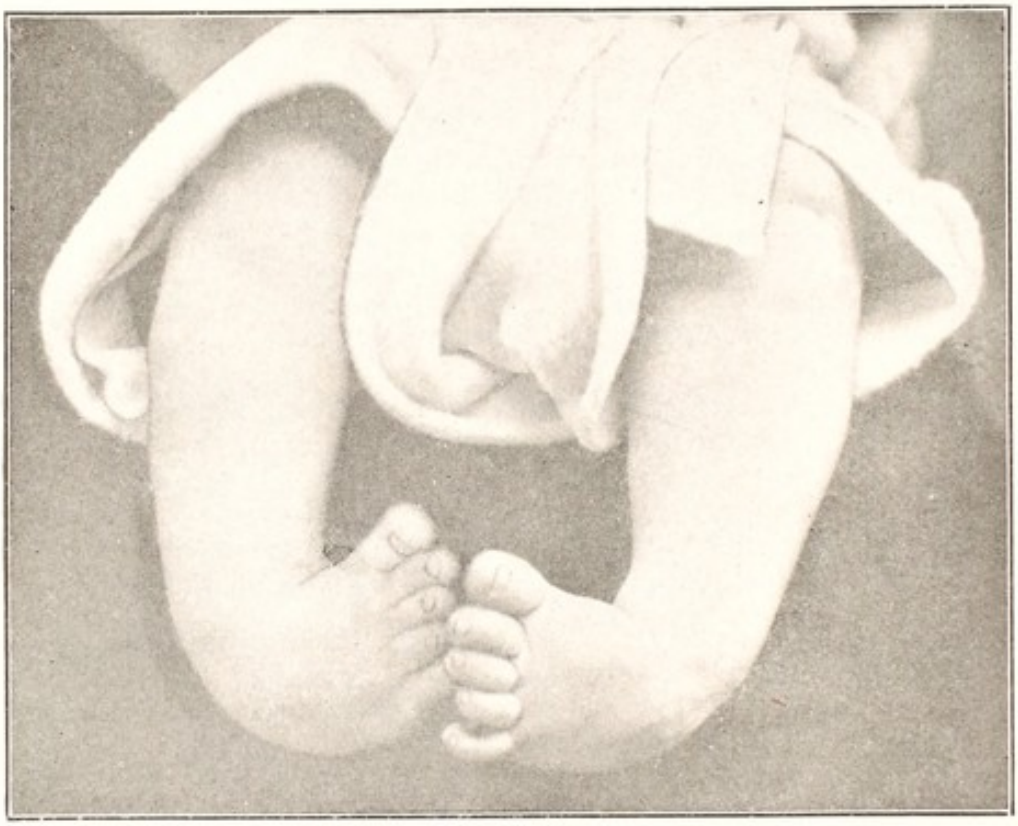


FIG. 546.—Typical congenital equinovarus (club-foot). (Whitman.)

neck of the femur usually co-exists as the result of mechanical derangement of the forces of locomotion.

Anatomy.—The deformity affects the whole foot and is not confined to any one part. *Astragalus* is extended at the ankle-joint, subluxated forward, and the anterior part of the upper articular surface is often so broad that the mortise of the tibia and fibula is too small to hold it, and this is an important cause of clinical failure to secure dorsiflexion at the ankle. The head and neck of the astragalus are twisted inward. An abnormal bony outgrowth is frequently present on the outside of the head and neck. A new nonarticular quadrilateral surface, which appears to be a continuation of the tibia, is frequently formed on the antero-external surface. *Os calcis:* Its long axis, instead of being directed horizontally, extends downward, forward, and inward, and the bone is rotated on this axis so that its inner surface is directed upward. *Cuboid:* Is displaced inward with the hypertrophied os calcis. *Scaphoid:* Is drawn upward and inward, often articulating with the internal malleolus, and is atrophied. *Cuneiform and metatarsus:* Follow the change

in direction of the foot, but are not altered in shape. *Tibia and fibula:* The lower ends are rotated inward on their long axes. *Ligaments:* On the dorsum and external border, they are elongated; in the sole and internal border, they are contracted, mainly the anterior portion of the internal lateral ligament of the ankle and the astragaloscaphoid and inferior calcaneoscaphoid ligaments. The posterior ligament of the ankle suffers compensatory shortening. *Muscles and fascia:* The tendons of the tibialis anticus, extensor longus digitorum, and extensor proprius hallucis are displaced inward. These muscles and the tibialis posticus are shortened and their tendons are tense. The tendo Achillis is displaced inward and aggravates the inversion of the sole. The plantar fascia is shortened and thickened.

The relapsed cases may be subdivided (from the operative standpoint) into two types of congenital club-foot. (*a*) That of the *long, comparatively*



FIG. 547.—Marked equinovarus deformity associated with spina bifida.

slender, foot where the osseous development has gone so far as to resist correction in spite of the tenotomy of the tendo Achillis to overcome equinus and forcible stretching followed by fixation in plaster-of-Paris or braces, and with still gradually relapsing adduction of the forefoot, particularly toward varus; and (*b*) another group which will include those cases of relapsed club-foot consisting of a *short chunky* foot in extreme varus. In many of these latter cases we find that the patient has by the impact of walking produced hypertrophy of the cuboid, the foot being so markedly inverted and supinated that the weight of the body rests directly upon the cuboid; the peroneal muscles, from long disuse, are undeveloped and elongated, and the dorsal flexors of the foot on the leg are shortened and act as direct agents to increase varus and supination of the foot. The technic of the author's operative procedures for the correction of these two particular types of club-feet will be found in the following pages.

Etiology.—The theories as to the causation of congenital club-foot are inconclusive and will be found fully discussed by Julius Wolff ("Club-Foot:

its Causes, Nature, and Treatment," Berlin, 1903). The most plausible theory is the mechanical, viz.: that from some unknown cause the foot has remained for an indefinite time in an abnormal, fixed attitude, and as the result thereof the deformity has developed.

Prognosis.—The degree of usefulness to be expected from mechanical or operative treatment is largely governed by the following considerations: (*a*) The *age* at which the treatment is begun, and the degree of the deformity; the younger the patient, and the less the degree of deformity, the greater is the possibility of obtaining a good shapely foot; (*b*) the amount of *rigidity*. If rigidity is due to structural alterations in the bones themselves, the outlook is less favorable than if it is due to contracted soft parts; (*c*) the presence of *other deformities* complicates the case; (*d*) *persistence* in treatment modifies the outlook: relapses are frequent without constant supervision after treatment has been concluded.

As to the duration of treatment, a moderately severe case may be relieved in a few weeks by manipulation and moulding of the foot into proper position, and its retention in a plaster-of-Paris cast. The prevention of relapse is most important and measures directed to that end should extend over a period of months to years; the child should be kept under constant observation until active walking is begun. "Active treatment is necessary only for weeks, care for years" (Tubby).

TREATMENT

General Considerations.—Obstacles to Reduction in Congenital Talipes Equinovarus.

I. *Infants.*—The chief obstacles to reduction are offered by the internal lateral ligament of the ankle, the plantar ligaments and fascia, the tendons of the tibialis posticus and anticus, and the tendo Achillis, the astragaloscaphoid and calcaneoscaphoid ligaments, and by the malformation of the astragalus and other bones of the foot. All these obstacles are removable in infants by tenotomy, fasciotomy, syndesmotomy, manipulation, and immobilization.

II. *Adults.*—All obstacles appertaining to infants, as well as the following: (1) Abnormal shape of the bone, especially downward and inward twist of the neck of the astragalus and subluxation of the cuboid and scaphoid; (2) more or less obliteration of pre-existing joints, *e.g.*, an overgrown astragalus with contracted tibiofibular mortise; (3) formation of new joint; (4) fixation of ligaments and tendons in abnormal positions. On account of hardness of the osseous tissue in the adult, bone sections must be resorted to in most instances.

Treatment in Infancy.—In his lectures to students, the author has been accustomed for several years to illustrate the necessity of beginning treatment of club-foot as soon as the deformity is discovered, by the overstatement that if, at the time of labor, the accoucheur finds a foot or breech presentation to be complicated by the presence of congenital club-foot, he should begin corrective manipulation of the foot before the birth of the head.

1. Manipulation of the foot by the physician, nurse, or one of the members of the patient's family, should be begun immediately, that is within the first few days of life, and forcible overcorrection of the affected foot obtained. It should, however, be realized that the general condition of the infant should be uppermost in the surgeon's mind at all times, and if it is noted that a poorly nourished child is rendered irritable or the health seriously impaired by constant manipulation of the foot, treatment should be temporarily suspended.

2. In a child two to three weeks old manipulations should be supple-

mented by adhesive plaster strips, half an inch in width, so placed on the outer side of the lower leg and foot that the foot is held in overcorrection.

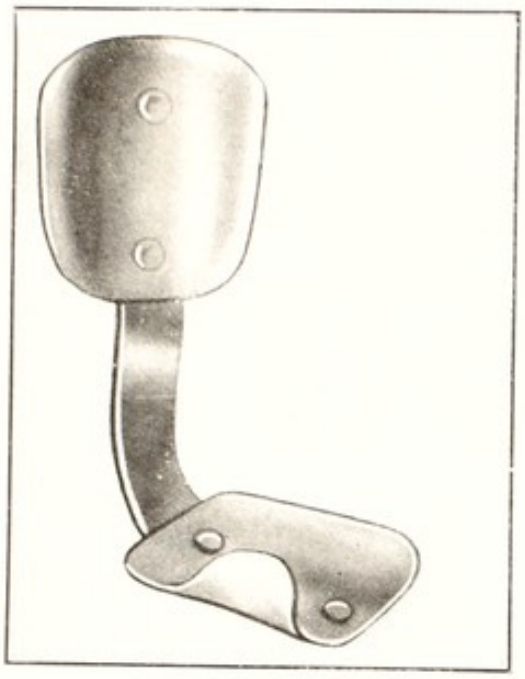


FIG. 548.

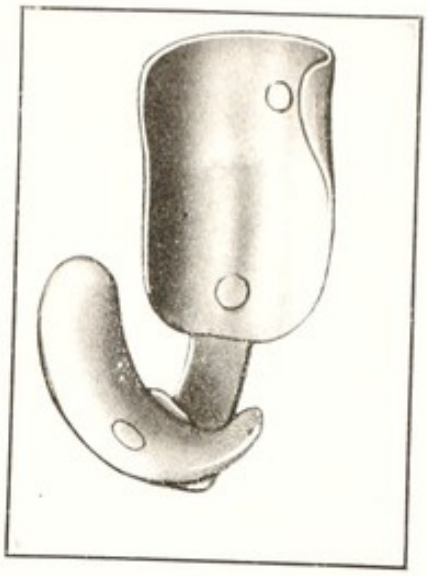


FIG. 549.

FIGS. 548 and 549.—Jones' club-foot splints. (Jones.)

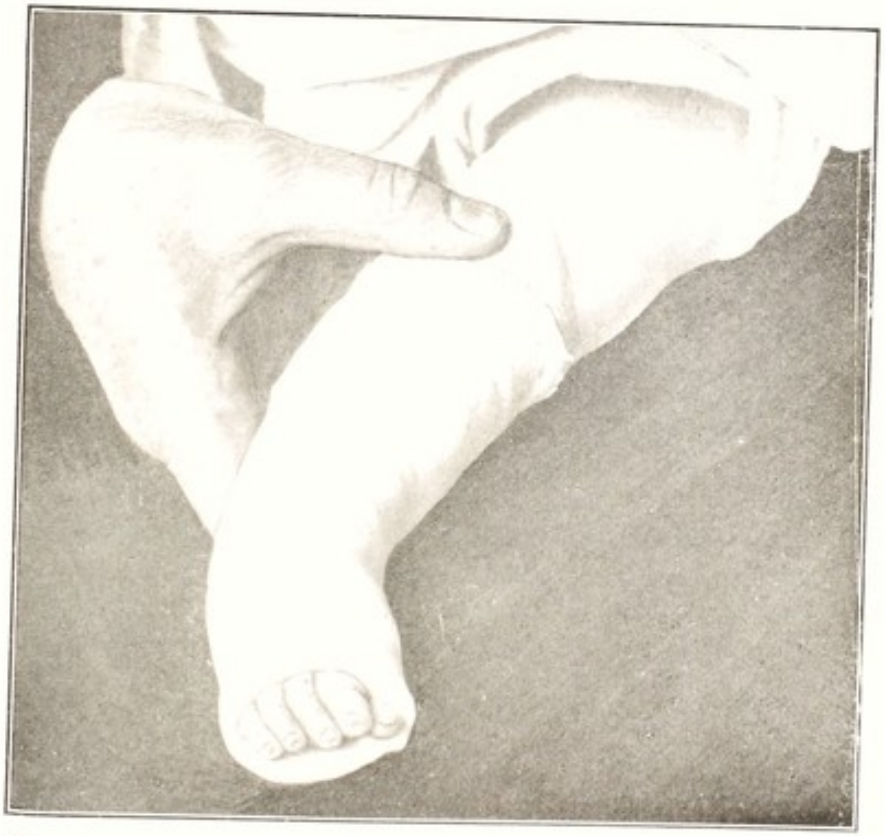


FIG. 550.—The first application of the plaster bandage, showing the improved position. (Compare with Fig. 546.) (Whitman.)

The presence of this adhesive strapping will not prevent the mother or attendant from executing manipulation as regularly as before. These strap-

pings should be renewed at intervals of one week, and are best held in place by gauze bandages applied over them.

3. At the age of two to four months, plaster-of-Paris dressings are substituted for the adhesive plaster (Fig. 550), and these are to be applied with the foot in as thorough overcorrection as it is possible to secure, and the plaster-of-Paris renewed every two to four weeks. If the deformity is extreme, more particular attention must be paid to the adduction and varus, as the equinus can always be corrected by tenotomy of the tendo Achillis at a later date, and the contour of the foot will not suffer thereby. In most cases in which treatment can be begun thus early and kept up with regularity, operations other than simple tenotomy are, as a rule, unnecessary. Emphasis is placed upon the importance of grasping the lower part of the leg, just above the ankle-joint, firmly with one hand while with the other hand the foot is forcibly stretched and everted. This precaution is observed to prevent the tibia from being fractured.

Treatment over Two and a Half Years.—(*a*) *Mild Cases.*—In children of six months or over at the time the surgeon is first consulted, radical procedures of varying nature, according to the type and severity of the deformity, are in order. In the mild cases, favorable to correction, a fasciotomy of the plantar fascia at its insertion into the os calcis and tenotomy of the tendo Achillis, with strenuous manipulative overcorrection with the Thomas' wrench, and repeated applications of a plaster-of-Paris bandage at intervals of two weeks will usually suffice.

Wrenching.—Of the great number of wrenches and osteoclasts for use in the correction of club-foot, the best is the one devised by H. O. Thomas, the principle of which can be readily understood by a glance at Fig. 571. The use of the wrench is usually preceded by a preliminary tenotomy of contractured tendons. The wrench can be applied to any position of the foot. Stretching should be carried to a point where the foot lies limp in the hand.

When the plaster bandage is applied to these mild cases, it should be continued on to the thigh to the junction of the middle and upper thirds, with the knee flexed. The author uses this type of plaster dressing in all cases of club-foot, both congenital and acquired, existing in older children. The rationale of this splint is that the foot is maintained in eversion and overcorrection by means of the reverse leverage action of the thigh with the leg flexed. The advantages of this dressing are obvious: the old conventional plaster-of-Paris bandage carried only to the tubercle of the tibia, prevents the relapse into adduction only by the friction between the cotton or flannel under the plaster-of-Paris and the skin of the lower leg; this may hold the foot in abduction for a time, but the atrophy of the calf muscle plus the compression of the padding beneath the cast soon causes looseness which permits of the easy relapse of the deformity.

Treatment of Cases over Two and a Half Years.—(*b*) *Severe Cases.*—In the relapsed or untreated cases, bone plastic operations are recommended only in the period beyond infancy, where the tarsal bones have become partially or completely ossified, and resist moulding by long-continued manipulations and fixation in overcorrection. Such cases have been made to yield to the varied technic herein described (Fig. 551).

In the more severe deformities, the Ober, the Cooke, the Phelps, or the Hoke operation may be necessary, or, in certain selected cases the author's procedure of removal of a wedge of bone from the cuboid in the outer side of the foot and its replacement in the split scaphoid of the inner side of the foot. (These operations will be fully described in the following pages.) In the most desperate cases alone should the surgeon be compelled to perform

astragalectomy (see Chapter XXI) associated with fasciotomy of the plantar fascia and tenotomy of the plantar flexors of the toes and of the tendo Achillis.

In certain cases where the varus and equinus have been entirely corrected and the patient stands with the plantar surface of the foot squarely on the ground but with an awkward adduction of the whole foot, the author has practised osteotomy of the tibia at the junction of the lower and middle thirds, and the forcible abduction of the foot followed by plaster splint from toes to upper thigh, as already described.

The deformed foot should be considered from a purely mechanical standpoint, and when it is necessary to remove a wedge or insert a wedge, or both, the surgeon should not hesitate to do either. The varieties of wedge are numerous, and the amount of bone, the plane in which it lies, etc., depend upon the case at hand, and each deformity should be judged on its individual merits.

Special Operative and Mechanical Procedures.—1. *Ober's Operation for Congenital Equinovarus Deformity* (ref. Frank R. Ober, Jour. A. M. A., vol. lxv, No. 7, Aug. 14, 1915, p. 621).—This operation is indicated in children over six months to one year of age, where the deformity is severe, particularly the type of short chunky foot, and in cases in which the bones have not become so ossified that they will not yield to pressure. It is an operation which has a wide field of usefulness in cases of this general type.

A fish-hook incision, 3 inches in length, is made about the internal malleolus. The incision begins 1 $\frac{1}{2}$ inches above the malleolus, half-way between the posterior border of the tibia and the Achilles tendon, a tourniquet having been previously applied. It is carried about $\frac{1}{2}$ inch below the malleolus and swung anteriorly and a little upward over the depression which represents the situation of the subluxated scaphoid. It is carried through skin, fat, and subcutaneous fascia, and the anterior flap is dissected well forward so that, in sewing up the wound, no undue strain is brought to bear on the skin edges of the wound. This incision exposes the deep fascia over the malleolus, the annular and deltoid ligaments.

A semilunar incision is now made, curved upward, $\frac{3}{4}$ inch above the tip of the internal malleolus through all the structures to the bone, avoiding the posterior tibial tendon. The flap is dissected off the bone in a downward direction, and includes both layers of the deltoid ligament, giving an excellent ligamentous flap and a wide exposure of the tibiotarsal articulation. The superior calcaneoscaphoid ligament is divided transversely by simply continuing the curved incision toward the plantar surface of the foot. By means of a tenotome the portions of the deltoid and inferior calcaneoscaphoid ligaments, which are respectively attached to the posterior and anterior borders of the sustentaculum tali, are incised longitudinally to the bone. With a blunt dissector or an osteotome, these ligaments with periosteum are actually cleaved from the inferior surface of the sustentaculum tali and well down on the internal surface of the os calcis. It is not often necessary to cut the posterior tibial tendon, but it is usually necessary to cut the tendo Achillis especially in older children. The plantar fascia may be divided if there is considerable cavus. The foot is now grasped, both by the forefoot and the heel, and is manipulated into an overcorrected position. The *os calcis everts easily*. The head of the astragalus and scaphoid rotate into normal position. Satisfactory overcorrection is obtained.

We must secure good eversion of the os calcis if we expect to relieve or cure club-foot. If we desire to lengthen the Achilles tendon, it may be cut at this time. The deltoid ligament is sutured at either corner, low down on the malleolus, so that this important structure will be preserved intact. The

foot should be so well overcorrected that it can be held in such a position with very slight effort. A sterile gauze dressing is applied which is covered by sterile sheet wadding. A plaster is applied from the toes to midthigh, maintaining the foot in the overcorrected position and the knee flexed to a right angle. A window is cut over the wound with a twofold idea: It relieves any subsequent pressure on the wound and allows the foot at this point to bulge into the wound, giving more correction.

2. *Phelps' Operation.*—The principle of this operation is incision through the contracted structures in the sole, and forcible rectification of the deformity.

Technic.—After applying an Esmarch bandage, the tendo Achillis and posterior ligaments of the ankle are divided subcutaneously. An attempt is then made to overcome plantar flexion manually or by the wrench. An incision is made from the internal border of the foot just below and in front of the internal malleolus downward, over the head of the astragalus, to include the inner fourth of the sole. Through this incision, all resistant structures are divided in order, as follows: (*a*) tibialis posticus and tibialis anticus (if the latter is resistant); (*b*) abductor hallucis; (*c*) plantar fascia; (*d*) flexor brevis digitorum; (*e*) flexor longus digitorum; (*f*) deltoid ligament. After division of each structure, an attempt is made to correct the foot, so as to avoid unnecessary division. The wound is dressed with gutta-percha tissue or rubber dam placed directly over the exposed raw surface, and over this protective a generous amount of shaken gauze. The foot is then put in the corrected position in plaster-of-Paris and the limb elevated. The wound closes by granulation in one to three months. The first plaster splint is changed at the end of four to five weeks, followed by weight bearing.



FIG. 551.—Removal of bone wedge from the outer side of the anterior end of the os calcis for correction of rigid club-foot in older children or adults. An operation recommended by Cook.

3. *Cook's Operation for Relapsed Club-foot* (ref. Ansel G. Cook: Am. Jour. Orth. Surg., vol. xiv, No. 1, Jan., 1916, pp. 9–17).—This is an operation for relapsed club-foot, cases that have resisted the ordinary methods of treatment. According to Cook there is no age limit, no preliminary treatment, and no after-treatment beyond the time required for the healing of the wound.

"First: If necessary, subcutaneously divide the fascia on the inner side of the foot and also the heel-cord; then bring the foot into as good position as possible, using nothing but the hands, and being careful not to bruise the tissues.

"Second: Make an incision through the skin and superficial fascia just in front of the external malleolus on the outer side of the foot. The skin incision should be perpendicular from the bottom of the foot to just above the bend of the ankle.

"Third: With an osteotome remove a large wedge of bone (Fig. 551); make the first incision far back, just in front of the fibula. Pay no attention to the periosteum or peronei tendons. Cut the bones *completely across* and remove everything. Be sure to make the wedge large enough.

"The foot can now be brought without force into excellent position, and by giving the anterior part of the foot a quarter-turn, its outer border can

be elevated. It is vitally essential to the success of the operation that the outer border of the foot be elevated. In order to do this, the tarsus is cut completely across to enable the operator to give the anterior foot the quarter-turn which elevates the outer border.

"It is claimed for this operation that flat clean surfaces of bone are opposed. There is no cavity to fill up. The wound is clean cut and there is no bruising or mangling of the surrounding tissues. No sutures except skin sutures are required. If the wedge of bone is sufficiently large and the angles of the wedge are correct, there is no tendency to, or possibility of, a relapse, as every step the patient takes tends to maintain the bone in its new position.

"Personally, I (Cook) use a light retention splint in preference to a plaster cast. (The author prefers a well-moulded plaster-of-Paris cast.—F. H. A.) Young children will often walk at the end of two weeks.

"The dressing is worn from six to eight weeks, when the patient is ready for an ordinary shoe.

"The important thing in this operation is to remove the right shaped wedge of bone. The older the patient, the less liability to relapse."

4. *Hoke's Operation.*—Michael Hoke (ref. Am. Jour. Orth. Surg., vol. ix, 1911–12, p. 379) has suggested an operative plan for the correction of relapsed and untreated talipes equinovarus with great bony deformity, and also in cases resulting from infantile paralysis in which bone deformity is great and has been present for years. Hoke's operative plan is really a series of operations on the various tarsal and metatarsal bones, one or all of which may be performed on an individual case at one or different sittings, as the circumstances of the case demand.

(*a*) *Metatarsal Osteotomy.*—To correct the inward inclination, outward rotation, and increase of the metatarsal angles participating in the deformity, short incisions are made over the posterior end of the metatarsal shafts, the periosteum is incised and elevated, and with a narrow osteotome, the shafts are cut nearly through. With a sand-bag under the sole, the metatarsals are fractured with hammer or hands, and the bones are restored to proper alignment. A plaster-of-Paris splint is applied from the toes to the tubercle of the tibia after which weight-bearing is allowed and massage instituted. This procedure relieves pressure on the hard painful corns and affords relief of anterior metatarsalgia, etc.

(*b*) *Osteotomy of the internal cuneiform* to overcome increase of the dorsal longitudinal diameter of the internal cuneiform which participates in the cavus feature of the deformity. Wedge-shaped osteotomy of the cuneiform is performed with the base of the wedge upward. The incision is made over the cuneiform, and a crucial incision made in the periosteum, the latter elevated, and the wedge removed. This procedure may be combined with metatarsal osteotomy and the same dressings are applied as in that procedure.

(*c*) *Osteotomy of Cuboid.*—This is a plastic procedure to reshape the cuboid by shortening the external border so that it will not offer resistance to abduction of the metatarsus, *i.e.*, to restore the normal shape of the bone. Inasmuch as the cuboid is distorted in various directions, according to the type of club-foot deformity, the shapes of the wedges to be removed will vary accordingly, but, in general, the base of the wedge is directed externally and upward.

(*d*) *Osteotomy of os calcis* to overcome adduction of the forefoot and restore normal alignment to the outer border of the foot. Two methods may be followed, either (*a*) to cut off the antero-external corner of the hypertrophied

os calcis, including the joint surface if the condition is due to the hypertrophy of that portion, or (*b*) cuneiform osteotomy of the anterior end of the os calcis behind the calcaneocuboid joint (see shaded wedge on os calcis, Fig. 551). The latter procedure is performed as follows: An incision is made parallel to and above the peroneus longus tendon over the tubercle to which are attached the extensor brevis hallucis and the extensor brevis digitorum; chisel to this tubercle and the tubercle attached to it and turn it forward, exposing the external surface of the anterior extremity of the os calcis and the adjacent calcaneocuboid joint. Remove a cuneiform wedge with its base outward, so shaped that when the foot is put in the normal position the outer border will be straight and the calcaneocuboid joint vertical and transverse instead of oblique. The tubercle with its muscular attachment is turned back in place and stitched to the periosteum with fine kangaroo-tendon sutures, the skin closed with a continuous suture of No. 1 plain catgut, and the foot put in normal position in plaster-of-Paris.

(*e*) *Curved Cuneiform Osteotomy of the Neck and Head of the Astragalus.*—The surgeon must exercise good judgment in selecting the place from which the bone shall be removed from the neck of the astragalus and the shape of the piece to be taken out. If backward excursion of the body of the astragalus is greatly limited and its neck is too long, the anteroposterior length of the astragalus should be shortened by cuneiform osteotomy, thus obviating the tendency of the long neck to turn the forefoot in, and permitting enough dorsiflexion to enable the patient to walk without adducting the forefoot. The surgeon is advised to remove a curved wedge to avoid prominence where a depression naturally occurs in the neck of the astragalus. If a curved wedge is not removed, although the patient can well abduct and dorsiflex the forefoot, the scaphoid will not be balanced in front of the head of the astragalus on account of the abnormal contour of the head, and there will be a tendency for the forefoot to adduct after operation. A curved incision is used so that the skin flap will overlie the incision in the bone, and therefore adhesions between the skin, subcutaneous fascia, and bone will be avoided. The foot is put up in dorsiflexion in plaster-of-Paris, in its normal position, *i.e.*, neither abduction nor adduction. This dressing is removed in three weeks.

(*f*) *Plastic Operation on the Body of the Astragalus.*—When the astragalus is so broad in transverse diameter through the front part of its body that the surgeon cannot get the bone back far enough for the two malleoli to be placed upon its sides, this plastic operation is offered as a compromise between the life-long use of apparatus and complete astragalectomy. After removal of the wedge from the astragalus, the external fragment which is left is pressed against the internal and is retained in position by lateral pressure of the external malleolus against it. The skin incision is the same as for the operation to be described below for bringing the external malleolus forward. This operation produces a better looking foot than total astragalectomy, a strong elastic foot, and obviates the use of apparatus.

(*g*) *Osteotomy of the Fibula for Backward Dislocation of the External Malleolus.*—If the external malleolus is dislocated backward and bound in this position by excessive development of the posterior capsule and by the "great club-foot ligament" (Hoke), a tremendous development of the posterior fasciculus of the external ligament of the ankle, extending from the posterior border and adjacent inner rough face of the external malleolus through the posterior end of the body of the astragalus, it is occasionally, not always, necessary to remove the external malleolus forward so that it can articulate laterally with the astragalus. This is desirable for several reasons, viz.: (1) With the

external malleolus in the posterior position, it is impossible for the astragalus to move backward if an attempt at dorsiflexion is made; (2) the ankle-joint is made wide enough to receive the body of the astragalus by this procedure and lateral stability is given to the joint; (3) if the os calcis is fixed in outward rotation and the external malleolus is bound to it in this posterior position, it is impossible to correct the ankle and straighten the heel unless the external malleolus is moved forward.

An incision is begun 1½ to 2 inches above the tip of the external malleolus, at a point over the shaft of the fibula, carried downward and backward toward the tendo Achillis, and when half-way between it and the malleolus it is curved forward and parallel to the peroneus longus. It is best to cut the posterior ligament of the ankle-joint and all other ligaments and tendons binding the external malleolus in its posterior position, *i.e.*, dissect the external malleolus entirely from behind, below, and in front, and from its attachments to the astragalus. Osteotomy of the fibula is performed about 2 inches from the tip of the malleolus. The interosseous ligaments between the tibia and fibula are severed as much as necessary. The external malleolus is slung forward, and at the same time the foot is abducted and slightly dorsiflexed. If the antero-external corner of the tibia is sufficiently hypertrophied to interfere, it should be removed. Two silk sutures are passed, one from the anterior border of the malleolus to the fascia in front, and one from the tip of the malleolus to the fascia or periosteum of the os calcis below. A plaster-of-Paris splint is applied to the foot in dorsiflexion, and slight abduction, and while the plaster is soft the splint is moulded behind and against the malleolus, to prevent backward rotation of the fibula during healing. In three weeks the patient is able to walk, when correct shoes, massage, and exercises are employed.

(*h*) *Cuneiform osteotomy of the os calcis* to correct outward rotation and bowing of the os calcis and faulty pull of the tendo Achillis. A longitudinal incision is made parallel with the long axis of the bone over its external surface. After incising and elevating the periosteum, a wedge is removed with the base outward, converging to an apex on the inner surface of the bone. The posterior end of the os calcis is manipulated until the heel occupies its proper anatomical position below the ankle. The periosteum is stitched, the skin closed, and plaster-of-Paris applied by re-duplicating a bandage from a point high up on the inner side of the calf downward across the sole of the heel and then up to the ankle; while the plaster is hardening, the surgeon should grasp the forefoot with one hand and the posterior end of the os calcis with the other, which makes the plaster grip the heel tightly. The heel is held in the corrected and normal position while this plaster is hardening, whereupon a second plaster is applied over the first from the toes to the tibial tubercle. Weight-bearing is allowed in three weeks.

5. *Operative Treatment of Long, Slender Club-foot.*—The technic of the operative treatment used by the author in dealing with the long, slender type of relapsed club-foot with marked varus and moderate abduction of the forefoot, is as follows:

The deformed foot, and the leg also, having been prepared for operation and a tourniquet securely applied above the knee, the equinus is first corrected by tenotomizing the tendo Achillis to enable the operator to force the foot into dorsiflexion on the leg. A narrow sharp tenotome is thrust through the skin, with its blade parallel with and just anterior to the tendon, and about three-quarters of an inch above its insertion into the os calcis. The cutting edge of the tenotome is turned posteriorly and the tendon is divided from before backward, care being taken to divide the plantaris tendon as

well. The division is easily perceptible in the sudden giving way of the resistance to dorsal flexion of the foot. The heel is brought down thoroughly by forcible dorsiflexion of the forefoot. The next step, when no true bone operation is done, is the thorough stretching out of the varus by manipulation, either manual or with the Thomas' wrench, with or without the wedge-block as a fulcrum. The foot is then so lax as to be easily placed in an overcorrected position, but it is obvious that if reliance is placed upon external correction alone, relapse would take place. This is very prone to occur following the Phelps' operation, where a free division of all soft structures is made down to the bone and the foot forced into valgus, leaving the wide gaping wound to heal by granulations, resulting in a contracting scar, and the articular surfaces



FIG. 552.



FIG. 553.

FIG. 552.—Congenital club-foot before operation.

FIG. 553.—Congenital club-foot after operation. Double tibial transplant into split halves of scaphoid bone by Albee's method. (Operation by E. W. Jones of Los Angeles.)

of the tarsal bones widely separated with no provision made to prevent these articulations from closing up again.

Having had exceptional clinical opportunity for observing a large number of relapses in club-feet following these soft tissue operations, it became evident to the author that if relapse was to be prevented, remodelling of the bony framework of the foot was essential. All previous club-foot bone operations have entailed removal of wedges of bone from the outer or long side of the tarsus, and have thus still further shortened an already short and undeveloped foot. Since the trustworthiness of the bone-graft had been so thoroughly proven, it occurred to the author in 1911 that the surgeon could well follow carpentry methods in carefully selected cases and remodel the tarsus by elongating the concave or short inner side of the foot by placing a bone-graft wedge between the split halves of the scaphoid bone (Figs. 552 and 553). At the same time that this corrects the bony deformity of the foot,

it may lengthen it sufficiently to avoid mismated shoes. Any degree of lengthening of the foot is far preferable to any further shortening of it.

Technic of Placing Bone-graft Wedge Between the Split Halves of the Scaphoid Bone (Albee).—A U-shaped skin incision is made on the inner aspect of the foot, and the flap with its subcutaneous tissue is dissected back, exposing the scaphoid bone. The apex of this incision should extend well forward in the region of the great toe; or a straight incision may be made over and parallel with the long axis of the dorsum of the foot, so that the superior surface of the scaphoid is approached. Whatever incision is employed, however, it should always be so situated if feasible that when the wound is closed the skin sutures do not overlie the graft. The development of the field of the bone operation should be carefully done, as the changed bone-formation and landmarks may be extremely distorted.

With a half-inch thin sharp osteotome, the scaphoid is split into anterior and posterior halves, either by a linear osteotomy through the long axis, or by a curved bone incision from above following the general curved contour of the bone. The foot is then forced into the required degree of overcorrection, and the gap between the halves is widened. All resistance by plantar fascia or other tissues is relieved by severing these structures with a scalpel through the wound already made, or by means of subcutaneous fasciotomy through an additional tenotome wound. The width of the gap is taken with calipers, as a measurement for the size of the bone wedge, to be obtained preferably from the tibia of the same limb. The skin and subcutaneous structures overlying the anterior internal aspect of the tibia are incised at about the junction of the lower and middle thirds of the shaft, which region is selected as it yields a denser and thicker bone cortex than higher up. The skin incision should be so situated that it does not overlie the cavity from which the graft is removed. Having freed the crest from muscle attachment, and with the skin and soft parts well retracted by sharp retractors, the width and thickness of the required wedge are marked off by a scalpel cutting into the periosteum. The motor-saw is then employed to cut the wedge graft from the tibia. The two cuts are made transversely through the cortex of the crest at the measured distance apart, and are caused to converge toward each other as the medullary cavity is approached.

Before its dislodgment from the tibia, the graft is drilled with a small motor-drill through the center of its cortex for retaining sutures, and is then removed from its bed with the aid of a sharp osteotome, and either placed in normal saline solution until used, or transferred directly to its position between the halves of the split scaphoid. It should fit so tightly as to prevent any return of varus and adduction deformity when the forefoot is released by the assistant.

If the cortex of the scaphoid is too dense to permit the passage of a short, strong, curved cervix needle, the edges of the scaphoid halves are drilled with the motor-drill. Ordinarily, in children, the scaphoid edges readily permit puncture by the cervix needle. The technic is carried out as follows, in either case: The kangaroo tendon (medium size) is threaded through the drill holes of the graft wedge, which is readily done on account of the stiffness of the tendon. With the graft in the center of the tendon-strand, a cervix needle is threaded to each end. These needles are thrust through the scaphoid edges from the cut surface side, either through the drill holes in the edges, or through holes made by the needles themselves. The bone-graft wedge is then forced into place between these scaphoid halves, the tendon is drawn taut and tied over the graft. The subcutaneous structures are then drawn together over the grafted area, and the skin-flap is closed over all by plain

catgut, without drainage. If the deformity is a severe one and the skin wound cannot be closed without too great tension and danger of slough, it is best not to attempt to approximate the flaps by too great tension; but if a skin gap is necessitated, it should be as far from the graft as possible, and will readily granulate over.

The dressings are then applied. Cotton is placed between the toes to take up secretion; the foot and leg, to a point above the knee, are covered with a shaker flannel bandage or sheet wadding, as a lining to the plaster-of-Paris fixation dressing, which is next applied with the foot held in slight overcorrection and the knee flexed nearly to a right angle. The knee is flexed to this angle in order to afford a leverage action against the tendency of relapse of the forefoot. This plaster dressing should remain in place for four to six weeks, when that portion above the flexed knee is cut off, the remainder of the dressing being left in place for four to six weeks longer, when the entire protective dressing is removed and massage and exercise of the foot and leg are instituted.

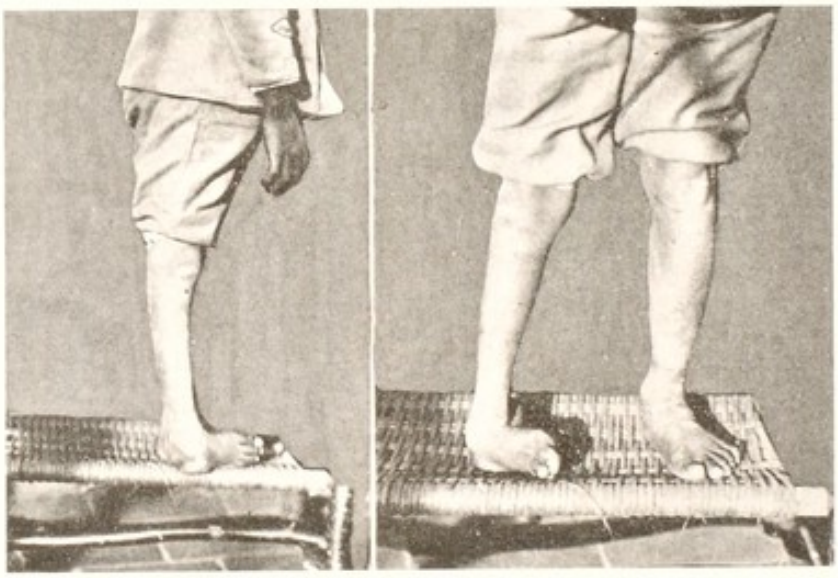


FIG. 554. FIG. 555.

FIGS. 554 and 555.—Marked untreated club-foot of a boy seven years old. Before operative correction. A wedge-shaped graft was removed from the cuboid bone on outer side of the foot and placed into the split scaphoid after the tendo Achillis and inner portion of the plantar fascia had been severed and foot forcibly corrected. (See Figs. 556 and 557 for result.)

Should it be deemed advisable for the comfort of the patient or as a means of maintaining the protective fixation for a longer period, the simple club-foot swing support is the most serviceable form of brace to be applied. It consists of a strip of canton flannel folded upon itself 4 to 6 times, making a flannel strip three-quarters of an inch to 1 inch wide, and long enough to encircle the ankle and pass down under the foot and up to the external malleolus; to the ends of the strip, a strong webbing strap is sewed, which extends up the outside of the leg to a point below the head of the fibula, where it is buckled to the upper end of a steel upright fastened about the upper part of the calf by a strap and to the shoe below between the heel and the sole. This steel upright has a simple joint at the ankle, or if there is still a need for preventing the tendency to equinus of the foot, a catch can be arranged at the joint to stop extension beyond a right angle. The pull of this sling with each step is sufficient to hold the foot in abduction and pre-

vent varus. A less efficient brace is that with an inner single bar and strap about the ankle.

6. *Operative Treatment of Short Chunky Club-foot* (Figs. 554 to 559).—The technic of the operative treatment for dealing with those cases in older children of relapsed club-foot with a short chunky foot in extreme varus, with the cuboid so hypertrophied and malformed as to resist any reasonable attempt at forcible correction of the foot, even after the scaphoid is split, is somewhat different. To these cases the author applies the bone-graft wedge between the halves of the scaphoid, split transversely across the foot, precisely as in the technic just described, with the exception that the bone wedge is removed from the body of the hypertrophied cuboid instead of from the crest of the tibia, and is inserted between the halves of the split scaphoid.



FIG. 556.



FIG. 557.

FIGS. 556 and 557.—Same case as Figs. 554 and 555 after correction of club-foot deformity by insertion of bone-graft.

The technic of the removal of the cuboid wedge is as follows: A skin incision is made through the calloused skin and subcutaneous tissue down to the cuboid along the outer border of the foot, sufficiently long to give a good exposure of this bone. Having previously determined with the calipers the approximate thickness of the wedge desired, this wedge is outlined with a scalpel, cutting through the periosteum transversely to the long axis of the foot, being careful to remove a wedge of sufficient width to allow full overcorrection of the foot. With the motor-saw, the bone is then cut, following the periosteal incisions; the planes are made to converge slightly, and as the entire division of the bone cannot be safely made with the motor-saw, the bone incision is completed with a thin, sharp osteotome driven into the saw-

cuts. Before dislodging the wedge from the cuboid, it is drilled at its center for the passage of the kangaroo fixation suture; then with curved scissors the soft tissues still holding the graft are freed and the wedge is removed, to be placed immediately in normal saline solution or put directly into its position between the split halves of the scaphoid.

The foot is thus divided transversely through its entire tarsal structure, which allows the forefoot not only to be swung outward at this point but to be rotated about the cuboscaphoid ligament; thus, at the same time, both adduction and varus are corrected. As this ligament lies approximately equidistant from the inner border of the scaphoid and the outer border of the cuboid, it is the center of a circle of which a wedge taken from the cuboid



FIG. 558.



FIG. 559.

FIGS. 558 and 559.—Illustrate method of applying plaster-of-Paris dressing for club-feet. The knee is flexed to a right angle and the thigh is used as lever to prevent the relapse of the adduction deformity of the forefoot.

is a sector, and when used to fill the gap formed by splitting the scaphoid and correcting the foot, it exactly fits and at the same time the gap formed by its removal from the cuboid is necessarily closed.

The foot and limb are included in a plaster-of-Paris dressing from the toes to above the knee, with the foot well overcorrected and the knee flexed. This dressing should remain on the limb for eight weeks, followed by a second plaster-of-Paris dressing up to the knee, which should remain on for four weeks.

Advantages of the Bone-graft in Club-foot.—(1) It lengthens an already much shortened foot; (2) it permanently lengthens the short side of the skeleton of the foot and insures in a most trustworthy way against relapse of the

deformity; (3) no joint is involved by the operation, therefore there is no interference with joint function or mobility; (4) it furnishes a means of permanently correcting selected severe types of club-foot.

OTHER VARIETIES OF CONGENITAL TALIPES

Types of congenital club-foot other than equinovarus are relatively uncommon; the deformity is slight and readily corrected by similar methods of treatment. For a further description of the different acquired varieties, the reader is referred to Chapter XXI.

2. Acquired Club-foot

The varieties common to both congenital and acquired club-foot and the etiological factors in acquired club-foot have been thoroughly discussed at the beginning of this chapter. The majority (80 per cent.) of cases of acquired club-foot are of spinal origin. The reader is referred for further information on this subject to Chapter XXI.

Differential Diagnosis.—The points of differentiation between congenital and paralytic equinovarus are well stated by Tubby (ref.: Deformities of the Bones and Joints, vol. i., p. 239) as follows:

	Congenital	Paralytic
History.	Affection has existed from birth.	Affection first noticed during second year or later, and preceded or accompanied by measles, and has been ushered in by convulsions.
Feet affected.	More often both.	More often one.
Circulation.	Good.	Feeble. Limb is cold, blue and clammy.
Wasting of muscles.	Little marked.	Often well marked.
Electrical reactions.	Present or slightly diminished in wasted muscles.	Reaction of degeneration.
Deficiency in growth of bones.	Not very evident.	Much shortening of leg and foot.
Furrows in sole.	Present.	Absent.
Prominence on dorsum of foot.	Several, and general outline is irregular.	Head of astragalus is prominent but general outline is rounded.

Treatment.—In rigid cases, whether acquired or congenital, identical methods of procedure are followed, as a rule, in correcting the deformity. In cases complicated by an unbalancing paralysis from any cause whatsoever, the restoration of muscle balance is indicated, if feasible, by tendon-transplantation (see Chapter XXI).

Treatment of Paralytic Equinovarus (Albee).—This type of club-foot is usually due to an attack of anterior poliomyelitis (infantile paralysis) and is caused by either partial or complete paralysis of the peroneal muscles, producing an unbalanced condition of muscle control of the foot. This

results in a deformity similar to that of congenital club-foot. The outer border of the foot drops, the forefoot adducts, and the patient walks on the outer aspect of the foot, causing it to adduct further by weight-bearing. Undue laxity of the astragaloscaphoid articulation results, and the unopposed muscle action of the anterior and posterior tibial muscles pulls the foot further into varus and adduction. The pull of the anterior tibial muscle, when the foot is in full adduction, forces the foot into further varus and adduction on the leg, and cases have been seen where the forefoot was so markedly adducted and inverted upon the leg that the patient walked wholly upon the outer side of the os calcis and cuboid bones. The forefoot in the more severe cases is limp and scarcely touches the ground, and there is sharp angulation at the mediotarsal joint.

This type of club-foot presents four principal defects, namely (1) equinus resulting from the shortened calf-muscles; (2) lack of support to the outer border of the foot; (3) abnormal laxity of the astragaloscaphoid articulation; and (4) misplaced center of weight-bearing in the foot, due to its faulty adducted varus position.

These faulty mechanical conditions are best met by the following measures: The leg and foot having been prepared for operation and a tourniquet applied above the knee, the equinus is overcome by subcutaneous tenotomy of the tendo Achillis and the heel is brought well down by forcible manipulation.

The astragaloscaphoid joint is reached by a U-shaped incision, precisely as described for congenital club-foot. The curved part of the skin incision should be well forward so as to afford an ample flap to cover in the grafted field. If preferred, the joint may be exposed by a straight incision parallel with the anterior tibial tendon on the dorsum of the foot. The articulating surfaces of the head of the astragalus and scaphoid are removed with a narrow osteotome and mallet, following the contour of the joint or forming plane surfaces, as may appear better adapted to the individual case at the time of operation, the idea being to secure the maximum amount of bone surface for contact with the graft.

If overcorrection of the foot is resisted by the soft structures, they are subcutaneously severed.

The overcorrection of the foot produces a wedge-shaped cavity between the separated cut surfaces of the head of the astragalus and scaphoid. This wound is packed with a hot saline compress.

To overcome the dropping of the outer border of the foot due to the paralysis of the peroneal muscles, the tendons of these muscles are made to serve as ligaments (Codivilla, Gallie), the external malleolus and tendons are exposed by a curved skin incision encircling the lower end of the malleolus.

An osteoperiosteal flap, with its overlying periosseous tissues, is lifted from the external malleolus and turned posteriorly on the peri-osseous tissues as a hinge. The osseous incisions for forming this trap-door are easily and quickly made with the author's small motor-saw, and further freeing of this flap is accomplished with a sharp osteotome. The peroneal tendon sheaths are split and the tendons are freed and placed under this osteoperiosteal trap-door. The foot is then forced into pronation, and the peroneal tendons are drawn taut by reefing or suturing them securely to the periosseous tissues above this bone flap. The edges of this osseous flap, as well as the adjacent cortex, are drilled, the tendons fitted into the grooves, and the trap-door is closed and held firmly in place by kangaroo-tendon sutures passed through the drill holes and tied. The skin wound is closed by a continuous catgut suture without drainage. The outer border of the foot is thus held firmly elevated in an overcorrected position. The saline com-

press is removed from the wound on the inner border of the foot, and while the foot is held by an assistant in a well-abducted position, an accurate measure is obtained of the resulting cavity between the head of the astragalus and the scaphoid. A saline compress is again placed in this wound, and a graft corresponding to the measurements obtained is removed from the central portion of the tibia where the cortex is of sufficient thickness, as in the case of the graft obtained for the correction of congenital club-foot. It is drilled for fixation sutures before it is dislodged from the tibia. If the bone of the head of the astragalus and scaphoid is too dense to permit the passage of a strong curved needle, the necessary holes are drilled with a motor-drill. Ordinarily, in children, the softness of the bones permits puncture by the strong cervix needle, and the technic is carried out as follows, in either case:

The kangaroo tendon is threaded through the drill holes of the graft wedge, by virtue of its own stiffness. A cervix needle is then threaded to each end of this tendon. These needles are thrust through the head of the astragalus and the scaphoid at their inner borders from their cut surfaces. The bone-graft wedge is then forced into place, and the tendon suture is drawn taut and tied over the graft.

Soule's modification of the author's technic, which is simple, in that it does not require drilling of bone or fixation suture, is recommended whenever it is found feasible. The astragaloscaphoid joint is approached from its superior aspect, and all the articular cartilage is removed from both bones, preserving the original contour of the joint. A mortise is formed in the inner portion of the cut surface of each bone, as shown by the diagrams. The graft is so shaped in its removal from the tibia that it fits accurately into these mortises when the foot is overcorrected. These mortises lock the graft in position, and the foot is wedged securely into full correction. By this method the foot is insured against relapse and at the same time the abnormal laxity of the mediotarsal joint is permanently overcome by the ankylosis of this joint. Weight-bearing is placed further toward the inner border of the foot, and the anterior tibial muscle, which was barely able to functionate before the operation, is now made to do more than its normal amount of work. A stable foot is produced, capable of weight-bearing, usually without the additional support of a brace.

In both instances, when the anterior tibial muscle is especially strong and the varus deformity marked, it is wise to balance the pull of this tendon by splitting it and implanting its outer half into the superior surface of the middle or the external cuneiform bone. This may be done through an enlargement of the original incision or by making a second incision over the external cuneiform, tunnelling to the subcutaneous tissues and carrying the tendon slip to be transplanted through this subcutaneous tunnel to its new insertion.

II. NON-CONGENITAL DEFORMITIES

1. Claw-foot

Synonyms.—Hollow or contracted foot; talipes arcuatus; talipes plantaris talipes cavus; pes cavus.

While at the battle front in Europe many surgeons, including Gen. Jones, directed the author's attention to the very large number of young men in their armies who were suffering from this condition, and it was everywhere emphasized that when present this condition interfered very materially with the efficiency of the soldier. The etiology of the condition is very uncertain. The degree of deformity varies within wide limits. The tendo Achillis is

usually somewhat shortened. Gen. Jones, in describing his experience in the British Army, enumerates five degrees, occurring in civil practice as well as in the army.

First Degree.—The first degree occurs in children; there is no appreciable increase in the height of the longitudinal arch. The parent observes that the child is clumsy and frequently stubs its toes and falls; examination reveals the fact that the foot cannot be dorsiflexed beyond right angle with leg, and that the tendo Achillis and plantar fascia have become shortened. This explains the child's tendency to strike the toe, since the shortening of these structures prevents him from raising the forefoot.

The treatment of this stage requires the lengthening of the tendo Achillis and the plantar fascia. Manipulation and stretching accomplish so little that operation should always be advised. Subcutaneous tenotomy of the tendo Achillis and of the plantar fascia as it converges to its insertion into the os calcis, is sufficient. The sequence of the tenotomy should be that of the plantar fascia followed by stretching with Thomas' wrench, and then tenotomy of the tendo Achillis. The foot is then put up in plaster-of-Paris at right angles to the leg, and the plaster moulded so as to overcome the cavus.

In the second degree of claw-foot, the plantar fascia and the tendo Achillis are much more shortened and the deformity is very apparent. The



a *b*

FIG. 560.—Claw-foot. *a*, First stage of the deformity; *b*, demonstrates the corrective effect upon the hammer-toe of pressure upward upon the anterior end of the metatarsal bone. This same corrective influence is obtained by transplanting the extensor proprius hallucis to the head of the first metatarsal.

arch is much exaggerated and the forefoot drops. There is hammer-toe deformity of the great toe, and the tendon of the extensor proprius hallucis stands out very prominently. Pressure under the ball of the toe causes dorsal flexion of the first metatarsal bone, the deformity of the toe is automatically corrected, and it straightens out surprisingly (Fig. 560). The other toes of the foot do not in this stage present deformities. There is tenderness beneath the ball of the toes near the heads of the metatarsal bones. If the patient is asked to dorsiflex his foot, the great toe is drawn up much beyond all the other toes. Soldiers suffering from this type of foot are much incapacitated and when on long marches fall out of ranks because of pain and fatigue. Operative treatment at this stage is imperative and is very satisfactory. The operation consists of lengthening the plantar fascia, followed by stretching the plantar structures with the Thomas wrench, tenotomy of the tendo Achillis, and transplantation of the tendon of the extensor proprius hallucis into the distal end of the metatarsal bone.

Technic (Fig. 561).—An incision is made over the tendon of the extensor of the great toe, about 1½ inches long, just back of the metatarsophalangeal joint. The bone is developed just back of the head and two drill holes are made with the motor-drill on each side of the outer median line of bone just

back of its head. The tendon is cut from its attachment, and a suture of fine kangaroo tendon is incorporated in its end. The tendon is then drawn through the holes by means of the kangaroo suture, and the lower end is firmly sutured to the upper portion of the tendon, after the foot has been forced to a right angle with the leg, and the tendon made slightly tense. The foot and the leg to the tubercle of the tibia are then fixed in a plaster-of-Paris cast with the foot at right angles to the leg, and the arch is flattened as much as possible.

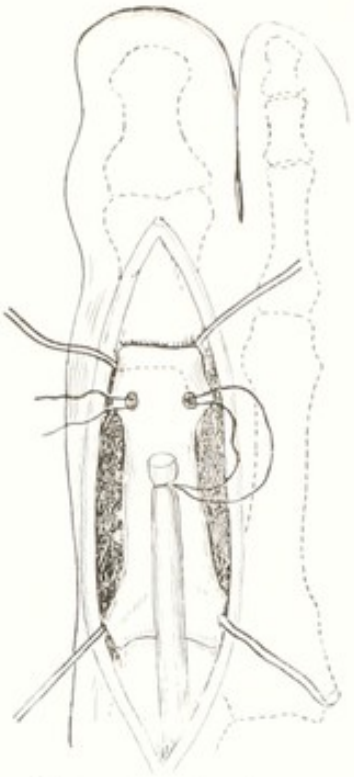


FIG. 561.—In the more severe cases of claw-foot, the hammer-toe of the great toe is controlled by transplantation of the extensor proprius hallucis into the distal end of the metatarsal. The bone is drilled and the tendon held with kangaroo-tendon. (After Jones.)

In the third degree of claw-foot the deformity remains the same, but is much more pronounced. Pressure under the ball of the great toe fails to raise the metatarsal bone, because of the increased shortening of the plantar structures. All the toes are hammer-toes, very similar to the great toe in the second degree. There are many sensitive corns and callosities in various locations on the bottom of the foot, especially under the metatarsals. The tendo Achillis is so short that it is difficult for the patient to put heel to the ground.

Operative Technic.—It is necessary to do a two-step operation in cases so severe. The plantar fascia is severed at its convergence into the os calcis, and the foot is wrenched to flatten the arch. The deformity of cavus is so severe in this stage that it is necessary to shorten the metatarsal bones by removing half an inch to an inch of bone from the shafts of the first, second, third and fourth. It is usually best to preserve the fifth metatarsal for its internal splint action. In most cases, it will be found necessary to divide both the extensor and flexor tendons. The tendo Achillis is preserved in order to get a better leverage control in holding the foot corrected of its cavus. At the second operation, some three to four weeks later, the tendo

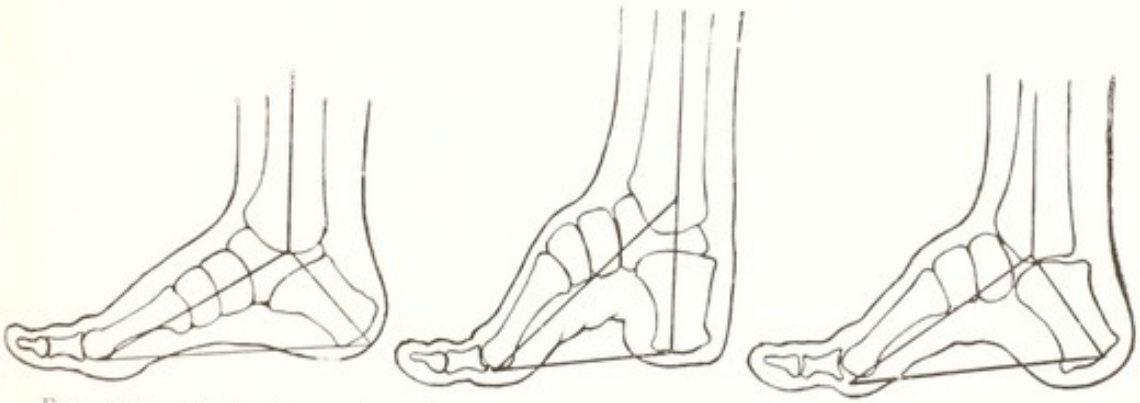


FIG. 562.—First illustration shows normal leverage of foot. Second shows faulty balance of calcaneocavus foot with heel much shortened. Third shows astragalus removed and stability and normal leverage of posterior part of foot partially restored. (After Whitman.)

Achillis is divided and the foot is wrenched into a position at right angles to the leg. After operations, shoes with low heels should always be worn.

Fourth Degree, Talipes Cavus.—In this stage the deformity is so severe that the foot functionates very poorly. The deformity is that of an equinovarus. The patient often chooses amputation. In cases of this severity, the astragalus should always be removed; also all the toes and the heads of all the metatarsal bones. The stumps of the metatarsal bones are covered over by flaps from the dorsal and plantar surfaces of the foot. Mr. Jones states that results from this operation are very unsatisfactory.

Steindler's Operation.—Steindler (ref.: Surg. Gyn. and Obst., vol. xxiv, No. 25, May, 1917) advocates a procedure which he thinks offers effective relaxation of the tissues and a fair guarantee against recurrence of the deformity. Cavus deformity from paralysis of the extensor muscles of the longitudinal arch of the foot, of the peronei, of the tendo Achillis, or the combined paralysis of these muscles, is the type to which Steindler has applied his operative procedure, the technic of which is as follows:

A horseshoe incision is carried around the heel, beginning at the inner tuberosity of the os calcis on the inner side and ending about three-quarters of an inch behind the calcaneocuboid joint on the outer side. The lower surface of the os calcis is stripped entirely to its anterior edge, to the point where the short flexors of the toes and the abductors of the first and fifth toes are inserted, together with the plantar fascia. A grooved director is passed under these structures and they are severed or stripped close to the bone, whereupon the concavity of the foot immediately yields to extension up to the point where contraction of the accessory flexor and of the long plantar ligament is responsible for the cavus deformity. In one or two cases, Steindler has resected these muscles and also incised the long plantar ligament at the calcaneocuboid joint, and resected this latter joint, but the flap necessary is so long that its nutrient condition becomes very unsatisfactory, and the ends slough off.

2. HAMMER-TOE

Hammer-toe is a deformity which usually affects the second toe, and consists of dorsiflexion of the first (proximal) phalanx, plantar flexion of the second, and flexion or extension of the third (distal) phalanx. The toes overlap the neighboring toes. The first phalanx is subjected to pressure by the upper leather of the shoe, and frequently presents a painful corn beneath which a bunion forms in the interphalangeal joint, often becoming inflamed and occasionally suppurating. Compression between the adjoining toes and against the sole of the boot, produces broadening and flattening of the tip of the terminal phalanx, hence the club-like and hammer-toe deformity.

The condition is usually bilateral, congenital in a small percentage of cases, or even hereditary, although the commonest cause is too short and too narrow shoes. The second toe is chiefly affected, because it is the longest and most frequently compressed, the narrow boots causing subluxation of the great toe which becomes crowded against the second. The deformity begins, as a rule, in childhood, when growth of the toes is most rapid, and when subjected to outgrown shoes and socks.

Symptoms arise from the painful corns and vesicles, and for them rather than for the distortion itself, is relief sought.

Treatment.—The chief obstacles to reduction of the deformity are the contracted lateral and glenoid ligaments. That the flexor and extensor tendons are not the resistant structures is proven by failure to correct the deformity after division of these tendons.

In infants, the distortion may be overcome by manipulation repeated at frequent intervals during the day, and the corrected position maintained

by narrow strips of adhesive plaster over and under the affected member, and about the neighboring toes. In older children, a digitated stocking and the use of wide boots may give relief or effect a cure. In adults, a T-splint, with the long arm under the toes and the latter strapped down to it sometimes corrects the deformity in non-resistant cases. Obstinate cases occasionally yield to forcible correction under an anesthetic after subcutaneous division of the long flexor tendon and glenoid and lateral ligaments, approaching them through the plantar surface opposite the first interphalangeal joint. Or this subcutaneous puncture may be enlarged to a transverse incision through which the head of the first phalanx is dislocated and resected with bone forceps or the whole joint excised (Fig. 563). After operation, the toe is kept in the corrected position on a plantar T-splint. Amputation is not only mutilating, but if performed in adolescence the great toe is gradually dislocated outward into hallux valgus and a bunion produced.

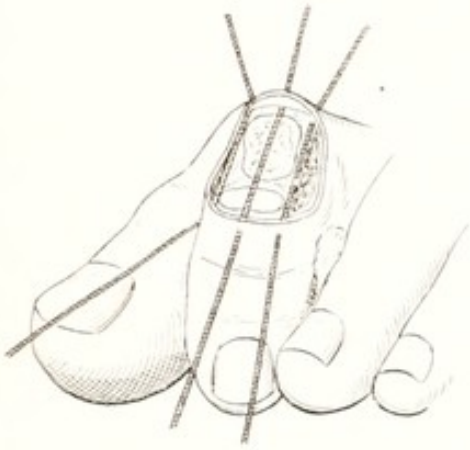


FIG. 563.



FIG. 564.

FIG. 563.—Hammer-toe of second digit. Wedge exsection of joint to allow the toe to be straightened. The toe-nail then receives the friction with the shoe and not the sensitive corn over the toe-joint. (After Jones.)

FIG. 564.—Hook for ingrown toe-nail. (Taylor, in the American Medico-Surgical Bulletin.)

3. Overlapping Toes

This condition is common in adults, in whom it is due to narrow shoes. It also exists occasionally as a congenital affection in infants. In the latter instance, it may be corrected by manipulation and retention of the toes by strips of adhesive, after the method described above, or by means of splints or a leather sole plate permitting each toe to be individually strapped down in place by tapes. Digitated stockings and wide shoes should supplement these procedures. Subcutaneous syndesmotomy is occasionally indicated in aggravated cases.

4. Contracted Toes

The first phalanx is hyperextended while the second and third phalanges are flexed. This is an acquired disorder, resulting from narrow, short boots, but is also encountered in spastic paralysis and Friedreich's disease. Anatomically, it is due to adaptive shortening of the extensor longus digitorum tendons.

Treatment consists of manipulation and the use of a sole plate with a separate compartment for each toe. If this is ineffective, it may be necessary

to sever the extensor tendons just above the metatarsophalangeal joints, and the flexor tendon at the first interphalangeal joint, and at the same point to divide the lateral ligaments; after the wounds have healed, the toes should be straightened on a sole plate and the patient furnished with digitated stockings and wide boots.

5. Papillomata (Warts)

The cause of corns is hypertrophy of the skin papillæ, which become enlarged to form the core. The projection of their overgrown epithelium subjects their nerve endings to pressure and consequent pain, and often to inflammation. Hypertrophy of an aggregation of several central papillæ, converts the corn into a papilloma.

Treatment.—Nitric acid applied about the periphery and in the center, followed by poulticing for several days, frequently effects a cure.

6. Corns

Corns arising from pressure alone are commonly found in the following locations: (*a*) beneath the heads of the metatarsal bones (contraction of the plantar fascia or tendo Achillis); (*b*) dorsal aspect of the toes (short tight boots and contracted toes); (*c*) sole under head of metatarsal bone (dropping of the corresponding head or of the fourth metatarsal head, anterior metatarsalgia or Morton's disease); (*d*) over false bursæ of bunions; (*e*) base of fifth metatarsal or cuboid (talipes varus); (*f*) over the scaphoid (flat-foot); (*g*) plantar surface of heel (exostoses of tuberosities of os calcis).

Treatment.—The treatment of corns includes *removal of the cause*, followed by the application of "salicylic collodion."

℞	Acid. salicylic	gr. v.
	Ext. cannab. indic	dr. ½
	Collodion flexile	oz. i.

This should be applied on several successive nights after soaking the foot in hot water. If this is ineffective the corns should be excised.

Bromidrosis, with which corns are frequently associated, must be briefly mentioned. The condition frequently gives rise to offensive odors, and is best treated by washing the feet 2 or 3 times a day, followed by bathing the foot in chromic acid lotion (grains ii, to ounces i), drying and dusting the feet and the insides of the socks with the following:

℞	Acid. salicylic	gr. ii.
	Pulv. talcis	oz. i.

7. Pain in Soles of Feet

Synonyms.—Plantar neuralgia; plantalgia.

The soles are soft and tender from (*a*) disuse after long illness, particularly after desquamation; the condition is also occasionally due to (*b*) wasting of the subcutaneous fat of the soles so that the os calcis and heads of the metatarsus bear directly on the skin in standing and walking, the subjects are frequently emaciated, neurasthenic women; (*c*) in flat-foot, pain in the sole is a common complaint, and is caused by the stretching of the plantar fascia, muscles, tendons, and ligaments, or it may be due to pressure on the plantar nerves: (*d*) increase of the arch of the foot (pes cavus, talipes arcuatus and plantaris) causes pain from tension on the fascial bands in standing, but may be relieved by fasciotomy; (*e*) rupture of the plantar fascia is another

cause of pain in the sole on standing; relief is obtained by rest and consequent healing of the ruptured fascia.

Numerous other causes of pain in the soles of the feet are as follows: (*f*) diffuse lipoma, (*g*) exostoses, (*h*) metatarsalgia, (*i*) constitutional disturbances, (*j*) rheumatic and gouty diathesis producing neuralgia, (*k*) Raynaud's disease, (*l*) endarteritis obliterans, (*m*) arteriosclerosis, (*n*) erythromelalgia, (*o*) dysbasia angiosclerotica.

Tender toes in typhoid fever deserve mention here. The condition occurs during the height of an attack or in convalescence. The plantar surfaces of the toes and occasionally the adjoining part of the foot are extremely tender. The patient first complains of pressure from the bedclothes, but the discomfort increases until eventually he is unable to bear the gentlest touch without distress. The condition is probably due to local neuritis.

8. Bony Outgrowths of the Foot

The commonest forms of exostoses of the feet are as follows: (*a*) hypertrophy and inward projection of the scaphoid in the long type of flat-foot of



Fig. 565.—Spur on os calcis.

adolescence; (*b*) downward projection of the bases of the metatarsals, particularly of the first, and dorsal projection of the cuneiforms in cavus; (*c*) enlargement of the internal condyle of the first metatarsal in hallux valgus; (*d*) exostosis of the posterior surface of the os calcis in achillobursitis, or spurs on its inferior surface usually at the insertion of the plantar fascia from gonorrhea and other causes (Fig. 565); (*e*) osseous outgrowths, particularly about the heads of the metatarsals in proliferative arthritis.

The treatment varies with the cause in the individual case. In the case of spurs on the os calcis, emphasis is placed on the importance of making the incision large enough. The most satisfactory incision is the fish-hook variety from the heel forward to the site of the spur, turning down all the tissues of the heel and laying bare thoroughly the inward and inferior surfaces of the

posterior part of the os calcis. The importance of a generous incision is illustrated by a case in the author's practice in which another surgeon had made a short incision, had failed to reach the offending spurs, and had scooped out a hole about 1 inch in front of the latter, which a subsequent *x*-ray revealed to have been left intact.

9. Painful Heel (Calcaneobursitis)

Pain in the inferior surface of the heel with sensitiveness to pressure on standing is a common condition, and arises from many causes, as follows: (*a*) if the condition is unilateral, it is frequently caused from standing too long on one foot, as the result of a short leg; (*b*) flat-foot; (*c*) achillobursitis; (*d*) there may be a localized tender point in the neighborhood of the inner tuberosity of the os calcis, due to a false bursa; (*e*) in cavus, the posterior attachment of the os calcis may be very painful; (*f*) spur formation on the tuberosities of the os calcis; (*g*) excessive standing (policeman's heel); and in rare instances painful heel may be symptomatic of (*h*) tuberculous or syphilitic epiphysitis of the os calcis. It may also be associated with the following general conditions: (*i*) gonorrhea, (*j*) acute rheumatism, (*k*) gout, (*l*) arthritis deformans.

Treatment.—Treatment is based on the etiological factor, combined with local rest, counterirritants, and sedative applications. If *x*-ray examination reveals the presence of spurs, they should be removed by an osteotome. Rubber heels (both inside and outside) and large boots should be worn.

10. Pain at the Base of the Fifth Metatarsal Bone

The commonest cause is (*a*) talipes equinovarus, due to direct pressure. The condition is also encountered in (*b*) Morton's disease, associated with inward twist of the metatarsus, or without such twist it may be due to (*c*) inflammation of a small bursa beneath the peroneus brevis; to (*d*) fracture of the base of the fifth metatarsal as the result of jumping, running, or during walking without assignable cause, in the latter case, the fracture is usually transverse and about ½ inch from the base, and may not be recognized until accidentally discovered during *x*-ray examination.

11. Circulatory Disturbances

(*a*) **Chilblains.**—Pathologically, there is capillary stasis followed by thrombosis, inflammation, and exudation, and occasionally a localized eruption, followed by ulcer. The affection is the result of localized cold. It is commonest in young persons, the subjects of status lymphaticus, in anemics, and in the limbs in infantile paralysis.

Treatment.—Woolen socks, wristlets, and gloves should be worn during the winter months by those predisposed to this affection. Tonics and cod-liver oil are advisable in such individuals. The calcium salts (*e.g.*, calcium lactate) act almost as a specific in some cases, if given regularly for a few weeks at the beginning of cold weather. Locally, friction with stimulants and counterirritants has a beneficent effect.

(*b*) **Erythromelalgia and Raynaud's Disease.**—These vasomotor disturbances are characterized by redness, swelling, and burning pain in the feet and legs, or in the arms and forearms. The circulatory phenomena may be discrete or exist as Raynaud's disease. These disturbances are a frequent complication of neurasthenia. An allied condition is found in the feet of

old people, with sclerosis of the tibial vessels. For treatment, works on medicine should be consulted.

(*c*) **Dysbasia Angiosclerotica** (Intermittent Limping).—The cause is disturbance of the arterial circulation, particularly of the legs, and may be so severe as to cause gangrene. The onset is often sudden, viz.: pain in the calf of the leg while walking, causing limp and necessitating stopping and resting. On resuming walking, the same symptoms return. During an attack, the circulation in the legs is appreciably retarded, and pulsation in the posterior tibial and dorsalis pedis arteries is diminished or suspended. Besides pain and cramp in the leg on walking, and diminished or absent pulsation in the arteries above mentioned, there are also pallor and coldness in the foot of the affected leg (which may be appreciable after retiring), pain in the leg while inactive, tenderness and induration in the calf, and pain in the leg if the limb is dependent at the time arterial circulation is restored.

The underlying cause of the deranged arterial circulation is in doubt. Atheromatous changes and obliterative endarteritis are the principal vascular lesions found at autopsy, and are probably responsible for the symptom complex. Occlusion of the vessels may be complete, resulting in gangrene and necessitating amputation.

Treatment.—Aside from absolute rest of the part until circulation is reestablished, there is no specific treatment. Sedatives are indicated in the event of severe pain.

(*a*) **Thrombo-angiitis Obliterans.**—This malady, described by Leo Buerger in 1909 (Jour. A. M. A., 1909, pp. 1319–1325) begins usually with indefinite pains in the sole of one foot, in the ankle, or in the toes, and causes difficulty in walking by cramp-like sensations in the calf or elsewhere in the leg. Trophic disturbances frequently occur. The pain is often excruciating. As the name implies, the lesions consist of obliteration of most of the larger arteries and sometimes of the veins as well, with an attempt at the production of a collateral circulation. The etiology is unknown. Males alone seem to be affected, especially Jews. Syphilis can be excluded as an etiological factor. Treatment is symptomatic.

III. STATIC DEFORMITIES

1. Static Deformity of the Foot, Flatfoot

Structure and Functions of the Normal Foot

The Arches.—Instead of following the usual conception of the foot as composed of two arches, longitudinal and transverse, it is better to regard each foot as forming a portion of a dome, which is completed by placing the two feet side by side, the apex of the dome being the astragaloscaphoid joints. This similarity to a dome is readily demonstrated by a plaster cast of the two apposed feet. From the apex of the dome, the arch falls abruptly behind to the tuberosities of the os calcis, more gradually outward to the external border of the foot beneath the cuboid, and forward to the metatarsophalangeal joints. A cross-section of the dome-like cast will reveal the transverse arch, while sagittal section gives the outline of the longitudinal arch.

The *longitudinal arch* is divided into internal and external parts. The internal is composed of the inferior surfaces of the os calcis, astragalus, scaphoid, three cuneiforms, and three inner metatarsals. The external, smaller and shorter and nearer the ground, is composed of the os calcis, cuboid, and the two outer metatarsals.

The *anterior metatarsal arch* is formed by the inferior surfaces of the heads of the metatarsal bones.

The *internal arch* is formed by the internal border of the foot and has its convexity *outward*. When both feet are placed side by side, this arch is apparent in the normal resting feet, but is obliterated on standing.

Functions of the Foot.—The functions of the foot are two, viz.: (*a*) passive support; (*b*) lever in walking.

(*a*) *The Foot in Standing.*—The foot in standing is supported by muscles, ligaments, and the plantar fascia. In action, it is supported chiefly by the muscles; when at rest, by the ligaments which allow more or less expansion of the normal arches. Diminution of elasticity allows abnormal pressure, and the production of corns and calluses; while, on the other hand, abnormal laxity of the foot permits depression of the arches and restriction of motion. Changes in shape of the foot in standing are due to the *normal motion in the intrinsic joints of the foot*, rather than to stretching of the ligaments and fasciæ.

The principal change of outline, when weight is borne by the foot, is obliteration of the internal arch (outward convexity of the internal border of the foot being the normal), due to inward and downward rotation of the astragalus on the os calcis, which results in prominence of the former, and depression of the inner border of the foot. This is the attitude assumed in rest.

(*b*) *The Foot as a Lever in Walking.*—As the result of action of the calf muscles, the foot becomes a lever, acting on the heads of the metatarsals as a fulcrum. To be an efficient lever, the foot should assume such a position in walking that the line of weight-bearing, extended downward to the center of the knee and ankle-joints, passes over the second toe and center of the foot, and, as the lever is raised, the leg is turned outward. Hence, in walking, the foot is temporarily abducted and the arch sinks slightly. There are alternating activity and rest; at the beginning of the step, the inner borders of the feet are parallel, the position of action; at the end of the step, the foot is abducted, the position of rest. Walking on the heels is an evidence of weak foot (flatfoot).

Movements of the Foot.—There are four primary movements, dorsiflexion (flexion), plantar flexion (extension), adduction, and abduction; and two secondary movements, inversion and eversion.

Dorsal and plantar flexion are executed at the ankle-joint. At the end of plantar flexion, more or less adduction occurs, and at the end of dorsiflexion, abduction. The range of normal flexion and extension is 60 to 80 degrees; of dorsiflexion, to an angle of 70 to 80 degrees with the leg, and of plantar flexion, to an angle of 140 degrees with the leg.

Abduction and adduction take place at the mediotarsal and subastragaloid joints, and may be defined as turning the foot respectively outward and inward in its relation to the leg. Adduction is always accompanied by inversion of the sole or supination, with rising of the longitudinal arch; and abduction, by eversion of the sole or pronation, and sinking of the arch. The terms inversion and supination are therefore practically more or less synonymous, as also are eversion and pronation. Motion at the subastragaloid joint consists of rotation on an axis extending from the inner part of the head of the astragalus downward and upward to the outer tuberosity of the os calcis. The positions of greatest strength and activity of the foot are adduction and inversion to the parallel position; those of weakness, abduction and eversion.

The muscles and ligaments which preserve the integrity and strength of the arches are: for the inner longitudinal arch, the tibialis anticus and posticus, flexor longus hallucis, flexor longus digitorum and the

inferior calcaneoscaphoid and calcaneo-astragaloid ligaments; for the outer arch, the peroneus longus and brevis, the former also helping maintain the posterior transverse arch. The short intrinsic muscles of the foot assist in binding the bones together.

THE WEAK FOOT

Synonyms.—Splay foot; flatfoot; pronated foot; pes planus.

General Considerations.—The most characteristic feature of weak foot is, as pointed out by Whitman, persistence of the passive attitude in place of active motion and alternation of posture. Suspension of function is followed by restricted adduction and plantar flexion, and later by fixed deformity in an extreme phase of the normal resting position of abduction and pronation. It should be noted from the beginning that depression of the longitudinal arch is not the essential feature of flatfoot, but that it is rather a change in the normal relationship between the foot and the leg, which characterizes the deformity.

Mechanism of Pronation.—The change of relationship between the foot and leg consists of inward displacement of the leg, so that the superimposed body-weight falls upon the inner side of the foot; at the same time, the leg is internally rotated to such a degree that if the line of the tibial crest is prolonged downward it will pass inside the great toe or even over the center of the internal border of the foot instead of through the second toe, as in the normal case.

The *astragalus* is rotated downward and inward off the os calcis—a subluxation (*i.e.*, exaggerated rotation and plantar flexion), until its head is palpable on the inner surface of the foot. The *os calcis* suffers depression of its anterior extremity and slight internal rotation, while its inner border is depressed. The *scaphoid* follows the head of the astragalus downward and away from the os calcis. Thus, inward protrusion of the inner border of the foot precedes a depression of the whole longitudinal arch. The whole sole may rest on the ground, and a callus may form at what was originally the highest point of the arch. The result is apparent broadening of the foot at the level of the apex of the original arch.

Associated anatomical changes are: Shortening of the tendo Achillis, a projecting heel, depression and anterior displacement of the external malleolus which becomes less prominent than usual, and projection of the internal malleolus. Adduction of the forefoot becomes impossible, while plantar flexion is limited, both due to displacement of the astragalus.

Pain begins with yielding of the ligaments, and is apparent before the arch is depressed, as is also the valgus position which is the marked deformity. In cases with previously existing low arch, the changes in the bones come on more gradually, and there is less pain. It must be emphasized that depression of the arch is of minor importance compared with the displacement of the foot. In some cases of weak foot, the arch is broken, in others it is normal, while the foot is abducted or pronated. In some cases the deformity is apparent only during weight-bearing, while in others there is fixed deformity from muscle spasm. In some cases there is great deformity but freedom from pain, while in others there is very slight deformity with great pain and weakness. Furthermore, in some cases the foot is incapacitated as the result of structural weakness; in others, only from improper use or malposition.

Associated Pathological Changes in the Foot.—The internal lateral ligaments of the foot and ankle are stretched and weakened. Denudation of the cartilage occurs on the unused portions of the joint surfaces. New

articular facets are formed. Osteophytes are developed at points of abnormal pressure from change in the shape of the subluxated bones. Atrophy of unused muscles is particularly noticeable in the plantar flexors and adductors (shrunken flabby calf). Overstretching of the muscles occurs in the internal border of the foot, with shortening and contraction of those in its upper and outer portions.

Etiology.—*Predisposing Causes.*—(1) Improper boots, particularly those with pointed toes, inducing abduction and preventing adduction of the great toe; (2) toeing out in walking; (3) standing with the feet abducted, putting undue strain on the ligaments.

Intrinsic Causes.—(1) Congenital or acquired abnormality or weakness of the structures of the feet (*e.g.*, lax ligaments of rickets and following sprains, fracture (Pott's), rheumatism, gout, arthritis deformans, anemia, etc.—in long narrow feet affected with unnatural laxity); (2) muscular weakness of the legs and feet (*e.g.*, convalescence, rickets, valgus of infantile paralysis); (3) overstrain and overweight; (4) improper attitudes, producing a mechanical disadvantage (*e.g.*, inequality of the length of legs); (5) tabes dorsalis and muscular atrophy.

Symptoms.—(1) *Pain.*—In the vast majority of cases, pain is the leading symptom. Its most frequent location is at the astragaloscaphoid joint, and next in order, the heads of the metatarsals, plantar surface of the foot, and center of the heel. It is less commonly localized between the external malleolus and the cuboid. In the legs, it is more frequently encountered in the calf than in the knee, and oftener in the knee than in the back. The intensity of the pain bears no constant relationship to the degree of the deformity. Pain may be of recent origin, even in a deformity of long duration. In any case, it is relieved by rest.

2. *Tenderness.*—The commonest point of tenderness is the center of the heel or the astragaloscaphoid joint; next, the sole; and, infrequently below the head of the first metatarsal.

3. *Swelling of the Feet.*—Localized puffiness is common, and in chronic cases edema of the feet may occur. Sweating is frequent. The surface temperature varies. Associated varicose veins sometimes exist in adults, and obstructed circulation may be the cause of relaxation of muscles and ligaments, and hence a predisposing cause of flatfoot.

4. *Disability.*—Lameness results from the pain and tenderness. Restriction of motion occurs, usually of inversion and adduction, and occasionally of dorsiflexion. In spasmodic cases, there is general restriction of motion. The gait is awkward and stiff, and in walking the heels are the first to strike the ground.

5. *Deformity.*—In some cases of flatfoot, there is abduction with a well formed arch; in other cases, the foot is abducted and flat, with the arch depressed; lastly, the foot is abducted and flat, with entire obliteration of the arch.

Types of Weak Feet.—(1) *Pronated Foot with Practically Normal Arch.*—Very common, particularly in large feet. The forefoot, anterior to the astragalus, is very slightly rotated outward on standing.

2. *Abduction of the Forefoot with a High Arch.*—Common in long slender feet.

3. *Pronation and Flatfoot with Prominent Scaphoid.*—May be corrected in moderate grades, but not in extreme cases, being abducted and everted with spasm of the peronei and extensor communis digitorum, the rigid spasmodic flatfoot.

4. *Abduction and Eversion from direct Depression, without Pronation.*

5. *Abducted Foot with High Arch.*—Pes cavus and contracted tendo Achillis.

6. *Childhood Types. Weak Ankle.*—Characterized by eversion, mainly at the ankle-joint, valgus position in walking, common in rickets. *Inward rotation of foot* (pigeon-toe), a sign of weak foot. "Outgrown joints," in older children—characterized by prominent internal malleoli, due to valgus, causing "interfering," an early sign of weak foot—may be the first sign to attract attention to the deformity.

7. *Irregular Types of Flatfeet.—Downward and inward displacement of the internal cuneiform*, at which point the maximum bulging of the internal border of the foot occurs, instead of in the region of the mediotarsal joint.

Diagnosis.—According to Whitman, systematic examination of the foot should be made as to appearance, functional capacity, and manner of its use, not so much for the purpose of diagnosis as to estimate the degree and nature of the changes in its structure and functions. He advises that minute details be observed as follows, viz.:

1. *Attitudes.*—The manner of standing and walking should be noticed. Walking on the heels, increased abduction, slouchy gait without complete extension of the leg, *i.e.*, abeyance of the function of the calf muscles, are all symptomatic of weak foot.

2. *Distribution of Weight and Strength.*—The shoes should be always carefully examined: inward protrusion of the arch and wear at the inner portion of the sole are of diagnostic importance. With the patient barefooted, a line drawn from the patella, following the crest of the tibia and prolonged over the foot, normally terminates at the interval between the second and third toes; if it ends over or inside the great toe, it indicates abnormal relationship between the positions of the foot and leg.

3. *Shape of the Foot.*—Normally, the internal border is slightly outcurved. When the feet are brought side by side, toes and heels of opposite feet together, an interval is left between the feet. If no such interval exists, or instead a convexity is present, it is a fair indication of weak foot. This is often the earliest and may be the only indication of deformity.

4. *Bearing Surface.*—By having the patient wet the foot in a basin of water, or, better still, by smearing the sole with vaseline and then standing on a sheet of white paper, the exact amount of bearing surface may be determined; the outline of the feet should be traced on the paper, for the purpose of comparing the amount of bearing surface with the size of the sole. This evidence may or may not be of clinical value.

5. *Range of Motion.*—A limited range of motion is one of the earliest signs of improper attitude and weakness. It must be borne in mind that the range of motion varies normally; it is greater in children than in adults, in slender feet than in massive feet, and in a properly used foot than in a misused one.

(*a*) *Flexion and Extension.*—The first test is for dorsi- and plantar flexion, with the knee extended and the foot neither abducted nor adducted. Flexion (dorsiflexion) should be 10 to 20 degrees less than a right angle, extension (plantar flexion) 40 to 50 degrees beyond a right angle, *i.e.*, the range of motion being between 50 to 60 degrees.

(*b*) *Adduction or Inversion.*—This is the most important test, involving the mediotarsal and subastragaloid joints. The patient extends the leg with the patella in the middle line, and inverts and adducts the foot. The range of motion can only be estimated, being difficult of mensuration, but is approximately 30 degrees. Limitation of this movement occurs very

early in weak feet, even in mild cases, while in advanced cases there may be no adduction possible.

(*c*) *Abduction and Eversion.*—This test is less important. The normal range of both these movements is one-half that of adduction.

(*d*) *Passive Motion.*—Passive movements should be tested in all directions. It must be borne in mind that all passive movements are a few degrees greater than active movements.

Dorsiflexion is 5 to 10 degrees more than voluntary motion; plantar flexion is equal in degree to voluntary motion at the ankle-joint, but can be increased by plantar flexion of the forefoot which increases the range of movement at the mediotarsal joint by several degrees. Passive adduction is much greater than voluntary adduction.

Passive motion will reveal the least used movement, restricted movement, and the presence of localized tenderness, *e.g.*, pressure in front of and below the internal malleolus (astragaloscaphoid joint) combined with forcible adduction of the foot causes pain at the point of pressure and a sensation of constriction in the dorsum of the foot, before the normal limit of motion has been reached. Passive dorsiflexion serves two purposes in diagnosis; (*a*) it puts the plantar fascia on the stretch and reveals its condition, viz.: a sensitive contracted plantar fascia may be sufficiently tender to cause the assumption of vicious attitudes of the foot and thus be a predisposing cause of disability; (*b*) a very reliable sign of flatfoot is the pain or strain extending up the calf muscles and felt most acutely in the region of the upper end of the gastrocnemius or in the popliteal space on forcible dorsiflexion of the foot, with the knee fully extended.

Prognosis.—No cure of the anatomical deformity is possible without treatment. The patient is forced to seek relief because of steady increase of pain and disability. In some cases, pain disappears voluntarily after a period of years when breaking down of the longitudinal arch is complete, but the foot has been irreparably damaged and is useless as a lever in proper walking.

The prognosis after supports have been applied, as well as the question of relief of symptoms, are dependent upon the conduct of the individual case. In practically every case, if sufficient opportunity has been given for treatment, foot plates can be discarded after a period of months, provided exercises are taken and a proper shoe is worn.

Treatment.—*General Considerations.*—Anemic patients should be given iron; rachitic children should receive cod-liver oil, fresh milk, and pure air; individuals who are overworked demand rest and change of occupation after treatment. Correct habits of walking should be inculcated, and abduction and pronation of the feet avoided, and in every case suitable shoes should be worn. Massage and exercises are important for the development of the muscles which maintain the adducted and inverted positions of the feet.[1] Rigid feet and those in which the deformity is fixed necessitate mechanical and operative treatment. *All* cases in which pain is marked, require local rest in the adducted inverted position.

There is no condition in the practice of orthopedic surgery in which the type or variety of treatment varies so widely as in that of flatfeet. In certain cases, the mere changing of the shoe is sufficient to give entire relief. The treatment varies in severity from this simple procedure to the removal of a large wedge of bone from the inner side of the tarsus and transplanting it to the outer border of the tarsus, combined with tenotomy of the tendo Achillis.

[1] For foot exercises, see p. 706, Fig. 423, etc.

Treatment will be arranged, as far as possible, in order of severity, to conform with the types of cases to be treated.

Foot-gear.—Since a considerable percentage of cases of flatfoot is due to faulty shoes, removal of the cause or the use of proper shoes is all that is necessary for the treatment of various early and simple cases.

A proper boot or shoe is convex, or at least straight along its outer border, and correspondingly slightly concave along the inner border to favor adduction. The forces producing adduction are applied chiefly at three points, viz.: on the inner side at the mediotarsal joint; at the outer side opposite the head of the fifth metatarsal bone; and on the outer part of the heel. Due respect must be paid to these points in building the shoe. The top cap should be deeper over the great toe than elsewhere. The width of the shoe should be equal to or a little greater than that of the weight-bearing portion of the foot when standing. The shoe should be firm behind, but flexible in front of the mediotarsal joint, tight over the instep, and should have a low, broad heel. The sole under the ball of the foot should be flat without downward or lateral convexity, in order to make the toes grasp the ground at the end of each step.

Colonel Munson, M. C., U. S. A. (Munson, E. L., "The Soldier's Foot and the Military Shoe," George Banta Pub. Co., Menasha, Wis., 1917), makes the following very pertinent statement: "The marching powers of foot troops are a most important factor in the conduction and success of battles and campaigns, and the army which marches best, other things being equal, is the successful army. Mobility is the key of military success, and troops which cannot march will not be given, by a more vigorous enemy, opportunity to fight except under what may prove to be decisive military disadvantage. The effect of badly fitting shoes upon the psychology of the war is very great. Even where the soldier is able to continue the march, the discomfort produced at every step soon reduces buoyancy of spirit, causes mental irritability, and materially diminishes fighting capacity."

If the advanced nature of the case has produced shortening of the tendo Achillis, throwing the foot into the equinus position, a shoe with a high broad heel should first be employed and the height of the heel thereafter progressively lessened as spasm of the gastrocnemius and soleus muscles abates and these muscles and the tendo Achillis are lengthened either by conservative treatment, such as strapping, or by operative lengthening of the tendon. Many patients have been made very uncomfortable and their condition has been aggravated by the ill-considered advice of their physician to wear low-heeled shoes.

Building Up the Shoe.—If mere changing of the shape of the shoe is insufficient to afford relief, it may be built up in such a manner as to produce adduction and inversion. Raising the inner border of the heel and sole is universally practised in the treatment of flatfoot. The inner border of the sole and heel should be made one-eighth to three-eighths of an inch higher than the outer, to throw the body-weight on the outer border. This is always serviceable in any grade of weak foot.

Massage and manipulative stretching of muscles and joints aid in overcoming spasm and pave the way for corrective exercises.

Exercises, Attitudes, etc.—Soaking the foot in hot water, alternating with cold douches, improves its circulation. Exercises should be begun as soon as the pain and muscle spasm have been eliminated. Of these exercises, (*a*) *correct walking* is best, inversion of the soles, adducting the great toes and walking on the outer edges of the feet; (*b*) tip-toe exercises with the feet parallel or adducted are useful in the later stages, but should not be

practised in the early stages of weak feet; (*c*) extend the leg, patella to the front, and first plantarflex and then turn inward and adduct, then invert, and finally dorsiflex the foot to the full extent. This exercise should be done first sitting and then standing; (*d*) walking back and forth on a "supination board," which consists of boards joined at their longitudinal edges at an angle of 164 to 165 degrees (Hovorka); (*e*) bicycling with the pedals thicker internally (Brunelle).

Adhesive Plaster Strapping.—Strapping the foot with adhesive plaster is indicated in all cases of flatfoot except the most rigid and those with marked deformity. It is surprising and gratifying to find (depending however upon the skill and technical ability of the orthopedic surgeon) how much can be accomplished in this direction. The importance of proper technic cannot be overemphasized. Neglect of the minutest details may lead to relapse of the case and return of the symptoms. The desideratum is to raise and support the arch of the foot.

Technic of Strapping for Flatfoot.—Zinc oxid plaster should be uniformly employed. The patient is seated in a chair opposite the surgeon and is directed to flex the knee and place the heel of the right foot on the surgeon's left knee, with the foot dorsiflexed and the arch held as high as possible. It may be necessary for an assistant or the patient himself, with a looped bandage placed over the anterior portion of the foot, to maintain dorsiflexion during the process of application.

The end of a strip of adhesive, about 15 to 16 inches long, is now applied to the superior external portion of the foot, brought beneath the central part of the longitudinal arch, and placed upon the antero-internal surface of the leg in such a way that its anterior edge can be made smoothly adherent to the dorsal surface of the patient's instep by pressure of the surgeon's hand. If this strip is placed too far anteriorly, it will be found that its free edge cannot be approximated to the skin of the instep, or, if placed too far back, it does not come under the central portion of the arch, and therefore fails to give the desired support.

A second adhesive strip (the same length and width as the first) is now applied over the first in exactly the same manner except that its anterior edge is placed one-fourth to one-third of an inch further forward. Over these two strips are then placed numerous figure-of-8 strips circling the foot and ankle. In a very heavy individual, it is wise to reinforce the longitudinal strip by a narrower one placed over its anterior border.

If the adhesive plaster does not readily adhere, it may be wise to place a carefully applied gauze bandage over the strapping. These strappings should be renewed at six day intervals. This has been found to be the time of election because at the expiration of this period the plaster begins to separate from the skin and also stretches and "gives." The number of such applications varies directly with the severity of the case and the amount of standing and walking which the patient practises during the progress of the treatment. The criterion for terminating the strapping treatment and for taking a cast and making the foot plates is the entire cessation of symptoms.

The method of treatment, devised by Cottrell and Gibney for sprain of the ankle, can also be modified to relieve the acute symptoms and as a useful adjunct to all types of flatfoot, viz.:

An adhesive plaster strip, 15 by 2 inches and of two thicknesses, is employed; one end is applied to the outer surface of the ankle, just below the malleolus; the foot is then adducted and inverted to the fullest extent and held in this position while the adhesive plaster strip is drawn taut

beneath the sole, up the inner side of the arch and leg, and held until adherent, when two or three plaster strips are made to encircle the leg, to aid in retaining it in position. Half inch strips of adhesive are applied above the arch and ankle with overlapping edges, in figure-of-8 fashion, and a muslin bandage applied over all from the toes to the tibia. Combined with the built up sole and heel, this treatment is especially efficacious. The strapping should be re-applied every five or six days until relief is secured, whereupon a plaster-of-Paris impression is taken and braces are made therefrom.

It is important to change the adhesive plaster with sufficient frequency to prevent the occurrence of dermatitis, because if this happens it will be necessary to omit the application of the adhesive plaster until the skin becomes normal, thus retarding the treatment or entirely defeating its object. Furthermore, the skin of the foot, after having been subjected to repeated applications of the adhesive plaster, becomes very sensitive, and its superficial layers become more or less excoriated, rendering it particularly liable to infection; for this reason, the fresh application of the adhesive should always be made immediately after the removal of the old strapping, and therefore the patient should not be allowed to remove the strapping at home prior to visiting the surgeon for its renewal. If this precaution is not observed, infection may occur from the stocking, shoes, etc.

Arch Supports.—The most efficient supports for the arch are the Whitman valgus plates. They are indicated in those cases where the foot is still flexible and can be passively replaced in its correct position, being particularly useful for the flabby type of flatfoot and for those cases without bony prominence on the inner surface of the foot. They are not to be used for rigid cases, inasmuch as one cannot adapt the foot to the support: it is necessary first to reduce the deformity either by adhesive strapping or operative treatment and to render the foot flexible. These plates are also the best form of treatment for the weak foot of childhood.

Cast of the Foot.—A brace, to be efficient, must hold the foot laterally as well as support the arch, but must not prevent normal motions of the foot. A brace to meet these conditions must in every case be modelled upon an exact plaster cast of the individual foot to be treated. The author makes the model in the following manner (Figs. 566 and 567):

The patient seats himself in a chair of ordinary height with the bare feet resting on a sheet of ordinary wrapping paper upon the floor. A quart of luke-warm water is placed in a basin and plaster-of-Paris sprinkled on its surface until it does not readily sink to the bottom, when it is stirred. When the mixture is of the consistency of very thick cream, it is ready for immediate use. The patient lifts the feet from the sheet of paper, upon which the plaster cream is then poured, and with the patient's legs held at right angles to the ground, and the feet at right angles to the legs, the surgeon places the feet one at a time lightly by their own weight in the plaster cream. The feet are held in the cream, the inner borders parallel and about 2 inches apart, until the plaster hardens. During the process of hardening, the plaster cream is heaped up in the interval between the inner borders of the feet, to the level of the internal malleoli, as well as on the outer borders, to insure a good impression of these regions. After the plaster has hardened, the cast is wrapped in the paper in which it rests, marked with the patient's name, and sent to the bracemaker who makes the plaster model from the cast and fashions the plate to fit it. Either the surgeon or the brace maker should remodel the mould so as to raise the arch sufficiently for the individual case (see page 856).

Whitman uses a different method in taking the plaster cast, viz.: the patient is seated in a chair opposite another chair somewhat less in height, on which is laid a thick pad of cotton wool covered with a square of cotton cloth. Then plaster-of-Paris is added to water until a mixture of the consistency of thick cream is obtained. The patient's knee is now flexed and the other side of the foot, previously rubbed with talc powder, is allowed to sink into the plaster which has been poured upon the cloth. The foot should be slightly plantar flexed with its transverse measurement perpendicular to the chair. It is an advantage to lift the foot and have the surface of the second chair so inclined that its highest side is toward the front of the foot. This, together with the weight of the limb, will assure slight adduction. The borders of the cloth are raised and the plaster is pressed against the foot until rather more than half is covered. As soon as the plaster is hard, it is re-



FIG. 566.—Plaster-of-Paris mixed with water to the proper consistency is placed upon a rubber cloth or paper placed upon the floor and the left foot placed in it, while the patient is sitting in a chair. The surgeon then builds the plaster mortar up about the foot sufficiently high to obtain a mould for the flanged foot support to be made from it.

moved, its upper surface covered with vaseline, and it is temporarily replaced. The remainder of the foot is then covered with plaster. The two halves are then removed, again greased, and bandaged together. The interior is dampened with soapsuds and then filled with plaster cream. On removing the shell, a cast of the foot is seen, which, when properly made, should stand upright without inclination to one side or the other.

In most instances it is an advantage to deepen the model at the inner and outer segments of the arch, in order that the arch of the brace or plate may be slightly exaggerated, especially at the heel, so that depression of the anterior extremity of the os calcis may be prevented. If the outer border of the cast is flattened by pressure, a little plaster should be added to approxi-

mate it to its normal contour. If there is prominence of the scaphoid or of the head of the astragalus on the inner side, the plaster should be thickened in the model over these points so that there is very slight, if any, pressure upon them when the brace is completed.

The Brace.—The outlines of the brace are drawn on the model (see Fig. 570). The material to be used is moulded on it, and tempered so as to be unyielding when in use. Various materials are employed in the manufacture of the brace. The author uses different gauges of aluminium or Monell metal, in accordance with the weight of the patient. The advantages of Monell metal are that it is very malleable in a cold state, does not rust or oxidize, and has the strength of spring steel. Whitman uses the best sheet steel, 18 to 20 gauge. Aluminium bronze is less likely to rust than steel but is not sufficiently strong to permit the manufacture of plates of light weight.

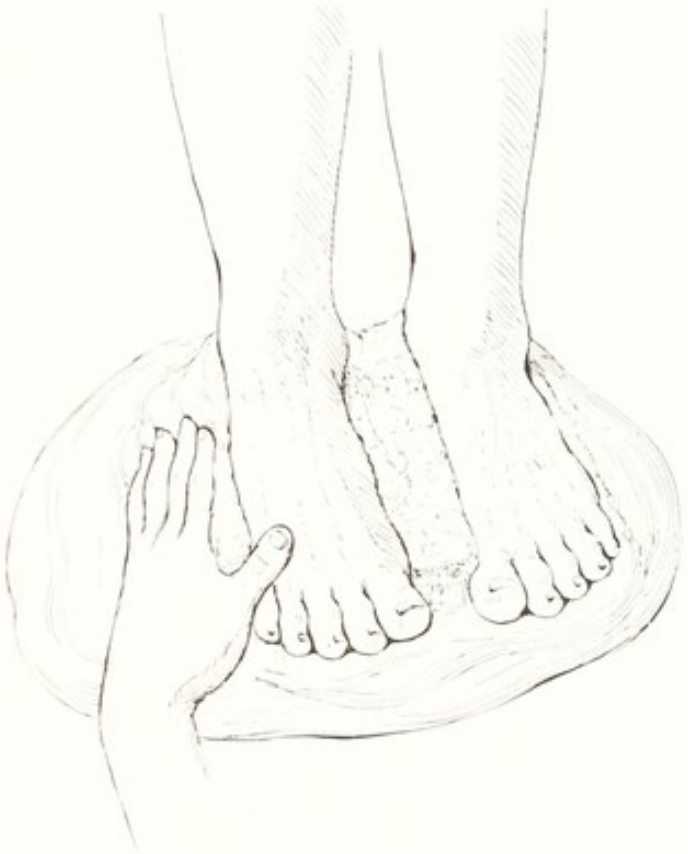


FIG. 567.—The right foot is placed beside left foot and the plaster mortar built up about it.

The object of the brace is not to serve as a comfortable support but effectively to restrain deformity and to enforce such an attitude of the foot that the patient cannot avoid using those muscles which when developed will keep the foot adducted and inverted; therefore the brace is made to clasp the weak part of the foot and to hold it together.

The brace consists of three parts: (*A*) the main part of the brace, fitted to the sole, extends from the center of the heel to a point just behind the ball of the great toe: it offers no restraint to the normal motions of the foot (Fig. 570); (*A*) a broad internal upright portion covers and protects the astragaloscaphoid joint, rising about the scaphoid bone (Fig. 568); (*B*) an external (smaller) upright arm covers the calcaneocuboid joint and holds the foot securely (Fig. 569). The brace is usually nickel-plated, but it is

unnecessary to cover it with leather or to place an inner sole over it in the shoe, or to use any attachment.

In special cases it may be necessary to modify the brace, *e.g.*, if the entire inner aspect of the foot is weak, the inner flange should be large enough to cover it, and in very heavy patients the plantar portion should be larger



FIG. 568.—A, the astragalonavicular joint. The internal flange of the brace should rise well above the prominent bones to a point about half an inch below the malleolus. (Whitman.)



FIG. 569.—B, the calcaneocuboid junction. The external flange extends from the center of the heel to a point just behind the base of the fifth metatarsal bone. (Whitman.)

than usual. It is usually necessary to wear the brace for three to twelve months, according to the condition of the patient and the amount of strain to which the feet are subjected. In children, braces are worn for one year on an average.

Great emphasis should be placed on the importance of careful adjustment of the support to the feet of the individual. This should be done by a round-faced hammer and lead anvil, and should be repeated at intervals of one or two days, until the plates have been so moulded by the hammer and anvil that they do not impinge on any bony prominence. In altering foot plates or braces, great care should be taken that the blows of the hammer are very gentle and properly located. Very often a saucer-shaped depression of considerable size is required to fit over the tubercle of the scaphoid. During the first few months, if the plates do not give relief, it may be necessary to raise them under the arch at intervals of one to two weeks, or, if the plate is a double flanged one, to make it narrower, so that it will more tightly grasp the foot. Sometimes, after being worn for six months or longer, the old symptoms of weak foot will recur; this indicates that the support must be both raised and made narrower, or in certain cases the foot may have so changed in shape and form that new impressions and plates may be necessary, and if the symptoms are greatly aggravated it may be necessary to precede the use of braces or plates by intervals of strapping with adhesive.

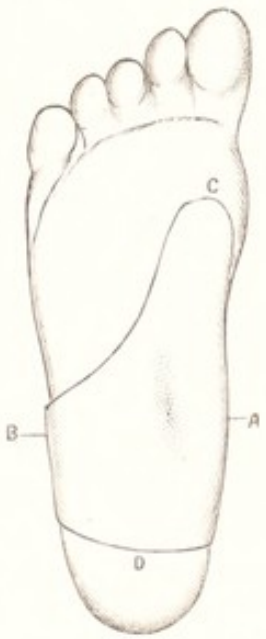


FIG. 570.—C, the great toe-joint; D, the center of the heel. (Whitman.)

Treatment of Rigid Type of Weak Foot.—In this type, the deformity is extreme, the symptoms are disabling and the foot is held rigid in the deformed position by muscle spasm and the resulting secondary changes in the structure of bones and ligaments. Instead of being hopeless from the therapeutic standpoint, they are the most satisfactory

cases. In the production of the deformity, the astragalus is dislocated downward and inward off the os calcis, and the latter tipped downward and inward into the valgus position. The forefoot is turned outward and thus thrown almost entirely out of use. The treatment consists first of reducing the dislocation of the astragalus and os calcis, overcoming the contracted muscles and ligaments to secure free motion, and then putting the foot at rest.

Forcible Overcorrection.—Full surgical anesthesia is required. Most of the restriction of motion is due to muscle spasm and yields to anesthesia. Whatever obstruction to motion remains must be removed by forcible manipulation of the foot, restoration of the arch, and fixation of the foot in plaster-of-Paris in extreme adduction—supination to insure against relapse of the deformity.

Manipulation consists of repetition of forcible extension, flexion, abduction, and adduction, until the foot is entirely flexible and flaccid (Fig. 571). The surgeon may have to take the foot between the knees to get sufficient force by the aid of the thigh muscles. Tenotomy of the tendo Achillis (as recommended by Hibbs) or peroneal tendon may be necessary in cases of accommodative shortening of the triceps suræ, or where it is desirable to remove all leverage from the foot in instances of pain and tenderness at the mediotarsal joint, as in traumatic cases. The foot is now forced downward, then inward and upward into extreme varus, and an attempt is made to get the extreme outer border of the inverted foot up to a right angle with the leg. Plaster-of-Paris dressings are then applied from the toes to the tibial tubercle.



FIG. 571.—Thomas wrench in position and adduction of foot at midtarsal joints in flatfoot or valgus deformity of the foot. (After Jones.)

Walking in the plaster cast should be begun as early as the patient is able to do so, often within twenty-four hours after operation, when full weight should be borne on the foot, with two objects in view: (*a*) still further to overcorrect the deformity; and (*b*) to create a habit of walking in the new unusual position.

At the end of three weeks, the plaster is removed and an impression is taken of the foot for the construction of a brace, which is made and fitted as hereinbefore described. For a few days after the removal of the plaster-of-Paris bandage, prolonged soaking of the foot in hot water combined with frequent massage alleviates local tenderness and swelling. Strapping with adhesive plaster, as already described, at intervals of five to six days, should be continued as long as there is any tendency for the foot to resume the valgus position. Strapping and the brace should be supplemented by raising the inner borders of the sole and heel.

The surgeon must repeat, at least once a day, practice of the full range of passive motion, particularly adduction, the patient sitting opposite the surgeon, who takes the foot in both hands and places it between the thighs to obtain reinforcement from the strong adductors as an aid to manipulation.

In most instances if the brace is followed in a few months after its adoption by proper exercises it can be dispensed with (see page 706, Fig. 423).

Operative Treatment of Flatfoot.—The operative procedures for the relief of flatfoot consist of (1) arthrodesis of the astragaloscaphoid joint; (2) the same with the addition of bone-graft peg (Soule). (These operations will be found fully described in Chapter XXI, pages 761 and 762.) (3) Perth (Deutsch. Zeitsch. f. Chir., Apr. 12, 1913) has recommended the removal of a wedge of bone from the scaphoid and its insertion in a cleft made for its reception in the anterior external extremity of the os calcis.

Other operations for the relief of flatfoot, of which limited space forbids detailed description, are: (4) transplantation of the tibialis anticus tendon to periosteum of scaphoid (Müller); (5) removal of wedge from astragaloscaphoid region (Fig. 572).

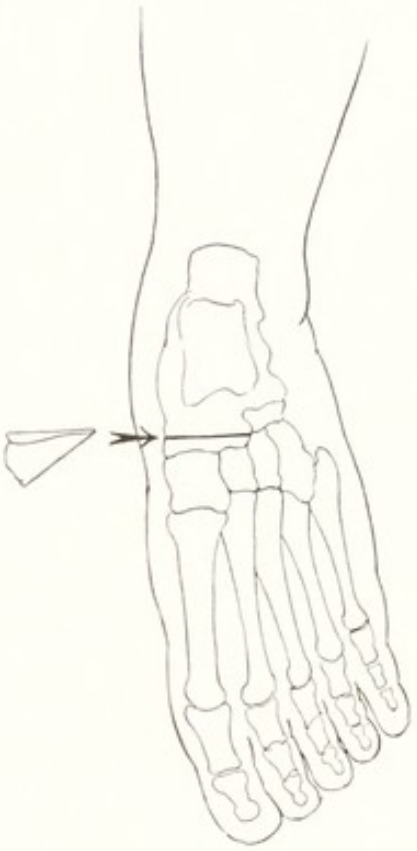


FIG. 572.—Shows correction of markedly pronated (exaggerated flatfoot) foot by the removal of bone wedge from astragalus and scaphoid bones, thus resulting in arthrodesis of the astragaloscaphoid joint. This operation is indicated in all extreme deformities of this type, especially in those of paralytic origin, where the peroneus longus is transplanted for the paralyzed anterior tibial muscle.

2. STATIC DEFORMITIES OF THE TOES

HALLUX VALGUS (Bunion)

Definition.—Excessive abduction of the great toe. Moderate grades of abduction of the great toe are very common, on account of the prevalent use of improper shoes, but the condition is not usually considered a deformity until the metatarsophalangeal joint is greatly enlarged and accompanied by the presence of a "bunion."

The distortion consists of subluxation of the proximal phalanx of the great toe on the metatarsal bone and in extreme cases the latter is adducted and widely separated from the second metatarsal, and at the same time the proximal phalanx is displaced outward and articulates only with the outer condyle of the metatarsal. The prominence, which is palpable, is formed by the inner condyle of the adducted metatarsal, which is exposed to pressure of the shoe and over which a bursa forms, while on its cutaneous surface a corn or callus is produced. The protuberant bone with the inflamed bursa and thickened skin comprise what is known as a bunion.

Pathology.—The pathological changes consist of atrophy of the cartilage of the exposed condyle, outward displacement of the tendons with the sesamoid bones, contraction of the tissues on the outer side, commensurate lengthening and atrophy of those on the inner side, and exostoses about the condyle.

Etiology.—The deformity may be produced by shoes of improper shape. The lateral constriction of the toes is occasioned by shoes that are too narrow at the tip and too short from heel to toe, that is, lateral and longitudinal pressure on the big toe. A weak arch aggravates the deformity by shoving the toes into the narrowest part of the shoe at each step. Contributory factors are, injury, gout, rheumatism, and the proliferative type of arthritis deformans, or these may be the sole causes of the distortion. The affection

begins in childhood and undergoes rapid increase in adolescence, although the symptoms may not appear until a later date. Both great toes are, as a rule, affected, but the symptoms are frequently more marked on one side.

Symptoms and Signs.—The chief sign is an outward distortion of the great toe with inward prominence of the base of the proximal phalanx and of the head of the first metatarsal, with accompanying outward dislocation of lesser degree at the interphalangeal joints. The deformity is aggravated by the extensor proprius hallucis tendon which, displaced outward, is stretched along the concavity of the external border of the great toe like a string on a bow.

The symptoms are pain, swelling, and redness, for which the patient seeks advice.



FIG. 573.—Method of immobilization of the great toe in corrected position after the removal of the head of the metatarsal bone for bunion. Thin sheet aluminium is used for the plantar splint and held in place by adhesive plaster. As a rule the author uses plaster-of-Paris for this purpose.

Treatment.—In mild cases, the proper shoe may suffice to correct the deformity. The shoe should be broad at the front, narrow at the heel, its sole straight along the inner border, and possess a wide outward sweep along the outer border, and, as Whitman advises, "thicker on the inner side so that the sensitive joint may be inclined away from the upper leather."

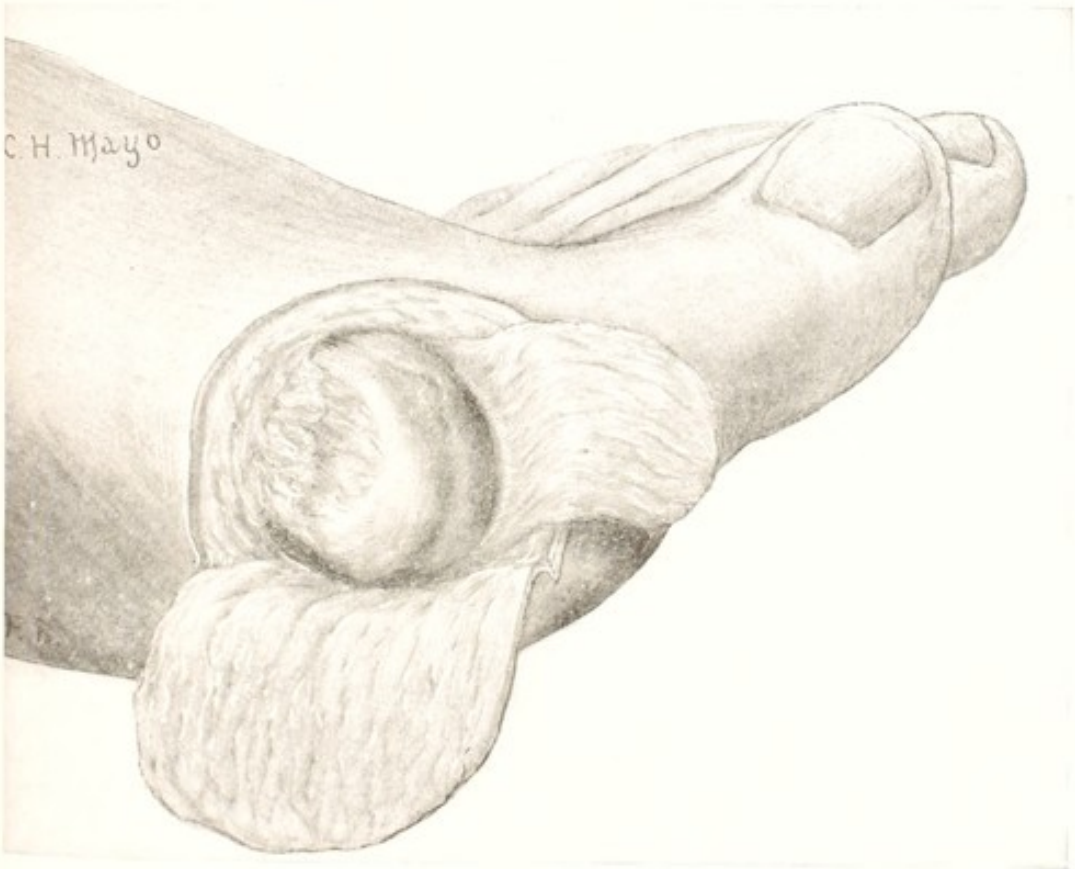


FIG. 574.—Bunion. C. H. Mayo's operation. Skin-flap turned downward and bursa turned forward, exposing the metatarsophalangeal joint and the large exostosis. (Mayo.)

Manual correction is rarely efficacious except in mild cases. The great toe should be drawn inward several times morning and night, and a wedge of cotton worn between the first and second toes at night. If the longitudinal or transverse arches are weakened or depressed, the patient should first be fitted to braces made from a cast of the foot.

Toe Posts.—Various types of toe posts are in use, one of the best being that devised by Sampson, made of tin and put in a cardboard inner sole to keep the great toe adducted (ref.: Sampson, Bull. Johns Hopkins Hosp., January, 1902). It must be stated, however, that these temporizing methods do not offer much hope of permanently correcting structural changes in the metatarsophalangeal joint. Attempts are also made to correct the deformity by means of adhesive plaster strapping about the toe and fixing the end to the inner aspect of the heel.

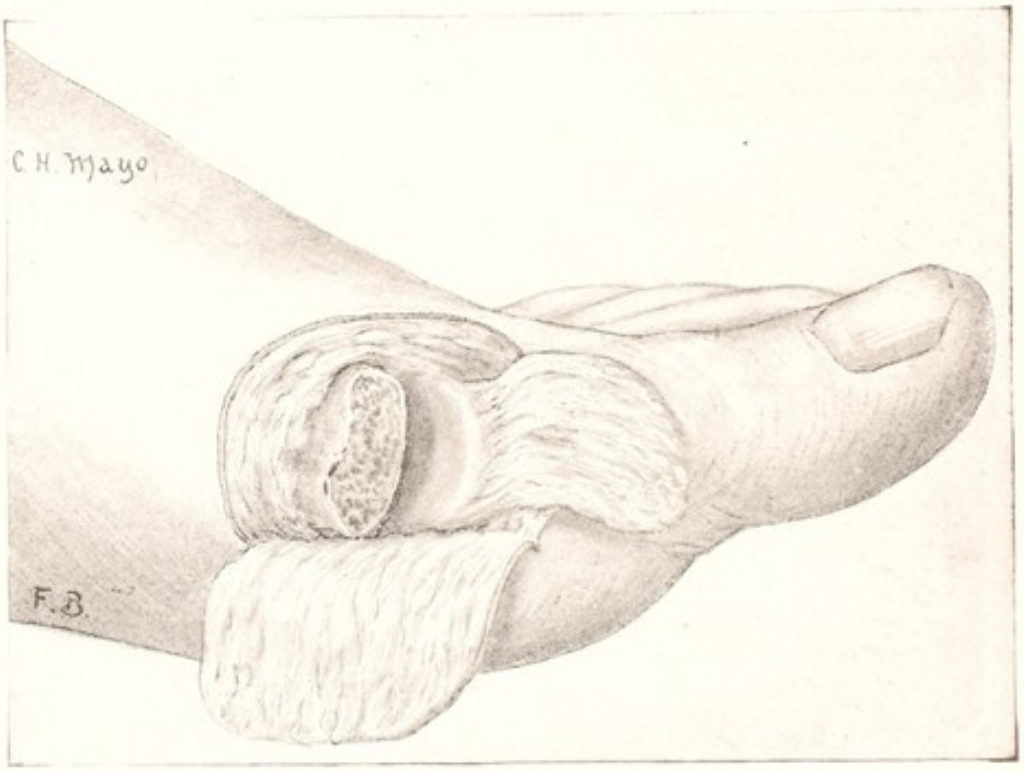


FIG. 575.—Bunion. Mayo's operation. Shows complete excision of the head of the first metatarsal bone.

Operative Treatment.—The object of one operation is to remove the projecting inner condyle of the head of the first metatarsal and any exostoses which are present. A semicircular incision is employed, its central point being below or to the outer side of the metatarsophalangeal joint of the great toe, to avoid pressure at that point. The condyle is removed with an osteotome, bone-cutter or motor-saw. The contracted tissues are divided, and the displaced toe is put in proper alignment. The wound is closed with No. 1 plain catgut, the great toe strongly abducted and held by a post of plaster between it and the second toe, and the foot and toes are put up in plaster-of-Paris dressings, or aluminium splint (Fig. 573) in which they are allowed to remain for three weeks. Or, the entire head of the first metatarsal may be removed. The bursa may be interposed between the joint surfaces after excision of the head as recommended by Mayo (Figs. 574, 575 and 576) to prevent pain from pressure of the distal end of the metatarsal on the sesamoids, but this procedure is not absolutely necessary. In this opera-

tion the sesamoids are dissected out. Section of the extensor proprius hallucis tendon is performed to prevent subsequent dorsiflexion of the great toe. Passive flexion and extension are begun at the end of the first week; at the end of the second or third week, the patient can walk with a painless movable joint. (It is remarked in passing that in the excision of any joint, if one of the joint surfaces is left intact, as a rule, good motion is secured.)

Another operation consists of cuneiform osteotomy, the wedge including the projecting bony surfaces. A recent operation consists of removal of the wedge of bone just posterior to the head of the metatarsus, its apex pointing internally, a green stick fracture being produced at this point, and the toe is straightened and immobilized.

After any of the operations, manual adduction of the toe must be practised, proper shoes worn, and the arches of the feet supported if they are weakened.

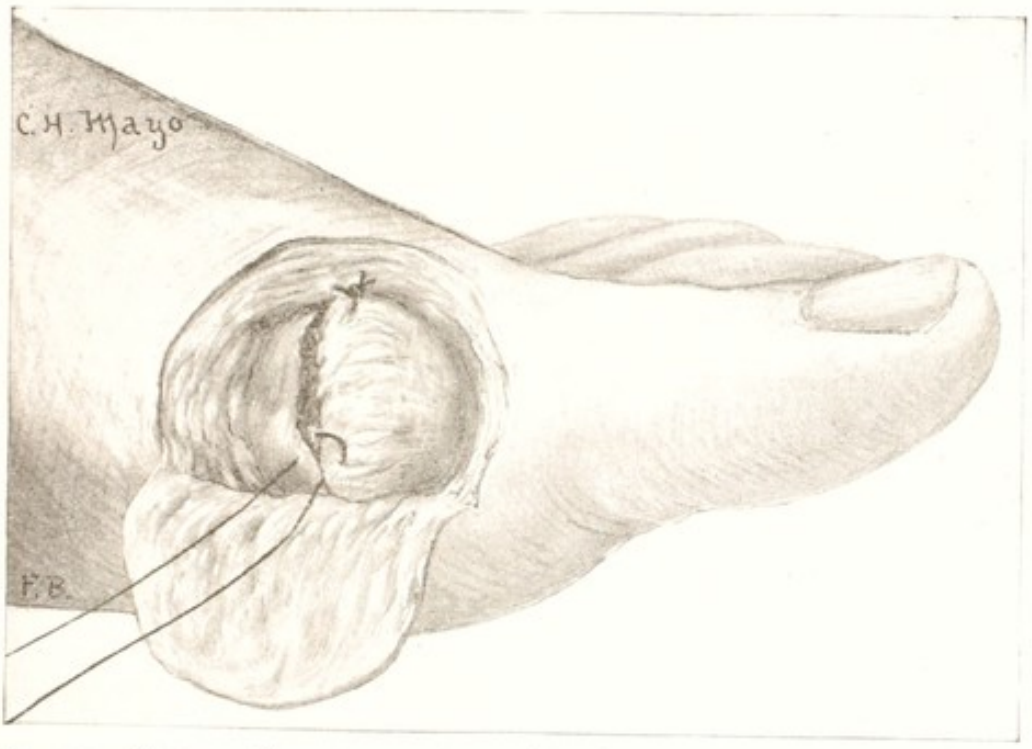


FIG. 576.—Bunion. Mayo's operation. The flap containing the bursa has been turned into the space between the metatarsal and the phalanx and fixed there by a few catgut sutures.

HALLUX RIGIDUS

Synonyms.—Hallux flexus, and painful great toe.

A painful condition of the great toe joint, with restriction of motion, particularly dorsiflexion. In the early stages, flexion and extension alone are limited and painful. At a later stage, all motion is restricted and the toe held rigid. Advanced cases of the deformity, according to Davies-Colley, are characterized by forced flexion of the proximal phalanx of the great toe, from 90 to 60 degrees, and occasionally of the second phalanx which is also held rigid.

Symptoms.—Pain on manipulation of the great toe, on either flexion or extension, with limited motion; burning or throbbing of the joint on standing or walking are the chief clinical features.

Etiology.—The deformity is frequently encountered in connection with flatfoot when the foot is crowded into a narrow boot. It is commonest in

males twenty to thirty years of age. According to Nicoladoni, plantar flexion of the toe may be the result of an instinctive effort to support a weakened arch. In other cases, trauma is the underlying cause, catching the toe against obstructions, kicking an object, etc.

Pathology.—The lesions consist of peri-arthritis followed by muscular spasm, secondary changes in the ligaments and tendons, and, in chronic cases, changes in the cartilages, in the shape of the articulating surfaces, hypertrophic outgrowths around the margins of the joint. Hypertrophy and inflammation affect the synovial pad between the sesamoid bones.

Treatment.—The treatment consists mainly of the use of a proper shoe and the treatment of flatfoot. The inner edge of the sole and heel should be wedged up and a steel brace inserted between the two layers of the sole. Hot soaks are useful, followed by massage, and painting the toe with iodin. It may be necessary to administer an anesthetic, forcibly overcorrect the deformity, and apply plaster-of-Paris bandages with the toe in its corrected position. If other methods of treatment fail, excision of the head of the metatarsal bone or arthrodesis of the joint may be necessary with excision of the sesamoid bones. A heavy, long, flatfoot plate with an extension for the great toe, often gives relief when no other conservative method succeeds.

HALLUX EXTENSUS

This condition is caused by reflex contraction of the extensor proprius hallucis in cases of irritable great toe joint. After a while, the toe is held rigid in the position of extension, although it is freely movable after an anesthetic has been administered. In the chronic state, ankylosis occurs from peri-arthritis and arthritic bony outgrowths. The treatment is the same as for hallux rigidus.

HALLUX VARUS (Pigeon-toe)

In this deformity, there is adduction of the great toe. The condition is common in infancy, associated with slight varus, and it occurs also in congenital equinovarus. The angle of displacement of the great toe may be 45 degrees or more. In some of the congenital cases, the feet and legs may be in good position, but the inner band of plantar fascia is contracted. Inward rotation of the great toes and feet may be associated with bow-legs or result in club-foot, in which the hallux varus persists after the chief deformity has been cured by operation; or it may be associated with coxa vara, in which the neck of the femur is concave anteriorly. In childhood, it is usually a symptom of weakness of the arch of the foot or of the knees (genu valgum).

Treatment.—Cases secondary to deformity elsewhere may be relieved by eliminating the cause. Primary cases can sometimes be corrected by raising the outer edge of the sole about an eighth or a quarter of an inch, and prescribing proper exercises. If the condition is due to limitation of external rotation at the hip-joint, correction of the latter may aid in overcoming the hallux varus. A simple apparatus may be devised to keep the foot and toes parallel, and may effect a cure. A certain degree of pigeon-toe is physiological and may often be outgrown.

3. Anterior Metatarsalgia and Morton's Disease

Anterior metatarsalgia is characterized by pain from mechanical derangement and weakness of the entire anterior metatarsal arch, and includes

Morton's neuralgia, an affection limited to spasmodic pain focused around the head of the fourth metatarsal bone.

Mechanism of anterior metatarsalgia (Fig. 577).—Normally the second and third metatarsal bones are longer and on a higher horizontal plane than the others; the arch resulting from their position is seen in the depression of the sole adjoining the great toe. The anterior arch disappears on weight-bearing, to return upon resting the foot. In normal walking, the weight is balanced on the head of the third metatarsal, assisted by the first and fifth, the arch being intact. In weakness and depression of the arch, pain results from direct pressure from below on the depressed metatarsophalangeal joints, and this position allows direct lateral compression by the narrow shoe of the heads of all the metatarsal bones, with resulting pain.

Etiology.—The shoe is the direct cause of pain, and is a predisposing cause of weakness of the arch, particularly women's high heels and narrow toes. The improper shoe also causes elevation of the fifth metatarsal, with depression of the fourth, which bears the weight of the outer border of the foot.

Neuritis from direct injury is a less common cause of pain. Morton's explanation that the pain is due to pressure on the digital plantar nerves is less plausible than that of contact between the neighboring heads of the



a *b*

FIG. 577.—The anterior (metatarsal) arch of the foot. *a*, Shows depression of the transverse arch in anterior metatarsalgia or Morton's disease; *b*, shows normal transverse arch of the foot.

metatarsal bones. Patients may exhibit an inherited predisposition to the affection. Other causes are weakness or injury to the longitudinal arch (flatfoot) combined with the same condition of the anterior metatarsal arch. A shortened tendo Achillis with equinus, bringing undue weight to bear on the anterior part of the sole, at which point pressure is further increased by calluses or corns under the depressed heads, may give rise to this symptom complex. These corns or calluses may be the sole cause of the condition, if localized at a particular point, and their removal may effect a complete cure. A local neuritis without mechanical derangement of the bones, may be responsible for the disorder. Other predisposing causes are gout, rheumatism, general debility, and neurasthenia. Females over thirty are the usual subjects. The condition is extremely chronic.

The **symptoms** are, briefly, pain which comes on in paroxysms, often severe in character; the pain occurs beneath the arch, usually opposite the fourth digit, although varying in localization, frequently shooting up the leg. The most constant and reliable symptom is *the desire to remove the shoe during the paroxysm.*

Treatment.—A proper shoe is essential. It should have a broad thick sole, high arch, and low heel. Adhesive plaster strapping applied over the metatarsus to compress the foot at this point, and a pad inserted under the affected joint or under the whole anterior arch, in addition to the use of a proper shoe, may be sufficient in mild cases to correct the condition.

The author's routine treatment of these cases is as follows: A pad of harnessmaker's felt with bevelled edges, and varying in size with the size of the foot and the necessities of the case, is employed. This pad, or

several layers of sheet wadding varying in diameter from 2¼ to 3 inches in length and from 1½ to 2½ inches in width, is fastened in place just posterior to the metatarsal heads by adhesive straps encircling the foot. This pad, about three-eighths of an inch in thickness is thickened each time the foot is re-strapped, at intervals of six days, until relief of symptoms has been secured. With this trial pad as a pattern, a permanent pad is made and held in place over the stocking by a cuff of thin leather held in place by silk lacing carried over the instep (Fig. 578).

Whenever anterior arch trouble is complicated by disability of the longitudinal arch, it is best to control both conditions by means of a long metal splint or support (Monell metal or aluminium), so moulded that both arches are controlled at the same time. This metal support should be made from a plaster cast of the sole of the foot, on which the longitudinal and anterior arches have been exaggerated. The anterior extremity of the brace is made as wide as the foot and extends forward, slightly beyond the metatarsophalangeal joints. This brace supports both the anterior and longitudinal arches. If one or more metatarsophalangeal joints are sensitive to motion, the plate may be extended from the heel nearly to the tips of the toes, to splint the foot for a time. If there is a weak longitudinal arch, it is advisable to raise the inner border of the sole and heel of the shoe.

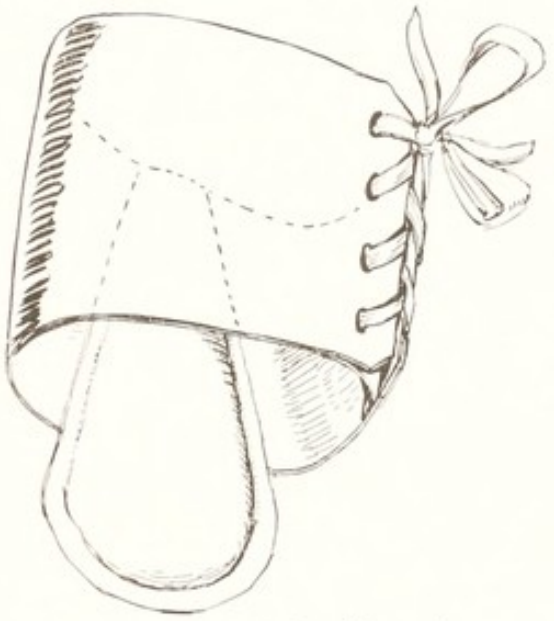


FIG. 578.—Pad for Morton's toe or metatarsalgia. This appliance consists of a felt pad which is placed over the sock and just back of the under surface of the heads of the metatarsal bones. It is held in place by a thin cuff of kid with thin silk lacing. As a rule the pad is best placed under the outer portion of the anterior arch.

After the symptoms have been relieved, regular exercises, forced flexion of the toes to elevate the anterior metatarsal arch, and massage of the foot and manipulation of the toes should be practised.

Rigid depression of the arch demands correction by manipulation, or forcibly under an anesthetic, before the brace can be worn. In cases resisting all other forms of treatment, the surgeon may be called upon to resect the neck and head of the metatarsal bone at the seat of pain. The incision is made on the dorsal surface of the joint, and the joint is excised with bone forceps, leaving the toe in position.

A. Mackenzie Forbes (Am. Jour. Orth. Surg., February, 1911) has suggested an operation for the relief of anterior metatarsalgia, including Morton's disease. He considers that the reposition of the depressed head should be the aim of all operative procedures, instead of its excision as practised by Morton and his followers. The reposed head can be maintained by the transplantation of the long extensor tendon into the head of the affected metatarsal bone. When this tendon is in spasm, it acts to the detriment of the patient while attached to the phalanx, but when transplanted to the depressed metatarsal head it acts solely to maintain the lost position of the head of the metatarsal as a component part of the anterior or transverse arch. The phalanx, when released from the long extensor, falls into a normal position and is held there by the short extensor tendon, which is

sufficient to maintain its position of equilibrium midway between flexion and extension.

The depressed head is raised by direct pressure from below, and if necessary it may be drilled from either side downward and to a fixed point near its center, thus forming a V-shaped canal for the reception of the silk or tendinous attachment; this bony attachment is found necessary because of the thinness and lack of strength of the periosteum of these bones. To obviate the dangers of infection, all sutures are buried as deeply as possible. This operation is not only efficacious in anterior metatarsalgia but may be employed also in those cases of claw-foot with symptoms resembling anterior metatarsalgia.

IV. AFFECTIONS OF THE TENDONS AND BURSÆ

ACHILLOBURSITIS

Synonyms.—Achillodynia; retrocalcaneobursitis.

Definition.—A painful condition about the insertion of the tendo Achillis from inflammation of the bursæ between the tendon and the os calcis, and between the tendon and the skin.

Varieties.—(1) Anterior achillobursitis (between the tendon and the upper part of the posterior surface of the os calcis); (2) posterior achillobursitis (between the lowest part of the tendon and the skin).

Etiology.—Adolescents and adults are chiefly affected. The *acute* form results from direct blow, strain in running or jumping, long-continued bicycling, or pressure by the seam in the upper of the boot. The *subacute* form; predisposition from rheumatism, gout, gonorrhea, aided by continued pressure of the shoe. This condition is also encountered in rickets, and is an early symptom of tuberculous epiphysitis of the os calcis.

Symptoms.—Acute pain occurs above the insertion of the tendo Achillis, radiating up the leg, and is so great that the patient is frequently obliged to walk on the toes with the foot everted. There may be acute inflammation with swelling and redness, and fluctuation from one side of the tendon to the other. If the adjoining tissues are infiltrated, the heel is broadened. Crepitation may be present from inflammation of the tendon sheath (tenosynovitis). In posterior achillobursitis, the swelling is superficial.

Pathology.—In the acute cases, the walls of the bursa are not thickened, but the sac contains clear fluid, rarely pus. In chronic cases (rheumatism, gout, gonorrhea, syphilis or tuberculosis) the walls are very thick, and pedunculated masses protrude from the lining and the contents are thick and grumous or caseous. In the gouty diathesis, chalk-stones are sometimes present in the bursa.

Treatment.—For the acute cases, absolute rest is essential, both local and general. The foot should be fixed in plantar flexion, and counterirritants, iodin, and hot stupes applied. After the urgent symptoms have subsided, plaster-of-Paris dressings are used to hold the foot inverted and at right angles to the leg, and are worn for one or two weeks, after which friction and light massage are employed.

In subacute cases, Whitman suggests that a long broad band of adhesive plaster be applied from the balls of the toes along the sole, and over the heel to the upper third of the foot, the foot being slightly plantar flexed. Narrow overlapping strips are applied about the metatarsus, heel, and calf.

In chronic cases, the constitutional cause must be sought and eliminated by appropriate treatment. The heel should be raised with a rubber heel $\frac{1}{4}$ to $\frac{1}{2}$ inch thick. The *x*-ray should be employed in these chronic cases to eliminate the presence of tuberculosis.

Operative Treatment.—The most satisfactory treatment in obstinate cases is excision of the enlarged bursa through an incision on the inner side of the tendon, followed by a plaster-of-Paris splint in slight equinus. It may be advisable at the same time to perform plastic tenotomy to lengthen the tendo Achillis, in order to take the strain off the region of the inflamed bursa.

Calcaneobursitis

Painful heel is often due to inflammation of the small bursa between the under surface of the os calcis and the fatty tissues of the heel. The symptoms are pain, referred to the bottom of the heel, and sensitiveness to pressure on standing; this tender point may be circumscribed at the inner tuberosity of the os calcis.

Treatment.—If the condition is a symptom of flatfoot, the latter should be treated first. A thick rubber heel will remove the jar of walking. In obstinate cases, the bursa may be removed through a curved incision following the lateral and postero-inferior margins of the heel, the flap being turned forward. If the cause is contusion or overuse, rest should be enjoined; and if overweight, efforts at reduction should be made.

Displacement of the Peroneal Tendons

The cause is sharp contraction of the muscles, deviating the foot outward while it is in dorsiflexion, the tendons being dislocated forward. Predisposing causes are congenital absence of the sustentaculum tali, malformation of the groove, certain fractures and sprains. It occurs also in paralytic talipes valgus. The symptoms simulate sprain, by local pain, swelling, and ecchymosis. The tendons are palpable on the external surface of the malleolus. They can be easily replaced by extending the foot, but again become dislocated on dorsiflexion.

Treatment.—The foot is placed at right angles and everted, the tendons are pushed back in place, a pad is put over them, and plaster-of-Paris dressings are applied. Relapse usually follows, however, hence operative treatment is the best.

Operation.—The tendons are held in an artificial groove formed by an osteoperiosteal hinge flap from the fibula. König sutures the free end of the flap to the periosteum of the os calcis over the tendons, while Lannelongue turns the hinge directly backward over the tendons and sutures the free edge to the posterior border of the fibula. The natural bony groove for the tendons should also be deepened.

Tenocellulitis of the Tendo Achillis

Inflammation of a tendon independently of its sheath is rare. Tenocellulitis is encountered chiefly in the tendo Achillis. It causes a painful swelling of cylindrical or spindle shape, well above the os calcis. Several separate nodes may be present at intervals along the course of the tendon. The affected part is stiff and the movement is accompanied by pain, while it is often tender to direct pressure when the tendon is relaxed. The onset is insidious. It may or may not follow punctured wounds, as in the author's case. Predisposing causes are overuse, strain, rheumatism, gout, gonorrhea, and influenza. It usually subsides by resolution in a few weeks, although it may persist and the swelling may remain permanently thickened and hardened (sclerosis), and may result in a fibroma.

The treatment consists of absolute rest, with the gastrocnemius relaxed (plantar flexion) and held so by strapping, under which a pad of cotton is inserted for pressure and a bandage applied over all. Iodin may be applied as a counterirritant in the acute stage, together with light friction followed by massage, vibration, and dry heat.

Tendonitis of the Tendo Achillis

Inflammation of the tendinous substance may result from infection or in the course of gouty or rheumatic diatheses, associated with overstrain of the tendon. The tendon is swollen and painful throughout its length and very tender on movement. Tophi (chalk-stones) may form in its substance. Treatment is directed against the constitutional disorder, combined with rest, dry heat, and temporary immobilization.

REFERENCES

CLUB-FOOT

Schwartz: "Des différentes espèces de pied bots et leur traitement." Thèse d'agrégat. Paris, 1883.
Ashhurst: "Encyclopedia of Surgery." vol. vi, p. 1003.
Lannelongue: "Du pied bot cong., Thèse d'agrégat." Paris, 1869.
Roberts, Sydney: "Club-foot." Phil. Med. News, March, 1886.
Whitman: "Orthopedic Surgery," 3d ed., p. 760, 1907.
Little, W.: "Holmes' Syst. of Surg." 3d ed vol. ii, p. 232.
Reeves: "Practical Orthopedics," p. 152.
Spitzy and Dane: Am. Jour. Orth. Surg., August, 1904.
Bradford, E. H.: Trans. Amer. Orth. Ass'n, vol. i, p. 89.
Phelps: N. Y. Med. Jour., Mar. 4, p. 387, 1895.
Tubby: Lancet, Feb. 17, 1894.
Bessel-Hagen: "Über die Pathol. des Klumpfüsses, etc." Verhandl. d. deutscher Ges. f. Chir., 1885 and Die Pathol. und Therapie. Petters, Heidelberg, 1889.
Bradford and Lovett: "Orthopedic Surgery" 3d ed., p. 518.
Townshend, W. R.: "A Statistical Paper on Club-foot." Trans. Med. Soc. of N. Y., 1890.
Adams: "Club-foot." 2d ed., p. 144.
Keetley: Brit. Orth. Soc. Trans., Jan. 31, 1895.
Little: On Deformities, 1853.
Nélaton: Arch. générales de med., April, 1891.
Parker and Shattock: "Congenital Club-foot," 1887.
Rochard: Revue d'orthopedie, Sept. 1, 1891.
Volkmann: "Zur Ätiologie der Klumpfüsse." Deutsch Klinik, Berlin, 1863.
Hartley: N. Y. Med. Rec., Aug. 18, 1894.
Wolf, Julius: "Club-foot, Its Causes, Nature and Treatment." Berlin, 1903.
Walsham and Hughes: "Deformities of the Foot."
Tubby, A. H.: "Discussion on the Treatment of Club-foot." Brit. Med. Jour., Oct. 9, 1909.
König: Beiträge, Centralbl. f. Chir., Nov. 25, 1890.
Freiberg: Medical News, Oct. 29, 1892.
Rédard: "Traité de chirurgie orthopédique."
Lave, Arbuthnuot: Lancet, Aug. 18, 1893.
Kellock, T. H.: Lancet, Mar. 30, 1895.
Jonas: "Annals of Surgery," April, 1897.
Krauss, G.: Deut. Zeitschr. f. klin. Chir., Bd. xxvii, Hefte, 3, 4, Annals of Surg., vol. ix.
Mackenzie, V.: Trans. Am. Orth. Ass'n, vol. iv.
Willard: Trans. Am. Orth. Ass'n, vol. v.
Phelps: Trans. Am. Orth. Ass'n, vol. v.
Tarsectomy:
Little: "Practical Observations on the Treatment of Club-Foot," 3d ed., p. 305.
Verbelzi: Centralbl. f. Chir., No. xxiv, 1877.
Davy: Lancet, Feb. 14, 1888, and Oct. 14, 1893.
Davies-Colley: Med. Chir. Trans., 2d series, vol. xliii, 1877.
König: Centralbl. f. Chir., No. xiii, 1880.

RUPPRECHT: Centralbl. f. Chir., Mar. 13, 1880.
HARTLEY: "Operative Treatment of Club-Foot." Annals of Surgery, March, 1894.
WILLARD, DEF: Trans. of Orth. Ass'n, vol. v.
BRADFORD, E. H.: Trans. of Orth. Ass'n, vol. i.
RAMSAY, A. C.: Ann. of Surgery, vol. xi.
GIBNEY: Ann. of Surgery, vol. xi.
EWEN: Brit. Med. Jour., Oct. 17, 1891.
GRIFFITHS: Brit. Med. Jour., Dec. 30, 1893.
LONSDALE: Lancet, September, 1855.
DUNN, L. A.: Path. Trans., 1892.

PES CAVUS

FISHER, F. R. On "Paralytic Deformity of the Foot." Lancet, vol. 1, 1889.

HAMMER-TOE

ANDERSON, WM.: "Lectures on the Contraction of the Fingers and Toes," vol. ii, 1891.
HOWARD, WARRINGTON: Lancet, May 6, 1893.
ROWAN: Brit. Med. Jour., June 10, 1893.

PAINFUL HEELS

BROUSSES ET BERTIER: Rev. de Chir., August, 1895.
BAER: Surg. Gyn. and Obst., July 2, 1906.

INTERMITTENT LIMPING

LOVETT, R. W.: Amer. Jour. Orth. Surg., vol. iv, No. 2, 1906.
AUERBACH: Deutsche Zeitschr. f. Nervenkeilkunde, xl, 142.
BERGMANN: "Beitr. zur Kenntniss d. Angiosklerose." Dorpat., 1890.
BORCHARD: Deutsche Zeitschr. f. Chir., 44, 131, 1897
BOURGEOIS: Thèse de Paris, 1897.
BRISSAUD: Rev. neurol., xiii, 1899.
CHARCOT: Comptes rend. et mem. de la Soc. de Biol. ,2d series, xii, 225.
CHARCOT: Prog. méd., 32 and 33, 1887.
CHARCOT: Bull. méd., December, 1891.
DANA: N. Y. Med. Rec., Feb. 22, 1912.
DEHIO: Deutsche Zeitschr. f. Nervenhlkde, vi, 1893.
DEHIO: Berl. kl. Wchsft, 37, 817, 1896.
DELAUNAY: Thèse de Paris, 1890.
DUTIL AND LAMY: Arch. de méd. exp. et d'anat. path., ii, 102, 1893.
EDGREN: "Kliniska studier öuer arterio-skleros." Stockholm, 1897.
ELZHOLZ: Wien. med. Wochenschrift, 49 and 50, 1892.
ERB: Deutsche Zeitschr. f. Nervenhlkde, xiii, 1, 1898.
ERB: Münch. med. Wochenschrift, May, 1904.
GORDON: N. Y. Med. Journal, 806, Sept. 10, 1900.
GOLDFLAM: Deutsche med. Wochenschrift, 36, 1895.
HIGIER: Deutsche Zeitschr. f. Nervenhlkde, xix, 1901.
HAGA: Virch. Arch., 152, p. 26.
HEIDENREICH: Sem. méd., 1892.
HOMÉN: Finska Däkalesällsk Handlingar, 1900.
IDELSON: Deutsche Zeitschr. f. Nervenhlkde, xxiv, 1903.
LAVERAN: Sem. méd., 100, 1894.
LEVET: Thèse de Paris, 1894.
LAPINSKY: Deutsche Zeitschr. f. Nervenhlkde, xiii, 1898, and xv, 1899.
LANCERAUX: Sem. méd., 1894.
MITCHELL AND SPILLER: Am. Jour. Med. Sciences, cxvii, 1, 1899.
MARIENSCO: Sem. méd., No. 9, 1896.
MARGOLIN: Inaug. Diss., Freiberg, 1905.
MASSAUD: Neurol. Centralbl., 953, 1901.
MEHNERT: "Über die Topog." Verbreitung d. Angiosklerose, etc., Dorpat, 1898.
MUSKAT: Verhandl. d. deutsche Ges. f. orth. Clin., 5th Congress, p. 184.
NOTHNAGEL: Zeitschr. f. kl. Med., xix, 1891.
OORDT: Neurol. Centralbl., 795, 1900.
OPPENHEIM: Deutsche Zeitschr. f. Nervenhlkde, xvii, 1900.

PANAS: Sem. méd., 265, 1894.
PITRES AND VAILLARD: Arch. de physiologie, 1885.
PUTNAM: Boston Med. and Surg. Jour., 182, Feb. 21, 1901.
RIESMAN: Am. Med., p. 343, May 25, 1903.
RIMEBERG: Die Ther. d. Gegenwart, 1900.
SCHLESINGER: Neurol. Centralbl., xiii and xiv, 1895.
STERNBERG: Wien. klin. Wochenschrift, 37 and 39, 1895.
STRASSMANN: Deutsche Arch. f. kl. med., 60, 1890.
SANGER: Neurol. Centralbl., 1067, 1901.
SCHROTTER: "Nothnagel's Spec. Path. und Ther.," Bd. v.
THOMA: Virch. Arch., 105, 1886.
THOMA: Deutsche Arch. f. klin. Med., xliii, 400, 1888.
WILL: Berlin kl. Wochenschrift, 1889.
WEISS: Deutsche Zeitschr. f. Chir., xl, i, 1895.
WINIWARTER: Arch. f. klin. Chir., xxiii, 202.
WIREDENSKY: Langenbech's Archiv, 1898.
WALTON AND PAUL: Boston Med. and Surg. Jour., Apr. 3, 1902.
ZOEGE MANTEUFFEL: Arch. f. klin. Chir., 42, 569, 1891.
ZOEGE MANTEUFFEL: Centralbl. f. Chir., No. 3, 1902.

FLATFOOT

THEVENOL, D. LEON: "La Tarsalgie des adolescents." Rev. d'orth., March, 1905.
DANE: Trans. Amer. Orth. Ass'n, vol. xiii.
HOKE: Chicago Med. Jour., September, 1902.
HOKE AND BRADFORD: Trans. Amer. Orth. Ass'n, vol. xiii.
SAMPSON: Johns Hopkins Hosp. Bull., January, 1902.
ROBERTS: "Contributions to Orthopedic Surgery." Phila., 1898.
BRADFORD AND LOVETT: "Orthopedic Surgery," 3d ed.
WHITMAN: "Orthopedic Surgery," 1017.
LOVETT, R. W.: New York Med. Jour., June 20, 1896.
LOVETT AND COTTON: Trans. Am. Orth. Ass'n, vol. xi.
LOVETT, R. W.: Am. Jour. Orth. Surg., August, 1903.
EUGELS: Zeitschr. f. orth. Chir., Bd. xii, Heft 3.
WHITMAN: N. Y. Med. Rec., Aug. 31, 1907.
LOVETT AND DANE: N. Y. Med. Jour., Mar. 7, 1896.
BLODGETT, W. E.: Am. Jour. Orth. Surg., 1904.
CABOT: "De la tarsalgie douloureuse des adolescents." Thèse de Paris, 1896.
KIRMISSON: "Difformités acquises."
HOFFA: Langenbeck's Arch., vol. 1, 1895.
POUCET: Ann. Med. Chir. du centre, Jan. 1, 1905.
THÉVENAT AND GAUTIER: "Tarsalgie des adultes d'origine Tuberculuese." Revue d'orth., Jan. 1, 1905.
MARTIN: Thèse de Lyon, 1904 and 1905.
HOVORKA: Zeitschr. f. orth. Chir., Band xii, Heft 3.
LITTLE, MUIRHEAD: Lancet, Apr. 6, 1901.
SAMPSON: Amer. Medicine, January, 1902.

METATARSALGIA

MORTON: "Peculiar Painful Affection of the Fourth Metatarsophalangeal Articulation." Am. Jour. of Med. Sc., 1876.
BRADFORD: "Metatarsal Neuralgia, or Morton's Affection of the Foot." Boston Med. and Surg. Jour., vol. xi, p. 523, 1891.
GIBNEY: "Non-Operative Treatment of Metatarsalgia." Amer. Jour. of Nervous and Mental Diseases, p. 589, September, 1894.
C. E. WOODRUFF: "Incomplete Luxations of the Metatarsophalangeal Articulation." N. Y. Med. Rec., Jan. 18, 1890.
GOLDTHWAIT: On "Obliteration of the Anterior Transverse Arch of the Foot as a Cause of Metatarsalgia." Boston Med. and Surg. Jour., cxxxi, No. 10, p. 233.
BOX: On "Morton's Disease." Archiv gén. de méd., July, 1894.
MORTON, T. S. K.: Trans. Phila. Acad. of Surg., 1893.
ROUGHTON, EDMUND: Lancet, March, 1889.
DANA: Med. Rev., N. Y., July, 1895.
GOLDTHWAIT: Trans. Am. Orth. Ass'n, vol. vii.
WHITMAN: Ibid., vol. xi, p. 36.

Bradford: Boston Med. and Surg. Jour., vol. cxxv, No. 23.
Morton, T. G.: Internat. Med. Mag., p. 322, 1896.
Jones and Tubby: Annals of Surgery, September, 1898.
Harsant: Bristol Med. and Chirurg. Jour., September, 1897.
Hoffman: St. Louis Courier of Med., June, 1902.
Peckham: Trans. Am. Orth. Ass'n, vol. xiv, p. 201.
Bradford: Ibid., p. 329, 1902.
Stern: Amer. Med., Feb. 6, 1904.
Guiseppe, Cristalli: Archivio di ostetricia e gingecologia, vol. ix, p. 752, on "Morton's Disease in Pregnancy."
A. Mackenzie Forbes: "An Operation for Anterior Metatarsalgia." Amer. Jour. Orth. Surg., vol. viii, No. 3, p. 507, February, 1911.

AFFECTIONS OF TENDO ACHILLIS

Schauz: "Eine Typische Erkrankung der Achillessehne." Zentralbl. f. Chir., 48, 1905.
Drehmann: "Eine Typische Erkrankung der Achillessehne." Zentralbl. f. Chir., 1, 1906.
Baracz, V.: "Tendonitis achillea arthritica als eine besondere Form der Achillessehnenerkrankung." Zentralbl. f. Chir., 1, 1906.
Raynal: "Cellulite, péritendineuse du tendon d'Achille." Arch. gen. de med., 1883.
Kirmisson: "Contribution àl'é tude des affections du tendon d'Achille." Arch. gen. de med., 1884.
De Boris: "Péritenosites." Un méd. du nord-est, 1899.

CHAPTER XXIV

CONGENITAL DISLOCATION OF THE HIP

Definition.—Congenital dislocation of the hip consists of a partial or complete displacement of the head of the femur from the acetabulum, probably due to congenital malformation of the parts entering into the formation of the hip-joint.

History.—Although congenital dislocation of the hip was known to the ancients, the history of its treatment dates from Dupuytren's description of its pathological anatomy in 1826.

Frequency and Occurrence.—It is the commonest and most important of congenital dislocations and constitutes about 1 to 2 per cent. of all orthopedic conditions.

About 88 per cent. of the cases occur in girls. Heredity is a marked factor. There is frequently a history of alcoholism (particularly in the maternal parent) and of hereditary syphilis.

PATHOLOGICAL ANATOMY

1. **Acetabulum.**—The acetabular cavity is gradually obliterated by failure of development of its rim and thickening and elevation of its floor. The loss of depth is more rapid than decrease of its diameter. The normally rounded shape becomes converted into a triangular depression with its apex in front and below, its base above and behind. The floor is thickened by a hypertrophy, which can be appreciated on the pelvic surface of the ilium by means of rectal examination. The rim is most deficient above and behind. In a röntgenogram the external surface of the ilium and the floor of the acetabulum are nearly in a straight line, instead of the right-angled projection at the upper part of the acetabulum. The contents of the shallow acetabular cavity consist of an overgrowth of cartilage, the remains of the ligamentum teres, and the Haversian gland, covered by the anterior portion of the capsule of the hip more or less adherent to the floor. The acetabular contents just enumerated are represented by röntgenography as a wide, light band between the pelvis and the remnants of the femoral head.

Formation of a New Acetabulum.—A true new joint *does not form* beneath the displaced femoral head. There is formed merely a depression lined with periosteum, worn away on the outer surface of the ilium, and in it the femoral head rests more or less insecurely, with a fold of the capsule intervening between the bones.

2. **Head of Femur.**—From a clinical standpoint, the head of the femur is of more importance than the acetabulum. Bad distortion of the femoral head renders non-operative treatment almost impossible. The head of the femur normally transmits the body-weight and acts as a pivot on which the movements of the hip take place. In congenital dislocation, the body is borne by the tension of the soft parts between the trochanter and the pelvis, the head becoming the short arm of a two-armed lever.

The pathological changes are atrophic. The head becomes conical, the neck short, and the upper end of the femur atrophied and smaller. The

usual conditions found are a small, atrophied head, flattened on its median and posterior aspects; a short anteverted neck with its angle diminished in a position of coxa vara or coxa valga. The atrophy may be so extreme that the head is absent. Flattening of the head is due to attrition on the ilium. If the head rests "dead" on the pelvis, it becomes buffer-shaped or, to quote Lorenz, like "a much used hammer whose striking surface becomes spread out and turned up around the rest of the head."

3. **Neck of the Femur.**—The neck is *shortened*, *depressed*, and *anteverted*. The shortening is sometimes so great that the head seems to be applied directly to the upper end of the shaft. This, of course, means a shortening of the limb.

The condition of anteversion is of extreme importance. The normal angle between the axis of the neck and the transverse axis of the condyles is 12 degrees. In this condition it may be increased to 90 degrees, although usually only to about 45 degrees, and is due to anteversion of the neck, which seems to come off directly in front of the shaft (Fig. 579). Torsion of the shaft may also exist. The practical application of this phenomenon is, that to bring the head of the femur completely within the acetabulum, the thigh must be rotated inward, in these cases, until the patella looks directly and entirely inward.

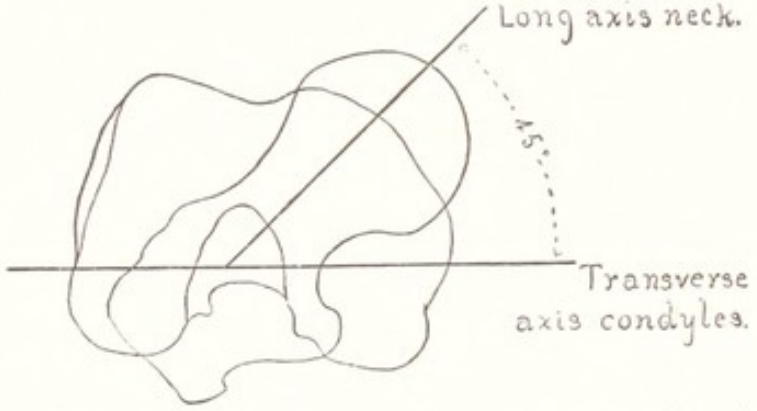


FIG. 579.—Twist of neck in congenitally dislocated femur, looking from above downward. (Bradford and Lovett.)

4. **Pelvis.**—Abnormalities of the pelvis depend upon whether the dislocation is unilateral or bilateral, and upon the position of the head of the femur.

(*a*) *Double Dorsal Dislocation.*—The deformity is symmetrical. The pelvis is tilted forward, the plane of the inlet making an angle of 90 degrees (instead of the usual 45 degrees) with the horizon. The normal lumbosacral lordosis is increased, the sacrum being tilted out and greatly curved. The innominate bones lie more vertically, the iliac crests being nearer together and the ischial tuberosities everted. The whole innominate bone is small and atrophied.

(*b*) *Unilateral Dislocation.*—The pelvis has a lateral inclination, the shape of the pelvic inlet being obliquely ovoid.

5. **Soft Parts.**—(*a*) *Capsule.*—The capsule is stretched and distended, covering the head like a hood. It assumes an hour-glass contraction of varying degree between the head of the femur and the ilium on account of compression by the iliopsoas tendon which crosses the capsule; the round ligament passes through the constriction. The greatest obstacle to reduction is offered by the strong internal part of the capsule which is stretched tightly across the entrance of the acetabulum from its posterior aspect; the aperture

leading from the distended capsule to the true acetabulum may be merely a small buttonhole. Occasionally the anterior part of the capsule blends with the soft tissues of the floor of the acetabulum. In effect, the capsule becomes a suspensory ligament, undergoing hypertrophy particularly at its anterior and lower portion.

(*b*) *Ligamentum Teres.*—The round ligament is extremely attenuated or altogether wanting. It is usually present up to the third year of the dislocation, but disappears after the fourth year.

6. **Muscles.**—Abnormality of the muscles between the femur and pelvis is the chief cause of failure to get the head opposite the acetabulum and is the main hindrance to its retention there.

Lorenz divides these muscles into three groups, viz.: the pelvitrochanteric, pelvifemoral, and pelvicrural groups.

(*a*) *Pelvicrural Group.*—This comprises the hamstrings, gracilis, pelvic portion of the rectus femoris, sartorius, tensor vaginæ femoris, and most of the adductor muscles. They all run in the same axis as the femur. When the femur is shortened, they contract to take up the slack. They present the most formidable obstacle to reduction, which often cannot be overcome except by division of the adductors and hamstrings, preliminary to operation, and by the pre-operative application of weight extension for some weeks.

(*b*) *Pelvitrochanteric Group.*—The superficial set of these muscles includes the glutei; the deep set, the obturators, quadratus femoris, and the psoas tendon. All show marked functional incompetency, especially the glutei; this is demonstrable clinically by the patient's inability to steady the palsy when standing on the affected leg; the pelvis droops (Trendelenburg's sign), and their incompetency is the cause of the typical waddling gait. The opposite condition exists in coxa vara, in which the patient standing on the affected leg *raises* the pelvis on the sound side.

The Gluteus Maximus.—On account of the shortening of the limb, the fibers of this muscle run more horizontally than normal, which changes the direction of the fold of the buttock. The elevated trochanter major projects above the upper border of the gluteus maximus and is more readily felt beneath the skin. The ischial tuberosities are more or less uncovered by its lower fibers.

The *psoas tendon* is displaced outward and winds outward and backward, compressing the capsule. The pelvis really rests in it as in a sling, the tendon acting as a suspensory ligament of the body-weight and dragging the lumbar spine forward. On account of its outward displacement, it occasionally creates an opening for a crural hernia (not a femoral hernia through the normal femoral ring) beneath Poupart's ligament. In open operations it is the greatest obstacle to reposition of the head in the acetabulum, and is recognized as a tight band beneath the head.

(*c*) *Pelvifemoral Group.*—The lower part of the adductor magnus and the adductor longus are particularly shortened.

Summary of Muscular Anomalies.—The greatest offenders against reduction are the muscles arising from the pelvis and inserted below the middle of the femur, viz.: the hamstrings, rectus, tensor vaginæ femoris, and the major portion of the adductors, the pelvicrural group. Relief can, however, be obtained if necessary by tenotomy, viz.: (*a*) at the inner side of the thigh, just below the symphysis pubis; (*b*) at the outer side of the thigh, just below the anterior superior spine; and (*c*) at the inner side of the knee for the adductor magnus and inner hamstrings.

Varieties of the Dislocation.—The usual position of the displaced femoral head is *upward* and *backward* onto the dorsum ilii. Another, less frequent,

location of the head is *anterior* at a point beneath the anterior *superior spines*. Further classification of positions is of no practical value, as in all of them the primary displacement is probably upward and backward onto the dorsum ilii.

The dislocation may be *complete* or *incomplete*. The latter, in which the head is not entirely out of the acetabulum, is only a step in the process.

This dislocation may be *unilateral* or *bilateral*. It occurs on both sides in 29 to 30 per cent. of the cases; on one side only, in 61 to 71 per cent. and of these about 53 per cent. occur on the right, and about 46 per cent. on the left side.

ETIOLOGY

Many theories have been advanced to account for the dislocation, the generally accepted one being the developmental theory.

1. **Developmental Theory.**—This is based on the assumption that the acetabulum is not primarily a socket but is *formed by a growth of pelvic cartilage up and around the head of the femur*, and that in congenital dislocation the growth of the acetabular cartilage fails to keep pace with the growth of the femoral head. In support of this theory, the following data are presented:

(*a*) The marked *hereditary* factor.

(*b*) Transmission through both male and female parents, and seen in collaterals.

(*c*) Girls are more frequently affected than boys, because early developmental errors are more common in the more primitive female type.

(*d*) The incidence of co-existing anomalies.

(*e*) Bilateral involvement.

(*f*) Occurrence in other members of same family.

2. **Mechanical Theory.**—It is argued by some that prolonged intra-uterine flexion, especially flexion and adduction, causes stretching of the capsule of the hip-joint, behind and below, and causes the head of the femur to distend it. Exaggeration of the normal intra-uterine flexion of the fetal ovoid is produced by oligohydramnios, multiple pregnancy, hydrocephalus, etc.

Other evidences of abnormal intra-uterine forces are congenital genu recurvatum, congenital club-foot, etc.

Additional theories, less plausible and hence less generally accepted, are:

3. *Intra-uterine trauma.*

4. *Birth trauma.*

5. *Muscular contraction* due to a central nervous lesion.

6. *Paralysis of anterior poliomyelitis.*

CLINICAL FEATURES

The three leading clinical phenomena of congenital dislocation of the hip are the characteristic gait, lumbar lordosis, and the specific deformity.

1. **Gait.**—The gait in bilateral dislocation has been variously described as a "duck-like waddle," "sailor's gait," etc., but baffles adequate description. In unilateral dislocation it is a limp or a lurch toward the affected side. This abnormal gait is due to functional disability of the gluteal muscles, shortening of the femur and displacement of its head, combined with lumbar lordosis and abnormal lateral mobility of the lumbar spine.

2. **Lordosis.**—Abnormal lumbar lordosis is more marked in bilateral than in unilateral dislocations, and is accompanied by corresponding protrusion of the abdomen (Fig. 580).

3. **Deformity.** (*a*) *Unilateral Deformity.*—The distance from the anterior-superior spine to the tip of the inner malleolus is shortened. The great trochanter lies above *Nélaton's* line and is prominent. The gluteal fold is directed upward, due to the stretching of the skin over the great trochanter and the altered direction of the gluteal fibers.

(*b*) *Bilateral Deformity.*—The lower limbs appear too short for the body, the disproportion in length of the thigh as regards the lower leg being the more marked. The perineal space is increased, that is, the thighs are far apart at their upper extremities, the trochanters are prominent, the buttocks broad and flat, and the ischial tuberosities uncovered by the gluteus maximus.



FIG. 580.—Double congenital dislocation of hips, demonstrating marked lordosis, which is always present in these cases. (Bradford and Lovett.)

DIAGNOSIS

Actual Diagnosis.—A limp or waddle accompanying a child's first attempt to walk and without pain; history of trauma, or antecedent disease offers *prima facie* evidence of congenital dislocation of the hip. It then devolves upon the surgeon to determine whether the head of the femur is out of the acetabular cavity and, if so, what is its location.

Complete or Partial Dislocation.—This point can be effectually determined by röntgenography (Figs. 581 and 582). The normally placed femoral head lies in the groin below Poupart's ligament and is crossed by the femoral artery. On rotation and palpation, if head and trochanter can be made out, the axis of rotation of the femur comes half-way between these two points in congenital dislocation; if coxa vara or allied condition exists, the axis of rotation is at the center of the femoral head. Clinically, the question can be answered by rotation of the limb accompanied by careful palpation. It is to be noted that the movements described by the femoral head in con-



FIG. 581.—Double congenital dislocation of hips.



FIG. 582.—Unilateral congenital dislocation of the hip.

genital dislocation are in a direction opposite those of the corresponding foot. As a rule, if the trochanter lies below Nélaton's line, the head is in the acetabulum.

Position of the Head.—This is usually on the dorsum ilii. If the head is in an anterior position, it is usually also superior to the acetabulum, a step in the process of posterior dislocation. In young subjects, "telescoping" (free vertical mobility) of the head can be accomplished by fixing the pelvis.

Differential Diagnosis.—The most confusing condition is coxa vara.

Disease	Points of resemblance	Points of difference
1. Coxa vara.	Elevation of trochanter.	Neck and head not felt. No abnormal mobility. *X*-ray.
2. Trauma (fracture of neck; separation of epiphysis).	Elevation of trochanter. Gait.	Pain on manipulation in recent cases; none in chronic. External rotation of the femur. Axis of rotation of femur at center of head. *X*-ray.
3. Extreme bow-legs.	Waddling gait.	Hip-joints normal in appearance and function.
4. Lumbar Pott's disease.	Waddling gait. Lordosis (occasionally).	Acquired, painful disease. Hip-joints normal. *X*-ray.
5. Pseudohypertrophic paralysis.	Gait and attitude similar.	No other points of resemblance. Hip-joints normal. Neurological tests. *X*-ray.
6. Paralysis of poliomyelitis.	Waddling gait. Shortness of limb.	*X*-ray. Hip-joints normal. Acquired. Paralysis apparent and may disappear.
7. Pathological dislocation. (osteitis with destruction of head).	Elevation of trochanter. Abnormal gait. Lordosis. Laxity of hip.	*X*-ray conclusive. Characteristic history. Axis of rotation of femur in center of trochanter.

PROGNOSIS

Without treatment the outlook is bad. Spontaneous cure is impossible. Deformity, lameness, and shortening rapidly and progressively increase during the adolescent period. With increase of age and weight, painful muscle spasm and rigidity occur, leading in obese patients to practical invalidism.

With treatment, the results vary with the method used. Manipulative, bloodless reduction yields less than 60 per cent. of cures.

The author's operation for deepening the acetabulum by bone-graft wedge offers success in a large percentage of cases (even in the 40 per cent. of failures by the bloodless method) and produces a strong joint with good motion and without pain and shortening (page 895).

TREATMENT

Treatment is divided into *manipulative* and *operative* methods. In every case, the bloodless conservative methods of manipulation, reduction, and retention should be given a thorough trial before resorting to operative interference.

(*A*) Manipulative Treatment

In conservative treatment of congenital dislocation of the hip, the author does not follow religiously any one method, because individual variations

do not permit of this; but on general principles the method of *Calôt* is preferable to that of *Lorenz*. The author does not advocate the old method of overstretching and laceration of the muscles about the hip or its capsule, inasmuch as these structures aid, if they are in tone, in retaining the head in position after reduction. As the technic of *Calôt* and *Lorenz* have been developed, however, they have more closely approximated each other. Each case should be judged on its own merits and studied as to the post-operative position which gives most stability to the head in the acetabulum.

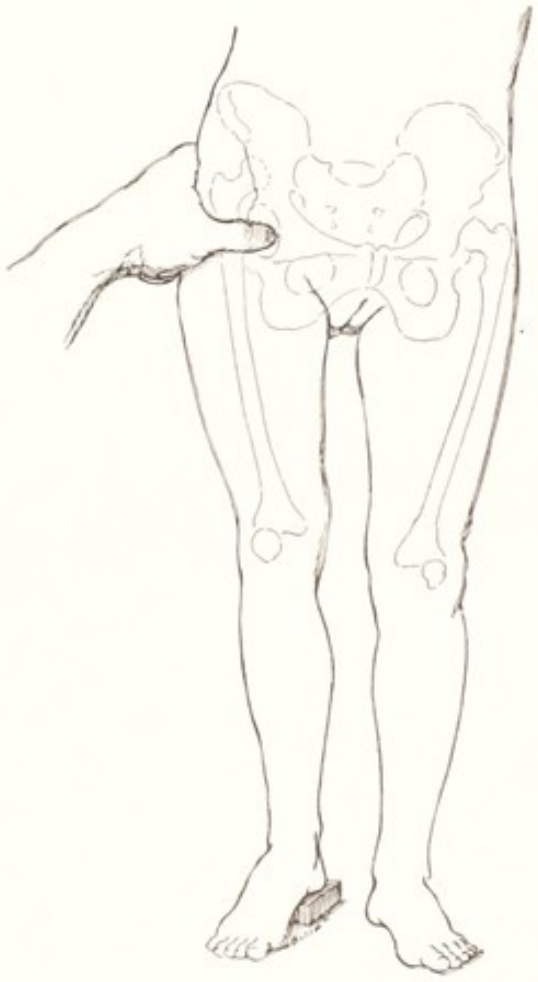


FIG. 583.—Congenital dislocation of the hip. Showing palpability of the acetabulum, in the absence of the head, as a diagnostic feature of considerable importance.

I. DISLOCATION IN CHILDREN TWO TO THREE YEARS OF AGE

(A) **Unilateral Dislocation.**—*Preliminary Measures.*—Prior to manipulation aiming at reduction, it is necessary to stretch the adductor muscles and other contracted peri-articular structures by circumduction of the hip in all directions, and by kneading and massage.

Massage of the Adductors (Fig. 585).—The pelvis is immobilized by an assistant who flexes the sound thigh upon the abdomen. A second assistant makes traction on the extended affected limb, followed by abduction and flexion to 90 degrees. When the adductors stand out as a firm cord at their point of origin, the operator practises deep kneading and massage with the knuckles applied at the point of tension. This preliminary measure alone will sometimes effect a reduction.

Maneuvers of Reduction.—The femoral head is made to follow the anatomical movements executed in the reduction of traumatic dislocations.



FIG. 584.—Old congenital dislocation of hip reduced many years before. Illustrating possible diagnostic error by *x*-ray unsubstantiated by clinical examination. Such cases have been diagnosed by the rontgenologist as tuberculosis of the hip, a possible error unless the history of the case is carefully considered.



FIG. 585.—Kneading of the adductors (on the right side) the affected thigh being in *flexion*. The thigh is carried into abduction after having previously been placed in flexion at an angle of 90 degrees. (After Calot.)



FIG. 586.—First maneuver made by two persons: an assistant makes traction on the affected thigh, grasping it with his two hands a little above the knee. The surgeon applies his two thumbs directly over the head of the femur in order to push it into the acetabulum.



FIG. 587.—Second maneuver. The surgeon flexes the thigh to an angle of 90 degrees, and then carries it into forced abduction. In this movement the femur see-saws under the thumbs of the surgeon who presses the head from below upward, the reduction being effected in a variable degree of abduction, according to the character of the individual case.



FIG. 588.—Third maneuver, characterized by adduction and internal rotation added to flexion. The child laid on its sound side, the assistant grasps the thigh at its lower third, carries it in flexion to 90 degrees, then in forced adduction and internal rotation of 90 degrees. The surgeon presses with his thumbs upon the head of the femur, which has become much more accessible in this position of forced adduction. One may have four persons for performing this maneuver, two for pushing the head of the femur and two for traction on the knee. (After Calot.)



FIG. 589.—Third maneuver (continued). The assistant at the knee, making continuous and strong traction toward him, raises himself gradually in order to reach the position of abduction. The surgeon continues to press upon the head of the femur. The second assistant shown here immobilizes the pelvis. (After Calot.)



FIG. 590.—Third maneuver (concluded). One brings the thigh gradually to an abduction of 90 degrees. (After Calot.)



FIG. 591.—Diagnosis of reduction. The maneuvers of reduction terminated, the surgeon brings back slowly the thigh inward at the same time pressing firmly on the knee. In a moment the head of the femur abruptly leaves the cavity, producing a more or less loud clicking sound, and one feels it again making a prominence behind the acetabulum as before the reduction. (After Calot.)

First Maneuvers (Fig. 586).—Flex the knee to 90 degrees and exert direct traction on the flexed knee without abduction, adduction, or rotation.

(*a*) Make the traction with one hand, and with the other press the head outward and inward to assist reduction.

(*b*) Two individuals make the maneuver, one pulling on the knee, the other making direct pressure on the head of the femur.

Second Maneuver (Fig. 587).—Abduction of the *thigh* to 90 degrees (no rotation).

Flex the thigh to 90 degrees; abduct it with one hand; with the other, press from below upward upon the head. Progressively increase the abduction.

Third Maneuver.—*Adduction* and *internal rotation* to 90 degrees (Figs. 588 to 590). The child lies upon the sound side. An assistant flexes the thigh to a right angle, adducts and internally rotates to 90 degrees while



FIG. 592.—Diagnosis of reduction by palpation. The left thumb is over the femoral artery. The surgeon ought to feel the head of the femur rolling under the left thumb when the right hand imparts movements of internal rotation to the thigh. (After Calot.)

making traction on the knee. The operator's two thumbs are simultaneously placed on the head above, pushing it toward the acetabulum. After the head is in place, an assistant makes traction and gradually brings about an abduction of 90 degrees.

Retention of the Reduction.—To insure the head's remaining in its new position, immobilization in a plaster spica extending from the umbilicus to the toes is maintained for five to six months in two positions, each being continuous for two and a half to three months.

(*a*) *First Position, First Plaster* (Fig. 593).—The position is expressed by the formula 70:70:0; which means 70 degrees flexion, 70 degrees abduction, 0 degrees rotation with the leg flexed on the thigh to 90 degrees. The plaster is applied by the ordinary circular method in common use in this country (Fig. 594). The child is kept recumbent for two and a half months.

Lange's Position.—For certain cases that are difficult to hold in position, Lange has advised the following position: Hyperextension and abduction

of the thigh to 45 degrees with the knee extended; foot rotated strongly inward; firm pressure maintained over the trochanter by moulding the plaster inward in this region (Fig. 595).

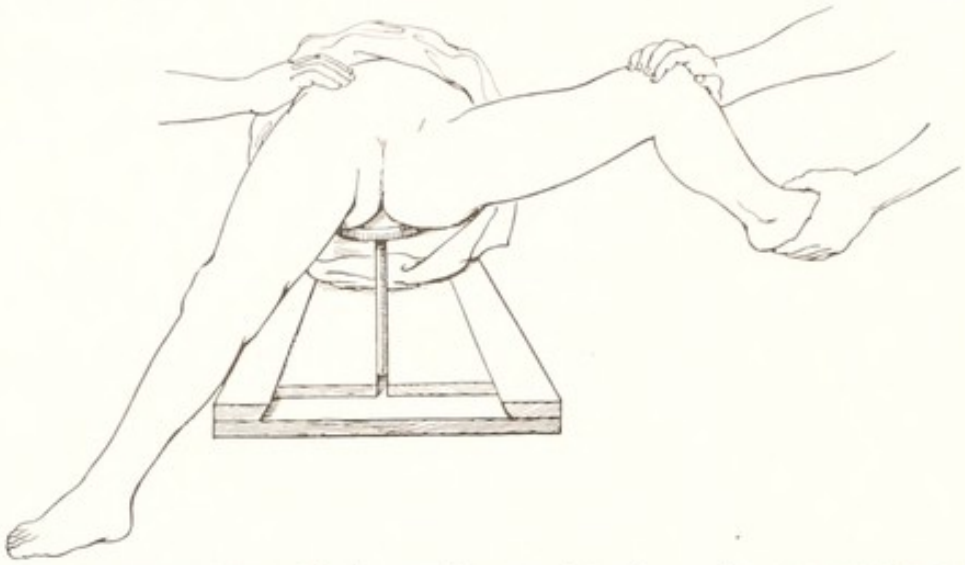


FIG. 593.—Chosen position. Flexion 70 degrees; abduction 70 degrees; rotation 0 degrees. (After Calot.)



FIG. 594.—Application of plaster-of-Paris rolls over the stockinet and cotton wadding.

(*b*) *Second Position, Second Plaster.*—The position is expressed by the formula 15 : 30 : 60, which, being translated, means 15 degrees flexion, 30 degrees abduction, and 60 degrees internal rotation. Reduce the flexion and abduction

of the primary position very gradually until the limb is almost straight upon the operating table. While traction is made on the foot, manipulate the upper thigh until internal rotation exists to such a degree that the patella is directed toward the sound limb. The plaster spica is applied as in the first position and is retained for two and a half months.

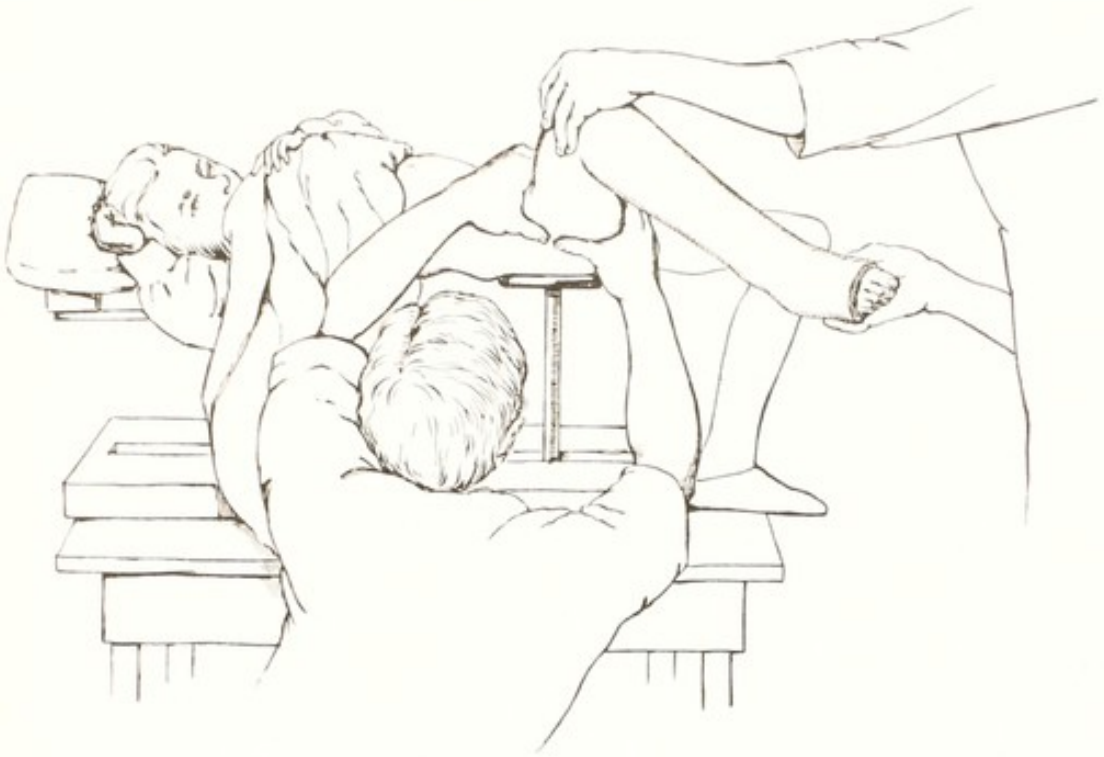


FIG. 595.—Moulding the plaster spica. After the plaster bandage has been completely applied with the limb in the corrected position, an assistant securely holds the limb in this position while the surgeon uses his thumbs to fashion a gutter behind the femoral neck while the plaster is drying. (After Calot.)

Treatment after Final Removal of Plaster.—After removing the last spica, recumbency is enjoined for two to three weeks, with daily friction and massage of the limb. At the end of five weeks, the patient may get upon the feet, walking at first by holding onto a chair or table. At the end of seven

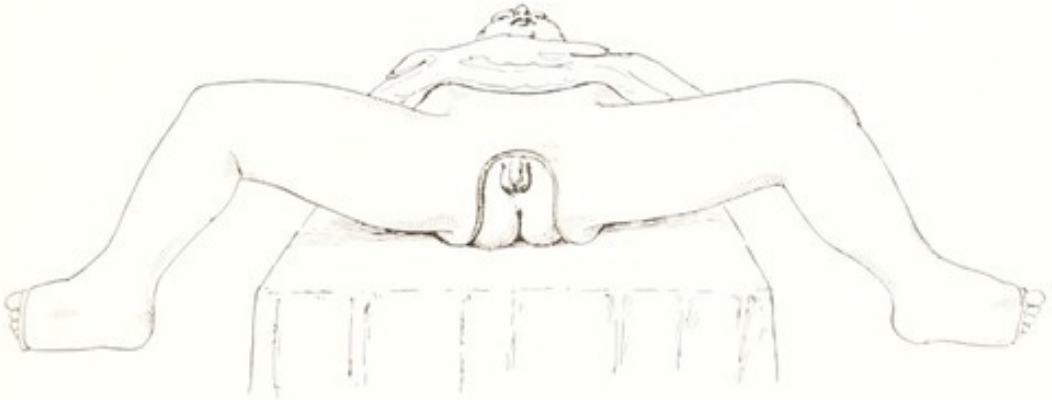


FIG. 596.—Long double plaster-of-Paris spica following reduction of congenital dislocation of hip.

to ten days, in this manner, he is allowed to walk with the assistance of a companion; and three to four weeks later, with the aid of two canes but still

assisted by a companion; after having been two or three months upon his feet, he may be allowed to walk without support of any kind.

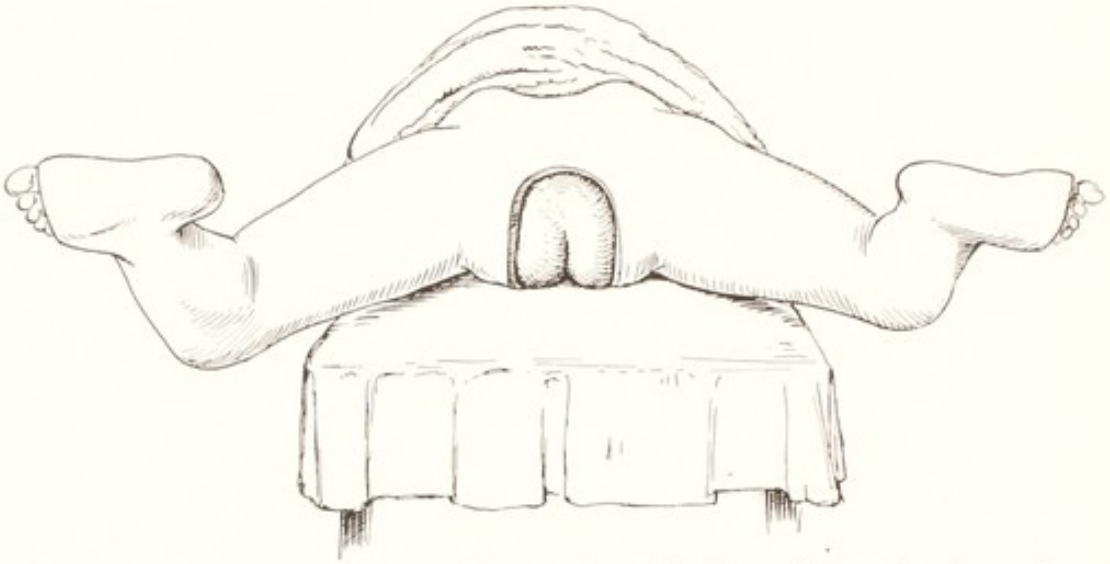


FIG. 597.—Long double plaster-of-Paris spica with hips and knee flexed to 90 degrees. The femora are rotated outward for the purpose of holding more securely certain types of congenital hips after reduction. Knee below plane of table to show the forced abduction.



FIG. 598.—*X*-ray taken through the plaster a few days after the reduction of a double congenital dislocation of the hips. The wisdom of always doing this is demonstrated in this case by the fact that both hips are shown to have slipped. One femoral head is above the acetabulum and the other below. In such cases if it is found that the hips will not stay in place, an open operation and the author's bone-graft construction of an acetabular rim is the operation of choice.

One year after final removal of the plaster spica, the patient should walk normally, without limp, if the reduction is successful and there is no severe bony malformation. Massage should be administered at frequent intervals.

(B) **Bilateral Dislocation.**—The same preliminary stretching and the same maneuvers are applied as outlined above for unilateral dislocation. Both sides should be reduced at one sitting if possible. If the shock of the first reduction shows untoward effects, the patient should be given a rest of seven to ten days before the second hip is treated. Both hips are immobilized as outlined for unilateral dislocation, and the subsequent treatment is the same.

Treatment of Postoperative Complications.—(*a*) *Persistent Abduction.*—Put traction on the sound leg by weight extension while counterpressure in adduction is obtained by a sand-bag against the abducted leg.

(*b*) *Persistent Flexion.*—Keep the patient in a prone position for half an hour three times a day, with a weight on the buttocks and a cushion under



FIG. 599.—Anterior relaxation: for correction one is often obliged to make internal rotation of the knee of more than 90 degrees. (After Calot.)

the patellæ; or in the supine position, with the cushion under the sacrum and weights applied to the knees; or alternate the above positions.

(*c*) *Persistent Internal Rotation.*—(1). If due to *malposition* only, apply a Velpeau bandage from trochanter to toes and pin the bandage to the mattress with the limb in external rotation.

2. If due to *anteversion of the neck of the femur*, it is advisable to correct the deformity by osteotomy, as recommended by Hibbs (ref. "Anteversion of the Neck of the Femur in Connection with Congenital Dislocation of the

Hip." Jour. A. M. A., lxv, 21, p. 1801), who states that many cases of anteversion of the neck of the femur are due to a twist in the shaft of the femur, which he corrects by osteotomy before attempting a reduction of the dislocation.

Osteotomy is performed upon the lower third of the shaft. After dividing the bone, Hibbs twists the lower fragment outward to the degree that the head is abnormally anteverted. After union, the patient is allowed to walk for eight to ten weeks, until external rotation is corrected by exercise and locomotion and the leg takes its normal place in walking, the patella and toes pointing forward. At this point in the treatment Hibbs reduces



FIG. 600.—Semi-axillary position suitable for holding certain congenital dislocated hips after reduction of a reluxation. (After Calot.)

the dislocation. The lower third of the femur is selected because at this point there is least interference with muscular attachment and because both fragments are large enough to permit of perfect control.

When the dislocation and consequent anteversion of the neck is bilateral, double osteotomy is performed at one sitting.

3. *Schede* controls internal rotation by driving a long nail through the great trochanter and neck of the femur, using it as a handle.

4. *Bradford* uses a knitting needle in like manner for the same purpose. Both Schede and Bradford previously osteotomize the femur.

5. *Calot* practises osteotomy just above the adductor tubercle.

6. *Codivilla* drives in a nail, as in the Schede procedure, rotates inward, and applies plaster, which he later cuts down to the lower third of the thigh, performs osteotomy, rectifies the limb, and replaces the plaster.

(*d*) *Reluxation.*—Should the hip undergo reluxation, it may in some instances be replaced by the following procedures:

Re-establish *flexion* by a cushion beneath the knee; secure *internal rotation* by applying a Velpeau bandage and pinning it to the mattress with leg internally rotated, or by a Hibbs' osteotomy followed by reduction. Correct adduction by fixing the limb as far from the middle line as possible by a Velpeau bandage pinned to the mattress in the proper position. Or flexion, abduction, and external rotation may be simultaneously produced by the positions indicated in Fig. 507.

II. DISLOCATIONS IN CHILDREN FIVE TO SIX YEARS OF AGE AND MORE

(A) **Unilateral Dislocation.**—1. *Pre-operative Treatment.*—It is necessary to overcome three obstacles before attempting reduction, viz.: (*a*) elevation of the head of the femur above Nélaton's line; (*b*) the contraction of the capsule; and (*c*) the partial occlusion of the acetabulum by the capsule.

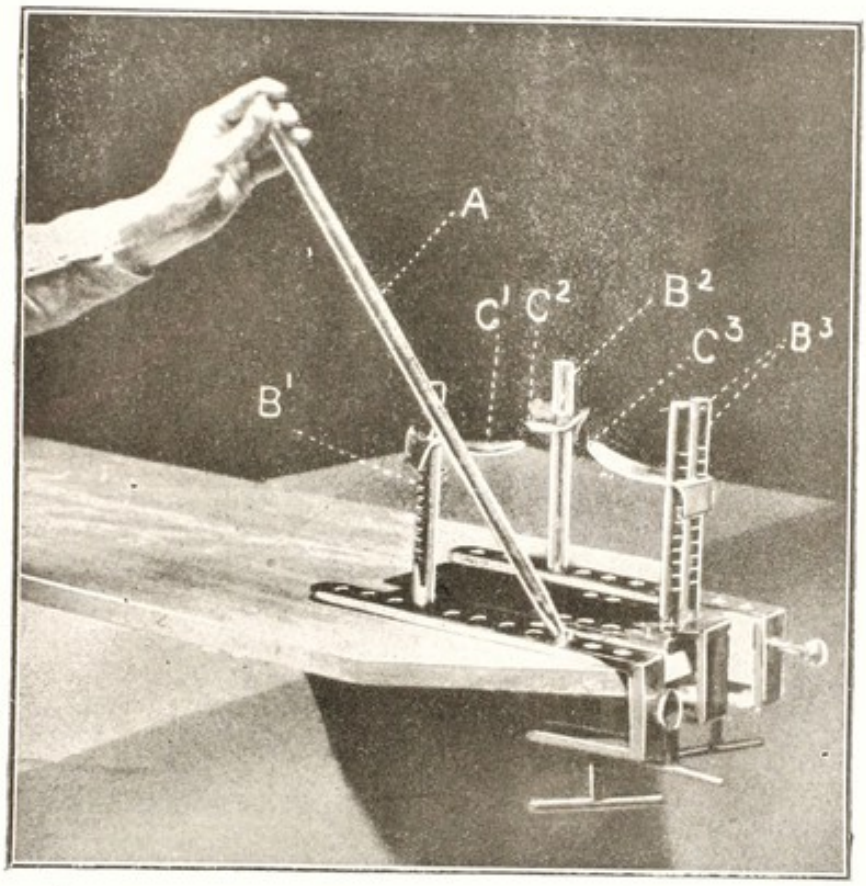


FIG. 601.—Apparatus for reduction of congenital dislocation of the hip, devised by Mr. Ralph W. Bartlett. *A*, Steel lever rod for exerting downward and inward force on the head and neck or to lift them over the acetabular ridge; B^3, perineal uprights; B^1, and B^2, steel pegs placed upright above the trochanter and close to the pelvis as the limb is abducted; C^1, C^2 and C^3, steel plates to prevent movement of the ilium and symphysis pubis. (Bradford and Lovett.)

(*b*) and (*c*) may be overcome by the maneuvers described under the treatment of cases two to three years old (page 880).

Elevation of the Trochanter.—Manipulate, stretch and massage the periarticular structures, and bring the thigh in the plane of the pelvis in abduction, and attempt reduction after the methods detailed above. If attempts to put the head in the acetabulum are unsuccessful, put the child to bed and apply continuous heavy extension to the limb by adhesive straps, weights and pulley for ten days to two weeks, when another attempt at reduction is made, with thorough stretching of the shortened structures about the hip.

If again unsuccessful, repeat the extension for ten days to two weeks. If after three such attempts at reduction the femoral head fails to enter the acetabulum, then an open operation is indicated.

Forced Extension; Bradford's Apparatus (Fig. 601). —Before finally abandoning bloodless reduction, attempts to overcome muscular, capsular, and postural obstacles may be made with Bradford's stretching machine (ref.: "Orthopedic Surgery," Bradford and Lovett, 1915, p. 336).

Traction is furnished by means of a movable traction rod playing upon a socket placed near the hip-joint and a screw force pulling upon a leather anklet bound on the patient's ankle. A counterforce is furnished by uprights pressing on the perineum to prevent the riding upward of the trochanter. As the limb is abducted, steel pegs are placed upright above the trochanter and close to the pelvis, inserted in a steel plate on which the patient lies. On these and on the perineal uprights, steel plates are placed, preventing movement of the ilium and symphysis pubis. The pelvis is firmly held. A steel lever rod, with its end inserted in a hole in the steel plate held by the surgeon, can be made to press on the trochanter and femoral neck and serve to exert force downward and inward on the head and neck, or to lift it over the acetabular ridge. When the limb is strongly pulled and abducted by this means, the head can often be forced safely through the capsular construction in resistant cases where manual manipulation fails.



FIG. 602.—This incision 3 to 5 inches directly downward from the anterior superior spine has been used extensively as an approach for the open reduction of congenital dislocation of the hip. The author has found the Sprengel approach superior to this and all others for most cases. (After Binnie.)

2. *Maneuvers of Reduction.*—These are essentially the same as for children of two to three years, but require a longer time and the exhibition of greater force. Four assistants are desirable, two to act upon the thigh and knee, and two to use their thumbs on the head of the femur to direct it into the acetabulum.

First, flex the femur to 110 to 130 degrees; abduct beyond 90 degrees; carry the knee below the plane of the table, and up toward the axilla.

The first plaster is applied with the limb in *forced* flexion and abduction, *i.e.*, instead of 70 degrees flexion, 70 degrees abduction, and 0 degrees rotation, apply 90 degrees; 90 degrees; 0 degrees for three weeks; then remove the plaster and apply the second plaster in the position 70 degrees; 70 degrees; 0 degrees. The second plaster is kept on as for children of two to three years of age.

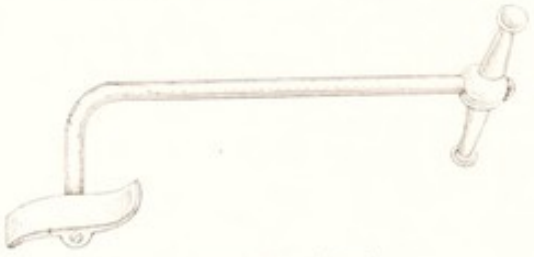


FIG. 603.—Binnie's lever.



FIG. 604.—Binnie's lever used to skid head of femur into the acetabulum in dislocation of the hip.

Hibbs has devised a very ingenious table for the reduction of congenital dislocation of the hip. Fitzsimmons and Sanford's table for the same purpose, also deserves mention as being useful in difficult cases.

Massage, exercises, etc., are even more necessary than in younger children to overcome stiffness after removal of the plaster.

(B) **Bilateral Dislocation.**—Reduce both hips at one sitting, after the manner described above. The results, however, are poor in cases of over seven years.

Treatment of Reluxations.—(A) *Anterior Reluxations* (anterior transposition).—These are the most frequent and are of three recognized degrees, viz.: (1) forward and inward; (2) directly forward; (3) forward and outward.

In all three degrees the femoral head is slightly elevated above the center of the acetabulum.

If of the third degree, reduce the reluxation under anesthesia. If of the first and second degrees, treatment depends upon whether the reluxation is recent or of long standing. If the reluxation is of long standing (six to twelve months or more), and if the lameness is inconsiderable, internal rotation is applied at night, the child being allowed to walk during the day. If, however, the limp is extreme, a fresh reduction with immobilization in plaster is indicated (Fig. 599).

1. *Reluxations of First and Second Degrees.*—Flexion is made to 120 to 130 degrees and abduction to 90 degrees, *i.e.*, the knee is carried as near the axilla as possible. This extreme position can be attained only after relaxation of the joint by massage and a period of traction by weight pulley for six to eight weeks.

After-treatment. First Plaster.—Two and one-half months.

Second plaster: Reduce flexion to 80 to 90 degrees and abduction to about 70 degrees. Maintain the position in plaster two and one-half months.

Third Plaster.—The position corresponds with the second and last positions of the original treatment.

2. *Reluxation of Third Degree.*—The leading deformity is external rotation of the femur.

One assistant immobilizes the pelvis. A second assistant supports the foot with one hand and grasps the midthigh with the other. The operator applies rhythmic internal rotation to the upper third of the thigh until the head can be strongly rotated inward. Then flex to nearly 90 degrees until, with combined flexion and internal rotation, the head enters the acetabulum by its superior margin, aided by strong pressure of two thumbs from before backward on the head of the femur. Next, abduct to 30 degrees, 40 degrees, or 50 degrees. The position is now flexion 60 to 80 degrees, internal rotation more than 100 degrees (equivalent to 180 degrees for the heel, which actually looks forward), and abduction about 45 degrees.

After-treatment of Anterior Reluxations.—*First plaster.*—Two months. Then remove, preserve the internal rotation but diminish the flexion by two-thirds or three-fourths.

Second Plaster.—Two months. Then allow the patient to walk without apparatus, but maintain internal rotation at night.

(B) *Posterior Reluxations.*—Diagnosis is confirmed by röntgenogram and is clinically founded on shortening, adduction, and external rotation, prominence of the great trochanter and its elevation above Nèlaton's line, and by feeling the femoral head in the buttock. The reluxation necessitates treatment because it is incompatible with walking.

Treatment.—The pelvis is fixed by an assistant. Flex the thigh to 90 degrees, then gradually carry it outward, forcing the head from below upward.

Abduction is maintained at 90 degrees, with flexion at 120 degrees, with the knee to the axilla (Fig. 600). The first plaster is worn two and one-half months; the second, two to three months (Fig. 599 without internal rotation).

Posterior reluxations are easier to reduce and to maintain in the corrected position than anterior reluxations.

RESULTS OF MANIPULATIVE METHOD

Statistics vary so tremendously, particularly regarding the results of manipulative treatment of congenital hip dislocations, some surgeons claiming as high as 90 per cent. of "cures," others as low as 10 per cent., that too much credence cannot be given to any single set of figures. Reviewing broadly the statistical tables of a large number of orthopedic surgeons, it is probable that success, functional or anatomical, or both, is obtained by manipulative treatment in less than 60 per cent. of all cases of all varieties.

Although perfect functional result is impossible without perfect anatomical reposition, yet undoubtedly many satisfactory anatomical repositions are accompanied by unsatisfactory functional results. The general tenor of results is affected by several factors, notably selection of cases, age limit, unilateral *versus* bilateral involvement, etc. As regards the age limit, Lorenz places it at the end of the seventh year in bilateral, and at the end of the tenth year in unilateral dislocations; Hoffa, at eight to ten years in unilateral and six to eight years in bilateral cases. In selected cases, however (with plastic condition of the soft parts, relaxed ligaments, slender build of the patient, etc.), the age limit may be increased.

ACCIDENTS AND COMPLICATIONS

1. **Fracture** of the neck or shaft of the femur. This is not an uncommon accident. The neck is the usual site.
2. **Rupture of Nerve Trunks with Paralysis.**—The nerves usually involved are the crural and great sciatic. *Crural* paralysis is temporary, as a rule, and uncommon, and is the result of hyperextension. Paralysis of the great *sciatic* is more serious. It is due to contraction or compression of the nerve between the femoral head and the pelvis, to overflexion, or to hemorrhagic effusion within the nerve trunk. Recovery is the rule, within six to twenty-four months. Peroneal paralysis is the most persistent type and is often permanent. As regards frequency, paralysis is seen in about 3 per cent. of cases.
3. **Rupture of blood-vessels,** with concealed hemorrhage.
4. **Crushing of the femoral head,** with subsequent absorption.
5. **Death,** as a result of manipulation, is very rare.
6. **Hernia** (Narath) due to displacement of the iliopsoas tendon.

(B) OPERATIVE TREATMENT

Arthrotomy.—If the "bloodless" method of reduction has resulted in failure, the joint may be incised for the purpose of exploration and for reposition of the femoral head. Rigid asepsis must be observed in order to minimize the danger of infection and ankylosis of the joint.

The Sprengel approach, which offers the greatest possible exposure of the joint, is exclusively employed by the author for this procedure. (For

technic, see Chapter XXVIII.) The joint is opened by an incision parallel with the neck of the femur, after which digital exploration of the acetabulum is made. If the capsule is at all contracted, it should be thoroughly stretched; this may be performed by inserting and opening a large pair of clamps passed through the rent in the capsule or by using the Goodell cervical dilators. It is advisable, in most cases, to remove the ligamentum teres when it is present.

After replacing the head, the capsule and overlying tissues are each closed with a continuous suture of No. 1 chromicized catgut. The limb is immobilized in a plaster-of-Paris spica, already described for "bloodless" reposition. If anteversion of the femoral neck is marked, the femur should be rotated internally to the necessary degree before immobilization: this is an important preliminary step when osteotomy for the correction of anteversion of the neck is contemplated.

1. **Bone-graft Wedge Remodeling Operation** (Albee).—This open method for retention of the femoral head in congenital dislocations has been applied only in those cases where the acetabulum is shallow and the hip will not stay in place after a reasonable trial by the bloodless method. An open operation for the reduction of hip dislocation must be considered a major operation and should be undertaken under strictest aseptic precautions. The result to be expected is a stable joint with the widest range of motion, without pain, and with the least shortening possible.

In many cases of hip dislocation, the acetabulum is found to be too shallow and with a superior brim insufficient to retain the femoral head. To obviate this defect, Hoffa, in 1890, did his first successful operation, which consisted chiefly in deepening the acetabulum by scooping out the contained fat, synovial membrane, articular cartilage, and bone, to furnish an adequate concavity to receive and hold the head of the femur. By this method, he was enabled to produce a stable joint, but in many instances with little or no motion without pain, and in many others producing a stiff hip with a varying amount of shortening of the leg, depending upon the amount of excavation made in the superior portion of the acetabulum to receive the head of the femur. In certain cases where motion seemed free shortly after the operation, a later examination showed it to be slight, if any at all; and at a still later period there was evidence of a proliferative arthritis.

The author's method, which has been performed successfully in a number of instances, obviates largely the above mentioned disadvantages and produces a stable joint with full and free motion, and without pain or shortening. The most important feature is that it preserves the entire acetabulum, synovial membrane and joint cartilage, thus guarding against any later joint changes.

The important points of advantage which it presents over the Hoffa open operation are:

1. It is an operation of less magnitude, producing less shock and mutilation of the anatomical joint structures.

2. The synovial membrane, hyaline joint cartilage, and ligamentum teres are preserved, the latter being undisturbed if present.

3. There is no disarticulation or extensive traumatization of the head of the femur, a most important factor in avoiding shock and subsequent traumatic degenerative change in the joint.

4. There is no shortening of the limb produced, since no portion of the existing articular structures is removed or scooped out, as in the Hoffa operation.

5. There are restoration of joint stability and reinforcement of the joint structures present, and an actual addition to the joint anatomy by the insertion of bone-grafts, to be described.

6. The author's method minimizes the possibility of limited motion of the remodeled joint or subsequent production of osteo-arthritis to limit motion or to produce painful motion.

Technic of the Operation.—All existing contractures having been overcome by forcible manipulation or open division, and the dislocation made easily reducible by weight and pulley traction or manipulation under ether, the hip-joint is entered by the Smith-Peterson (Sprengel) route, which is far superior to all others and which the author has used exclusively since it was described by Smith-Peterson before the American Orthopedic Association in June, 1917. (For description of technic, see Chapter XXVIII and Figs. 605 and 606). The earlier method used by the author is herewith described

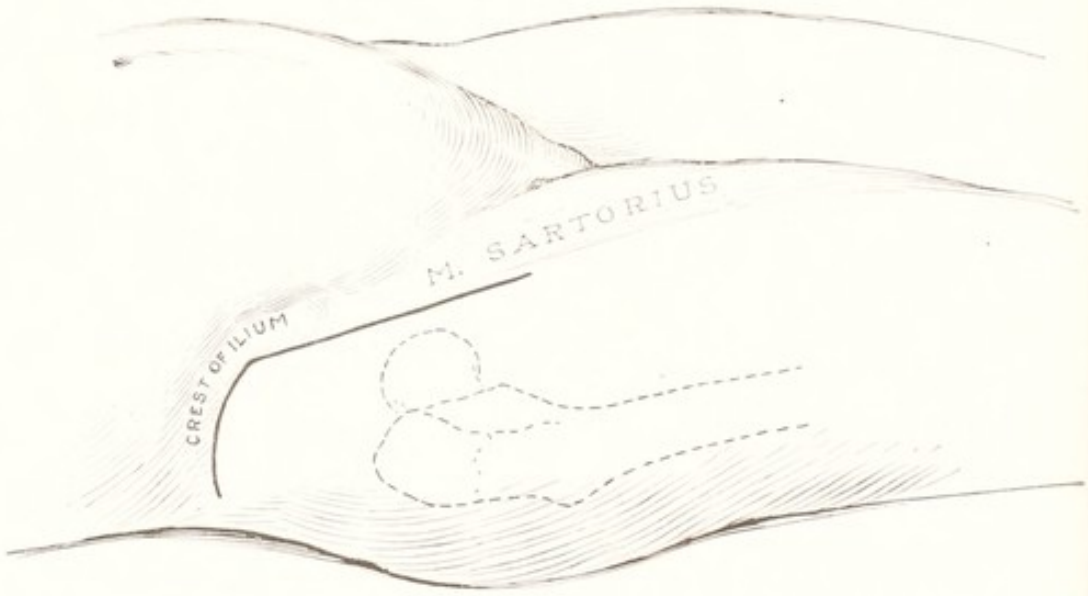


FIG. 605.—Sprengel (Smith-Peterson) incision for approaching the hip-joint. The incision begins at a point about 3 to 5 inches below the anterior superior iliac spine is carried upward following the outer border of the sartorius to the anterior superior spine, thence is curved backward following the crest of the ilium for a distance of about 2 to 4 inches. The gluteal muscles are then readily stripped down with the periosteum of the ilium adherent to them, giving wide exposure to the hip-joint.

for the sake of completeness. An incision is made from the anterior-superior spine of the ilium to the great trochanter, thence backward 1 to 2 inches in the direction of the ischial tuberosity; the skin and subcutaneous structures are dissected back and the trochanter is exposed; the tip of the trochanter is developed with its muscle attachments and sawed off with the motor-saw. The trochanter tip with its attached muscles is turned upward, giving a free exposure of the superior and posterior portions of the capsule of the joint, together with its attached portion on the superior and posterior acetabular rim; this portion of the capsule is seen and felt to be lax if the head is in the acetabulum, and if the head of the femur is disarticulated it distends the capsule by pressure from beneath and further displacement of the head is resisted. Upon manipulation of the femur, the head is readily felt as a rounded hard surface slipping about beneath the capsule.

The amount of deficiency of the acetabular rim can be very easily determined at this stage by direct palpation, and manipulation of the thigh, and

also the amount of laxity of this portion of the capsule. Above the capsular attachment to the acetabular rim, the bone surface is cleared of soft tissue, and with a narrow thin osteotome the bone is incised just above the insertion of the capsule in a semicircular line in this posterior-superior-anterior surface, at the outer border of the insertion of the capsule into the pelvis, to conform to the natural curvature of the superior rim of the acetabulum (Fig. 609). This semicircular bone incision produces a strip of the superior curved bone margin of the acetabulum with its attached and undisturbed capsule segment. This curved acetabular bone segment is pried downward and outward with the osteotome to deepen the acetabulum sufficiently to offer an obstruction to displacement of the femoral head, *i.e.*, this superior curved rim of the acetabulum is made to overhang and more securely grasp the head of the femur when placed in the socket (Fig. 608). The prying downward and outward of this curved superior bony rim segment produces still more laxity

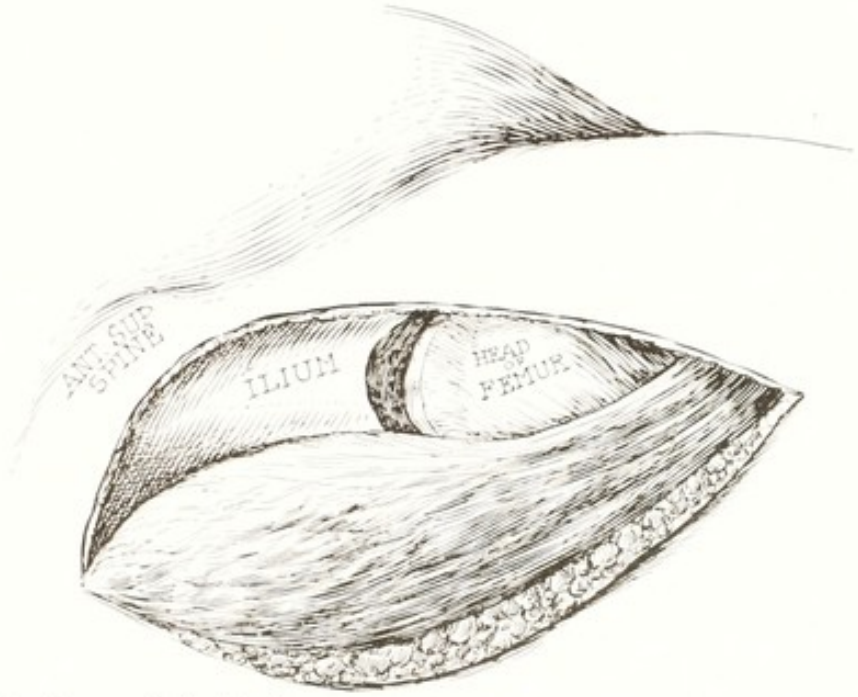


FIG. 606.—Sprengel (Smith-Peterson) incision for approaching hip-joint. To show simplicity of approach: Brim of acetabulum has been separated at outer edge of capsule through a semicircular bone cut, obliquely toward inner part of top of hip-joint. The acetabular rim has been pried outward and downward by osteotome or instrument suitable for that purpose. The semicircular bone cavity is shown ready to receive grafts.

and wrinkling of the attached portion of the capsular ligament. The slack is taken up by reefing this portion of the capsule by a row of mattress sutures of kangaroo tendon placed obliquely to the long axis of the neck of the femur (Figs. 608 and 610). The stitches are so placed as to make the reef of the capsule lie equidistant from the two ends of the capsular bone insertions. This reefing avoids entering the joint, takes up the slack of the capsule, and at the same time holds the new-formed or placed acetabular rim in position.

One may or may not incise the capsule (in a direction corresponding to the neck of the femur) at its superior surface, for the purpose of more accurate orientation and for inspection of the rim of the acetabulum.

To fill in the bone gap produced by the prying downward and outward of this curved bone rim segment, and further to secure the permanent fixation of this new-formed acetabular rim, proceed as follows:

After the rim of the acetabulum has been depressed, one or two small wedge-shaped portions of the upper surface of the gap are removed with a sharp osteotome, and into these are inserted the bevelled ends of short tibial bone-grafts (about ¾ to 1 inch in length). The other ends of these grafts rest on the depressed portion of the acetabular rim, thus producing permanent overhanging of the latter. When such grafts have been inserted, the more the pressure from muscle spasm or weight-bearing exerted on the rim of the acetabulum, the more firmly are the grafts held in place (see diagrams, Figs. 608 and 611). This is the technic which the author follows at the present time in such cases. For the sake of completeness, however, his earlier technic, with the method of securing the wedges with bone-graft pegs, is herewith described.

A segment of bone having a triangular cross-section is removed from the crest of the tibia, long enough, when cut into three or more portions, to fill



FIG. 607.

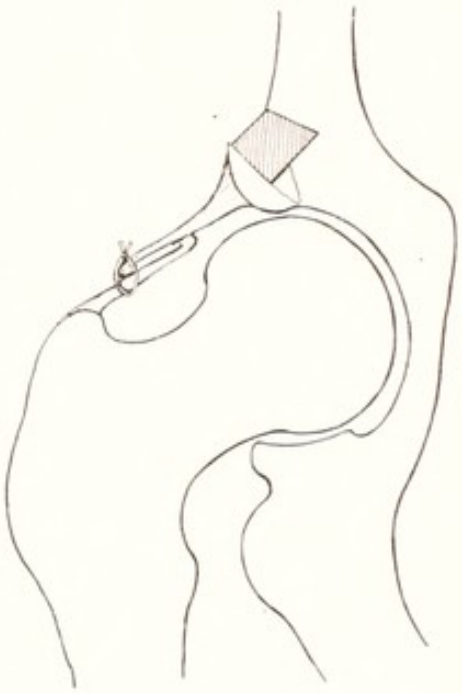


FIG. 608.

FIG. 607.—Diagram to show location of the bone incision for turning outward and downward the rim of the acetabulum.

FIG. 608.—The rim of the acetabulum has been turned down and is held depressed by a wedge-block of bone obtained from the tibia; this wedge-block is so shaped that the upward thrust of the femur holds it more securely in place. The capsule has been reefed to aid in maintaining the hip in the newly formed acetabulum.

in this gutter. Before disengaging this graft from the tibia, six drill holes are made in this bone segment, so placed that when the long graft is cut into three portions there are two holes in each portion.

Bone-pegs, if used, are made from additional strips of bone obtained from the tibia just above where the bone-graft is obtained, and these are turned to fit the previously formed drill holes in the graft segments. This is quickly accomplished by the motor driven surgical lathe. The long wedge graft is removed from the tibia and cut into the three mentioned portions, which are placed in position and wedged to the pelvis. As a rule, the cancellous bone structure of this portion of the pelvis is satisfactorily penetrated by the cortical bone-pegs without further drilling. These pegs should extend through the graft and into the pelvic bone for half to three-quarters of an inch. In

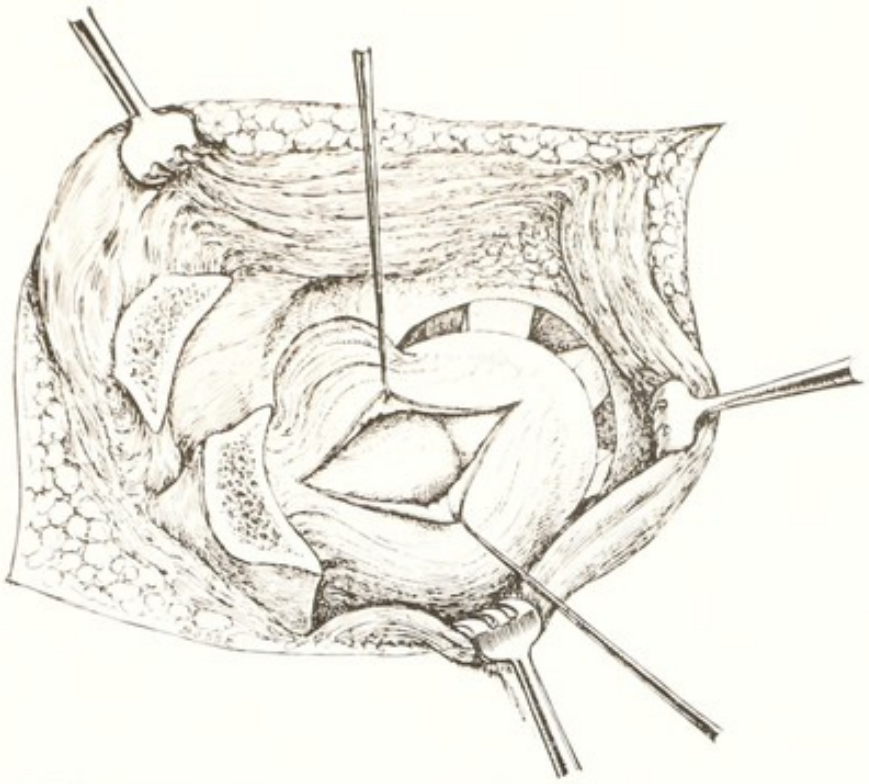


FIG. 609.—This drawing illustrates method of approach to the hip by resecting the tip of the great trochanter which is here shown reflected with the gluteal muscles attached. This approach has been abandoned in most instances in favor of the Smith-Peterson method (Fig. 606). The wedge-blocks are here shown in position depressing the rim of the acetabulum. The capsule may or may not be incised (for the purpose of inspection of the femoral head) preliminary to reefing.

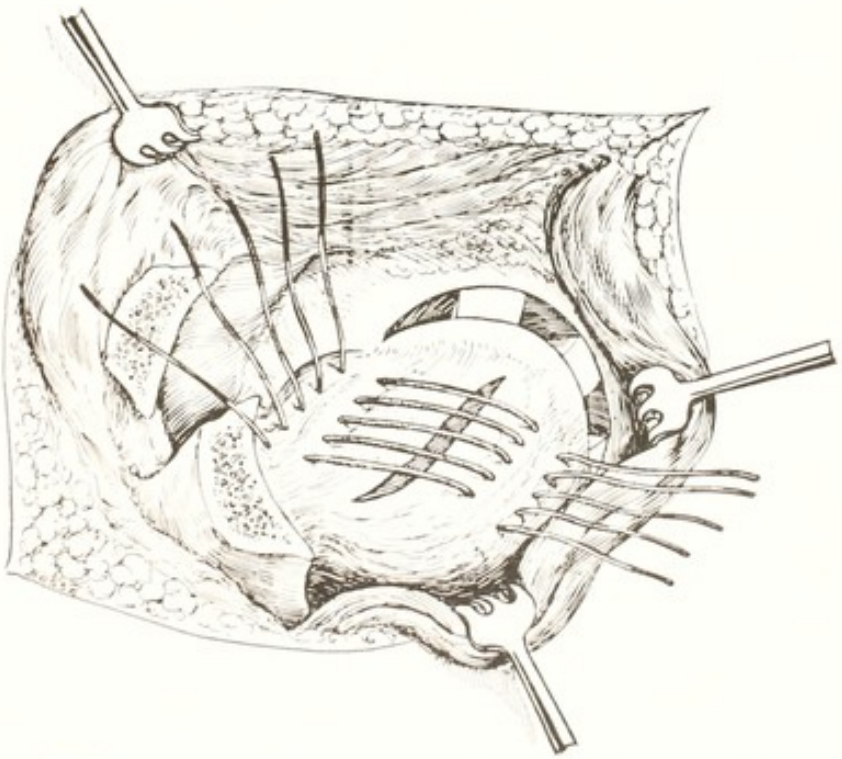


FIG. 610.—Reefing the capsule of the hip-joint. Five or six sutures of small or medium kangaroo-tendon are placed obliquely (crossing the femoral neck at an angle of about 45 degrees) from a point behind near the *posterior* region of the neck and trochanter to a point in front near the *anterior* margin of the acetabulum, so that when these sutures are tied they will tend to pull the head forward and inward and so prevent posterior redislocation.

certain cases it has been found that these bone-pegs to hold the graft in position are unnecessary and that sufficient fixation is produced by drawing the soft tissues over the graft with kangaroo-tendon sutures.

When the Smith-Peterson incision has been used, the gluteal muscles are drawn up and held in position by a continuous suture of No. 1 chromicized catgut placed in the attached overlying fascia and rim of the ilium. The skin is closed with a continuous suture of No. 0 plain catgut. The muscles are brought back in position against the side of the pelvis in a very satisfactory manner by this method of suturing, while the overlying plaster cast (when properly applied) aids in approximating the muscles to the underlying bony structure of the ilium.

If the earlier technic has been employed, the tip of the trochanter with its attached muscle insertions is returned to its normal position and sutured with kangaroo tendon through the peri-osseous structures. The skin is closed with continuous sutures of No. 0 plain catgut, without drainage. After the skin has been sutured, mole-skin stickers are placed on the thigh and upper

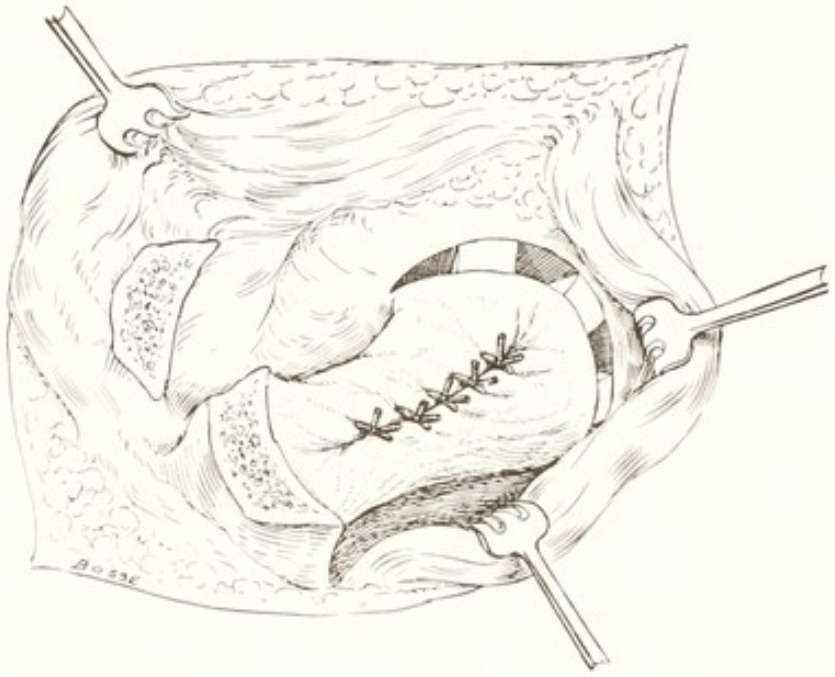


FIG. 611.—Reefing of capsule of hip-joint completed.

portion of the leg and the lower ends are brought out through the sides of the plaster dressing, just above the ankle-joint; by this means, traction of 6 to 15 pounds weight is applied, in accordance with the age of the patient, and is continued for four weeks. It is important that the patient be kept under *full surgical anesthesia* until he has been placed in bed and traction weights have been applied. The limb is placed in an abducted position and fixed by a long plaster-of-Paris spica reaching from the thorax to the toes, which remains on for eight weeks. The cast is then removed and passive and active exercises are instituted, together with massage and guarded functional use of the limb.

2. **Operative Treatment of Dislocations Impossible of Reduction** (Hoffa, Lorenz).—If, on account of the patient's age and the marked amount of shortening of the limb, with the femoral head far above the acetabulum, it is found to be impossible to effect its reposition, a new socket may be made according to the method of Hoffa. (For reasons already given, this operation is not recommended, and therefore will not be described.)

A procedure having many advantages over Hoffa's method is the following: A large area of the outer table of the ilium is turned down and fixed there by brace-grafts, precisely as described for pathological dislocation of the hip (see Chapter XIV).

REFERENCES

Fröhlich and Kirmisson: Rev. d'orth, January, p. 21, 1906.
Vögel, Karl: Zeitschr. f. orth. chir., p. 143, 1905.
Bade: Wiener. Klin. Rundschau, Nos. 45 to 48, 1900.
Tubby: Clin. Soc. Trans., vol. xxxii, p. 268.
Thompson, Ralph: Lancet, Sept. 11, 1909.
Paci: "Studio ed observazione sulla lussatione congenita della anca e sua cura razionale," 1888.
Fournier: "L'Hérédo-syphilis tardive." Paris, p. 105, 1907.

ANATOMY

Wöllenberg, G. A.: Zeitschr. f. orth. chir., xv, p 1.
Graewitz: Virchow's Archiv, Bd. lxxiv, Heft 1, 1878.
Holtzmann: Virchow's Archiv, Bd. lxxiv, S.,272, 1878.
Delanglage: Revue mens des mal. de l'enfance, May, 1897.
Froning: "Case of Congenital Dislocation of the Hip in an Eight Months' Fœtus." Inaug. Diss., Kiel, 1899.
Lockwood: Path. Soc. Trans., vol. xxxviii.
Sainton, R.: Thèse de Paris, 1803.
Kirmisson: Rev. d'orth., July, 1905.
Potocki: Rev. d'ortn., July, 1905.
Lépage and Grosse: Ibid., p. 257, 1901.
Canbet: Arch. med. de Toulouse, Mar. 15, 1907.
Heusner: Zeitschr. f. orth. Chir., Bd. x, Heft 4, 1902.
Jackson-Clarke: Brit. Med. Jour., Sept. 30, 1905, and vol. 1, p. 1028, 1899.
Jackson-Clarke: "Congenital Dislocation of the Hip-joint." Baillière, Tindal & Cox, London, pp. 7–10, 1910.
Canbet, H.: Rev. d'orth., Sept. 1, 1906.
Hoffa and Bade: Zeitschr. f. orth. Chir., p. 143, 1905.
Calôt: "Congenital Dislocation of the Hip."
Blencke: Münch. med. Wochenschr., xxxiv, 1906.
Tubby: Proc. Roy. Soc. Med., March, 1908.
Lorenz: "Pathology and Treatment of Conge nital Dislocation of the Hip." Wien, 1895.
Drehmann: "Beitr. z. Lehre der Coxa Valga" Zeitschr. f. orth. chir., Bd. xvi; Hefte 1 und 2; und Bd. xvii.

ETIOLOGY

Narath: Zeitschr. f. orth. Chir., p. 133, 1905.
von Ammon: "Die angeborenen chirurgischen Krankheiten der Menschen." Berlin, 1842.
Lockwood: Trans. Path. Soc., vol. xxxviii, p. 303, 1886.
Petersen: Arch. f. Anat. u. Physiol., 1893.
Freidländer: Zeitschr. f. orth. Chir., Bd. ix, p. 515.
Vögel, Karl: Ibid., Bd. xiv, p. 154.
Grawitz: Virchow's Arch., Bd. lxxiv, 1, 1878.
Lorenz and Reiner, Mox: Joachimstal's Handb., Lief. v, p. 125.
Ewald: Deutsche Zeitschr. f. Chir., Bd. lxxx, Hefte 3, 4.
Wöllenberg: Zeitschr. f. orth. Chir., xv, 1, pp. 118–150.
Jackson-Clarke: Trans. Brit. Orth. Soc., vol. 1.
Tridon: Rev. d'orth., November, 1905.
Ardonin, P.: Rev. d'orth., pp. 193–198, March, 1907.
Henssner: Zeitschr. f. orth. Chir., Bd. x, Heft 4, 1902.
Hoeftmann: Zeitschr. f. orth. Chir., p. 303, 1906.
Brodhurst, d'Outrepont and Phelps: Trans. Amer. Orth. Ass'n, 1891.

DIAGNOSIS

Preisel, G.: Zeitschr. f. orth. Chir., pp. 265–275, 1907.
Gangele, Karl: Zeitschr. f. orth. Chir., pp. 332–361, 1906.

Jackson-Clarke: Lancet, January, 1903.
Fröhlich: Rev. d'orth., January, 1906.
Drehmann: Fünfte deut. Kongress f. orth. Chir., 1906.
Broca: "Luxation brusque an début d'une coxalgia." Rev. d'orth., September, 1906.
Kirmisson: "Sudden Luxations in the Course of Coxalgia." January, 1899; Bull. de l'acad. de Med., Mar. 13, 1900.
Jonon: Rev. d'orth., January, 1901 and Thèse de doct. de Paris, 1901.
Drehmann: Zeitschr. f. orth. chir., xiv, p. 712 et seq.

PROGNOSIS

Fröhlich: Rev. d'orth., January, 1907; also pp. 404–406, July, 1907.
Nové-Josserand and Kirmisson: Ibid., pp. 404–406, July, 1907.
Ridlon: Trans. Amer. Orth. Ass'n, vol. xv, pp. 294,–295.

TREATMENT

Lorenz: "Pathology and Treatment of Congenital Dislocation of the Hip, Based on a Hundred Operative Cases." Vienna, 1895.
Margary: Arch. di art., p. 381, 1884.
Ogston: B. M. j., vol. ii, p. 1116, 1885, and vol. i, p. 500, 1886.
König: Centralbl. f. Chir., S. 146, 1891.
Lannelongue: Bull. de la Soc. de chir., p. 770, 1891.
Kirmisson: Rev. d'orth., p. 265, May, 1906.
Witzel: Centralbl. f. Chir., No. 40, 1901.
Lorenz: Centralbl. f. Chir., No. 31, 1892.
Sherman, H. M.: Amer. J. Orth. Surg., January, 1905.
Jackson-Clarke: Congenital Dislocation of the Hip-Joint." London, pp. 69 et seq., 1910.
Bradford, E. H.: Amer. Jour. Orth. Surg., vol. vii, p. 57 et seq.
Jackson-Clarke: Lancet, Mar. 9, 1907.
Lorenz: Amer. Jour. Orth. Surg., p. 227, January, 1905.
Bradford and Lovett: Ibid, p. 507.
Werndorff: Zeitschr. f. orth. Chir., Bd. xiii, Heft 4.
Nové-Josserand: Rev. mens. des mal de l'enfance, 1900; Bull. de la Soe. de chir. de Lyons, p. 247, 1901.
Véan and Cathala: Arch. de méd. des enfants, No. 1, 1902.
Oschner: Ann. of Surg. vol. xxxvi, No. 2.
Wilson and Pugh: Amer. Jour. of Orth. Surg., pp. 247, 265, February, 1904.
Müller: Zeitschr. f. orth. Chir., Bd. xi, Heft. 2, 1903.
Allison: Am. Jour. Orth. Surg., October, 1905.
Calôt: "Traitement de la luxation congenitale," p. 227.
Kirmisson: Rev. d'orth., July 1, 1906.
Lorenz: "Joachimstal's Handbuch," p. 222.
Hoffa: Amer. Jour. Orth. Surg., January, 1905.
Fröhlich: Rev. d'orth., No. 4, 1905.
Jackson-Clarke: B. M. J., vol. ii, p. 1589, 1905.
Burghard: B. M. J., Aug. 29, 1903.
Stern: N. Y. Med. Record, Sept. 15, 1906.
Wilson, H. Augustus: Therapeutic Gazette, November, 1910.
Blencke: Zeitschr. f. orth. Chir., vol. xv, p. 317.
Deutschlander: Zeitschr. f. Chir., Bd. lxxiii, 1004.
Davis, G. G.: Am. Jour. Orth. Surg., p. 267, February, 1904.
Jones, Robert: Brit. Med. Jour., Aug. 29, 1903.
Gocht: Zeitschr. f. orth. Chir., xiv, pp. 644–661.
Steele, A. J.: Am. Jour. Orth. Surg. p. 347, April, 1905.
Reiner, Max: Centralbl. f. Chir., No. ii, 1904.
Weischer: Centralbl. f. Chir., 1904, No. 15.
Kirmisson: Rev. d'orth., p. 468, September, 1906.
Makins: Brit. Med. Jour., vol. ii, p. 365, 1895.

CHAPTER XXV

OTHER CONGENITAL AND ACQUIRED DEFORMITIES

CONGENITAL DEFORMITIES OF THE ARMS AND HANDS

1. **Congenital Absence of the Radius.**—This anomaly is rare. It is more often unilateral than bilateral, and generally right-sided. There is usually complete absence of the bone. The forearm is shortened and atrophied, and



FIG. 612.—Complete congenital absence of the radius. Contraction of either the extensors or flexors of the forearm caused even more marked adduction of the hand on the forearm than shown in this photograph, on account of lack of skeletal support of the radius.

The author has met this condition in two ways, either by restoring the complete radius (see Fig. 616) or, preferably, by mortising a graft into the radial side of ulna (at the junction of its middle and lower third) and the scaphoid bone. The latter graft functionates better and benefits by the distal growth of the epiphyseal cartilage of the upper end of ulna. (See Figs. 613 and 615.)

the ulna usually has a concavity toward the radial side. The hand is in radiopalmar deviation and is small and atrophied. One or more metacarpal bones are often absent, with or without absence of the corresponding pha-

langes. The thumb is rudimentary or absent and without a metacarpal bone. Other congenital anomalies frequently co-exist. Individuals afflicted with this congenital deformity usually exhibit low resistance and die young or are stillborn.

Treatment.—The only treatment of any avail is restoration of the defect by bone-graft, the material for which is obtained preferably from the patient's

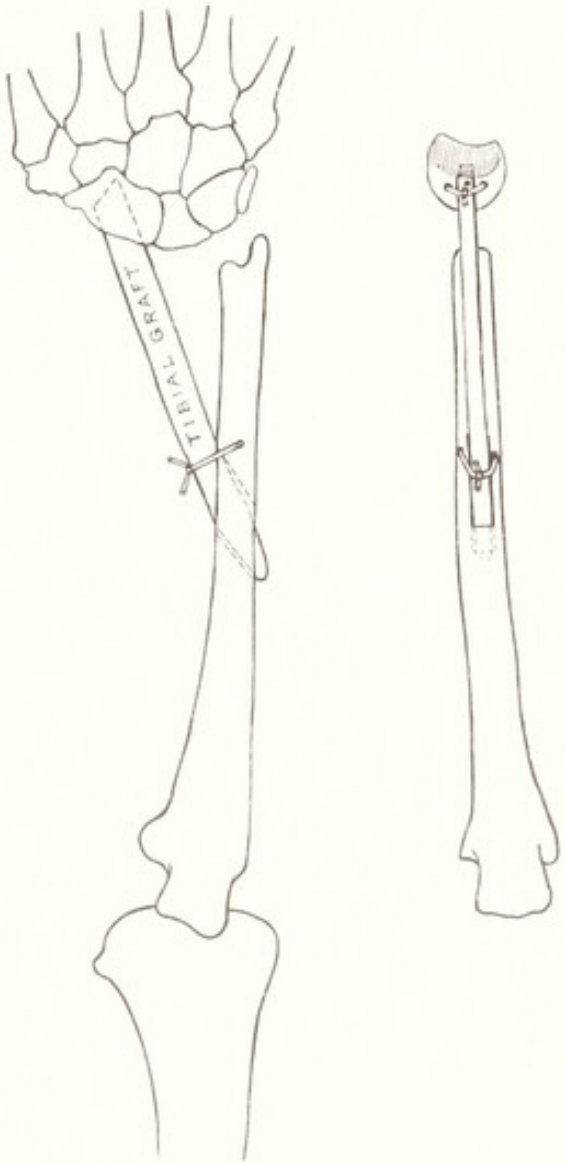


FIG. 613.



FIG. 614.

FIG. 613.—Drawing illustrating author's technic for congenital absence of the radius. The tibial graft is mortised into the ulna and scaphoid bones.

FIG. 614.—Complete congenital absence of the radius. A tibial bone-graft was mortised into ulna and scaphoid bones two weeks before. The shadow to the left and parallel to the ulna is another tibial graft placed about six months before and was unsatisfactory because it did not afford sufficient mechanical support.

tibia. The two ends of the graft should be fashioned either into a wedge or peg-shape, and inserted in properly prepared orifices in the carpus below and the shaft of the ulna above (see Figs. 612 to 616).

2. **Congenital Absence of Ulna.**—This condition is much more rare than the preceding one. The hand is deviated to the ulnar side but is more useful than in the case of absent radius. As a rule, the third, fourth, and fifth fingers are suppressed.

3. **Club-hand.**—When the axes of the forearm and hand do not coincide, the condition is known as club-hand, which is therefore the analogue of club-foot. The affection may be congenital or acquired. Congenital club-hand: These cases may exist without defect in the bone (either analogous to congenital club-foot, or contractural, or congenital dislocation of the wrist, all are exceedingly rare), or, more commonly, the congenital cases are associated with partial or complete defects of one of the forearm bones. Acquired club-hand is caused by (*a*) paralytic and neuromuscular lesions; (*b*) distortion of the hand from destructive disease of the wrist-joint or carpus (tuberculosis, etc.); (*c*) acquired curvature of the bones of the forearm (rickets, etc.); (*d*) Madelung's deformity.

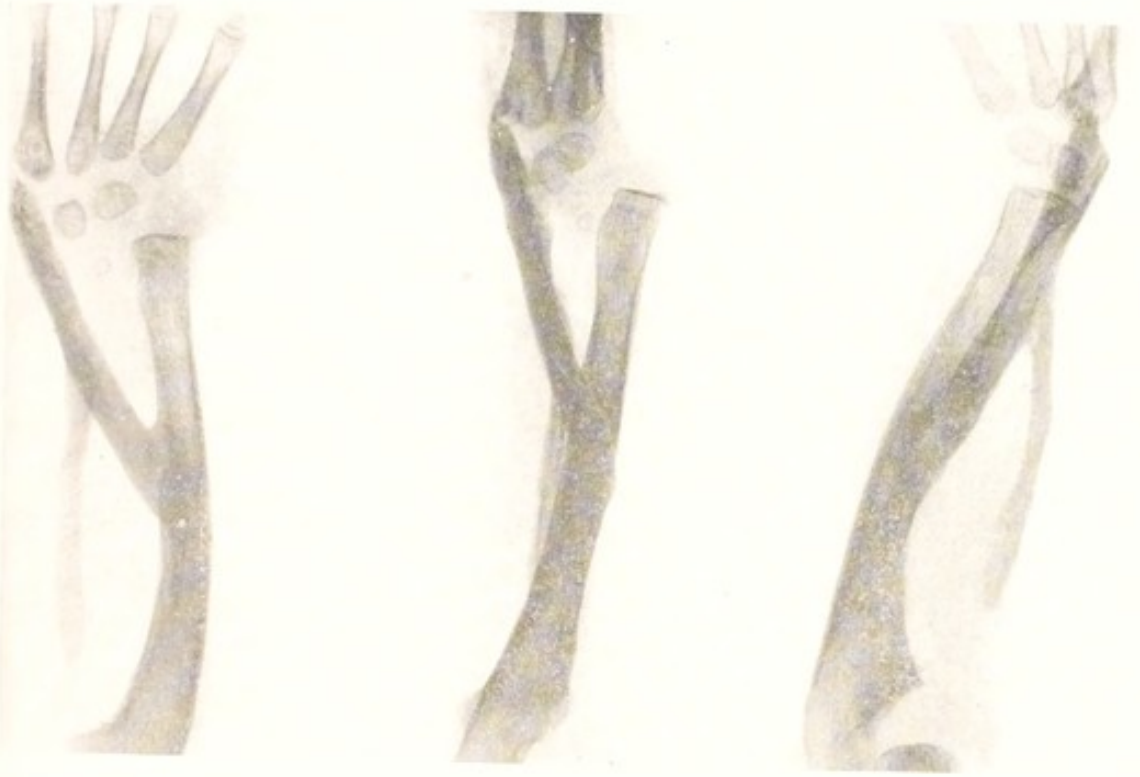


FIG. 615.—Same as Fig. 614, six months after the implantation of the second tibial graft. The grafts have become firmly united and the increase in strength and dimensions of the second (mortised) graft is very striking. The mechanical support of the wrist is excellent.

Abnormalities usually co-exist elsewhere in the body, so that club-hand is but one of multiple distortions. Commonly associated anomalies are: pes varus, polydactylism, various congenital dislocations, atresia ani, malformations of the genitalia, etc. The etiology is not clear. Treatment consists of various plastic procedures of varying degrees of efficiency.

4. **Congenital Contraction of the Fingers.**—The condition is distinct from Dupuytren's contracture of the palmar fascia. The thumb, or one or more of the fingers, is involved. The deviation may be palmar, dorsal, or lateral. If of severe grade, subluxation of the affected joint, usually the proximal interphalangeal, occurs. Contraction is usually limited to the fifth finger, and is often associated with congenital hammer-toe, usually the second toe of both feet. There are no contracted bands or shortening of the skin. The contraction is reducible by gentle manipulation, but relapse occurs at once on release of the pressure; in later life, the finger is more rigidly fixed in deformity.

In the early stages, malleable iron splints are indicated to keep the finger in extension. At a later period, subcutaneous fasciotomy may be performed for each phalanx of the affected finger, with subsequent splinting in the position of extension.



FIG. 616.—Complete absence of the radius restored by a tibial bone-graft the upper end of which was placed against the capsule of the elbow-joint overlying the inferior surface of the condyle of the humerus and the lower end was contacted likewise at wrist. It is usually preferable, however, to mortise the graft into the ulna.

5. **Web Fingers.**—*Synonym.*—Syndactylism The union of adjacent fingers may be (*a*) by skin alone; (*b*) skin and fibrous tissue; (*c*) more or less fusion of the bones. Syndactylism may be associated with other anomalies. The fingers may be united distally and free proximally. The affected fingers are usually those on the inner side of the hand. Syndactylism is probably the result of arrested development, since the fingers are bound together for a time during fetal life by webs of greater or less density and extent. The condition is markedly hereditary.

Treatment.—If the osseous fusion affects only the terminal phalanges, it is easy to split it with bone forceps, followed by a plastic operation on the soft parts. If fusion affects the soft tissues alone, a plastic operation may be performed with the flaps so arranged that on closure, the raw surfaces are not in apposition (Figs. 618 and 619). Many methods are employed for this purpose. The limits of the book will not permit a detailed discussion of the various technics, for which the reader is referred to works on general surgery.

6. **Supernumerary Fingers.**—*Polydactylism* (Fig. 617).—Supernumerary fingers in as great a number as eight, are occasionally seen. Other abnormalities (syndactylism or rudimentary fingers) sometimes co-exist. The condition is often hereditary and frequently affects the toes as well as the fingers. The supernumerary digits are usually marginal, less commonly central, and are usually underdeveloped and lack the corresponding metacarpal bone. The commonest type is the supernumerary little finger, and next in order the supernumerary thumb.

Treatment.—Prior to operation an *x*-ray examination is essential, to be certain which is the supernumerary digit. Disarticulation, with removal is the operation of choice.

7. **Suppression of Fingers.**—Although of little practical importance, the fact must be mentioned that the fingers may be deficient in number or length, or both. These defects may be marginal, central, or terminal. Marginal: The thumb or little finger, frequently associated with absence of radius or ulna. Central: If well marked, and with absence of the corresponding metacarpal bone, it constitutes the well-known condition "claw-hand," "lobster-claw hand," or "cleft-hand." Terminal: Abnormal shortness of one or more fingers is due to one of several factors (*a*) reduction

in the length of one or more phalanges; without diminution in number (brachydactylia); (*b*) suppression of a phalanx; (*c*) intra-uterine amputation

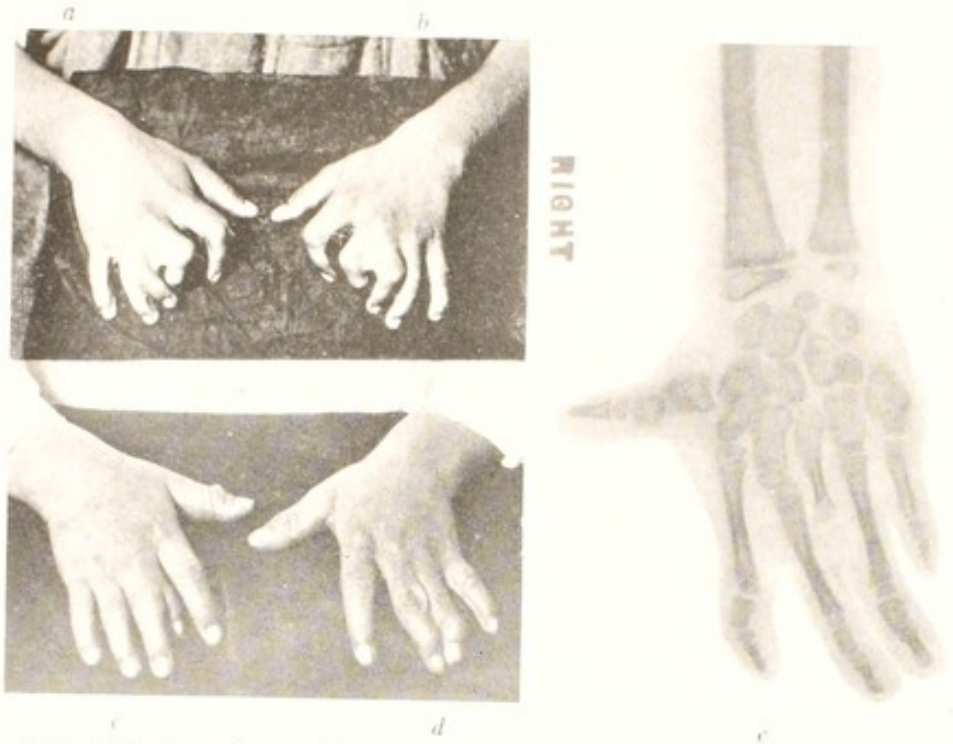


FIG. 617.—Polydactylism and syndactylism. *a* and *b* Right and left hands of same patient. *a*, Exhibits syndactylism of the second and third digits and a supernumerary finger between them; *b* exhibits syndactylism of the second and third digits. *c* and *d* right and left hands of another patient; *c* shows supernumerary digit between the first and second fingers; *d* shows syndactylism of the second and third fingers, while the *x*-ray (*e*) of this same hand shows a rudimentary phalanx or metacarpal between the second and third fingers, representing suppressed polydactylism.



FIG. 618.

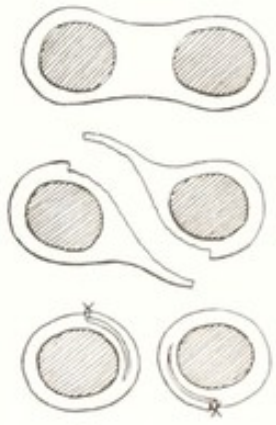


FIG. 619.

FIG. 618.—Didot's operation for webbed fingers (syndactylism). Diagrams of the incisions and flaps. The dotted lines indicate the limits of the flaps on the adjacent fingers. (After Tubby.)

FIG. 619.—Didot's operation for webbed fingers (syndactylism). Cross-section of the fingers before, during, and after the flaps have been adjusted. (After Tubby.)

(amniotic adhesion), with which are commonly associated furrows and constrictions of the forearm. Occasionally a rudimentary finger is present on a truncated, deformed and shortened limb.

8. **Hypertrophy of the Fingers.**—The condition may exist in several forms, viz.: (*a*) hypertrophy of all the tissues of the fingers (gigantism); (*b*) lymphatic enlargement of the subcutaneous tissues; (*c*) nevoid metamorphosis of the soft tissues; (*d*) supernumerary phalanges. No treatment is necessary unless the finger is an obstruction to the use of the hand, when it is better to amputate it.

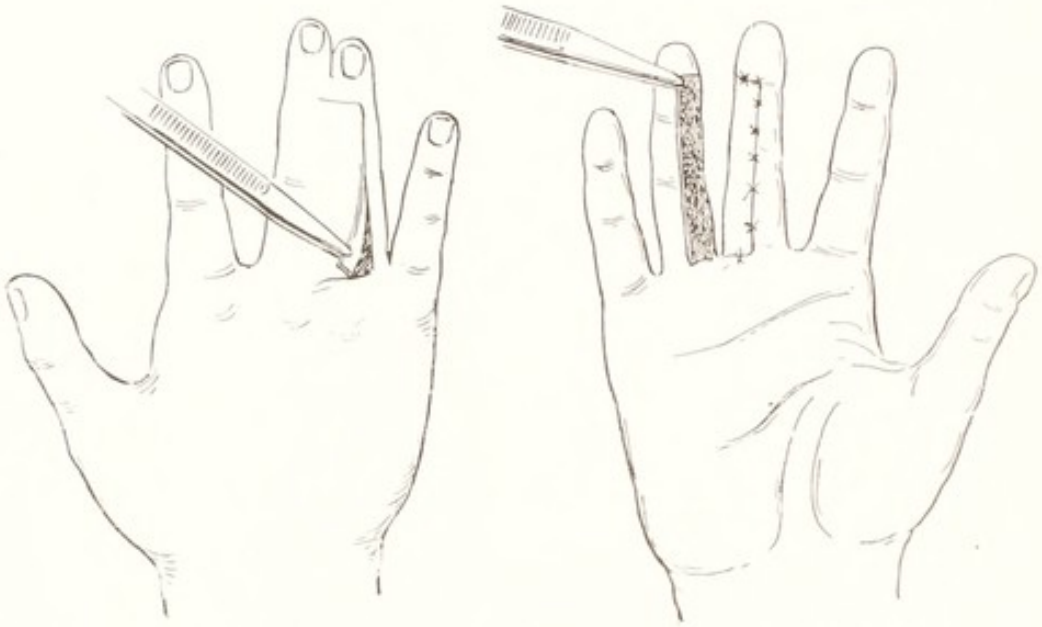


FIG. 620.—Didot's operation for webbed fingers (syndactylism), showing dissection and suture of flap. (After Tubby.)

ACQUIRED DEFORMITIES OF THE ARMS AND HANDS

1. MADELUNG'S DEFORMITY

Synonym.—Madelung's spontaneous subluxation of the wrist. This is a true occupational deformity, consisting of subluxation at the radioulnar joint, and more or less complete luxation of the ulna from the carpus. The condition comes on spontaneously and is not associated with injury or disease. It occurs chiefly in women (particularly washerwomen, as the result of wringing clothes) and pianists. The deformity frequently begins in adolescence, progresses steadily, and in the beginning is associated with much pain in the wrist. It is reducible in the early stages, and if thoroughly treated spontaneous cure may result, but often the condition goes on to permanent deformity, although pain and more or less disability pass away. About two years is required for the deformity to be fully established.

Physical Characteristics.—From the dorsum, with the ulna in profile, the lower ends of the ulna and radius, particularly the former, are unduly prominent. From the palmar aspect, the upper row of the carpus is conspicuous, particularly the pisiform, and the flexor tendons stand out in relief. From the radial side, the deformity is not so marked. From the ulnar side, the distortion is very noticeable, and the wrist looks and is unusually thick. Pressure on the ulna reduces it to the level of the radius, but immediate relapse occurs on releasing the pressure, due to laxity of the lower radio-ulnar articulation.

Treatment.—Massage, exercises, and electricity should be applied to the extensor muscles to strengthen them in overcoming the flexors. Over-

extension of the hand on a splint, with massage of the extensors, may be of benefit.

Osteotomy has been successfully performed for this condition. Others advocate an incision down to the bones of the carpus and the projecting bone, subperiosteal exposure, and removal of sufficient amount of the carpus to allow the projecting ulna to be replaced. After this operation, a plaster-of-Paris followed by a leather splint is worn for three months more or less. During immobilization of the wrist, the fingers should be given free play.

2. Acquired Deformities of the Fingers

(*a*) **Dupuytren's Contracture of the Palmar Fascia.**—*Definition.*—Permanent flexion of one or more fingers from contraction of the palmar fascia and its digital processes.

Etiology.—The condition is much more common in men than in women, and is an affection of adults, being rare in young people. In many instances it is hereditary. Although it is encountered in those who continuously use the palm of the hand during work (carpenters, engravers, gardeners), and in those whose occupations demand constant flexion of the fingers (writers and pianists) it is more frequent where no vocational factor is present, and as a bilateral affection in those who use one hand almost exclusively. Traumatism is sometimes a direct cause; the trauma may be single (a fall on the hand with the fingers outspread) or repeated (pounding on a stake with the palm, constant friction of a cane in the palm, using the pestle and mortar, etc.). Occasionally, nodules can be demonstrated in the affected palmar fascia, and in such cases it is a question whether or not they are cicatrices from minute ruptures of fascial bands.

Fingers Affected.—The ring finger is first affected, then the little finger, and later the middle finger. The thumb or the forefinger is rarely involved. Flexion takes place first at the metacarpophalangeal joint; next at the proximal interphalangeal joint; later, at the second interphalangeal joint. Both hands are often affected but not synchronously nor to an equal degree.

Causation.—That traumatism is not the only cause, is proved by the increased frequency of the affection in advanced age, its bilateral occurrence, the fact that the right-handed cases are not in the marked majority, numerous cases being reported where the occupation and history exclude trauma, and by the marked hereditary tendency of the condition. A history of gout or rheumatism can be frequently but not constantly established.

Dupuytren's contraction occurs also as a trophoneurosis, complicating diseases of the central nervous system, *e.g.*, tabes, multiple sclerosis, syringomyelia, and local spinal lesions. It is also encountered in arteriosclerosis, quite frequently in diabetes, and has been noted in syphilis. In both the latter classes of cases, marked improvement follows treatment of the general condition. Its infectious origin has been suggested, bacteria presumably gaining entrance through microscopic lesions in the skin of the palms, although micro-organisms have never yet been isolated in excised portions of the fascia, as far as we are aware; nevertheless the plausibility of this theory cannot be denied.

Pathology.—Dupuytren's contracture appears to be a fibrosis, due to senility, trophoneurotic changes, or metabolic derangements, and is favored in many instances by traumatism. Its morbid anatomy has been exhaustively studied. The disease is primarily a contraction of the fascia, secondarily, of the skin, the tendons taking no part in the morbid process. The fascia is affected by fibroid hypertrophy, which in some cases is a local

change represented by the formation of small fibromata or nodules, while in other cases there is a general hyperplasia of one or more fascial bands followed by their contraction. Occasionally the fat of the palm is diminished or absent, so that the palmar fascia and subcutaneous tissue are continuous. The deeper layers of the skin may be thickened. Disappearance of the fat is possibly the first stage of the process, and is probably incidental to senility, trauma, and inflammation; and after its disappearance the palmar fascia is subject to more direct pressure against the heads of the metacarpals.

Symptoms.—Early signs are tightness in the palm and inability fully to extend the fingers. Later, there may be nodules in the palm over the heads of the metacarpals. There is frequently more or less neuralgic pain in the hands. The skin, which at first is movable over the indurated fascia, is later adherent, dry, thickened, and umbilicated at the transverse crease. Flexion of the affected fingers takes place first at the metacarpophalangeal joint; second, at the proximal interphalangeal joint, while the terminal phalanx remains in normal extension except in very advanced cases. When the skin becomes adherent to the fascia, tense bands, both visible and palpable, appear and can be traced to the lateral aspect of the fingers. The progress of the case may be slow or rapid.

Prognosis.—Although slow in forming, the contraction is continuous till, in advanced cases, the nail of the flexed finger may wound the palm. Spontaneous arrest is very rare.

Differential Diagnosis.—Dupuytren's contracture may be confused with the following:

(*a*) *Congenital Contracture of the Fingers.*—In this condition, however, the onset occurs in infancy or childhood, is more common in females, affects the fascia of the finger instead of the palm, and the central instead of the lateral portion of the prolongation of the palmar fascia, while the position of the phalanges is different; in congenital contraction, the first is hyperextended, the second flexed, and the third extended; in Dupuytren's contracture, the first and second are flexed, and the third is extended.

(*b*) *Contracture of the Tendons from Hemiplegia or Nerve Lesions of the Forearms.*—There are no fibrous bands in the palms. The presence of nodules and the adherent skin distinguish Dupuytren's contracture from it. The tendons above the wrist move freely on passive extension of the fingers in Dupuytren's contracture. Wasting of the thenar or hypothenar eminences, or both, occurs in these nerve lesions.

(*c*) *Adhesions of the Tendons to Their Sheaths, Producing Flexion of the Fingers.*—The tendons cannot be moved on passive flexion of the fingers, while their sheaths stand out prominently in the palm of the hand in severe cases. Passive extension obliterates the prominence; the opposite occurs in Dupuytren's contracture.

(*d*) *Osteo-arthritis, with Contraction of the Hand.*—Although the whole fascia may be indurated and the fingers flexed into the palm, no cord-like bands or localized thickenings are present.

Treatment.—Attempts to stretch the contracture by gradual mechanical extension are not only futile but painful, and may increase rather than diminish the contracture.

If the case is not suitable for operation, injections of fibrolysin are often followed by more or less softening of the contracted fascia, and increase of extensibility of the fingers. Injections are made once a week, 5 minims at first, increasing the dose to 30 minims, and should be given in the shoulder or back, and not, as a rule, directly into the palmar fascia, as this

causes pain and occasionally sloughing. Fibrolysin may also be employed in recurrent cases and as an adjunct to operative treatment.

Operative Treatment.—Contracted bands may be divided by multiple subcutaneous division of the fascia and its prolongations, keeping the fingers subsequently extended on some form of splint. Relapses are so common, however, that open operation is more satisfactory.

Open Operation: Dissection of the Palmar Fascia.—The greatest care is necessary in securing preliminary asepsis of the hand. After the application of the tourniquet and the usual sterilization procedure, a linear incision is made beginning just below the superficial palmar arch, following the most prominent band of fascia and carried down the affected palmar surface of the finger. This primary incision may be enlarged by a transverse incision at the web of the fingers. The flaps are reflected, exposing the fascia, whose appearance is indurated, dull white, and frequently of cartilaginous consistency. Care should be taken to avoid buttonholing the skin and injuring the digital nerves which issue from beneath the palmar fascia. The affected palmar fascia should be dissected out through its entire extent, including its digital prolongations together with a considerable portion of healthy fascia, to avoid recurrence of the contraction. Complete hemostasis is important, for which purpose hot saline compresses may be applied for a few minutes after the completion of dissection, although the tourniquet is still on. Ligatures should be avoided as much as possible. If it is considered inadvisable to dissect out the digital prolongations, multiple subcutaneous division of these structures can be made on the flexor and lateral aspects. Careful adjustment of the skin edges is made with interrupted sutures of No. 1 plain catgut. A plaster-of-Paris splint is applied as far as the elbow, with the fingers well extended. The tourniquet is not removed until the plaster-of-Paris splint has been completely applied. This is done for the purpose of securing firm, even compression, which can be enhanced by a compression dressing in the palm of the hand, prior to the application of the splint. The plaster-of-Paris dressing is left undisturbed for ten to fourteen days, at the end of which time it is removed and massage begun to maintain full extension of the fingers.

As has been previously stated, collateral treatment by means of fibrolysin is advisable as an adjunct to the dissection operation, although by the latter the vast majority of cases is completely cured. It is inadvisable, however, to perform this radical operation in cardiorenal cases or in diabetics.

(*b*) **Trigger-finger.**—*Synonyms.*—Jerk-, snap-, spring-finger. In this condition, after "making a fist" when the patient attempts to extend the fingers, one remains flexed; yet when passively extended, it "flies open like a knife blade with a snap" (Abbe).

The middle finger is most frequently affected, and often presents a circumscribed swelling in the course of the tendon, the obstruction being located as a rule near the metacarpophalangeal joint. Next in order of involvement are the ring-finger and thumb, the index and little fingers being seldom affected. The right hand more than the left is the seat of the deformity.

Etiology.—Overuse, overstrain, and some form of manual labor to which the patient has not been accustomed are the usual exciting causes, while the rheumatic diathesis is present in a considerable proportion of the cases. Women are more frequently affected than men. The process usually begins in adult life.

Pathology.—Several different pathological conditions may produce the affection, viz.: thickening of the tendon or its sheath, narrowing of the tendon sheath or of its osseofibrous groove, bands of fibrous tissue bridging across and

narrowing the sheath, exostosis of the head of the metacarpal bone, partial division of the tendon, the retracted cut fibers producing a nodule, new growths on the tendon, and ganglia on the flexor tendons or their sheaths. Of these, the commonest causes are: narrowing of the tendon sheath with grooving and constriction of the tendon itself, or thickening of the vascular fringes resulting from tenosynovitis.

Treatment.—In all cases the exact spot where the jerk occurs should be localized. Fixation of the finger on a splint with pressure exerted on the spot where movement is restricted, may be tried. If this affords no relief, the finger should be incised and the tendon exposed at the site of obstruction, which is usually found in the neighborhood of the metacarpophalangeal joint. If the tendon is thickened, enough of its substance should be shaved off to permit smooth gliding; if its groove is narrowed, it should be widened; if a ganglionic or solid nodule is found, it should be excised.

(*c*) **Mallet-finger.**—This is a rare condition which occasionally occurs in athletes. It arises from a blow on the tip of the finger (tending to flex it) while it is in strong extension, resulting in fraying or partial rupture of the tendon at or near its point of insertion into the dorsal surface of the terminal phalanx. The terminal phalanx "drops" (*i.e.*, remains flexed), and cannot be "raised" (*i.e.*, extended), during extension of the other phalanges of the fingers.

Baseball player's finger is the reverse of the above condition, and consists of violent backward dislocation of the terminal phalanx on to the dorsum of the middle phalanx. Reduction is usually impossible, because of the fact that the flexor tendons become wrapped about the head of the second phalanx, the latter slipping through a buttonhole in the capsule.

Symptoms.—A semiflexed position of the terminal phalanx is assumed immediately after injury, and is accompanied by swelling and ecchymosis over the terminal interphalangeal joint, a circumscribed point of tenderness on the dorsal surface of the terminal phalanx, and inability actively to extend the latter, although all the other movements of the phalanges are intact. Unless treated, the terminal phalanx remains fixed in its flexed position.

Treatment.—Hyperextension should be secured and maintained by a splint for three to four weeks. If at the end of that time the power of extension is still absent, the site of the lesion should be exposed by incision and the tendon sutured or attached at a new position under an osteoperiosteal flap raised by means of a small osteotome at the base of the terminal phalanx.

CONGENITAL DEFORMITIES OF THE LEGS AND FEET

1. **Rudimentary or Absent Patella.**—This anomaly is associated with imperfect development of the quadriceps extensor femoris, and is frequently associated with congenital genu recurvatum. If the latter condition is adequately treated, the patella usually develops. The anomaly is of no clinical importance.

2. **Congenital Genu Recurvatum.**—This rare condition is encountered in infants with absent patella, or as a symptom of congenital posterior dislocation of the tibia and fibula, in which case other deformities of the lower extremity usually co-exist.

Treatment.—If no congenital dislocation is present, frequently repeated flexion of the leg may be practised, with retention of the flexed position in the interim of manipulations, using for this purpose a malleable iron splint with straps and buckles, and bending it from time to time to follow the increase of flexion. The manipulations should be supplemented by massage



FIG. 621.—A result after the correction of congenital deformities of both feet and the insertion of bone-grafts obtained from two cadavers. The deformities in this case were very unusual and due to the absence of the internal cuneiform and partial absence of the scaphoid bones. The forefeet were consequently markedly adducted because of the lack of bony support. (For roentgenogram, see FIG. 622.)



FIG. 622.—*AB* is a graft consisting of about one-third of a humerus obtained from the body of an infant strangulated at birth, and used as a prop support to the inner side of the foot. One end is inserted into a notch made in the side of the first metacarpal bone and the other end into a cup-shaped cavity made in the anterior surface of the underdeveloped scaphoid. *CD* is a portion of a femur obtained from the body of another infant strangulated at birth, and inserted by the same technic. Both bone-grafts were immersed in sterile vaselin and left forty-eight hours in a cold storage plant at 4 to 5° C. This case has been under observation three years since the insertion of the graft. The result is excellent.

of the flexor muscles of the leg. Cases resisting this treatment, demand section of the quadriceps tendon with shortening of the hamstring tendons.

If dislocation is present, an attempt should be made to reduce it, supplemented by tenotomy of the contracted quadriceps tendon if necessary, and by shortening of the hamstrings. If the dislocation persists after puberty, arthrodesis of the knee-joint may be indicated if the deformity offers an obstacle to walking.

3. **Congenital Absence of the Tibia or Fibula and Congenital Curvature of the Leg** (Figs. 626 to 633).—These anomalies are rare. Either the tibia or the fibula may be partially or entirely absent, the tibial defect being associated with congenital equinovarus; the fibular, with congenital equinovalgus. The fibula is more often defective than the tibia. Co-existent deformities are frequently encountered, viz.: absence of the patella, genu recurvatum, congenital dislocation and other malformations of the knee, shortening



FIG. 623.—Congenital maldevelopment of the lower extremity especially the femur and tibia in this case.

of the femur, syndactylism, suppression of one or more toes, malformations of the tarsus, etc.

According to Corner, 200 cases of absence of the fibula are on record. If the fibula is partially or entirely defective, the tibia is curved at the junction of its middle and lower third and shortened. The skin is frequently umbilicated at the summit of the convexity, and adherent to the bone.

Without operative treatment, the prognosis in these cases of deficient tibia and fibula is bad. Growth is retarded, and it is impossible to keep the foot and leg in an efficient weight-bearing position with apparatus. The prognosis is worse in the case of the tibia than of the fibula.

Treatment.—Corner states that all operative treatment of congenital absence of the fibula is generally unsatisfactory and "amputation in consequence is only too often necessary."

Wille, in 1909, did an arthrodesis by driving a portion of a fibula (obtained

from an amputated leg) up from the sole of the foot through the os calcis, astragalus, and tibia, and obtained a fair result, but without motion.

Where there is found to be a congenital deficiency, the implantation of bone shaped and adapted to correct the resulting deformity can be resorted to. The following case in the author's practice illustrates the treatment of such a condition:



FIG. 624.—Congenital maldevelopment of bones of leg, especially the femur, the head and neck of which are absent. (Dr. E. W. Jones Case.)

A child was born with the foot and lower third of the right leg absent. A conical stump containing an undeveloped tibia projected backward from the posterior aspect of the thigh. The left fibula was entirely absent, and on this account the foot on this limb had become displaced from weight-bearing and muscle-pull to a pronated position, with its plantar surface facing directly outward and firmly contractured. The lower end of the internal malleolus had become the chief weight-bearing portion of the foot.

The problem which presented itself in this case (a child five years of age) was to correct, if possible, the distorted foot and provide a means of main-

taining the correction, without at the same time interfering seriously with its function by the loss of ankle motion. The most feasible method in these cases is to supply the missing support of the lower end of the fibula. This is best done by restoring the bony anatomy of the part, which can be accomplished in no other way than by resorting to the use of the bone-graft.

In this instance, excellent material for this purpose was easily obtained from the conical stump of the right leg (Figs. 626 and 628). The technic of this procedure was as follows: A curved incision, so placed that its closure would not bring the skin sutures over the contemplated site of the graft, was made over the outer and lower end of the tibia and the outer surface of the os calcis. The position of the foot was corrected after extensive division



FIG. 625.—Congenital absence of the fibula with the characteristic anterior bow-leg and shortening of the tibia.

of fascia, ligaments, and contracted tissue. The outer aspect of the lower end of the tibia was exposed, and the periosteum was split longitudinally from a point about half an inch above the epiphyseal line, extending upward for about $1\frac{1}{2}$ inches. These periosteal flaps were retracted laterally, and, with the twin-saws adjusted about one-fourth to three-eighths of an inch apart, cuts were made in the long axis of this bone from a half inch above the epiphyseal cartilage, upward for about 1 inch. The strip of bone between these saw-cuts was then removed with the help of the small circular motor-saw, and a sharp narrow osteotome. Caliper measurements were taken, and the size and shape of the desired graft planned. The lower end of the tibia near its outer portion was drilled for a kangaroo fixation suture anteroposteriorly, about $\frac{1}{4}$ inch above its epiphyseal cartilage.

The wound was packed with a hot saline compress, and the conical stump of the right leg containing the undeveloped tibia, was removed through an elliptical incision so planned that a satisfactory artificial limb-bearing stump would be produced. This wound in the right leg was closed by a continuous catgut suture, and sterile dressings were applied. The conical stump of the right leg, which had been removed, was then freed of its undeveloped tibial segment, which was moulded with motor tools to simulate the contour of the lower end of the fibula. With the twin motor-saws



FIG. 626.—Congenital absence of the right leg. The conical stump contains an underdeveloped tibia, shown in Fig. 628 *A*, as well as small underdeveloped foot bones. It was necessary in any event to remove this conical projection in order to furnish a suitable stump for an artificial limb.

The fibula is entirely absent from the left leg and the foot and on account of lack of support of the external malleolus the foot is so distorted that the internal malleolus rests on the floor. The deformity of the foot was corrected by lengthening the tendons and severing the soft tissues on the outer side of the ankle, and the underdeveloped tibia of the amputated stump of the right leg served as an ideal graft according to the technic illustrated in Fig. 629. This case was kindly referred by Dr. C. B. Lufburrow, Plainfield, N. J.

adjusted for making the gutter in the tibia, cuts were made into the upper end of this graft for the purpose of fashioning a tongue which could be mortised into the groove already prepared in the tibia (Fig. 629) which prevented the graft from riding up on the tibia. The upper end of this mortised tongue was shaped into an extended hook, for the purpose of inserting it under and internally (medullary side) to the cortex of the upper end of the tibial groove.

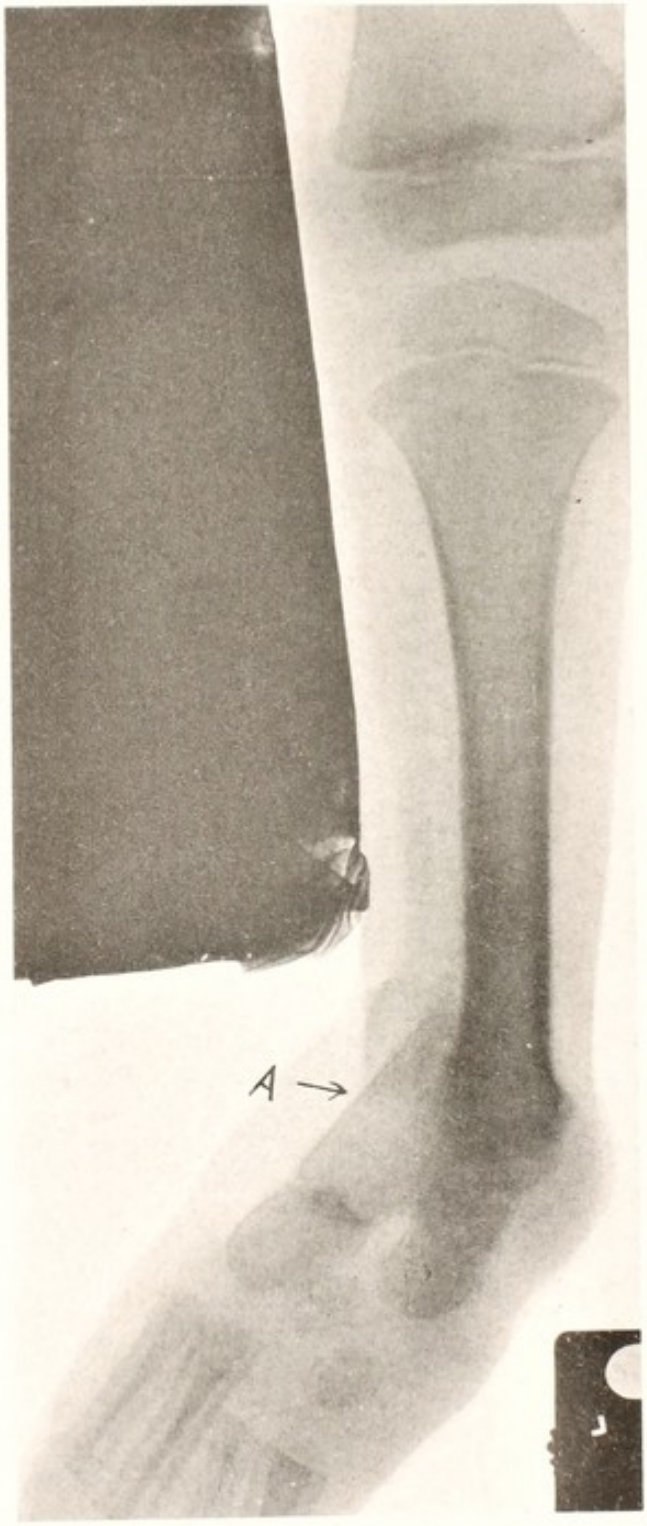


FIG. 627.—Anterior-posterior röntgenogram of same case as Fig. 626. The absence of the fibula and the displacement of the os calcis, A, and astragalus is shown.

When the graft was in position, this mortised joint fitted accurately because both the groove in the tibia and the mortised tongue of the graft were fashioned with the twin saws adjusted at the same distance apart.

The graft was further secured in its position by passing heavy kangaroo tendon through drill holes in the lower end of the tibia and tying the tendon securely about the graft (Fig. 629). The freshened surfaces of the graft, on either side and below the mortised joint, were held in close apposition to the periosteal denuded surface of the lower end of the tibia. An attempt to close the skin over the graft, disclosed the fact that the correction of this extreme deformity had so elongated the outer side of the leg and foot that the contracted skin was not sufficient to cover it, and therefore the skin



FIG. 628.—A roentgenogram of stump of same case as Fig. 626. It shows the underdeveloped tibia which was used as a graft to restore the external malleolus of the child's left leg.

wound could not be closed. To overcome this difficulty, an oval segment of skin (a Wolff graft) about two and a quarter inches long by one and a half inches wide, was dissected from the trimmings of the right leg. This was sufficient to complete the skin closure, and was placed so as not to overlie the bone-graft or bring the skin sutures over the graft. Sterile dressings were applied, and a plaster-of-Paris dressing was put over all.

The convalescence was uninterrupted. All the wounds healed by first intention, and both skin- and bone-graft healed in perfectly. The result after six months was most gratifying, the foot having been corrected and held in excellent position by this improvised malleolus.

Another case of a similar nature, but with only a portion of the lower half of the fibula absent, was corrected by taking a sufficiently long graft

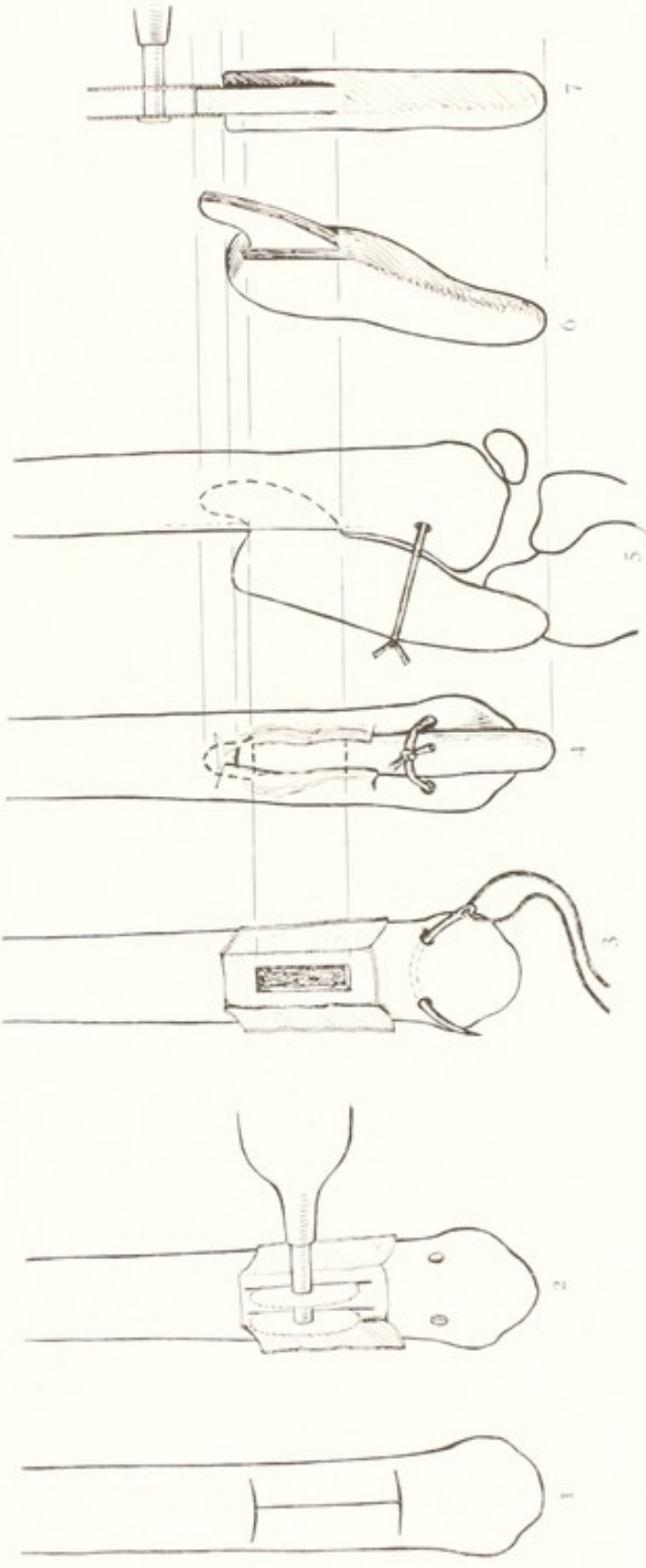


FIG. 629.—Improvising an external malleolus. 1. Periosteal incisions. 2. Formation of gutter to the medullary cavity in the outer aspect of the lower end of the tibia with the motor twin saws, after turning back the periosteal flaps. The drill holes for fixation sutures. 3. The gutter formed and a curved cervix needle threaded with strong kangaroo tendon inserted in the drilled holes. 4. The graft secured in position, lateral view. 5. The graft secured in position, anteroposterior view. 6 and 7. With the motor twin saws adjusted the same distance apart as when forming the gutter in Fig. 2, the hook is accurately shaped on the graft. This hook is important in that it prevents the upward displacement of the graft by muscle-pull and weight-bearing.

from the tibia and beveling one end on both sides into the shape of a wedge, that it might be slipped in between the two halves of the split lower end of the remaining portion of the fibula. The lower end of the graft was made to take the place of the absent external malleolus and prop the foot into a corrected position (Figs. 631 and 632).

4. **Congenital Hammer-toes.**—This condition is associated with congenital contraction of the fingers. The deformity is usually confined to the second, but the third, fourth, and fifth toes may also be congenitally deformed. The shortened structures are primarily the flexor tendons, and at a later date, the lateral ligaments and extensor tendons. The treatment is the same as that of acquired hammer-toe.



FIG. 630.—Photograph of the same case as Fig. 626, four months after operation. Shows correction of the distortion of the left foot, also the well-formed stump of the right leg. The arrow indicates a Wolff's skin graft (about 2 1/4 in. by 1 1/2 in.), which had been obtained from the trimming of the stump of the right leg.

It was found after the correction of the valgus deformity of the foot and the insertion of the bone-graft that there was not enough skin to close in the external side of the leg, and a skin graft was used to fill in the uncovered area. Both skin and bone-grafts healed in by primary union.

5. **Other Congenital Deformities of the Toes.**—Syndactylism, polydactylism (Fig. 634) suppression, hypertrophy, intra-uterine amputations (Fig. 636), etc., affect the toes in a manner similar to the fingers, and require the same treatment.

ACQUIRED DEFORMITIES OF THE LEGS AND FEET

1. **Acquired Displacement of the Patella.**—The displacement may occur upward, outward, or inward. The causes are rickets, infantile paralysis, infantile hemiplegia, cerebral diplegia, and repeated inflammations of the synovial membrane of the knee-joint.

Upward displacement occurs almost always in connection with infantile hemiplegia, in which condition it may rise one or more inches higher than



FIG. 631.—A röntgenogram of the same case as Fig. 627. Shows the correction of the marked valgus deformity and the bone graft, *AB*, united in position four months after its transplantation.

normal. Outward displacement is common in genu valgum, and is partial or complete. If complete, the displacement occurs during flexion, so that the patella lies on the outer side of the external condyle. Inward displacement occurs in advanced genu varum.

Symptoms.—In some cases there are none. In other cases, the disability is considerable. On flexion of the leg (*e.g.*, going down stairs), displacement of the patella may cause a fall, while carrying of weights may be impossible. Falling in these cases is due not only to sudden loss of support of the knee, but also to the fact that displacement of the quadriceps extensor tendon temporarily converts it from an extensor to a flexor of the leg.



a *b*

FIG. 632.—Same case as Figs. 627 and 631 two years after operation and insertion of graft. Function excellent. *b*, Shows graft in place two years after insertion and the maintenance of the correction of the deformity by it.

Treatment.—The first consideration is correction of the genu valgum or varum. If displacement still continues to take place, an osteoplastic operation should be performed, as in the case of congenital or habitual dislocation of the patella (see Chapter XVIII) by lifting the anterior portion of the external or internal condyle, as the case may be, by a bone-graft wedge to block the recurrence of the dislocation. This is far more reliable than any operation tending to correct the deformity by reefing the quadriceps tendon or transplanting the tibial tubercle with the tendon attached and, furthermore, it obviates the necessity of a brace or other apparatus.

2. **Enlargement of the Tibial Tubercle** (Schlatter's Disease).—This condition has already been considered (see Chapter XV).

3. **"Right-angled Contraction of the Tendo Achillis."**—Under this title, Tubby (Reports of Soc. for Study of Diseases in Children, vol. vii, 1907)



FIG. 633.—Congenital absence of the fibula.

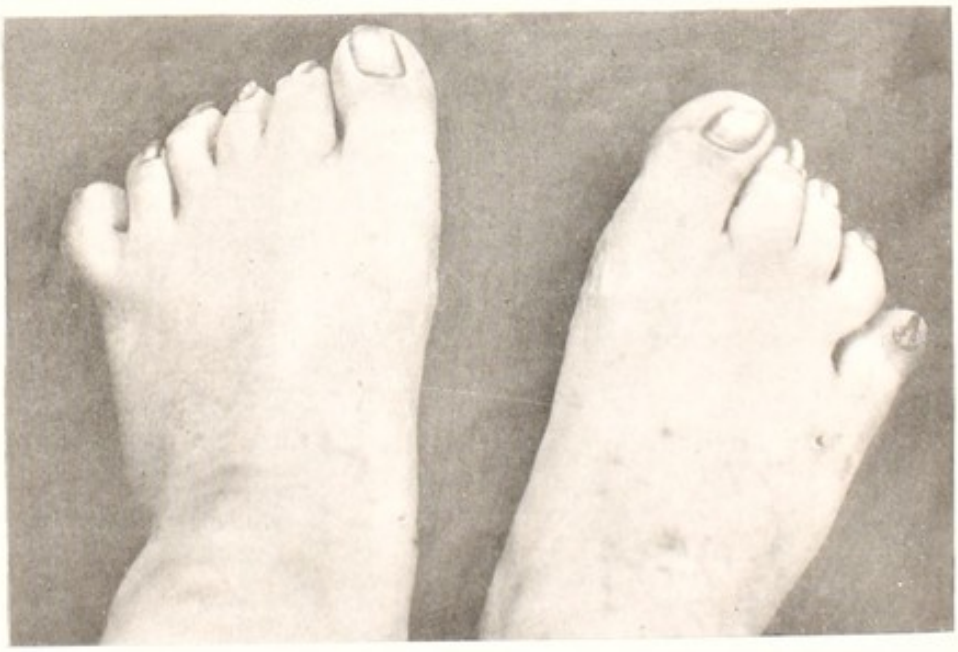


FIG. 634.—Polydactylism. Supernumerary toe of left foot.

has called attention to a condition which he terms "Right-angled contraction of the tendo Achillis," found in children who have had infantile paralysis from which "the anterior muscles of the leg have all but recovered." The condition follows also tonsillitis and diphtheria, and is found in women who habitually wear high-heeled boots.

Various clinical manifestations are encountered, viz.: (*a*) the patient



FIG. 933.—Polydactylism. X-ray of same case shown in Fig. 934 of supernumerary toe of left foot.

tires on walking, suffers pain in the calves and about the knees, cannot run well or swiftly, and frequently stumbles and falls; (*b*) the gait is shambling, executed with short steps and with knees bent, the patient being apparently unable to take longer steps without increasing the flexion of the knee; (*c*) cases in which the patients are continually "spraining" the ankle; (*d*) eversion of the feet, with integrity of the arches, or (*e*) inversion, toeing in, and walking

on the outer side of the foot. The cause in all these cases is inability completely to dorsiflex the foot beyond a right angle with the knee extended, or in less marked cases, dorsiflexion is limited to 5 to 10 degrees, without bending the knees to relax the gastrocnemius.

Treatment.—If dorsiflexion cannot be accomplished beyond a right angle, plastic tenotomy should be performed by overlapping L-shaped incisions to lengthen the tendo Achillis.



FIG. 636.—Intra-uterine amputation of the toes. The deep clefts in the left foot and leg are presumed to be the result of constriction by bands of amniotic membrane.

REFERENCES

MADELUNG'S DEFORMITY

JONES, S. FOSDICK: "Bilateral Congenital Dislocation of the Lower End of the Ulna." Am. Jour. Orthop. Surg., November, 1911.

DUPUYTREN: "Leçons orales de clinique chirurgicale faites à l'Hotel Dieu de Paris," vol. iv, 197, 209–210, 1834.

BÉGIN: Article. "Radio-Carpien, Dictionnaire abrégé des sciences medicales," xiii, 493, 1825.

SMITH, ROBERT W.: "Fractures and Dislocations in the Vicinity of Joints and on Certain Forms of Accidental and Congenital Dislocations." Dublin, Chapter vii, 1847.

CRUVEILHIER: "Anatomie Pathologique du Corps humain," Part ix, 3, 1829–1835.

JEAN, A.: "Double Luxation Congénitale complete du cubitus et incompléte du radius. Sur les os du carpe." Bull. de la Soc. Anat. de Paris, x, 3d ser., 398–400, 1875.

MADELUNG: "Die Spontane subluxation der Hand nach vorne." Archiv, f. Chir., xxiii, 1878.

VOLKMANN, RICHARD: "Wachsthumstorungen der Gelenke." von Pitha and Billroth's Handbuch der allgemeinen und Speciellen Chirurgie, vol. ii, Part 2, 1882.

HIRSCHBURG: "A Discussion of Madelung's Paper," 1879.

CZERNY: "A Discussion of Madelung's Paper," 1879.

VON LANGENBECK: "A Discussion of Madelung's Paper," 1879.

POOLEY, J. H.: "American Practitioner," vol. xxi, 1880.

FELIX, JOSEPH: "Etude sur la subluxation spontanée du poignet en avant." Thése de Lyon, 1884.

VON BERGMANN: Deutsche med. Wochenschrift, xiv, 861, 1888.

ABADIE: "De la luxation progressive du poignet." Rev. d'orthopdique, iv, 2d ser., 1903.

HOFFA, A.: Lehrbuch der Orthopädischen Chirurgie, 1891, and 5th Ed., 1905.

SAUER, F.: "Die Madelungische Deformitat des Handgelenkes." Bruns Beiträge zur Klinischen Chirurgie, xlviii, 1905–1906.

ESTOR: Revue de Chirurgie, xxxvi, 1907.
SIEGRIST: Deutsche Zeitschr. f. Chir., xcl, 1907–1908.
KIEFFER, C. F.: "Congenital Dislocation of Both Ulnæ at Wrists." Annals of Surgery, xxxviii, 110, 1903.
PECKHAM, F. E.: "A Report on a Case of Congenital Deformity of the Wrist-joints." Am. Jour. Orthop. Surg., iv, 388–389, 1906–1907.
STETTEN, DE WITT: "Idiopathic Progressive Curvature of the Radius, or So-called Madelung's Deformity of the Wrist." Surg., Gyn. and Obst., viii, January, 1909.
KIRMISSON: "Subluxation progressive du poignet. Les difformités acquises de l'appareil locomoteur pendant l'enfance et l'adolescence." Paris, 1902.
ROBINSON AND JACOULET: "La luxation congenitale de l'extremité inferieure du cubitus." Archives Gen. de Chir., Janvier, 1909.
BRINSMADE, W. B.: "Madelung's Deformity of the Hands." Annals of Surg., May, 1908.
STOKES, A. C.: "Spontaneous Forward Dislocation of the Wrist-joint (Madelung's Deformity). Annals of Surgery, lii, August, 1910.
PELS-LEUSDEN: "Madelung'sche Deformitat der Hand." Centralbl. f. Chir., No. 7, 1907.
COTTON: "Dislocations and Joint Fractures," pp. 359–361.
DAVID, M.: "Geundriss der orthopaed." Chirurgie, Berlin, 1906.
VOGT, P.: "Die Chirurgischen Krankheiten der oberen extremitaten." Deutsche Chirurgie, 64, 1881.
VOLKMANN, TH.: "Ueber Madelung'sche Subluxation nach vorn." Inaugurale Dissertation, Leipsig, 1905.
LEVY: Berliner klin. Wochenschrift, Dec. 14, 1908.
GANGELE: "Madelung'sche Handgelenks Deformitat." Archiv f. klin. Chir., lxxxviii, 1908–1909.

CONGENITAL ABSENCE OF RADIUS

M'CURDY: Annals of Surgery. January, 1896.
KRONIG: B. M. J., Mar. 10, 1894.
ANTONELLI: Zeitschr. f. orth. Chir., Bd. xiv, 1905.
TAYLOR, H. L.: Trans. Amer. Orth. Ass'n., vol. x, p. 174, 1897.
BLANCHARD: "Sur le rôle de l'amnion dans les malformations congénitales." Paris, 1902.
BLENCKE: Rev. d'orth., November, p. 562, 1905.
RÉDARD, P.: Trans. Amer. Orth. Ass'n. vol. xiv, 1901.
THOMPSON, C. E.: Trans. Amer. Orth. Ass'n. vol. ix, p. 96.
SAYRE, R. H., AND PARK, ROSWELL: Trans, Amer. Orth. Ass'n. vol. xiv, p. 145, 1901.

CONGENITAL ABSENCE OF ULNA

KÜMMELL AND HOFFMANN: Trans. Amer. Orth. Ass'n. vol. xiii, p. 96.

CLUB-HAND

ROSENKRANZ, E.: "Über kongenitale Kontrakturen der oberen Extremitäten." Zeitschr. f. orth. Chir., Bd. xiv, Heft 1, 1905.
ELLIOTT, G. R.: Trans. Amer. Orth. Ass'n. vol. xii, 1899.

CONGENITAL CONTRACTION OF THE FINGERS

KÖLLIKER: "Digitus Valgus et Varus." Joachimstal's Handbuch.
TUBBY: "Deformities," 1st edition, Figs. 105, 106, 108, 110, 111.
ADAMS, WILLIAM: "Contraction of the Fingers and Hammer-toe," 2d edition, p. 96, Churchill London.
GERHARDT: "Handb. der Kinderkrankheiten."
LONSDALE: Lancet, September, 1855.
HESTER: Med. Times, March, 1851.
ANNANDALE: "Malformations, Diseases and Injuries of the Fingers and Toes." Edinburgh, 1865.
ANDERSON, WILLIAM: "Lectures on Contraction of the Fingers and Toes." Lancet, July, 1891.
LOCKWOOD, C. B.: Path. Soc. Trans. 1886.
FORT: "Des Difformités congénitales et acquises des doigts." Thèse, Paris, p. 60, 1869.
MAJER: Hoffman's Jour. f. kinderkrankheiten, Band lviii.
VOGT: "Die chirurgischen Krankheiten der oberen Extremitäten." Deutsch. Chir., Lief. lxiv, S. 15.

COUDRAY: "Traitement de la flexion du petit doigt par le resection." Sem. med., No. xlii, 1895.
LITTLE, MUIRHEAD: International Med. Mag., May, 1894.

CONGENITAL DEFORMITIES OF HANDS AND FINGERS

KLAUSSNER: "Über Missbildungen der menslichen Gliedmassen." Wiesbaden, p. 66, 1900.
ROUCAYROL: Rev. d'orth. January, 1905.
RASCH: Beiträge zur klin. Chir., Bd. xviii, Heft 2, 1897.
GOLDMAN: Beiträge f. klin. Chir., 1891.
AUDEBERT: "Syndactyle et polydactyle héréditaire." Soc. d'Anat. et de Physiol. de Bordeaux, No. 10, 1896.
EBSTEIN: Virchow's Arch., Bd. cxliii, Heft 2, 1898.
NORTON: B. M. J., August, 1881.

POLYDACTYLISM

RASCH: Beiträge z. klin. Chir., Bd. xviii, Heft 2, 1897.
MURRAY: Med. Chir. Trans., 1865.
GIRALDÉS: "Maladies chir. des enfants." Paris, 1865.

SUPPRESSION OF FINGERS

VOGT: Préface des mammifères.
TUBBY: "Deformities," 1st edition, p. 506.
JOACHIMSTAL: Virchow's Arch., Bd., cli, S. 420.
ROUGHTON: Lancet, vol. ii, p. 19, 1897.

HYPERTROPHY OF FINGERS

HERMANN, H.: Inaug. Dissert., Munich, 1895.
HAWKINS-AMBLER: Lancet, Feb. 4, 1893.

CHAPTER XXVI

TORTICOLLIS OR WRY-NECK

Definition.—A congenital or acquired deformity characterized by lateral inclination of the head to the shoulder, accompanied by torsion of the neck and deviation of the face.

Varieties.—A greater or less degree of permanent twisting of the neck is a symptom of many dissociated clinical conditions. Two main varieties of torticollis are recognized, viz.: congenital and acquired; of the latter, there are several etiological types.

CONGENITAL TORTICOLLIS

Etiology.—The condition is comparatively rare. It is commoner in females than in males. It may be present at birth or develop during the early months of life. It may be hereditary and co-exist with other congenital malformations (club-foot, congenital dislocations, etc). Obstetrical paralysis of the shoulder may also be present; cases of wry-neck frequently occur in association with difficult delivery occasioned by dystocia from malpositions and malpresentations of the fetus, necessitating forceps delivery, but this history of dystocia is not universal. The characteristic lesion of torticollis is almost always limited to the sternomastoid muscle.

Theories. (*a*) *Stromeyer.*—Injury of the sternomastoid muscle during labor, with contraction resulting from the formation of scar tissue. This theory is invalidated to some extent by the fact that the hematomata, pseudohematomata, blood pigments, etc., in the affected area are as frequently absent as present.

(*b*) *Mikulicz.*—Injury with subsequent infection of the sternomastoid muscle. It can be said of this theory that no micro-organism has ever been isolated from the sternomastoid muscle in a case of congenital wry-neck.

(*c*) *Syphilis.*—A localized syphilitic sclerosis of the sternomastoid yields quickly to specific treatment, while true congenital torticollis is unaffected by antisyphilitic medication.

(*d*) *Mechanical Theories.*—These theories refer the condition to malpositions of the fetus *in utero*, amniotic adhesions, etc., but evidence of their etiological bearing is inconclusive.

(*e*) *Nervous Origin.*—Theories of either central, medullary, or peripheral nervous lesions are not plausible.

(*f*) *Ischemia.*—According to this theory, congenital wry-neck is analogous to the ischemic paralysis with degeneration of muscle fibers from prolonged partial obstruction of the circulation described by Volkmann. The blood-supply of the sternomastoid is such that it can readily be obstructed by certain positions of the head. This theory appears to the author the most reasonable of any hitherto advanced.

Pathology.—The underlying lesion is a sclerotic interstitial myositis, with Zenker's waxy degeneration of the muscle fibers, producing dense induration and shortening of the affected muscle.

Clinical Features.—The chief phenomena are a lateral flexion of the head to the affected side, and rotation of the face to the opposite side. The chin is elevated and thrust forward, while the shoulder on the affected side is raised. The head, *as a whole*, is shifted toward the sound side. The affected muscle is more vertical than normal, and feels hard on palpation, but is not tender to touch. Secondary changes occur in the fascia and cervical spine. In very chronic cases, the platysma, splenius, and scaleni are shortened.

Asymmetry of the face and cranium is noticeable but is most marked after the deformity has been corrected; it may persist for several months to two or three years, but gradually disappears. Lateral curvature and rotation of the cervical spine, with or without compensatory curves, is the rule. This curvature may disappear after the cure of the torticollis, but if of long standing, the distortion usually persists.



FIG. 637.—Bratz apparatus for torticollis. (Sayre.)

Treatment.—There are two methods of procedure: manipulative and operative.

Manipulative.—The child's mother or attendant can perform these manipulations as follows: Flex the head to the opposite side, at the same time turning the chin to the affected side, and repeat the manipulation several times a day. In mild, early cases, these manipulations may check the progress of the deformity or cure the condition.

Operative.—To be successful, an operation for torticollis must include complete division of all tendinous, muscular, and fascial bands which prevent restitution of the head, retention of the head in corrected position, and postoperative correction of the lateral curvature of the cervical and dorsal vertebræ.

Subcutaneous tenotomy is not always successful, and is accompanied by the danger of injury to important vessels and nerves, therefore open division of the contracted tissues is preferred.

Open Division of the Sternomastoid Muscle.—The muscle may be divided in three situations: (*a*) sternoclavicular; (*b*) mastoid; (*c*) center.

(*a*) *Sternoclavicular.*—The muscle is here superficial and is most easily reached. Some surgeons divide the scalenus anticus also, in that it aids correction of the cervical scoliosis, but this procedure is rarely indicated. The incision is oblique or horizontal. If the latter is used, it need be only one to one and a half inches in length. Oblique incisions along the border of the muscle must be made longer. The sheath is opened and the tendons divided on a director from before backward, first the sternal, then the clavicular tendon of origin. All fascial bands are picked up with forceps and severed. The wound requires careful suturing to avoid an unsightly scar, therefore from the cosmetic standpoint the oblique incision is preferable.

(*b*) *Mastoid.*—The muscle is stripped and separated from its bony attachments by a curved incision extending from the mastoid backward into the scalp; the scar is thus concealed by the subsequent growth of hair.

(*c*) *Center.*—Division of the muscle is performed by some surgeons at the middle point, in the belief that there is less liability of the deformity to relapse because separation of the cut ends is greater when this point of division is selected.

Overcorrection.—Kneading of the muscle must be performed after division, at the same time traction is being made on the arm and head. The head is then rotated away from the contracted side, to aid in correcting scoliosis of the cervical spine and the shoulder of the affected side is simultaneously depressed. The head is now fixed in its overcorrected position by a plaster-of-Paris cuirass from the costal borders around the neck and over the vertex and sides of the head, coming down on the forehead to the supra-orbital ridges. The cuirass is worn for four to eight weeks; it is then cut down, and massage, manipulation, and appropriate muscle exercises are instituted. Forcible passive overcorrection of the head is performed twice a day. One method of applying passive overcorrection is by self-suspension in the sling used for applying plaster-of-Paris jackets.

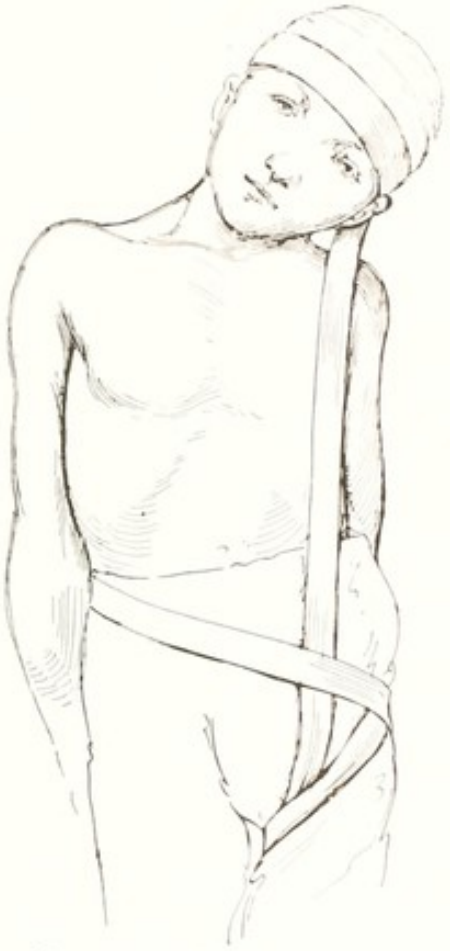


FIG. 638.—Fixation dressing consisting of muslin bandage and adhesive to hold the head overcorrected after an operation for torticollis.

If the deformity tends to return, some form of apparatus must be worn. A jury mast incorporated in the plaster jacket is useful, or a Bratz or Sayre's apparatus may be used (Fig. 637). The latter consists of a shoulder-ring on the sound side, and a fillet for the forehead; between the two extends a strong elastic band which can be gradually shortened to overcorrect the deformity.

In the simpler cases of wry-neck, the author uses a band of adhesive 2 inches in width passed over the side of the face in front of the ear and chin, and carried on to the back, holding the head in an overcorrected position

with the chin pointing to the opposite shoulder (Figs. 639 and 640). In the severer cases, where structural changes have occurred in the cervical spine and there is shortening of the soft tissue structures, which cannot be



FIG. 639.—Torticollis from shortening of the left sternocleidomastoid muscle which usually occurs from trauma at birth. The resultant obliquity of the eyes in the skull is very evident.



FIG. 640.—Same case as Fig. 639 after myotomy of sternocleidomastoid muscle, and the application of the adhesive retention strap to hold the head in the overcorrected position. The drawing represents two adhesive straps of equal length fastened together by safety pins or sewing with their adhesive surface opposite to each other.

surgically approached, the head is held in a plaster-of-Paris "Minerva" jacket; the plaster is moulded over the frontal, occipital, and mental regions of the head, over the shoulder, and reaches well on to the thorax. This jacket

should be worn for a period of two or three months, and if there is still a tendency for the deformity to relapse, a similar plaster-of-Paris "Minerva" is reapplied and a brace subsequently worn in persistent cases.

Recurrence of the deformity is due either to incomplete operation or to insufficient after-treatment, and is therefore avoidable. Postoperative massage and manipulative overstretching of the structures of the neck are quite essential in the convalescent postoperative treatment of most types of torticollis.

Congenital posterior torticollis is less common than the anterior form (Fig. 641). The common cause is contraction of the trapezius and levator anguli scapulæ, with frequently complicity of the deeper muscles (complexus, splenius, trachelomastoid).



FIG. 641.—Posterior torticollis.

Section of these muscles is very difficult. Stretching under anesthesia and maintaining of the correction by plaster-of-Paris jacket or apparatus may be tried.

ACQUIRED TORTICOLLIS

Varieties.—Tubby (ref: vol. I, pp. 74, 75) gives a comprehensive table of the varieties of torticollis, of which the following is an abbreviation:

A. Acute.—1. Myositis of the cervical muscles, ordinary stiff neck.
2. Secondary to angina or suppurating glands of the neck.
B. Subacute.—Glands of the neck, tonsils, diphtheria, measles.
C. Chronic.—1. Trauma (dislocation).
2. Cicatrices (skin and muscles).
3. Reflex irritation from caries of the spine (Pott's disease).
4. Brachial plexus neuralgia.
5. Scoliosis.
6. Astigmatism, ocular.
7. Occupational, frequent repeated movements of the head from side to side.

8. Rickets.
9. Paralysis of spinal accessory nerve.
10. Spasmodic.
11. Psychical.
12. Meningitis (cervical opisthotonos).
13. Anterior poliomyelitis.

Acute Torticollis.—*Etiology.*—This is the most important variety from the standpoint of permanent distortion. It is also the most frequent of the acquired forms. The simple form is due to direct irritations of the muscle from injury, perimuscular inflammations combined with irritation of the peripheral nerve, causing reflex contraction of the muscle. In children, simple acute torticollis often begins with fever and malaise, while the muscle is tender to pressure and movement. The distortion is purposeful, to relax the inflamed muscle. The deformity usually disappears when the inflammation subsides.

Another cause of acute wry-neck is cellulitis; another is disintegration of tuberculous glands of the neck. These causes may lead to permanent deformity if the tissues of the neck are damaged by suppurative inflammation.

Torticollis may be spastic, from irritation of branches of the spinal accessory nerve, in the course of tonsillitis, pharyngitis, diphtheria, and other affections of the nasopharynx. Spastic torticollis may also be hysterical in persons who are subject to nervous instability.

Symptoms.—The onset is sudden and febrile. The contraction may involve several muscles, *e.g.*, sternomastoid, trapezius, the posterior group of cervical muscles, etc. The muscle is tender to touch, and to movements of the head. Neuralgic pains in its neighborhood are common. The duration is usually short, but when a local inflammatory process is at work, persistent deformity may result from structural changes in the muscles and fascia; the muscle may undergo atrophy and degeneration.

Diagnosis.—(*a*) Confusion with Pott's disease is the commonest error, but in acute torticollis the onset is sudden without preceding stiffness, and with neuralgic pain, and movements of the head are restricted only when the inflamed muscle is put on the stretch, all other movements being unrestricted. In Pott's disease, on the other hand, the chin is frequently pointed toward the side toward which the head is inclined; traction of the head relieves pain instead of increasing it, as is the case in acute torticollis; reflex spasm limits motion in all directions.

(*b*) Arthritis of the atlo-axoid joint (rheumatic or infectious) is sudden in onset, but *all* muscles of the neck are affected by spasm rather than a single group, as in acute torticollis.

Treatment.—The mildest forms can usually be cured by the local application of heat and the use of a collar made of sheet wadding, cardboard, and adhesive plaster.

Spastic Types.—If possible, remove the cause of irritation and treat the general condition of the patient. The most urgent requirement is to relieve the tension of the muscle. For this purpose, the collar above described is usually insufficient; hence a jury-mast incorporated in a plaster-of-Paris jacket may be required until the acute symptoms have subsided, when exercise, massage, and manipulation may be begun.

In cases of longer standing, anesthesia and forcible correction may be necessary, to be followed by the use of a jury-mast incorporated in a plaster-of-Paris jacket.

Chronic Torticollis.—Of the various forms of chronic torticollis enumerated above, only one, spasmodic torticollis, requires special mention.

Spasmodic Torticollis.—This affection bears no relation to the acute torticollis from affections of the peripheral nerves described above. Spasmodic torticollis is a convulsive spasm of the muscles of the neck, in a general way similar to the phenomenon known as "writer's cramp." It occurs chiefly in adults.

Clinically, the onset is gradual; the initial symptoms are stiffness and discomfort of the muscles of the neck, with twitching or slight contraction pulling the head toward one side. Gradually the characteristic attitude of torticollis is assumed, but the patient can, in the early stages of the affection, correct the attitude voluntarily and stop the twitchings by holding the head. But usually the spasm is uncontrollable and may also involve the muscles of the face or even of the chest. Spasm is increased by excitement or the execution of sudden movements, and is usually accompanied by neuralgic pain in the head and neck.

The cause is not definitely known. There is, not infrequently, a neurotic family or personal history, while overwork, nervous shock, etc., are predisposing causes. Constrained positions of the head in certain occupations and eye-strain from defective vision suggest an analogy to writer's cramp. Hypertrophy and shortening of the affected muscle are both compensatory.

Treatment.—The general condition should receive first attention. If the patient is of neurotic or hysterical type, psychotherapy may effect a cure. If the condition is of occupational origin, change of work should be enjoined. In early cases, massage, muscle exercises, and a mechanical support should be prescribed.

In chronic cases, certain cure is offered only by resection of the nerves innervating the affected muscles, if the sternomastoid and trapezius, resection of the spinal accessory; if other muscles, or recurrence after division of the spinal accessory, resection of the posterior branches of the upper cervical nerves, with division of the contracted muscles. The spinal accessory nerve may be exposed at a point 1 to 2 inches below the tip of the mastoid. The posterior branches of the upper cervical nerves may be exposed by an incision downward from the occiput parallel with the spinous processes of the cervical vertebræ; after division of the complexus, these nerves are exposed and the branches of the three upper nerves are resected. Paralysis following these operations is of no practical importance, as the head can invariably be held erect.

REFERENCES

KEMPF: Deutsch. Zeitschr. f. Chir., vol. lxxxviii, June, 1904.
NOVÉ-JOSSERAND AND VIANNY, CHARLES: Rev. d'orth., Sept. 1, 1906.
MAASS: Zeitschr. f. orth. Chir., 1903.
JOACHIMSTAL AND VOLCKER: Hanb. f. orth. Chir.
WHITMAN: Trans. of the Amer. Orth. Ass'n, vol. iv.
CLUTTON, H. H.: St. Thomas's Hospital Reports, vol. xvii, 1888.
KEETLEY: Orthopedic Surgery.
WITZEL: Zeitschr. f. Chir., Bd. xviii, 1883.
HELLER: Zeitschr. f. Chir., Bd. xlix.
LÜNING AND SCHULTHESS: Zeitschr. f. orth. Chir., Bd. 1, Heft. 1, 1891.
MIKULICZ: Centralbl. f. Chir. No. 1, S. 2, 1895.
KADER: Beitr. z. klin. Chir., Bd. xxvi, S. 188, 1900.
KEMPF: Deutsch Zeitschr. f. Chir., 1904.
VOLCKER: "Das Caput Obstipum." Brun's Beitrage, Bd. xxxiii, 1903.
KEMPF: Zeitschr. f. orth. Chir., Bd. ii.
HÜBSCHER: "Symmetrische Einschränkung der Blickfelder bei Torticollis." Beiträge z. klin. chir., Bd. x, S. 209, 1893.
WITZEL: Deutsch Zeitschr. f. Chir., Bd. xv, 1883.
RÉDARD: Traité de chirurgie orthopédique.

Lorenz: Wiener med. Presse, Feb. 19, 1893, Centralbl. f. Chir., 1895, No. v, Wiener med. Wochenschr., Nos. ii and iii, 1902.
Reiner: Wien. klin. Wochenschr., No. xliii, 1895.
Brackett: Trans. of Amer. Orth. Ass'n, 1897.
Bradford and Sever: Boston Med. Jour., Aug. 22, 1907.
Gerdes: Centralbl. f. Chir., Feb. 9, 1907; ibid. No. 1, 1895.
Bocker: Centralbl. f. Chir., Apr. 20, 1907.
Bocker: "Ü de spät. Resultate der Resection des Kopfnickers beim muscularen Schief halse nach Mikulicz." Zeitschr. f. orth. Chir., Bd. ix.
Tubby: Encycl. Med., vol. xl, p. 304.
Walton: Boston Med. and Surg. Jour., cxlix, 17, 445.
Döllinger: Pesther med.-chir. Presse, No. 48, 1889.
Bradford: Trans. Amer. Orth. Ass'n. vol. 1, 46.
Stevens: Arch. f. Ophthal., 1887.
Annandale: Lancet, vol. i, p. 555, 1879.

CHAPTER XXVII

NEOPLASMS OF BONE

Newgrowths of bone are either *primary* or *secondary;* the former are of the connective tissue type, while the latter are composed of tissue found in the tumor from which they originate.

Primary neoplasms arise in the periosteum, cortex, epiphyseal cartilage or medulla and are divided into: I. Benign neoplasms. II. Fibrocystic disease of the bones (a group intermediate between the benign and malignant tumors, inasmuch as many of the cysts partake of a sarcomatous nature, while others are purely innocent). III. Malignant neoplasms.

I. BENIGN NEOPLASMS

This group embraces the osteomata, chondromata, fibromata and the rarer myxomata, lipomata and angiomata.



FIG. 642.—(J. K., case referred by Dr. Vincent.) Osteochondroma of upper end of humerus.

1. **Osteomata.**—Two varieties are recognized, viz.: (*a*) *ivory exostoses* and (*b*) *cancellous exostoses* (the latter from ossification of chondromata.)

Ivory exostoses are commonly found in the orbital and skull bones and are of slow growth and generally sessile. Unless interfering with function or

causing pressure on important structures, they may be disregarded. Their extreme density makes their removal difficult, even with an electrically driven motor-saw, drill or burr.

Cancellous exostoses arise from the epiphyseal line or cartilage. Their growth is apparently influenced by repeated irritation or injury. Common situations for them are the bones of the hands, phalanges of the feet, particularly the terminal phalanx of the great toe (subungual exostosis), the lower end of the femur, either from the site of the adductor tubercle, or from the external supracondylar region, as in a case in the author's experience where the tendon of the biceps femoris (outer hamstring) played over an exostosis in that locality, causing discomfort in walking and exercising; they are also encountered in the shoulder and wrist. Cancellous exostoses vary in size from a pea to a baseball or even larger (2 mm. to 8 cm. or more). They cause inconvenience only from pressure symptoms or from tendons, nerves, etc. slipping over them during muscular exertion. Sometimes they are multiple. The diffuse form of osteoma is exemplified by leontiasis ossea. The treatment is exposure by an incision and removal of the growth by motor-saw, chisel or gouge.



FIG. 643.—(L. M., case of Dr. E. W. Jones, Los Angeles, Cal.) Multiple osteochondromata with gigantism of feet.

2. **Chondromata.**—Benign tumors of cartilaginous origin which do not become converted into osteomata (see above), are encountered as degenerative structures, such as myxochondromata (Fig. 642) and chondrosarcomata.

Unmixed (benign) chondromata are slowly growing, smooth tumors, often multiple (Fig. 643) and resilient to pressure. Their usual point of origin is the surface of bone; when growing from the interior of a bone they are denominated enchondromata. If a chondroma begins to become soft or to increase rapidly in size, myxomatous or sarcomatous changes should be suspected.

Treatment consists of removal by gouge, chisel or saw, which is an easy matter unless the tumor lies in close relation to important vessels and nerves.

3. **Fibromata.**—A common example of a fibroma of bone is the simple epulis of the jaw. Fibromata of bone may be firm in consistency or soft and highly vascular.

Myxomata, lipomata and angiomata are too rare and unimportant to be of much clinical interest.

II. FIBROCYSTIC DISEASE OF THE BONES

Under this comprehensive heading are included the following: Benign cysts. Osteitis fibrosa. Osteitis fibrosa with tumors and giant-celled sar-

comata (von Recklinghausen's disease). Mollities ossium with giant-celled sarcoma.

The knowledge possessed by the profession with regard to bone cysts and allied condition is, to say the least, rather hazy. The history of solitary cysts of the long bones dates from Virchow's description in 1877 of a cyst of the humerus.

Cysts occur in many of the long bones, more rarely in the skin and small bones. They may be single or multiple, may be simple or surrounded by an area of diseased bone often of the nature of von Recklinghausen's disease (osteitis fibrosa). They may occur in association with other pathological conditions of the bones (*e.g.*, Paget's disease, osteomalacia, osteo-arthritis, etc.). They may result from the degeneration of cartilaginous tumors and of giant-celled sarcomata; also from the breaking down of true sarcomata of bone. They have been observed in the callus at the site of a fracture.

Owing to our comparative ignorance of the significance of microscopic changes in the pathology of bone and the confusion of attempts to classify bone-cysts and allied conditions according to their microscopic or gross pathology, they will be grouped in the following description according to their site, after the classification of Elmslie as contained in his excellent monograph on "Fibrocystic Disease of the Bones" (ref.: Brit. Jour. of Surg., vol. ii, No. 5, 1914).

Distribution.—Silver (Am. Jour. Orth. Surg., 1912, ix, p. 563) has classified 97 cysts of bone which gives a good idea of the relative frequency of involvement of the various bones. This table forms the basis of Elmslie's classification from which much of the following text has been derived. It will be noted that the femur occupies the first position, the humerus being a close second, and the tibia third.

Cysts of Bone According to Site. (Silver)

Site	Number	Site	Number
Femur	31	Metacarpal	1
Tibia	15	Phalanges	7
Fibula	6	Astragalus	1
Humerus	25	Calcaneum	2
Ulna	2	Metatarsal	1
Radius	1	Clavicle	3
Carpal scaphoid	1	Pelvis	1

Affections of Single Bones

Humerus.—Cysts of the upper end of the humerus will be described at some length because they form so clear a clinical picture and are relatively common in this situation.

Cysts in this location have been recorded by many observers. The clinical picture is very clear and the diagnosis of cyst in the upper part of the humerus can be made with considerable facility.

Clinical History.—The majority of cases occur in *children* from four onward through adolescence, but may be encountered in adults, as in Virchow's classical case found postmortem in an individual of fifty-six.

(*a*) *Fracture.*—In the great majority of cases the diagnosis is made by accident in examining a röntgenogram of a case of fracture. When an *x*-ray examination of a fracture is not made, many cysts escape detection. Many fractures coincident with cyst formation are incomplete and hence go undetected by physical examination. Spontaneous fracture, or fracture resulting from an inconsequential injury is the commonest physical sign of cyst of the humerus.

(*b*) *Pain* and *swelling* are, next to fracture, the most frequent symptoms. They may arise spontaneously, but usually follow an injury. The frequent association of injury does not, however, substantiate the traumatic origin of these cysts, but is an argument for the theory that the injury causes incomplete fracture through a pre-existing cyst, and that pain and swelling result from further enlargement of the cavity.

(*c*) *Deformity* and *disability* arise only after an injury or a definite fracture. The onset, without previous injury, of much disability with muscular atrophy, should cause suspicion that the enlargement of the humerus in this situation is due to some condition other than cyst.

X-ray Appearances.—The cyst is usually central and more or less completely fills the bone. The bone is slightly expanded and the cavity single, as a rule, at the time of fracture. There is no sclerosis of the surrounding bone and no thickening of the periosteal bone.

Cysts of the humerus most often lie close against the upper epiphyseal line of the humerus and extend downward 1 or 2 inches. They may, however, extend one-third the distance down the shaft or may occupy the entire diaphysis. Growth at the epiphyseal line moves the cyst constantly downward so that its location is more or less of an index of its age, viz.: a cyst lying close to the upper end of the bone is of recent origin; at the middle of the shaft, of greater age; one occupying the whole shaft probably arose in early life and continued to extend. Growth of the bone appears to be uninfluenced by the cyst, even in cases where its upper margin has been actually formed by the epiphyseal cartilage.

Differential Diagnosis.—In the upper end of the humerus, cysts are more common than other endosteal tumors. However, they may be confused with any of the following:

(*a*) *Secondary Carcinoma.*—This may cause confusion, especially in older subjects.

(*b*) *True Endosteal Sarcoma.*—This can be differentiated by its very painful character and the *x*-ray appearance which shows it to have expanded beyond the limits of the bone.

(*c*) *Chronic Abscess and Gumma.*—These two conditions are rare in this location and can be distinguished by the accompanying periosteal thickening.

(*d*) *Enchondroma* closely resembles the cyst in its *x*-ray appearance, but the swelling and disability occur independently of accident, there is sclerosis of the surrounding bone, and the translucent area is subdivided by trabeculæ and is not centrally located.

Absolute diagnosis is made on the clinical history (spontaneous or post-traumatic fracture from insufficient cause) followed by pain and the presence of a swelling supplemented by the characteristic *x*-ray picture. In case of doubt, an exploratory operation is conclusive.

Pathology.—According to Elmslie the pathological changes in these cysts of the humerus are complicated but remarkably uniform.

(*a*) *Cyst contents* are always fluid, yellow to deep reddish-brown, clear or containing cholesterin crystals from previous hemorrhages, and almost invariably sterile. Solid masses in the cysts are rare.

(*b*) *Cyst walls* vary in character. When smooth, they consist of adult fibrous tissue merging externally into fibrous marrow which replaces the normal marrow in the neighborhood of the cyst. This fibrous marrow is found in the wall of all cysts, irrespective of whether or not, they have a proper lining and contains bone, osteoid tissue, cartilage, patches of calcification, giant-cells and hemorrhages.

(*c*) *Bone.*—The outstanding feature of the bone changes is active ab-

sorption by osteoclasts and the presence of osteoid tissue representing bone which has never been calcified or else has been deprived of its lime-salts. There is some evidence of osteogenesis and at the periphery, a thin residue of normal cortex.

(*d*) *Cartilage.*—Cartilage may be abundant but occurs in small patches and not *en masse* as in enchondromata. It is usually fibrous but may be hyaline and partly calcified with evidence of absorption by osteoclasts at its periphery.

(*e*) *Marrow.*—Patches of calcification, hemorrhage and pigment granules (hemosiderin) are scattered throughout the adjacent marrow.

(*f*) *Giant-cells.*—These are an important feature, and are undoubtedly osteoclasts lying in close proximity to the bone and cartilage but also found singly and in clumps in the fibrous marrow, which latter varies from adult fibrous tissue arranged in parallel bands, to loose, vascular, spindle-celled tissue. These giant-cells bear no resemblance to those found in tuberculous tissue, nor do they occur particularly in the neighborhood of hemorrhages or pigment patches. *They resemble and are apparently identical with the osteoclasts.* Where collections of these giant-cells occur in a spindle-celled stroma, the appearance closely resembles that of myeloid tumor.

Myxomatous degeneration of fibrous tissue or cartilage has not been noted.

The interpretation of the above pathological picture has varied with different observers. Elmslie summarizes the various views on the subject (*loc. cit.*) as follows:

1. The cysts are derived from *enchondromata* by degeneration or by absorption of the cartilage by osteoclasts (Virchow's theory.)

2. They are derived from myelomata in which the bulk of the tumor formation has been absorbed, the surrounding changes being the reaction in the surrounding bone and marrow.

3. They result from a form of chronic inflammation in the marrow, *osteitis fibrosa.*

4. They result from *hemorrhages into the bone*, the other changes being secondary reactions in the marrow and bone.

5. They result from a perverted growth of bone and marrow, the balance between bone formation and absorption being disturbed, the osteoclasts, taking on excessive function and connective tissue elements in the marrow, developing to an extreme degree. Upon this theory the condition would be named *osteodystrophia cystica* (von Mikulicz) or a metaplasia of bone and marrow.

Clavicle.—Few cases of involvement of the clavicle have been recorded. Their structure is intermediary between bone-cysts and frank myelomata.

Ulna.—Involvement of the ulna by cyst formation is very rare (Fig. 644).

Radius.—Cysts of the radius are extremely rare. Myelomata of the lower end of the radius are comparatively frequent, and cyst formation in them may occur. Chronic abscess of the shaft of the radius may cause great confusion of diagnosis from bone-cyst, on account of the complete absence of periosteal thickening.

Femur.—More cases are on record of cysts or osteitis fibrosa of the femur than any other bone. The cases do not, however, form so clear or well defined a group as do those of the humerus. The clinical picture is more complex, there is often a large solid tumor, and in a larger percentage of cases there is associated affection of one or more other bones.

Clinical History.—Fracture is very common, sometimes is incomplete and frequently occurs spontaneously without the patient's knowledge. As a

rule, subsequent union is good but is often followed by bending and swelling, there being apparently an increased formation of new fibrous or fibrocartilaginous tissue with resulting enlargement and bending of the bone.

The age distribution is of wider range than in the case of the humerus. While the simple cysts occur in young children, the formation of fibrous and other tissue masses may go on at any age.

Röntgenology.—The diagnosis depends upon *x*-ray examination. The expansion of the bone with the formation of cysts is very characteristic. There always remains a shell of cortical bone around the tumor except at the site of fracture; if the cortex has disappeared at any point, sarcoma should

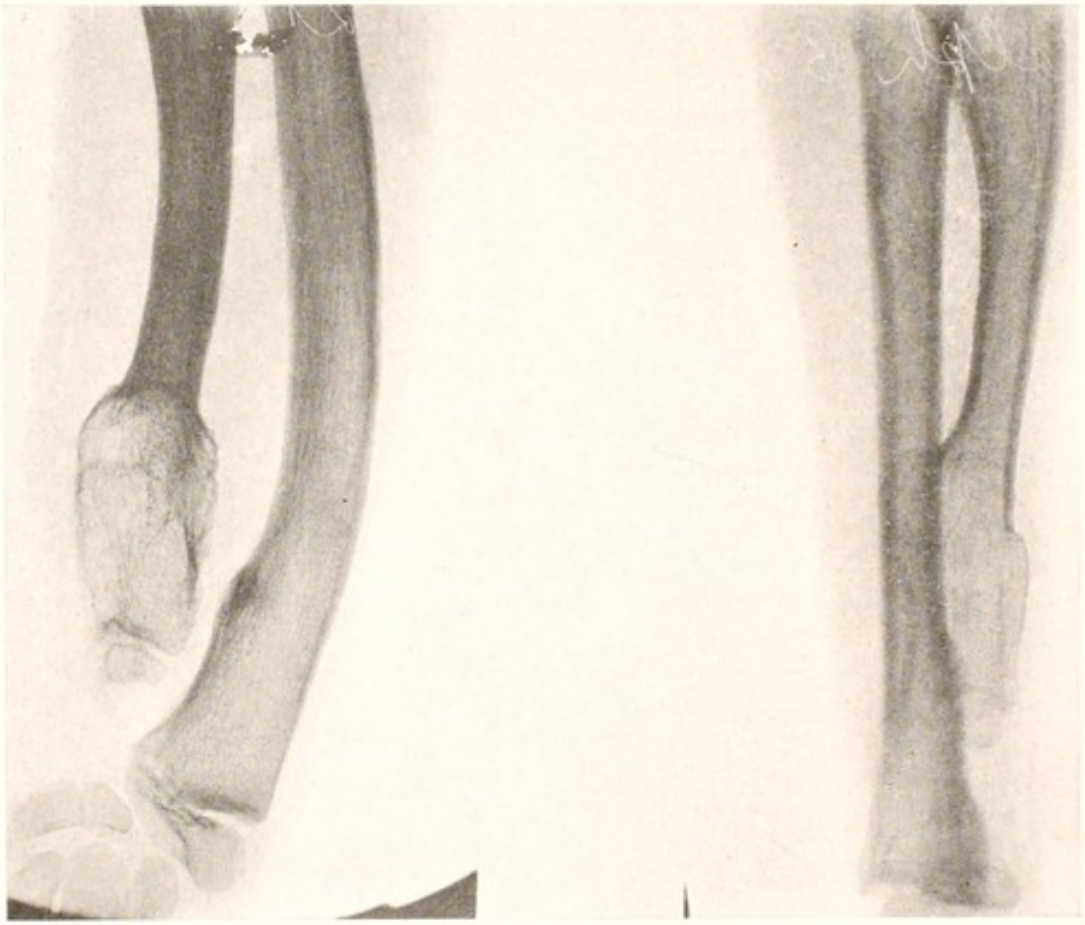


FIG. 644.—(R. B.) Fibrocystic disease of lower end of ulna with extreme resorption of bone, interference of growth, shortening of the ulna, with bowing of ulna and radius. The growth was excised and the continuity of the ulna restored by bone-graft with excellent anatomical and functional result. Patient twelve years of age.

be suspected. Important points in the *x*-ray picture are the central location of the tumor, absence of periosteal thickening and of sclerosis of surrounding bone. Slight or deficient expansion of bone makes the diagnosis difficult. Trabeculation of the cysts is more frequent in the femur than in the case of the humerus (Figs. 645 to 649).

Differential Diagnosis. (*a*) *Simple Traumatic Fracture.*—The differentiation can be positively made only by means of the *x*-ray.

(*b*) *Sarcoma* of bone presents very real difficulty. The length of the clinical history and the *x*-ray findings (the central location, persistence of a layer of cortex, absence of periosteal changes in case of a cyst) will help in the differentiation.

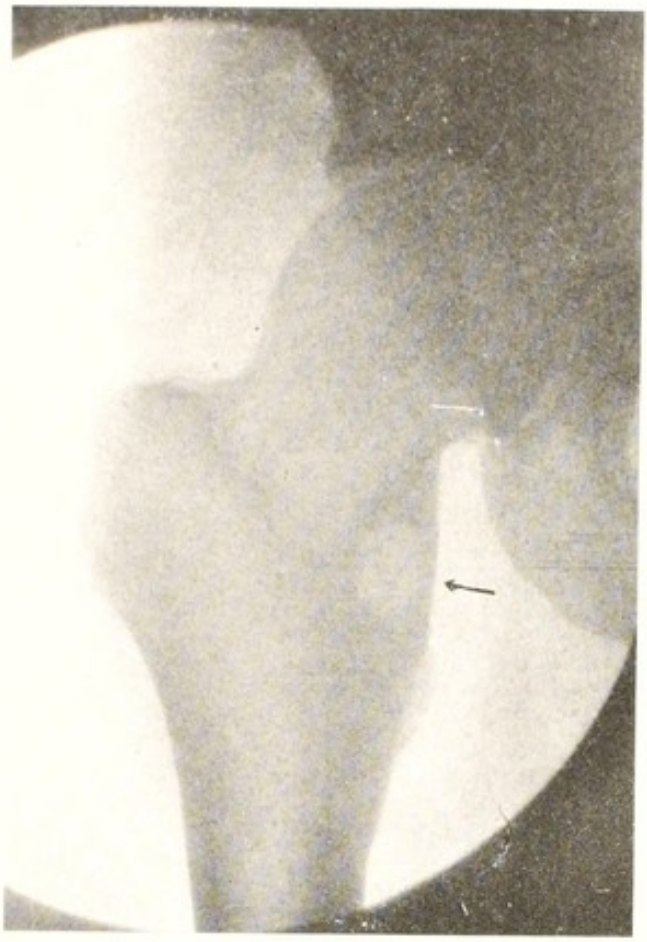


FIG. 645.—Bone cyst of femur. Unusually well defined. Cyst finally ruptured into soft parts at location of the arrow. Removal resulted in complete relief of symptoms. (Dr. H. L. Taylor's case.)



FIG. 646.—Multiple fibrocystic disease of upper end of femur followed by spontaneous fracture.



a *b*

FIG. 647.—Osteosarcoma of lower end of femur of very slow growth. *a* Was taken one year prior to *b*. Symptoms simulated tuberculosis, a diagnosis of which was previously made. *X*-ray findings conclusive.

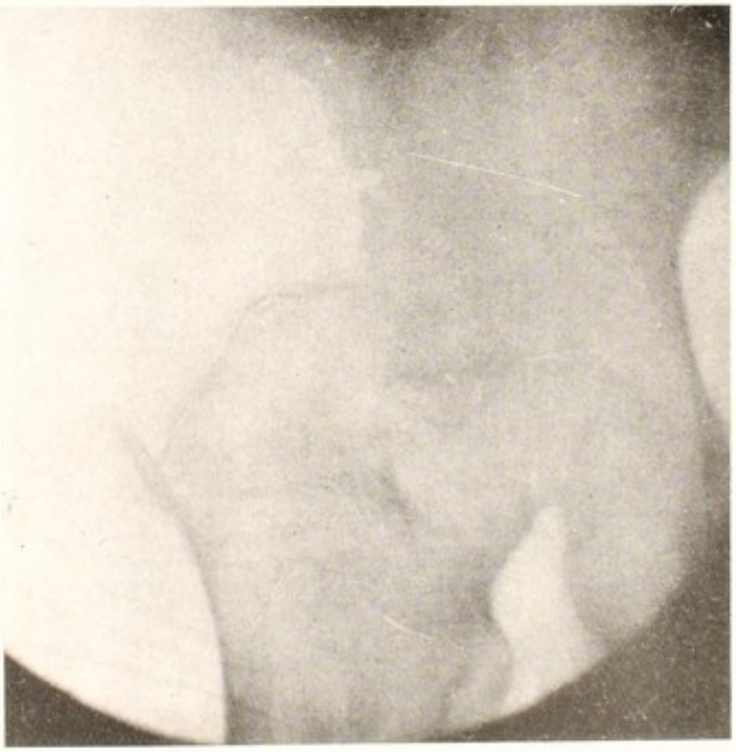


FIG. 648.—(M. G.) Echinococcus cyst of head of femur in a patient from New Zealand. Head and portion of neck of femur have been removed by operation followed by swabbing of hip-wound with phenol and alcohol.

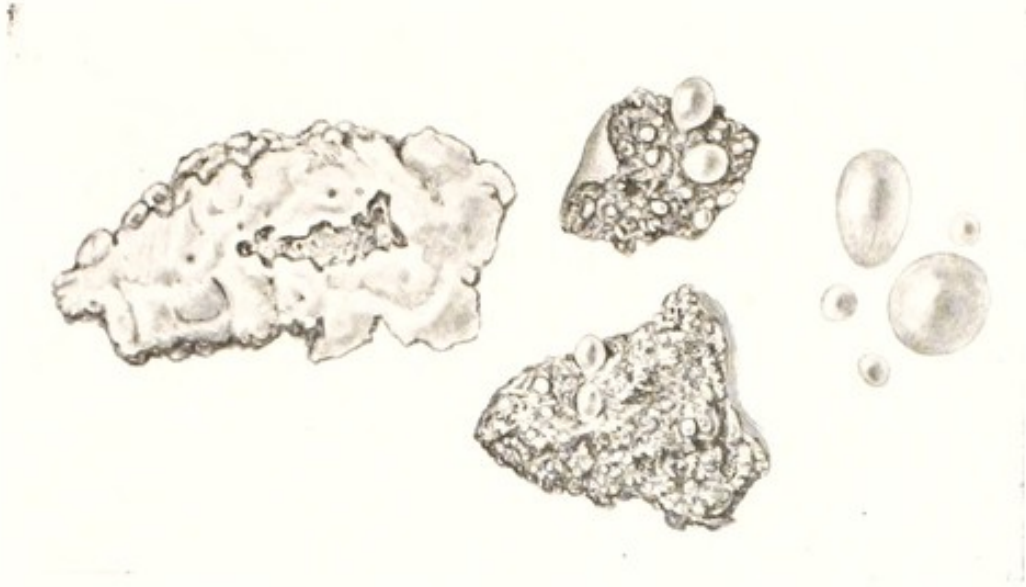


FIG. 649.—(M. G.) Drawing of echinococcus cysts removed from head and neck of femur in case shown in Fig. 648. ⅔

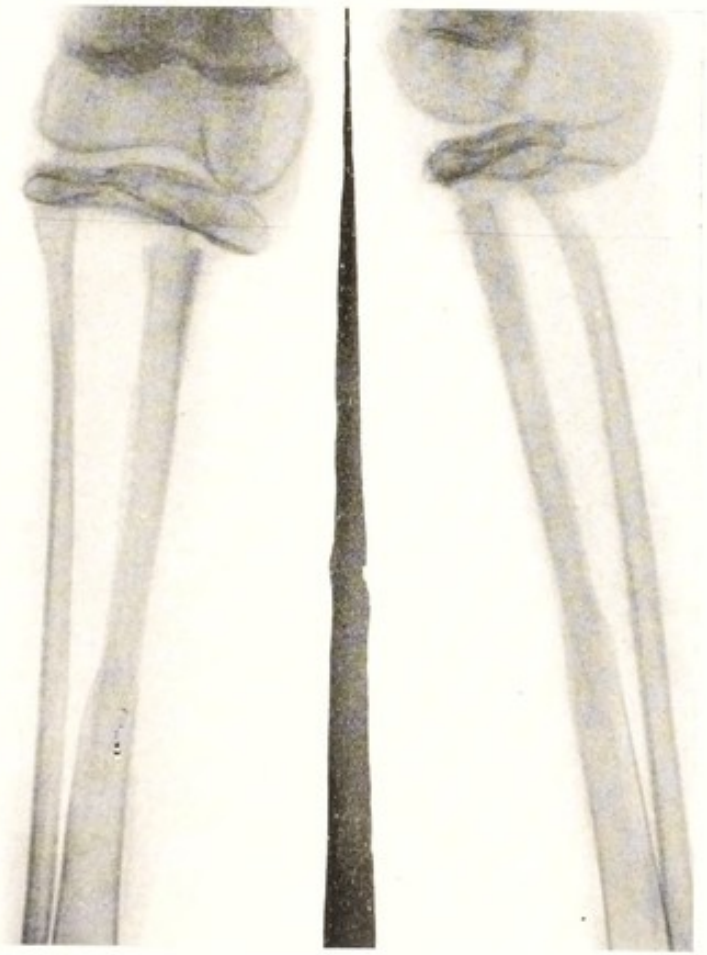


FIG. 650.—Fibrocystic disease of tibia. Restoration of upper half of tibia (after its eradication for fibrocystic diseases) by bone-graft. (Case of, and operation by Dr. Michael Hoke, Atlanta, Georgia.)

Pathology.—Two definite types of these conditions are recognized pathologically in the upper end of the femur.

(*a*) *Young Children*—Simple cysts are the rule in these subjects, the cysts closely resembling those of the upper part of the humerus, both clinically and pathologically. The cyst-wall contains fibrous tissue in various stages of organization, cartilage, bone exhibiting absorption and deposition, and hemorrhages.

(*b*) *All Ages.*—Pathologically the tumor is a mass of new growth containing one or more cysts. In its early stages, the cyst is the more important, the growth extending later. The structure of the solid mass consists variously of cartilage (hyaline or fibrous) spicules of bone showing deposit by



FIG. 651.—Fibrocystic disease of upper end of tibia.

osteoblasts and absorption by osteoclasts, fibrous tissue of all sorts, and foci of myxomatous degeneration. In fact the whole pathological picture is very complex.

Lower End of the Femur.—Cysts in the lower end of the femur are comparatively rare. Some occur as simple cysts or as osteitis fibrosa; others exhibit some analogy to myeloid sarcoma.

Tibia.—Several distinct types of fibrocystic disease have been found in the tibia. Cysts in the upper end of this bone resemble those in the upper part of the humerus in their clinical and pathological characters (Figs. 650, 651 and 652).

They occur in young people, often arise, or are first noticed, after an in-

jury. Pain and swelling are the leading features. Cureting has invariably resulted in cure.

In the majority of cases recorded of the tibia the cysts were simple, lined by fibrous tissue with a few patches of cartilage and showed no evidence of growth. Others showed in places at least, the structure of a myeloma. Another type of cyst in this locality is the periosteal cyst lying external to the cortex of the bone. Still another variety has been recorded in which there is a development of large masses of tissue of fibrous nature in the tibia; a case described by Pitts and Shattock (ref.: Trans. Path. Soc., 1897, xlviii, 176) as non-calcifying plastic osteitis of the tibia, is probably of the same nature.

Hands and Feet.—Cysts in the carpal and tarsal bones are exceedingly rare. Cysts of the carpal scaphoid, astragalus and os calcis (Fig. 653) have been reported, but most of the cysts of metacarpal and metatarsal bones and phalanges have been definitely myxomatous structures from degeneration of enchondromata.

Patella.—Only one case has been recorded, that of a cyst around a splinter of metal. It is of interest as being, according to Elmslie (*loc. cit.*), the only recorded case of simple cyst of bone around a foreign body.

Skull.—Several cases are on record of cysts of the skull associated with surrounding osteitis fibrosa.

Pelvis.—Instances have been noted of multilocular cyst of the ilium and of cyst of the sacrum.

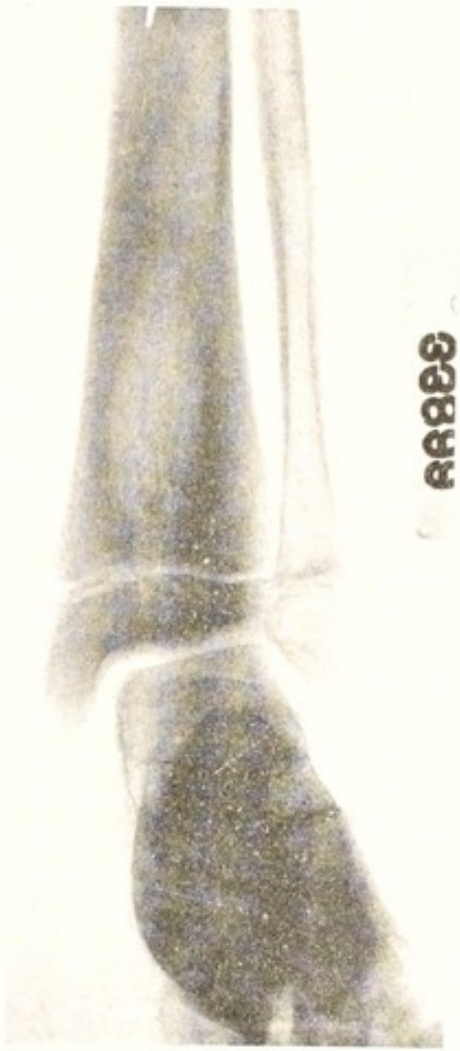


FIG. 652.—(J. A.) Bone cyst of lower end of tibia. Trap-door of periosteum and bone was turned up by operation, cyst-wall removed, cavity filled with Mosetig-Moorhof bone-plugging material and trap-door closed and sutured. Satisfactory result.

MULTIPLE LESIONS

Cystic tumor or fibrocystic disease of more than one bone, has been frequently reported. They apparently belong to more than one pathological group.

SUMMARY OF CLINICAL TYPES OF FIBROCYSTIC DISEASE

Their Relationship and Pathology (after Elmslie, *loc. cit.*).—The following classification may be made:

1. *Simple Single Cysts.*—Locations: upper end of humerus, neck of the femur in young children, lower end of the femur and occasionally in other bones.

2. *Cysts Resulting from Alteration in Myelomata.*—Locations: clavicle, radius, lower end of femur, tibia, fibula.

3. *Cysts Intermediary Between These.*—Scraps of myeloid tissue are found in what was apparently an innocent cyst. Locations: humerus, lower end of femur, tibia and fibula.

4. *Fibrous Osteitis.*—Cysts embedded in masses of composite tissue. Locations: Femur, tibia and skull.

5. *Fibrous Osteitis without Cysts.*—Location: tibia.

6. *Multiple Cysts.*

7. *Multiple Lesions.*—Some cysts, some solid tissue containing cysts, some solid tissue without cysts.

8. *Myeloid sarcomata and cysts*, in a diffuse disease of the bones which has caused softening and fracture.

Treatment

Humerus.—The treatment of these cysts of the humerus has varied from no treatment at all to amputation of the limb. In some cases the



Fig. 653.—Cyst of os calcis. This is an unusual location for this condition.

enveloping bone has been apparently strengthened after fracture, subdivision of the cyst by trabeculæ occurring and the arm acquiring strength thereby. In some cases, after repeated fracture, the growth of the cyst has apparently ceased.

The usual treatment of these cysts has been to incise and curet them, the wound being sometimes closed, and sometimes packed with gauze and allowed to granulate.

Resection of the affected portion of the bone, with transplantation of an autogenous bone-graft taken from either the tibia or fibula, is however, a more satisfactory and effective method and is the procedure adopted by the author. In cases with a gradual extension of bone involvement, with or without pain, accompanied by weakening of the structure with varying

degree of deformity and at times fracture, either the segment of bone affected should be removed and a graft of bone removed preferably from the tibia—substituted or (see Fig. 750) if there is but a small portion of the diameter of the bone involved, that portion can be chiseled and cureted away and a graft of bone implanted by the inlay method to reinforce the weakened area. Numerous cases of this character have been experienced where, if substitution had not been made by some means, as by grafting bone, great bowing, shortening and crippling deformity would have resulted, or even amputation would have been deemed advisable.

In cases where thorough cleaning out of this cystic fibrous portion has been effected, fracture of the weakened wall has taken place, either at the time of operation or at some subsequent period. An autogenous graft of bone properly adapted and accurately contacted or inlaid throughout the weakened area, fulfills all requirements in strengthening and preventing further distortion or loss of function by excessive shortening.

The author believes that in all instances when possible, the inlay method of fixing the graft into the fragments on either side of the hiatus left by the removal of the tumor should be employed.

Femur.—The statements made on pathology in the treatment of cysts of the humerus, apply with even greater force here where the affected bone is required to support the superimposed body-weight, *i.e.*, that the affected segment of bone should be removed in toto and a bone-graft substituted for the resected portion of the shaft, or in case *only* a small part of the diameter is involved, it should be chiselled and cureted away, and a graft implanted by the inlay method to reinforce the weakened area and to prevent fracture of the bony wall which has been weakened by operation and attenuated by resorption of bone.

Murphy ("Surgical Clinics," Vol. 2, No. 5) reports three instances where such a procedure was adopted by him in osteitis fibrosa cystica of the upper end of the femur, tibia, and humerus. The first case was that of a male, twenty-seven years of age who applied for treatment on account of deformity of the right thigh. The history states that when the patient was nine years old (1895) he fell, while running, and landed on both knees, striking harder on the right than on the left. He could not get up on account of severe pain extending from the right hip to the knee. He was confined to bed for two weeks after the injury and had pain in the right thigh for the next two months. No chills or fever. When fourteen years old (1900) he tried to jump, slipped and fell, one leg extending forward, the other backward. He immediately had severe pain in the right thigh just below the hip, was unable to rise and was carried home. Acute pain continued for the next two weeks, shooting in character extending down the right thigh to the knee. The slightest movement of the leg increased the severity of the pain. It gradually subsided, but continued as a dull pain for the following three months. At the end of three months he was able to walk and after six months was free from pain. When the pain ceased he noticed a change in his gait. The right leg seemed to be shorter than the left and slight bowing appeared in the upper third of the thigh. Röntgenograms were taken and it was judged that a greenstick fracture had occurred with a possible focalization of a low type of infection. Bowing gradually increased and after walking a little distance pain was experienced; shortening was compensated for by the addition of a high shoe. There was a history of a Neisserian infection: he had also had measles, scarlet fever, whooping-cough and pneumonia. No history of lues. Family history negative.

The Application of the Autogenous Bone-graft in the Operative Treatment of Osteitis Fibrosa Cystica in the Upper End of the Femur.—The technic of operation was as follows: An incision was made on the outer aspect of the thigh, between the flexor and extensor groups of muscles and directly over the lesion: by resecting the soft parts the tumor was exposed. The overlying periosteum was incised and easily lifted free by a periosteal elevator, as it was deemed advisable to save it. The canopy or roof of the tumor was broken down with a chisel so as to expose the underlying cyst pockets, which

were cleaned out thoroughly preparatory to inserting the transplant, which was applied on the slant through the affected area. The lining granulation tissue was removed with a curet. The walls between the pockets were broken down sufficiently to admit the graft. Care was taken not to fracture the femur during this process, as the result of this cleansing out of the cyst pockets left but a thin cortex to the shaft. From the crest of the tibia of the other leg, a graft with its periosteal covering attached was removed in the usual way, the transplant measuring 7 inches in length by $\frac{1}{2} \times \frac{1}{4} \times \frac{3}{8}$. The graft was placed in its bed and the wound closed by approximating the cut edges of the aponeurosis with plain catgut, and the skin edges with horsehair. (For detailed technic of method of inserting graft, see Chapters XVII and XXX.) By placing the aponeurotic sutures well back from the edges, the muscle was caused to roll into the bone cavity and fill it when the suture was drawn taut. As both ends of the graft were securely bound by a shelf of bone, no nailing was necessary. The periosteal surface of the graft was turned outward. The usual dressing was applied, and a Buck extension with a 25-pound weight attached. The patient remained in bed for seven weeks with extension. The wound healed *per primam*. The stitches were removed on the seventeenth day, when the first dressing was made. After seven weeks the patient was allowed up and about on crutches. He was without pain or discomfort in the leg.

The author believes that in all instances, when possible, the inlay method of fixing the graft into the fragments on either side of the hiatus left by the removal of the tumor should be employed whether or not the whole diameter of bone has been removed (see Fig. 749).

CHRONIC (NON-SUPPURATIVE) HEMORRHAGIC OSTEOMYELITIS (Barrie)

According to Barrie (Barrie, George, "Hemorrhagic Osteomyelitis," Surg. Gyn. and Obst., vol. xix, No. 1, July, 1914, p. 42) "the term hemorrhagic osteomyelitis is meant to embrace a majority of those traumatic, localized, non-infective (so far as we know at present) non-suppurative, low grade, inflammatory lesions that have their onset in spongy bone."

Under the single heading "Hemorrhagic osteomyelitis" and its division into two forms, Barrie includes the different phases which the chronic lesion assumes. He offers the following classification:

HEMORRHAGIC OSTEOMYELITIS

Traumatic. Localized. Non-infective. Non-suppurative.
(Acute, never observed).
Chronic:
Type A.—Hemorrhagic (shows little or no metaplastic change).
Type B.—Fibrocystic (due to later metaplasia).
(A) *Chronic hemorrhagic osteomyelitis:*
Synonyms:
1. Medullary giant-cell sarcoma.
2. Myelogenous giant-cell sarcoma.
3. Myeloma.
4. Medullary giant-cell tumor (Bloodgood).
(B) *Chronic fibrocystic osteomyelitis:*
Synonyms:
1. Benign bone cyst.
2. Osteitis fibrosa.
3. Chronic osteomyelitis fibrosa, cystic or solid (Bloodgood).
4. Traumatic solitary bone-cysts (Felten and Stolzenberg).

The disease occurs in or near the ends of the long bones, and is usually classified as above. However, Barrie considers these terms in his classification as misnomers, and believes that hemorrhagic osteomyelitis should be classified with the inflammations or granulomata.

The apparent "giant-cell riot" in this lesion has, according to Barrie, caused it to be known as medullary giant-cell sarcoma, whereas these giant-cells are merely scavengers and similar to those found in other pathological processes involving bone, and are therefore simply foreign body giant-cells.

Clinical Features.—There are no acute inflammatory symptoms, and in fact no clinical manifestations of any other sort in the acute stage. Clinical features are wanting until many months have elapsed from the onset.

Inception in the chronic stage occurs in the same areas of bone structure as in the acute form, but the process is extremely slow. The lesions are due probably to mechanical pressure-necrosis. There is no suppurative evidence of cell death, but abundant proof is not lacking of attempted repair and regeneration in the presence of granulation tissue. Coincidently there occur continuous trauma from pressure necrosis, death of the delicate bony cancellous structure, and regeneration, with efforts at repair by the formation of granulation tissue. The granulations persist as such indefinitely, without change to connective tissue. These fungoid formations constitute granulomata. The presence of great numbers of giant-cells in the inflammatory lesions indicates a low grade, non-suppurative form of inflammation; their sole function is the removal of injured or dead extraneous products surrounded by or embedded in the granulation tissue. Barrie believes that the overproduction of granulation tissue is the result of more or less constant irritative changes which take place within the bone and that it does not represent true tumor growth; the process of repair in bone is slow compared with that of the soft tissues.

Chronic hemorrhagic osteomyelitis is frequent in children, as the result of injury to the ends of the long bones; the reparative processes, however, are sufficiently active in children to prevent any progressive chronic stage. The duration of the disease is several months to several years. The increase in size of the affected bone is very slow and is characterized by spheroidal expansion; the mass very rarely breaks through the capsule. Slight traumatization may inaugurate this low grade mild inflammatory process, in which destruction constantly proceeds while regeneration produces no more than a primitive granulation tissue. If regeneration is sufficiently active to convert the granulation tissue into connective tissue, retraction of the structure takes place with the development of the so-called osteitis fibrosa, with or without cyst formation.

It has been shown that temporary ligation of an animal's leg for ten to fourteen hours caused extravasation and circumscribed hemorrhage into the marrow of the bones (Ullman).

A kick or sprain may injure the highly vascular and delicate tissue and cause effusion, with damage to the bone from interference with its nutrition. Minute fractures of the bony trabeculæ are occasionally found after such injuries. This destruction of the trabeculæ removes support from the venous sinuses, causing thinning, dilatation, and varicosity, with transudation and possible rupture. These varicose vessels, with the surrounding granulation tissue, aid the pressure-necrosis of the bony canals, and the chronic inflammation stimulates the reticulum of the bone-marrow to increased proliferation of granulation tissue.

Clinical Diagnosis.—The clinical diagnosis is based on the following data: (1) Age of patient. (2) Duration of the lesion (a slow, chronic inflammation occupying a period of months or years). (3) The onset of trauma of

greater or less severity. (4) Pain, not marked until the swelling has noticeably increased near the joint. (5) Tenderness, constantly present from the beginning. (6) *X*-ray appearance; circumscribed erosion of bone; a mass may protrude through the lesion. A point in the differentiation from a bone-cyst is the fact that the latter, as a rule, has a complete, distinct investment of cortex in which erosion rarely occurs, while in chronic osteomyelitis hemorrhagica the bony shell is very frequently eroded.

Pathology.—Fresh material has a typical appearance. It consists mainly of vascular granulation tissue unsupported by connective tissue, is deep red in color, and oozes without being handled. Disseminated areas of hyalin thrombosis and fresh blood-clots in a smooth mass of myxomatous character frequently appear. Areas of adult connective tissue may or may not be present, together with patches of osteitis fibrosa.

Treatment.—The only satisfactory treatment is operative interference, which should, however, be confined to the area of bone which is diseased, and consists of the thorough removal of unhealthy exuberant granulation tissue and inflammatory débris, followed by packing the cavity, or, as advised and performed by Bloodgood, transplanting bone to the resulting cavity. Bloodgood states (Annals of Surg., lvi, 1912, p. 237; Ibid., August, 1910) that he was the first to recommend and practise direct transplantation into the bone cavity after cureting. The Esmarch bandage should always be applied prior to this operation. The cavity should be swabbed out with iodin, which not only does not cause necrosis of tissue, but by its irritant properties stimulates the growth of healthy granulations. If preferred, a Mosetig-Moorhof plug or Beck's bismuth paste may be used or the cavity may be packed with iodoform gauze. Amputation is never required.

Summary.—The affection begins from trauma. The clinical and pathological picture is that of a low-grade inflammation, a granuloma. The enormous number of giant-cells is no indication of malignant new growth but is simply indicative of phagocytosis. The etiological picture is that of a low grade, ever-present irritant or inflammatory process resulting in the formation of masses of vascular granulation tissue.

III. MALIGNANT NEOPLASMS

Malignant tumors of bone are either primary or secondary. *Primary* tumors are sarcomata and endotheliomata. *Secondary* growths arise by direct extension from some adjacent focus or by metastasis, and are composed of cells akin to those of the primary tumor.

Primary Malignant Newgrowths

1. **Sarcomata.**—The sarcomata vary in character according to the amount of cellular tissue they contain, the size and nature of the individual cells and the quantity of connective tissue present in them.

(*a*) *Cellular Variety.*—These consist of a mass of soft, rapidly proliferating cellular material with little or no connective tissue framework. The individual cells are spindle, round or oval. The tumor originates in the medulla, epiphysis, or periosteum of the long bones or in the cancellous tissue of the skull, pelvis, vertebræ (Figs. 654 and 655), and jaws.

The small round-celled sarcoma is the most malignant of this variety. It grows very rapidly and metastasizes early. Highly cellular sarcomata cause destruction rather than expansion of bone, hence early spontaneous fracture is often the first sign of their existence.

(*b*) *Connective Tissue Variety.*—In this variety the connective tissues (*e.g.*, fibrous tissue, cartilage, and bone) are intermingled with cellular elements. Their usual origin is in the deep layer of the periosteum, and hence they are known as "periosteal" sarcomata (Fig. 656). Ossification of these sarcomata is quite common, and the result is a peculiar coral-like formation. After penetrating the periosteum, they often appear superficially as fungous masses. There is often a history of injury prior to their appearance. The cells of connective tissue sarcomata are usually spindle-shaped, but they may be round, oval, or mixed. When these tumors contain bone,

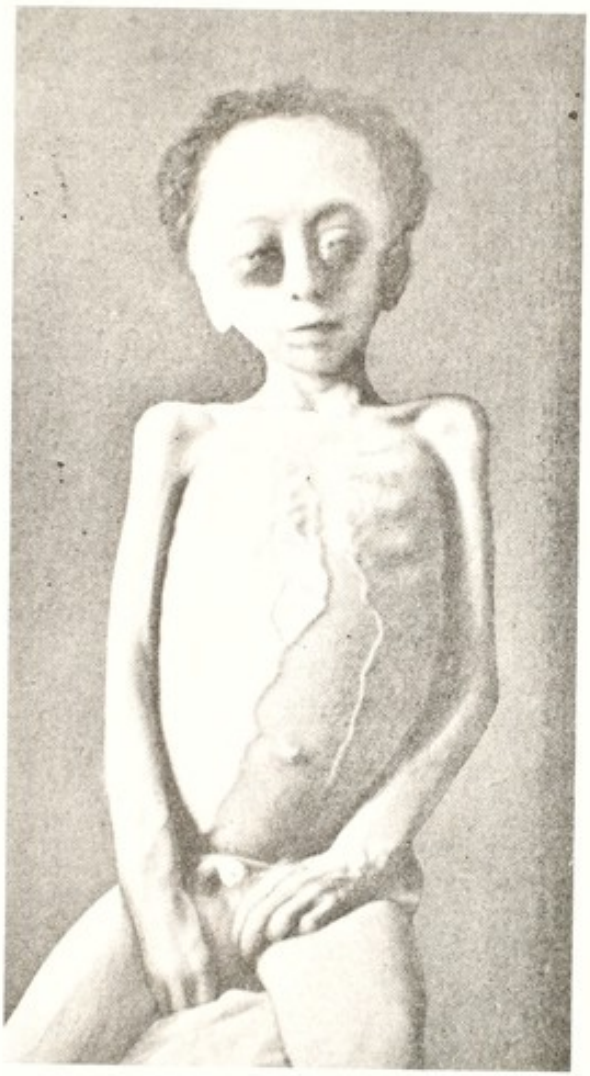


FIG. 654.—Sarcoma of spine, showing disturbance of venous circulation and metastatic growth in orbit. (James K. Young.)

fibrous tissue or cartilage, they are variously designated fibrosarcoma, osteosarcoma, and chondrosarcomata.

From their point of origin on the surface of the bone, they grow in both directions, toward the surface where they form a circumscribed swelling, and inward, replacing the medulla with a white new growth.

Clinically they are commonest in children and in adults under thirty. The younger the patient, the greater the malignancy of the growth. They rapidly metastasize, chiefly to the loins. The commonest locations of sarcomata of bone are the region of the knee-joint, the upper end of the humerus and the fibula. Eggshell crackling (crushing of the thin shell of bone and

of the coral-like formations of new bone) is characteristic on palpation. The tissues overlying the growth gradually become edematous and occasionally present signs of inflammatory reaction, if the tumor is of very rapid growth.

Diagnosis.—The *x*-ray is the most valuable aid to diagnosis. The diffuse outline and coral-like formation of new bone with elevation and obliteration of the periosteum, are very suggestive.

If the *x*-ray picture is not confirmatory of sarcoma, an exploratory incision, removal of a segment of tissue, its immediate microscopic examination, followed at once by operative removal of the tumor (if sarcomatous), are justifiable.

Errors in diagnosis are caused by confusion of sarcoma with chronic periostitis, osteitis, myelitis, and tuberculous or syphilitic osteitis.

Prognosis.—The outlook depends upon several factors, viz.: (*a*) *character* of the tumor, periosteal being more malignant than central sarcomata.



FIG. 655.

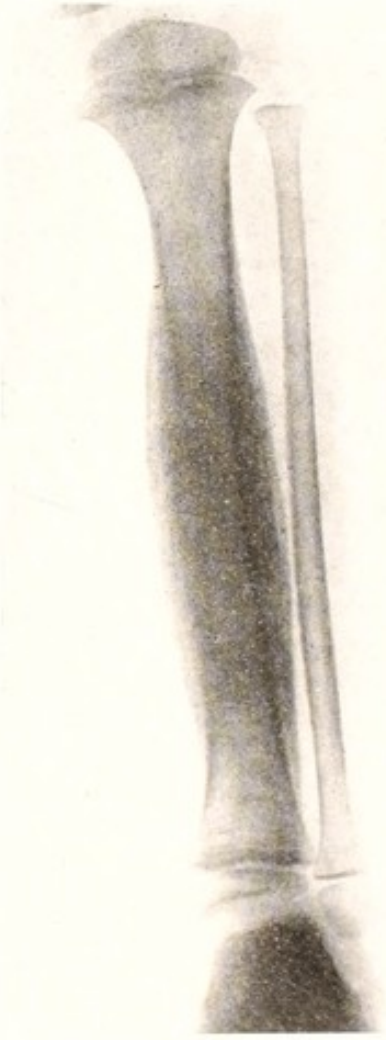


FIG. 656.

FIG. 655.—Sarcoma of spine, showing deformity. (James K. Young.)

FIG. 656.—Periosteal sarcoma of tibia. Attention is called to the laminated appearance of the growth and to the fact that the growth has extended completely around the bone. Such tumors, if seen early, may be resected and bone restored by bone-graft.

(*b*) *Accessibility*, *i.e.*, as regards operative removal, sarcomata of the cranial and pelvic cavities offering a very grave prognosis.

(*c*) *Age of the Patient.*—The younger the subject the more malignant the growth, *e.g.*, a child with periosteal sarcoma of the hip or femur usually succumbs in eight to nine months.

reatment.—In periosteal and central sarcomata of very rapid growth amputation may in certain cases be imperative either at a considerable distance above the tumor or at the joint immediately above.

In the more benign types of sarcomata resection of the affected portion of bone and restoration of the resulting defect by substituting portions of other healthy bones or by bone-grafts give the most satisfactory results.

Schulze-Berge (Centralbl. f. Chirurg., No. 48, 1913) records the case of a patient, a woman twenty-six years, with a spindle-cell sarcoma of the head of the tibia. As no fresh joint was available for transplantation, the writer endeavored to preserve a useful leg, though abandoning motility in the knee-joint. After resection of the diseased articular end of the tibia to an extent of about 8 cm., the femoral condyle as well as the head of the fibula was freshened and, for the substitution of the tibia, a piece of the fibula of the healthy side, of suitable length, was transplanted into the tibia as well as into the femoral condyle. The transplanted bone segment healed solidly in place, although the covering of the soft parts could not be firmly applied around the transplanted bone, which led to suppuration.

Röntgenograms taken one year later showed that the transplanted bone had attained the strength of the tibial diaphysis by periosteal proliferation. In the lower half, the transplanted bone had disappeared through absorption while in the upper half it still remained viable. The leg was solid, except for possibly slight motion from before backward.

In the case of a young woman suffering from sarcoma of the distal fragment of the radius, Walther performed a resection, followed by substitution for the defect of a bone fragment from the proximal end of the fibula. The patient made a good recovery, and was enabled to make use of her hand about two months later, with almost normal mobility of the wrist and fingers.

Rovsing reported a case of sarcoma of the internal condyle in which a resection of the lower end of the femur was performed and a temporary insertion of a piece of humerus was applied, articulating with the tibia, in order to preserve the length and form of the leg while the patient was under observation for a recurrence. No recurrence having taken place at the end of two and one-half months, the dead humerus was replaced by a femur newly amputated from another individual, after freshening the upper end of the tibia. The patient made a good recovery, was free from recurrence one year after the first operation, able to walk with a cane, and in a condition to work.

This case is illustrative of an important principle, *i.e.*, the support and the prevention of shortening of a limb from which a malignant bone growth has been removed, the hiatus being supplied by a temporary graft until sufficient time for observation as to a recurrence has elapsed, or until suitable material for a permanent joint-graft can be obtained, although the author prefers to insert the graft at first hand.

2. **Endotheliomata.**—These are rather rare tumors of bone. They have their origin in the lining membrane of blood-vessels supplying nourishment to the bone, and may also arise from synovial membrane, sinuses, and lymphatics. Goldthwait, Painter, and Osgood (Dis. of Bones and Joints, p. 376) cite a case of angioma of the knee which they state is the only neoplasm of this description within their knowledge. Pulsating aneurism may result from an endothelioma of vascular origin.

3. **Myelomata.**—This tumor, although occasionally metastasizing and causing destruction of the bone cortex, should properly be classed with the benign new growths. It arises in the bone-marrow and occurs as a systemic affection of the marrow cells. There are two kinds of myelomata, each composed of a different variety of cell, viz.: (*a*) lymphoid myeloma and (*b*) *myeloid* myeloma; the former is gray or reddish gray on section, while the latter is deep red and soft. Both encroach upon and erode the cortex, produce fracture at such weakened spots, and, associated with both types,

the urine contains a peculiar albumose (Bence-Jones protein). Cystic formation is common in myelomata, the cystic contents consisting of serum or blood.

Myelomata are commonest in early midlife. The most frequent locations are the lower end of the femur, the upper end of the tibia, the lower end of the fibula, and the distal extremity of the radius. Growth is slow, and for a considerable time, painless. The size of the tumor may mechanically interfere with the joint in its immediate neighborhood. In its *x*-ray appearances it may be mistaken for a cyst. In case the bony cortex, soft tissues and skin are all perforated in the course of its growth, the tumor presents a fungating, readily bleeding surface.

W. G. MacCallum (Text-book of Pathology, 1916, p. 776) cites a case where there were no tumors springing from the bones, but nearly all the ribs were broken and the thorax collapsed.

Treatment.—In early cases, when the myeloma is circumscribed, enucleation may be possible. In later cases, resection of the affected segment of bone with restoration of the defect by bone-graft, is the most satisfactory treatment (see Fig. 749).

Secondary Malignant Newgrowths

Any form of malignant tumor may occur in bone by metastasis, especially from the breast, the new growth always partaking of the nature of its prototype. Secondary carcinoma of bone may be the result of direct extension to the bone of a neighboring neoplasm.

Pulsating Sarcoma and Aneurism of Bone.—These originate in congenital nevi or angiomata, vascular cysts in myelomata, endotheliomata or sarcomata. Sinus tracts are developed in these neoplasms at the expense of the tumor substance. Their location is generally the epiphysis of a long bone. They resemble true aneurisms in their expansile pulsation and bruit, with the additional phenomenon of the so-called eggshell crackling which is frequently present.

Treatment.—Treatment depends upon whether the pulsating tumor is benign or malignant in character. If purely benign, ligation of the main artery of the affected limb should be practised. If malignant, resection of the affected portion of bone should be performed, with restoration of the defect by bone-graft or in the event of extensive malignant disease, amputation of the affected limb may be demanded.

REFERENCES

FIBROCYSTIC DISEASE OF THE BONES

Albarran: Rev. de Chir., 1888.
Alberta: Provence Med., 1890.
Adams: Trans. Path. Soc., v, 254, 1854.
Almerini: Zeit. f. Krebsforsch., vii, 389, 1909; Centralb. f. Chir., xxxvi, 809, 1909.
Anschütz: Münch. med. Woch., lv, 1717, 1908; Ibid., lvi, 2083, 1909.
D'Arcis: Archiv. Internat. d. Chir., ii fasc. 6, 1906; Centralb. f. Chir., xxxiii, 602, 1906.
Baer: "Discussion on Silver's Paper."
Battle: Clin. Soc. Trans., xxvii, 290, 1894.
Beck, Carl: Archiv. f. klin. Chir., lxx, 1099, 1903; Amer. Jour. Med. Sci., cxxi, 666, 1901.
Billroth: Wien. med. Blat., vii, 238, 1884.
Blake: Boston Med. and Surg. Jour., clv, 267, 1906.
Bland-Sutton: Trans. Roy. Soc. Med., vi, 1912–13, Surg. Sect., 11.
Bloodgood: Jour. Amer. Med. Ass'n, Oct. 15, 1904; Progr. Med., 1903; Ibid., 183, 1904; Ibid, 275, 1905; Ann. of Surg., lii, 145, 1910.

Bockenheimer: Archiv. f. klin. Chir., lxxxi, 230, 1906; Ibid, lxxxv, 549, 1908.
Borchard: Deut. Zeit. f. Chir., xciii, 1, 1908.
Boström: Festschr. d. Naturforscherversamml. im Freiburg, 50th Congress, 89, 1883.
Böttcher: Verhand. d. deut. Gesell. f. Chir., 276, 1903.
Brade: Münch. med. Woch., lviii, No. 27, 1454, 1911.
Braun: Beit. zur klin. Chir., lii, 477, 1906.
Von Brunn: Ibid., xlv, 344, 1905; Ibid., 1, 70, 1906.
Buchanan: Glasgow Med. Jour., xvii, 340, 1882.
Butlin: Trans. Path. Soc., xxxi, 277, 1880.
Carle: Lyons Med., No. 27, 1878.
Chiari: Wien. med. Woch., No. 9, xxviii, 204, 1878; Verhand. d. deut. path. Gesell., 1904.
Codman: Boston Med. and Surg. Jour., cliii, 211, Feb. 25, 1904.
Cohn: Deut. med. Woch., xxxiii, 570, 1907.
Corson: Ann. of Surg., xxxv, 505, April, 1902.
Curtis: Amer. Jour. Med. Sci., cvi, 30, 1893.
Czerny: Wien. med. Woch., 894, 1873.
Decken: Dissert., Giessen, 1900.
Deetz: Beit. zur klin. Chir., xxvi, 120, 1900.
Dreesman: Centralb. f. Chir., xxxi, 1323, 1903.
Dumreicher: Woch d. Wien. Aertze, No. 6, 1868.
Von Eiselsberg: Archiv. f. klin. Chir., lxxxi, 20, 1906.
Elmslie: Trans. Roy. Soc. Med., iii, Clinical, 102, 1909–10; Brit. Med. Jour., Nov. 16, 1912; St. Barts. Hosp. Rep., xlviii, 73, 1912.
Engel: Dissert., Giessen, 1864.
Eve: Trans. Path. Soc., xxxix, 272, 1888.
Fedden: Trans. Roy. Soc. Med., iv, Clinical, 130, 1910–11.
Felten and Stoltzenburg: Zeit. f. orth. Chir., xxx, 437, 1912.
Fleischaner: Deut. med. Woch., No. 19, 1905.
Frangenheim: Deut. Zeit. f. Chir., xc, 87, 1907.
Franke: Verhand. d. Gesell. f. Chir., i, 71, 1912.
Fraenkel: Ibid., 1904.
Froriep: Chir. Kupfertafeln, Tafeln 438, 439, 440, 1826.
Fujii: Deut. Zeit. f. Chir., cxiii, 1, 1911; Ibid., cxiv, 25, 1912.
Garré: Monograph.
Gask: Brit. Jour. of Surg., i, No. 1, 49, 1913.
Gehring: Dissert., January, 1910.
Glimm: Deut. Zeit. f. Chir., lxxx, 476, 1905.
Goldefroy: Thése, Paris, 1882.
Goldmann: Münch. med. Woch., xxxiv, 1902.
Gosselin: Clin., iii, 1879.
Gottstein: Jahresber. d. Schles. Ges. Varterl. Cultur., lxxxi, 132, 1903.
Gould, Pearce: Trans. Roy. Soc. Med., iii, Clinical, 194, 1909–10.
Von Haberer: Archiv. f. klin. Chir., lxxvi, 530, 1905; Ibid., lxxxii, 873, 1907; Ibid., xciii, 701, 1910; Centralb. f. Chir., xxxviii, 33, 1911; Beiträge.
Von Hacker: Wien. klin. Woch., No. 1, 1908.
Halstead: Johns Hopkins Hosp. Bull., xv, 262, 1904.
Hart: Beit. z. path. Anat., xxxvi, 559, 1904.
Hartmann: Beit. zur klin. Chir., lxxiii, 627, 1911.
Heath: Trans. Med. Soc., London, xxxiv, 252, 1911.
Heineke: Beit. zur klin. Chir., xl, 481, 1903.
Helbing: Verhand. d. deut. Gesell. f. Chir., 1902; Centralb. f. Chir., xxix, Supplement, 138, 1902.
Hirschberg: Beit. zur. path. Anat., vi, 511, 1889.
Hunt: Centralb. f. Chir., 1904.
Hugel: Münch. med. No., 14, li, 430, 1904.
Joachimsthal: Berlin klin. Woch., xlviii, 685, 1911.
Jones and Morgan: "Archives of the Röntgen Ray," xi, 336 and 343, 1907.
Josserland et Bérard: Rev. de Chir., xv, 136, 1895.
Kammerer: Ann. of Surg., xxxix, 105, 1904.
Kaposi: Jahresber. d. Schles. Ges. Varerl. Cultur., lxxxvi, 241, 1908.
Kehr: Deut. zeit. f. Chir., xliii, 180, 1896.
Kidd: Trans. Roy. Soc. Med., iv, Clinical, 106, 1910–11.
Knaggs, Lawford and Gruner: Ibid., ii, Pathological, 26, 1908–9.
Koch: Archiv. f. klin. Chir., lxviii, 977, 1902.
König, F., Jr.: Ibid., lvi, 607, 1898.
König: Sr. Verhand. d. deut. Gesell. f. Chir., i, 174, 1906; Centralb. f. Chir., xxxiii, 1906, Supplement, 26.
Körte: Verhand. d. deut. Gesell. f. Chir., i, 194, 1906; Deut. Zeit. f. Chir., xiii, 42.

KONJETZNY: Beit. zur klin. Chir., lxviii, 1910; Münch. med. Woch., 2083, 1909.
KROGIUS: Finska Läkaresällskapets Handlingar, lv, 291, 1913.
KÜSTER: Archiv. f. klin. Chir., lv, 594, 1897.
LABERT: Atlas.
LEDIARD: Trans. Roy. Soc. Med., iv, Clinical, 132, 1910–11; Lancet, clxxx, 736, 1911.
LETT: Lancet, ii, 1202, 1910; Trans. Roy. Soc. Med., iii, Children, 98, 1909–10.
LEXER: Archiv. f. klin. Chir., lxxxi, 363, 1906; Verhand d. deut. Gesell. f. Chir., 1906.
LOW, WARREN: Trans. Med. Soc. London, xxxiv, 414, Nov., 1910; Ibid., 1913–1914.
MCDILL: Ann. of Surg., lviii, 553, 1913.
MAUCLAIRE AND BURNIER: Archiv. Gén. de Chir., Aug., 1911.
MEISSNER: "Zur Pathogenese der Kochencysten." Dissert., Erlangen, 1884.
VON MIKULICZ: Centralb. f. Chir. xxxi, 1323, 1904.
MILLNER: Deut. Zeit. f. Chir., xciii, 328, 1908.
MÖNCKEBERG: Verhand. d. deut. path. Gesell., 232, 1904.
MOSER: Beit. zur klin. Chir., xxv, 503, 1899.
MÜLLER: Univ. Penn. Med. Bull., Sept., 1906.
MUMMERY, LOCKHART: Trans. Roy. Soc. Med., iii, Clinical, 195, 1909–10; Ibid., Children, 99.
MURPHY: Surgical Clinics of J. B. Murphy, Aug., 1913.
NÉLATON: Elements de Path. Chir., ii, 48, 1847.
PAUS: Surg., Gyn. and Obst., Internat. Abstract, 635, Dec., 1913.
PERCY, J. F.: Ibid., xvii, 536.
PERTHES: Münch. med. Woch., lv, 1400, 1908.
PFEIFFER: Beit. zur klin. Chir., liii, 473, 1907.
PITTS AND SHATTOCK: Trans. Path. Soc., xlviii, 176, 1897.
POLLARD, BILTON: Ibid., xxxvi, 388, 1895.
PONZIO: Archiv. di Ortoped., xxix, 293, 1912.
VON RECKLINGHAUSEN: Festschr. f. Virchow. d. Assistenten, 1891; Tagebl. d. Naturforscherversamml, Heidelberg, 321, 1889; Unterschunger über Rachitis u. Osteomalacie, Jena, 1910.
REHN: Beit. zur. klin. Chir., 1911; Verhand. deut. Gesell. f. Chir., 1904.
RETZLAFF: Münch. med. Woch., lviii, 874, 1911.
RIEDEL: Verhand. d. deut. Gesell. f. Chir., i, 174, 1906.
RITTER: Deut. Zeit. f. Chir., xciii, 166, 1908.
RÖPKE: Archiv. f. klin. Chir., xcii, 126, 1910.
ROUGHTON: Lancet, i, 973, 1909.
RUMPEL: Münch. med. Woch., liv, 1507, 1907.
SCHLANGE: Archiv. f. klin. Chir., xxxvi, 117, 1887; Ibid., xlvi, 373, 1893; Verhand. d. deut. Gesell. f. Chir., i, 173, 1906; Beit. z. anat. u. klin. Kenntnis der Cyst. in den lang. Röhrenkn., Fests. für Esmarch, 431.
SCHMEIDEN: Deut. Zeit. f. Chir., lxx, 207, 1903.
SCHMIDT: Ergeb. d. path. Lubarsch, Ostertag., 5 and 7.
SCHMORL: Verhand. d. deut. path. Gesell., 1904; Ibid., 1907.
SCHÖNENBERGER: Virchow's Archiv., clxv, 189, 1901.
SILVER: Amer. Jour. Orth. Surg., ix, 563, 1912.
SIMMONS: Boston Med. and Surg. Jour., clxi, 393, 1909.
SOLLY: "Cysts in Mollities Ossium." Med. Chir. Trans., xxvii, 1844.
SONNENBURG: Deut. Zeit. f. Chir., xii, 314, 1879–80; Fortschr. a. d. Gebeite. d. Roetgenstrahlen, viii.
STILLING: Virchow's Archiv., cxix, 542, 1890.
STUDENY: Arch. f. Chir., xcii, 495, 1910.
STUPARICK: Wien. med. Presse, No. 49, 1901.
STRUMPF: Deut. Zeit. f. Chir., cxiv, 417, 1912.
TIETZE: Beit. zur klin. Chir., lii, 495, 1906; Verhand. d. Gesell. f. Chir., i, 167, 1906.
VIRCHOW: Monatsbericht. d. kgt. Akad. d. Wissenchaften, 369, 1876; Virchow's Archiv., lxx, 502.
WHITMAN: Ann. of Surg., xl, 121, 1904.
WILMS: Deut. med., xxxi, 1624, 1905.
WOHLGEMUTH: Centralb. f. Chir., xxxi, 1023, 1903.
WOLLENBERG: Zeit. f. orth. Chir., xxiii, 301, 1909; Therap. Rundschau, ii, 773, 1908.
WREDE: Berlin med. Woch., 616, xlviii, 1911; Centralb. für Chir., 1400, 1908; Discussion of Franke's Paper.
ZIEGLER: Virchow's Archiv., lxx, 205, 1878; Ibid, lxxiii, 355.
ZERONI: Arbeit. aus d. path. Institut. Göttingen, 1893.

SARCOMA OF THE LONG BONES

COLEY, W. B.: "Sarcoma of the Long Bones; The Diagnosis, Treatment, and Prognosis, with a Report of 69 Cases." Annals of Surg., March, 1907.
GROSS: "Sarcoma of the Long Bones, with a Report of 165 Cases." Amer. Jour. Med. Sci., 1879.
REINHARDT: "Sarcoma of the Long Bones; 54 Cases Observed at the Göttingen Clinic (König's), 1880 to 1895." Deutsche. Zeitschr. f. Chir., xlvii, 523, 1898.
NASSE: "Sarcoma of the Long Bones Observed at v. Bergmann's Clinic during Fifteen Years". Archiv. f. klin. Chir., xxxix, 888, 1889.
KÖCHER, O.: Beiträge z. klin. Chir., Bd. 1, 1906.
BUTLIN: "Operative Treatment of Malignant Disease." 2d Ed., 1900.
MCCOSH: "Observations of the Results in 125 Cases of Sarcoma." Annals of Surg., August, 1904.
MIKULICZ: "Resection of the Long Bones for Malignant Tumors." Verhandlgd. Deutsch. Gesell. f. Chir., Archiv. f. klin. Chir., Bd. 1, 1895.
D'ARCIS: "Cysts of the Long Bones." Arch. Internat. de Chir., vol. ii, No. 6, 1906.
BLOODGOOD: "Cysts of the Long Bones." Jour. Am. Med. Ass'n, p. 1124, 1904.
BARLING: Trans. Clinical Soc., London, xxxi, 175, 1898.
DENT: Trans. Med. Chir. Soc., lxxxi, 221, 1898.
KRAMER: Beiträge z. Chir. Behandlung der bösartigen Sarkome der langen Röhren-Knochen. Archiv. f. klin. Chir., lxvi, 1902.
ZIEGLER: "Über die Beziehung der Traumen zu den malignen Geschwülsten." Münch. med. Wochenschr., No. 27, 28, 1895.
ZIEGLER: "The Influence of Injury upon the Development of Sarcoma." Annals of Surg., March, 1898.
COLEY: "Observations upon the Symptomatology and Treatment of Sarcoma." Trans. Lehigh Valley Med. Ass'n, 1903.
KÜSTER: "Über Sarcome der langen Röhrenknochen." Deutsch. med. Wochenschr., S. 913, 1890.
LÖFFLER: "Zur Prognose der Knochen-Sarkome." Inaugural Dissertation, Halle, 1896.
COLEY: "Late Results of the Treatment of Inoperable Sarcoma by the Mixed Toxins of Erysipelas and Bacillus Prodigiosus." Am. Jour. Med. Sci., March, 1906.
MAYER: "Des Résultats éloignés du traitment Chirurgical des sarcomes des membres." Ann. de la Soc. Belge de Chir., Jan., No. 1, 1904.
COLEY: "Amputation at the Hip-joint for Sarcoma, with a Report of seven cases without Mortality." Trans. South. Surg. and Gyn. Ass'n, 1903.
LEXER: "Über die nicht parasitären Cysten der langen Röhren-Knochen." Arch. f. klin. Chir., Bd., lxxxi, Theil, ii, S. 363, 1906.
BOKENHEIMER: "Die Cysten der langen Röhren-Knochen u. d. ostitis fibrosa in Chirurgisch-ätiologischen Beziehungen." Arch. f. klin. Chir., Bd. lxxxi, Theil ii, S. 236, 1906.
KUMMER: "Nature et origine des kystes des os, en particulier des kystes simples des os longs." Rev. de Chir., 12, p. 806, 1906.
LOWENTHAL: Die Traumatische Entstehung den Geschwelste Archiv. f. klin., Chirurg. Bd. xlvix.
SCHNIEDER: Deutsche med. Wochenschr., No. 1, 1902.
JEANBRAU ET RICHE: "La survie après l'amputation interscapulo thoracique pour tumeurs malignes." Rev. de Chir., t. 32, p. 153, 1905.
BERGER: Ibid., p. 186.

CHAPTER XXVIII

ANKYLOSIS AND ARTHROPLASTIES FOR MOBILITY

ANKYLOSIS

Ankylosis is the permanent stiffness occurring in a joint from bony, articular, and ligamentous changes, *i.e.*, the condition in which two or more joint surfaces become bound together and immovable. It must here be stated that every case of stiffness of a joint does not necessarily indicate ankylosis, *e.g.*, muscular contraction in joint disease, or joint immobility from shortened muscles, tendons, fasciæ, and skin from any cause. Ankylosis may be complete or incomplete.

Varieties.—(1) *Fibrous Ankylosis.*—In this variety, bands of fibrous tissue connect the joint surfaces. The degree of movement depends upon their extent and length. Fibrous ankylosis is produced by injury (*e.g.*,



FIG. 657.—Congenital ankylosis of the elbow with fracture of the lower end of the humerus.

dislocation and fracture of a joint), also by pyogenic infection, gonorrhea, tuberculosis, rheumatic or gouty diatheses.

2. *Cartilaginous Ankylosis.*—When the two cartilaginous surfaces are adherent, the ankylosis is complete.

3. *Bony Ankylosis.*—In this form, there is osseous union between the articulating surfaces. The usual cause is suppurative arthritis, but the condition may also occur in non-suppurative lesions, such as syphilis, tuberculosis, etc.

4. *Ankylosis in the proliferative type of non-tuberculous arthritis* (arthritis deformans), as described by Nichols and Richardson (see Chapter XI). According to these investigators, ankylosis is produced in three ways, viz.: (*a*) proliferation of the perichondrium which is readily transformed into cartilage or bone; (*b*) in other instances, new bone is formed from osteoblasts arising in the bone-marrow; (*c*) rarely, fibrous tissue is transformed into bone.

5. *Congenital Ankylosis.*—This type is very rare, but cases have been recorded (Fig. 657).

Pathology.—The pathological changes in the proliferative type of non-tuberculous arthritis leading to ankylosis have been fully described in Chapter XI.

The nature, sequence, and duration of the tissue changes which lead to bony ankylosis have been experimentally studied by Allison and Brooks (Surg. Gyn. and Obst., November, 1914, pp. 568–581). Four experimental methods were used by them, viz.: (*a*) partial excision of joints; (*b*) destruction of joint cartilages; (*c*) injury to the joint cartilage; (*d*) direct infection of normal joints. As the result of these studies, Allison and Brooks conclude as follows:

"From the experiments in which the joint cavity was infected with tubercle bacilli or staphylococci, or in which a slight injury was done to the joint cartilage, we are led to believe that any inflammatory process within the joint which is of sufficient severity to result in the formation of granulation tissue will destroy the joint cartilages. The cartilage is absorbed at its margin by granulation tissue from the synovial membrane and at its base by granulation tissue in the bone-marrow.

"By the experiments in which the cartilage was removed by operation, or the joint partly excised, we have shown that ankylosis by bone is a slowly developing process which consists of the following stages: first, there is union by granulation tissue; second, there is union by dense fibrous tissue; third, there is a metaplasia of fibrous tissue into fibrocartilage, and a direct transformation of this tissue into bone. The shortest period of time in which complete bony ankylosis was observed experimentally was 180 days. In man, the duration of the process is equally prolonged.

"The long duration of the process of osseous ankylosis, we believe, explains the following: After arthroplasty, a joint may allow motion for some weeks, and subsequently become stiff. Fractures of the epiphyses unite by bone slowly. It also suggests that the conclusion reached by certain investigators that the interposition of soft parts prevents bony ankylosis is misleading, in that many of the experiments were of insufficient duration.

"The long duration of the fibrous stage of ankylosis also shows conclusively that any method of arthroplasty should have as its object the prevention of fibrous ankylosis rather than bony ankylosis; also that the insertion of an irritative substance into a joint should be avoided.

"We believe that the difference which exists between the epiphysis and diaphysis, in the capacity for bone regeneration, is explained by the fact that there is no periosteum on the epiphysis."

Etiology.—The causes of true ankylosis are acute and chronic inflammation of a joint from any causes whatever, suppurative or non-suppurative.

Prophylaxis.—The danger of ankylosis may be lessened or even eliminated by judicious treatment of its primary cause, viz.: (1) early incision and thorough drainage of suppurating joints; (2) by avoiding too prolonged immobilization of joint fractures; (3) early and efficient protection and fixation of a tuberculous joint, by limiting the extent of the lesion, will modify the

degree of eventual ankylosis; (4) traction and the avoidance of wide open drainage of infected joints, which exposes the synovial membrane to drying.

Complete bony ankylosis is not always an undesirable condition, if the limb and the joint are in a favorable mechanical position. This is most forcibly illustrated by the joints concerned in locomotion, *i.e.*, a knee-joint, firmly ankylosed in full extension, is a far more useful agent in walking than a knee-joint with only 5 degrees or 10 degrees of mobility.

Diagnosis.—The extent of the ankylosis is estimated by several factors, the etiology, examination under anesthesia, radiography, and manipulation. Differential diagnosis between fibrous and bony ankylosis is made as follows: In the fibrous variety, even though it be firm, forcible manipulation beyond a certain point causes pain, which does not occur on extreme movement in bony ankylosis. When the differentiation between the fibrous and the bony varieties still remains uncertain, the *x*-ray or examination under anesthesia will usually settle the difference and establish the pathological variety.

Prognosis.—The probability of ankylosis supervening in a given case depends on the nature of the pathological process and the character of the treatment. Suppurative processes usually terminate in bony ankylosis; tuberculous processes, in fibrous. There are, however, exceptions to this rule in both instances. In the case of partial fibrous ankylosis, if active movement and manipulation are not followed by further limitation of the function of the joint, the outlook for usefulness is good; the contrary is also true. In a general way, fibrous ankylosis is often made worse rather than better by forcible manipulation.

Treatment.—From the therapeutic standpoint, there are two types of cases, fibrous and bony, each of which is treated along different lines.

Fibrous Ankylosis.—Having ascertained that all inflammation is at an end, the procedure is as follows: gradual stretching of the adhesions by manipulation; application of hot wet packs followed by massage should precede manipulation of the joints. Forcible or too frequently repeated manipulation should be avoided, as it may cause recrudescence of the ankylosis; the daily amount should be judged by daily increase of movement without pain. Adjuncts to manipulation are: baking, vibratory massage, and occasionally Bier's hyperemia. Various forms of electricity and electric light baths may also be tried. Some writers favor ionization of the joint, particularly with sodium chloride, the chlorine ions set free at the negative pole being accredited with the property of causing resolution of the fibrous tissue which is responsible for the ankylosis. Mechanical adjuncts to the treatment of fibrous ankylosis include adjustable splints and weight extension.

Forcible stretching under anesthesia is reprehensible practice if promiscuously performed. Unless it can be appreciated during manipulation that the adhesions are giving way, force should not as a rule be employed. Accidents attending brisement forcé are: separation of an epiphysis; fat embolism; the lighting up of an old process; rupture of an artery or vein; gangrene of the limb; permanent paralysis from nerve stretching; and fracture of the bone near the joint.

In selected cases of fibrous ankylosis, it may be advisable to open the joint, divide the adhesions, remove exostoses, etc. In other cases, division of contracted muscles, tendons, and fasciæ prior to manipulation may be justifiable.

Bony Ankylosis.—The only means of securing mobility in bony ankylosis is by operation. If correction of malposition only is desired, osteotomy is sufficient. The formation of a new joint is the desideratum, however, in

every case. The reconstruction of a joint should not be undertaken lightly, but with due consideration of the merits of the individual case and with varying prospects of success, according to the joint in question. It is useless to perform a nearthrosis if stability of the limb is thereby destroyed, or if the limb is less useful to the individual with partial mobility than when firmly ankylosed.

The resection of the tissues after an arthroplasty depends a good deal upon the pathological character of the primary lesion. Thus, after such lesions as gonorrhea or other pyogenic infection, the osteogenetic activity of the bone-cells is increased and the fibrous tissues tend persistently to contract, hence recurrent ankylosis after nearthrosis has been performed is very likely to occur. On the other hand, after tuberculous arthritis, there is little new bone-growth and very little formation of new fibrous tissue, hence old tuberculous ankylosed joints are well suited for arthroplasty from this standpoint, but, on account of the danger of the tuberculous process undergoing rejuvenation as the result of the operation, a long time must elapse after the last symptoms have been noted before arthroplasty should be considered. Adults are more favorable subjects for arthroplasty than adolescents under thirty, after that, the osteogenetic power of the periosteum and the bone have become less active and re-ankylosis is less likely to occur.

Arthroplasty for the Mobilization of Ankylosed Joints

Arthroplasty consists of the interposition of certain substances between denuded joint surfaces, for the purpose of restoring joint motion. For attaining this end, various materials have been employed. It may be said in the beginning, that better results are obtained by the use of organic rather than inorganic substances.

The first successful interposition was apparently made by Helferich (Arch. f. klin. Chir., 1894, xlviii, 864) in 1893, in a case of bony ankylosis of the temporomaxillary joint, in which he used flaps of temporal muscle. Mikulicz in 1895, used for the same condition a flap from the masseter. The use of muscle flaps then came into general use by Lentz, Henle, Rochet, Hoffa, Nélaton, and others. Gluck, in 1902 (Verhandl. d. Deutsch. Gesellsch. f. Chir., 1902) used a skin flap. Chlumsky (Wien. klin. Wcinschr., 1902; Zentralbl. f. Chir., 1900) and Hoffa (Zentralbl. f. Chir., 1904, No. 23) used non-absorbable materials, *e.g.*, zinc, rubber, celluloid, silver, and layers of collodion, while Orlow has even employed metal plates. R. Tunstall Taylor (Surg., Gyn. and Obst., April, 1912, pp. 326–337) has advocated a wax method, but it has been very little used, and from a mechanical standpoint is worthless, since there is danger of puncture by apposed bony surfaces. Chlumsky later substituted for his non-absorbable materials, absorbable plates of decalcified bone, ivory, and magnesia. Murphy (Jour. A. M. A., 1905, Trans. Am. Surg. Ass'n, 1904, xxii) used pedicled fascial flaps; he believed that his pediculated fascial flaps led to the formation of a new joint cavity which he called a bursa, analogous to the normal embryological development of a joint cavity. Weglowski (Centralbl. f. Chir., Apr. 27, 1907) reported the transplantation of cartilage from a rib to an ankylosed elbow-joint, obtaining 60 to 70 degrees of motion in five weeks. Kirschner (Beitr. z. klin. Chir., 1909, lxv, 472; Verhandl. d. Deutsch. Gesellsch. f. Chir., 1911) demonstrated the practicability of free fascial flaps, and he showed that they require little nourishment and remain viable when transplanted into various tissues. Baer (Am. Jour. Orth. Surg., 1909, vii, 1) advocated the use of chromicized pig's bladder.

Experiments by Sumita (Arch. f. klin. Chir., xcix, 755) with pedunculated flaps of muscle, tendon, and fascia, showed that these tissues undergo fibrous degeneration, leading to the formation of a cavity which precedes bony union, and assumes the character of a ganglion rather than a bursa, as presumed by Murphy. Sumita's conclusion was that pressure causing hemorrhage and degeneration, was the main factor in producing this cavity.

Allison and Brooks (Surg., Gyn. and Obst., December, 1913, pp. 645–663) have reported results of an experimental study of the mobilization of ankylosed joints. The knee-joints, anterior surfaces of the patellæ, and the femoral condyles of the experimental dogs were denuded of their cartilage, and the substances to be studied were placed over the denuded femora and sutured in place, the patellæ and their tendons were replaced, and the joints closed. They experimented with the following substances: (1) cargile membrane; (2) free fascia from the fascia lata; (3) pedunculated fascial flaps; (4) chromicized pig's bladder; (5) fascia impregnated with metallic silver. Their primary object was not the study of functional results, but the "behavior of the experimental joint to these various substances; specifically, to determine the possibility of the interposed substance healing in, the length of time it may persist, the amount of reaction it produces, and its efficacy as a factor in the restoration of an anatomical articulation. To obtain additional information as regards the behavior of the surrounding tissues to these substances, we implanted them beneath the rectus abdominis muscle."

Allison and Brooks, as the result of these experiments, draw the following conclusions:

1. In all the experiments, the process of healing of the joint surfaces from which the cartilage was removed was the same. Following the injury, the ends of the epiphyses acted in a manner strikingly different from that seen after injury to the diaphyses. There was very little new bone formation from the denuded bone area at the end of sixty days. The new bone formation seen was always under the joint cartilage which had not been removed. The denuded joint surfaces were at the end of five days covered with granulation tissue which grew from the marrow spaces. This granulation tissue developed into fibrous tissue.

2. With two denuded joint surfaces approximated directly, the granulation tissue united the two surfaces. This process obviously leads to a fibrous ankylosis, which, according to Hoffa, is the primary stage of osseous union.

3. With the interposition of fascia lata, either in free pieces or in pedunculated flaps, the direct union of the denuded joint surfaces was prevented only in case the fascia transplant underwent necrosis and absorption. In those cases in which the transplanted fascia persisted in parts, the persistent islands acted as adhesions between the joint surfaces.

4. In the experiments with fascia, there was no evidence of any advantage of a pedunculated transplant; on the contrary, in each instance the pedicle persisted as an intra-articular band which checked joint movement.

5. With the fascia fixed and impregnated with silver, the union of the denuded joint surfaces was prevented.

6. The more irritating chromicized pig's bladder membrane always led to a much greater amount of fibrous tissue formation, and the fibrous tissue formed in every instance more or less completely united the opposed joint surfaces.

7. The relatively small amount of new bone formation from the ends of the bones in the joint makes the prevention of union between raw joint surfaces a problem which is identical with that of cavity production in soft

parts. With the transplantation of living tissue into soft parts, in case the transplant preserves its vitality, it heals in the tissues without cavity formation. If the insert undergoes necrosis and absorption, or is an absorbable, non-living substance, which excites very little inflammatory reaction, it disappears, leaving a cavity. If the insert is of such a nature as to set up a marked inflammatory reaction, the tendency of the process is to close the cavity occupied by the insert in a manner similar to the closing of an abscess cavity.

In his own experience, the author has found the free fat fascial flap to be the most satisfactory substance for interposition, if taken from the fascia lata with as much fat adherent to it as can be dissected away without button-holing the skin.

The author wishes to state, furthermore, in this connection that he has seen many joints whose range of motion has been greatly impaired by the formation of scar tissue and adhesions in the overlying soft parts, *i.e.*, in the various muscle planes. The use of pedicled fascial flaps necessitates the extensive removal of tissues favoring gliding motion of these parts, and therefore whenever it is possible he prefers to obtain the fascial graft at a point some distance from the joint. Since Allison and Brooks have shown by their experimental work that the efficacy of the fascial graft in arthroplasty is greatest when degeneration occurs, it is evident that the free graft is at least not inferior to the pedicled graft.

In all arthroplastic work, it is essential to get out every fragment of bone that collects in the process of rounding off the articular surfaces, because here the object sought is just the opposite of that in arthrodesis, where excessive osteogenesis is to be encouraged; in arthroplasty, as little bone growth as possible is the desideratum.

AUTHOR'S TECHNIC OF ARTHROPLASTY

The joint surfaces having been freed from their osseous ankylosis, and smoothed off as much as possible (see following pages) the fascial flap is obtained as follows: A wide semicircular incision is made in the outer surface of the thigh, about the junction of the upper and middle thirds, at which point the fascia lata is thickest. The skin flap is reflected by dissecting it away from the subcutaneous fat, allowing as much of the latter as possible to remain adherent to the fascia. With knife and scissors, a quadrilateral piece of fascia with its adherent fat, is removed; the size varies according to the joint surface to be treated, but in any event it should be of generous proportions. (In the case of the hip, the flap is inserted so that its fatty surface is in the acetabulum, *i.e.*, as a rule the fatty surface is placed against the weight-bearing portion of the joint.) The flap is interposed with some care, so that at no point do raw bony surfaces come in contact. It is then sutured to the margins of the cavity with fine chromicized catgut sutures. The skin of the thigh and that over the joint are closed with a continuous suture of No. 1 plain catgut, the deep tissues over the joint having been carefully approximated with interrupted sutures of No. 1 chromicized catgut. It is most important that in every arthroplasty the joint cavity should be carefully sealed off by layer sutures, for a leak through the skin may ruin the result. A plaster-of-Paris dressing (varying in extent with the joint in question) is applied, and the part immobilized for a period not exceeding ten to fourteen days. The surgeon is cautioned not to continue the fixation too long, since mobility is the desideratum.

The technic of application of this method of arthroplasty to individual joints will be found in the following pages.

The knee is the most unfavorable of all the joints for arthroplasty, and

it is a question whether the procedure should ever be attempted in that situation, at least in the present status of our technic. In order of favorability for nearthrosis, the joints may be arranged in the following order: first, temporomaxillary; second, elbow; third, hip. The other joints do not vary strikingly as to favorability except that the knee stands at the bottom of the list, as noted above.

HENDERSON'S TABLE

Arthroplasties Reported by 51 Surgeons. Classified: Good, Fair and Poor. Elbow, 126 (30%); Knee, 117 (29%); Hip, 98 (24%); Jaw, 32 (7%); Ankle, 22 (5%).

	Elbow	Knee	Hip	Jaw	Ankle	Totals
Good	97 (76%)	18 (15%)	56 (57%)	30 (93%)	3 (13%)	204 (51%)
Fair	21 (16%)	30 (25%)	18 (18%)	1 (3%)	13 (59%)	83 (21%)
Poor	8 (6%)	69 (59%)	24 (24%)	1 (3%)	6 (27%)	108 (27%)
Total	126	117	98	32	22	395

Treatment of Ankylosis of Individual Joints.—1. *Temporomaxillary Joint.*—A moderate grade of fibrous ankylosis of one or both of these joints is not very disabling, if sufficient movement remains to permit the mastication of food. When there is marked rigidity, with insufficient movement for mastication, operation is indicated. If the ankylosis is fibrous, excision of the condyles may be performed; if ankylosis is bilateral, the excision of one condyle alone gives very satisfactory results, although the bilateral operation is preferable.

For bilateral *bony* ankylosis, bilateral nearthrosis is necessary. The technic varies somewhat, viz.: either the condyles, with or without the coronoid processes, are removed, or osteotomy of the ramus is performed; in the former case, some organic substance (preferably a free fat fascial flap) is interposed. Rectal or transnasal anesthesia is necessary during this procedure. Incisions of various shapes and locations have been advocated. The author prefers an incision of semilunar shape, with its point of greatest convexity backward over the temporomaxillary joint; this gives ample exposure for resection of the condyle and coronoid processes. After removal of a portion of the zygoma, the coronoid process and condyle are removed with a bone forceps or a sharp thin osteotome, the rough edges of glenoid fossa, condyle, and coronoid process are smoothed by means of a rongeur, special curet or motor burr, and a free fascial flap is interposed and sutured to the stump of the condyle, the fatty surface being turned toward the glenoid fossa. Osteotomy of the ramus, with interposition of a fascial flap, is advisable only in case arthroplasty at the temporomandibular junction is contra-indicated for any reason.

2. *Elbow.*—The commonest cause of fibrous ankylosis of the elbow is fracture into the joint. Bony ankylosis results as a rule, from the same cause or from synostosing arthritis. For the relief of ankylosis, the results of arthroplasty of this joint are second only to those of the temporomaxillary articulation.

Technic.—An Esmarch or an ordinary tourniquet having been applied to the arm, a vertical incision, 6 inches in length, is made on the posterior surface of the elbow, directly over the olecranon, extending from a point 2 inches below to a point 4 inches above it. The ulnar nerve is displaced and held aside with a loop of gauze to protect it from injury. The skin and subcutaneous flaps are dissected laterally from the bone and fascia for 1½ inches on each side of the incision. The olecranon is sawed through obliquely from within outward to get a broad bony surface. After the bony connection between the olecranon and humerus has been severed with a narrow sharp

osteotome, the olecranon with the triceps attachment undisturbed is retracted upward, and the interior of the joint exposed. If there are bony adhesions present between the head of the radius and the lesser sigmoid cavity, they should be separated with an osteotome, and the coronoid process is freed from the trochlea by the same means, while the bony deposit filling the olec-

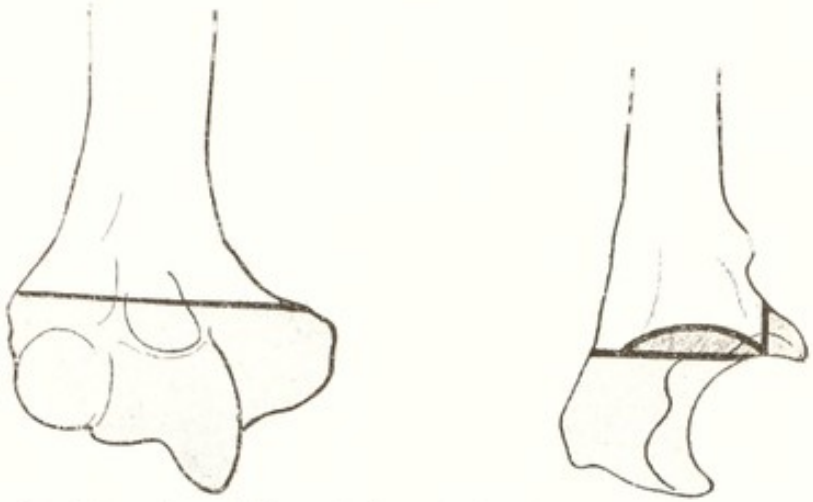


FIG. 658.—Arthroplasty for mobility of elbow, indicating amount of bone removed from humerus and ulna. (Huguier.)

ranon fossa is removed with a gouge. Exostoses are cut away from the head of the radius, and the head, separated from its attachment to the external condyle, is itself reduced to normal size with the rongeur. The free fascial flap must be carried high up on the anterior surface of the humerus, to permit of good flexion. The margins of the flap are secured to the capsule

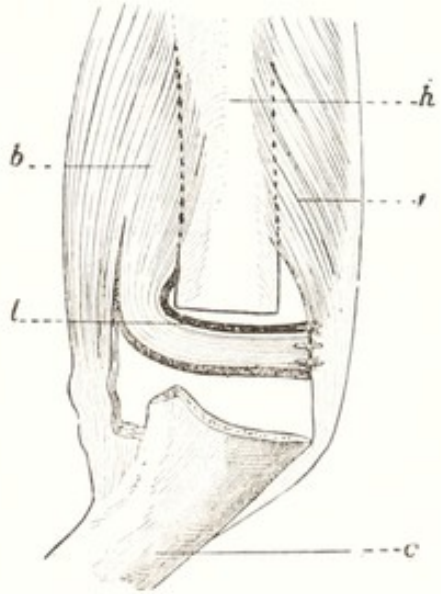


FIG. 659.—Arthroplasty for mobility of elbow. *b*, brachialis anticus; *h*, humerus; *c*, ulna; *l*, anterior ligament turned in with flap. (Huguier.)

of the joint on all sides with interrupted sutures of No. 1 chromicized catgut, and the olecranon brought into position and fastened to the shaft of the ulna by means of a bone-graft peg or kangaroo tendon and interrupted sutures of No. 1 chromicized catgut used to close the periosteum. The ulnar nerve is replaced in its groove beneath the inner condyle, and the skin closed with

interrupted sutures of No. 1 plain catgut. The arm is put up at right angles in a plaster-of-Paris splint and kept there for ten days, when passive movement is begun to stretch the muscles and permit as free flexion and extension as possible.

MacAusland, of Boston, has advised sawing off the olecranon at right angles with the ulnar shaft. This procedure gives rapid exposure and excellent access to the joint.

MacAusland's technic (MacAusland, W. R. "Ankylosis of the Elbow, with Report of Four cases Treated by Arthroplasty." Jour. Am. Med. Ass'n, Jan. 23, 1915, lxiv, 312–317) is as follows:

After the usual preparation and the application of a tourniquet, a U-shaped incision is made, beginning on the lateral aspect about 3 inches above the elbow-joint and passing over the middle of the olecranon to a



FIG. 660.—Arthroplasty of hip-joint for ankylosis due to fracture of the acetabulum caused by the head of the femur being driven through it into the pelvis. The photograph shows the range of motion in flexion of the hip secured by the operation.

corresponding position on the opposite side. The skin and superficial fascia are dissected up to a base line at the end of the incision, and then retracted. The skin and fascia are then dissected a little on both sides and on the forearm end of the incision. The ulnar nerve is dissected out of its sheath and gently retracted with gauze. A straight incision is made extending from one lateral aspect of the condyle to the opposite, crossing midway on the olecranon. If the capsule and fascia are adherent, the incision is made down to the bone over the condyle so as to elevate *en masse* the tissue which would serve as a new capsule. The olecranon is then sawed across and separated. If there is extensive bony ankylosis, the joint cannot in some instances be broken open, even with the use of extreme force, so that it becomes necessary to saw directly across



FIG. 661.—(I. H.) Bony ankylosis of right hip in flexion-adduction deformity, following a suppurative arthritis two years previously.



a *b* *c*

FIG. 662.—(I. H.) Same case as shown in *x*-ray in Fig. 661 after arthroplasty for mobility. Both the scars of the old incisions (one over hip, the other over mid-thigh) are plainly visible. The very satisfactory amount of painless flexion and extension of the right hip resulting from arthroplasty is shown in *b* and *c*.

the line of the old joint. When about three-fourths through the joint, it is usually possible to fracture the remainder.

The capsule, fascia, and ligaments are dissected back to allow the lower end of the humerus to protrude from the wound, so as to permit its square

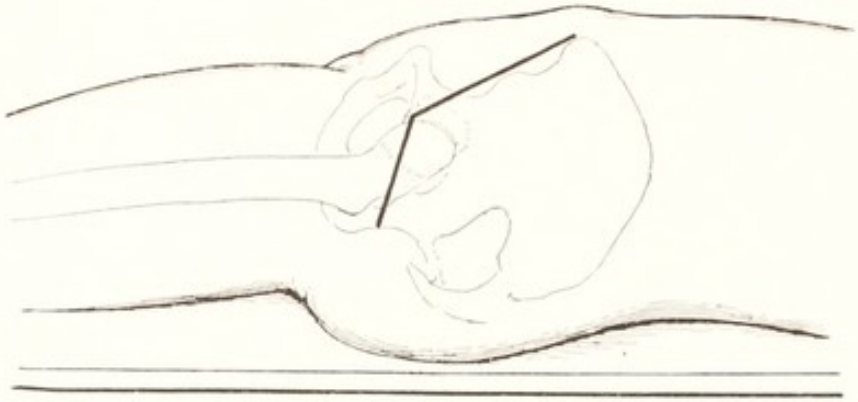


FIG. 663.—Arthroplasty of hip-joint. Skin incision from anterior superior spine of ilium to center of great trochanter, thence posteriorly for about 1½ inches in adult. Flap is turned back, exposing trochanter and superficial fascia. (This approach was formerly employed by the author exclusively in plastic operations on the hip-joint. Recently, however, the Smith-Peterson approach has been found superior to it.)

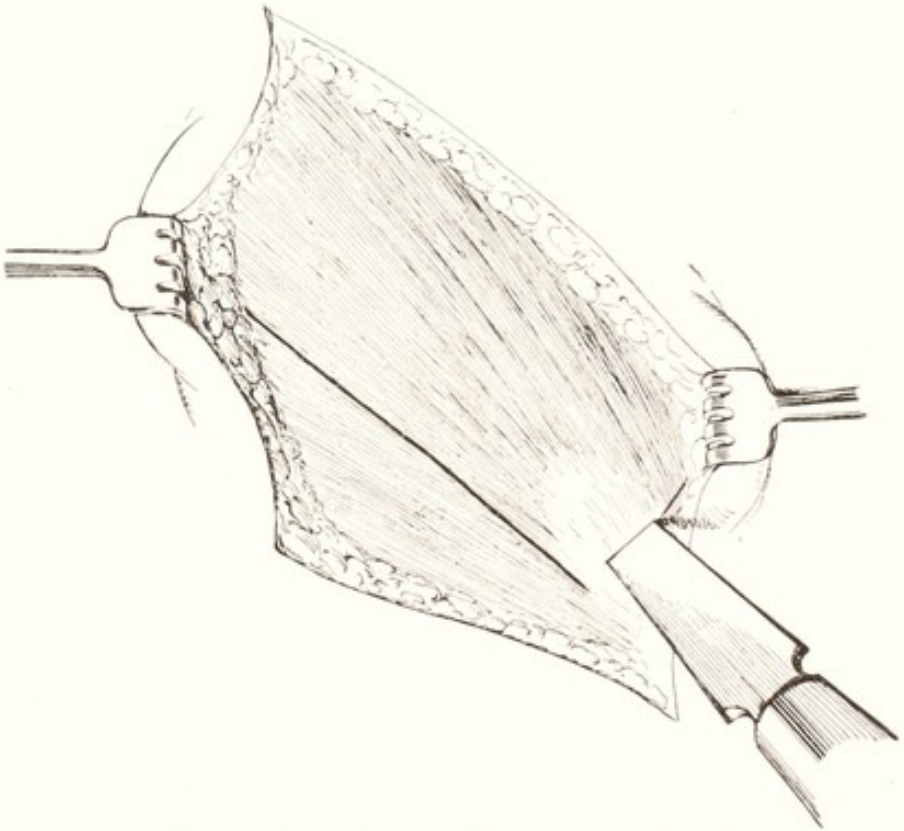


FIG. 664.—(Right hip.) Arthroplasty of hip-joint. Trochanter being freed with osteotome. Incision in fascia anterior to trochanter preliminary to reflection of the gluteal muscles.

edges to be snipped off with the rongeur forceps and a new trochlear or intercondylar surface to be formed. A shoemaker's rasp may be used to file this extremity as nearly like a normal humeral end as possible. A piece is then removed, corresponding to the olecranon fossa in the normal humerus.

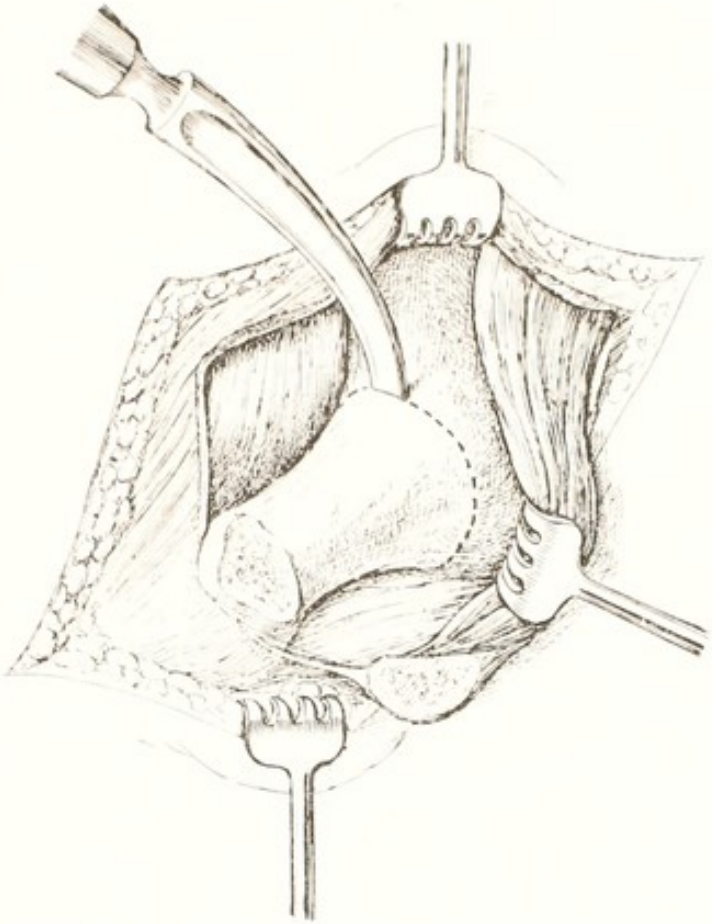


FIG. 65.—Arthroplasty of hip-joint. Trochanter turned up. Initial bone incision being made with large gouge at junction of femoral head and acetabulum.

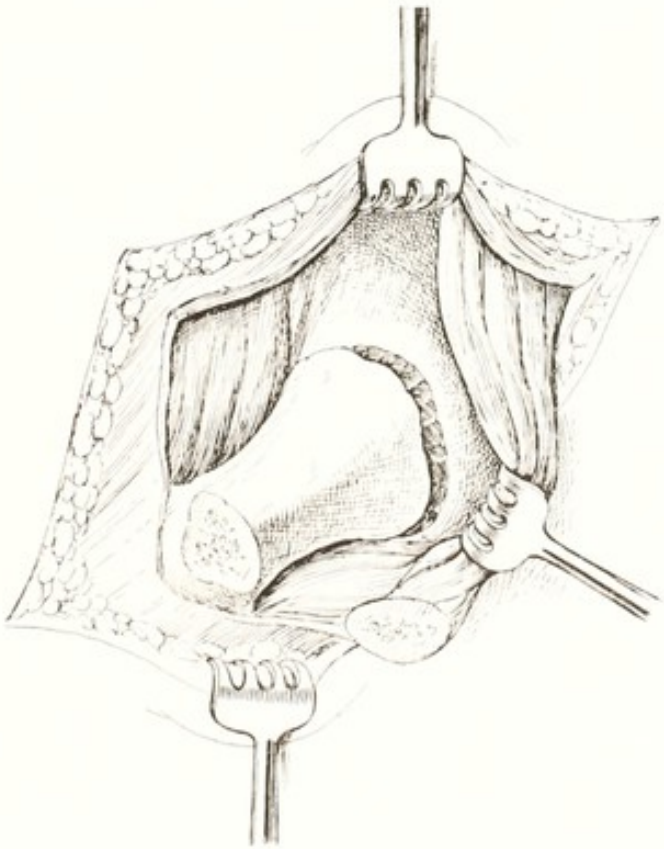


FIG. 66.—Arthroplasty of hip-joint. Bony ankylosis between femoral head and acetabulum partially severed.

After this cavity is prepared, the corresponding surface of the olecranon is cureted so as to receive the new humeral extremity. This modelling of the joint MacAusland does largely with a saw and file. To insure good joint function, the joint surfaces should fit accurately before the fascia be removed as will permit free motion. If too much of the ends of the bones is removed, a flail joint may result, giving the operation no advantage over an excision. When this mortising has been completed, the fascial flap is dissected out of the thigh.

MacAusland makes a 5- to 6-inch incision on the outer side of the thigh a little below the middle, extending below the fascia lata. A piece

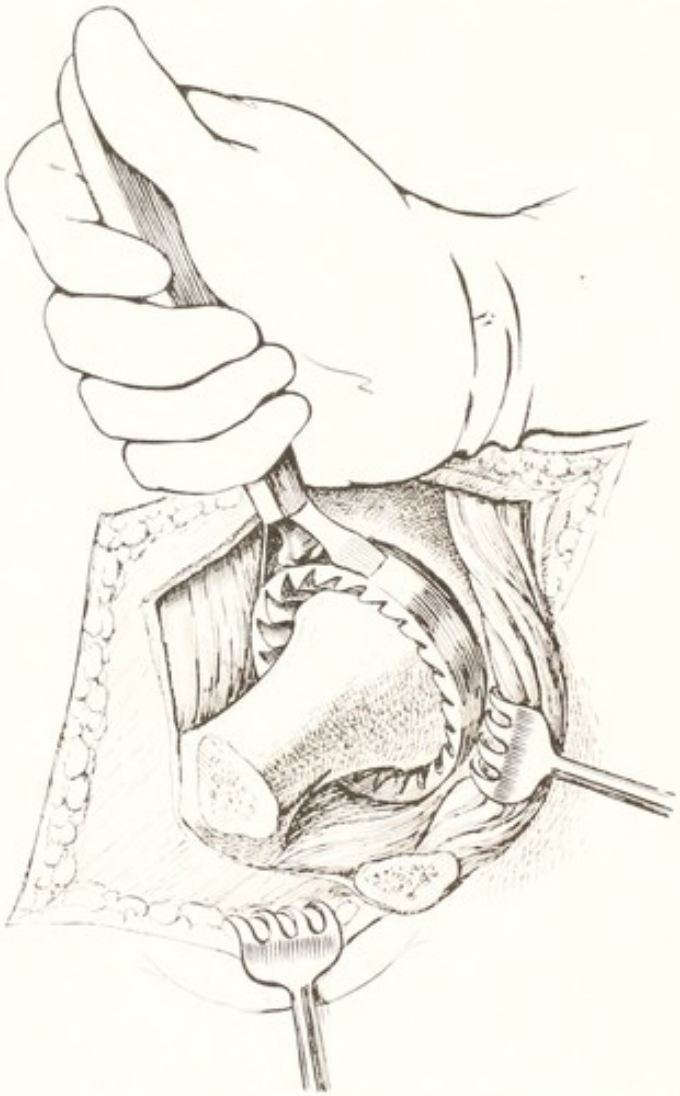


FIG. 667.—Arthroplasty of hip-joint. Smoothing and rounding femoral head with author's hip-shaper after head has been dislodged from newly-formed acetabulum.

is dissected out about 5 × 4 inches, and the wound closed. This fascia, free from all fat, is placed about the new humeral condyles by attaching it first to the anterior capsule of the joint, and then tying it about the condyles so that all rough surfaces are covered, and a purse-string suture is applied.

The fascia, ligaments, and old capsule are then sutured with chromic catgut. The olecranon is sutured with double chromic catgut. The skin is closed with silkworm-gut, and a voluminous dressing applied with the arm at a right angle. Arm and forearm are placed on pillows with heavy dressings, but no splint. Passive motion is begun on the fifth day.

3. *Hip.*—Ankylosis in this joint may be fibrous or bony. Of the fibrous varieties, the tuberculous is the commonest. Much can be done to prevent permanent malposition during the development of ankylosis by weight extension in the proper direction, and by proper ambulatory splinting and support.

In the case of bony ankylosis, if the position of the limb is good, it is better let alone, unless the condition is bilateral or the patient insists upon mobility by operation. If rectification of position alone is desired, a circular osteotomy (see Chapter XIV) may be performed.

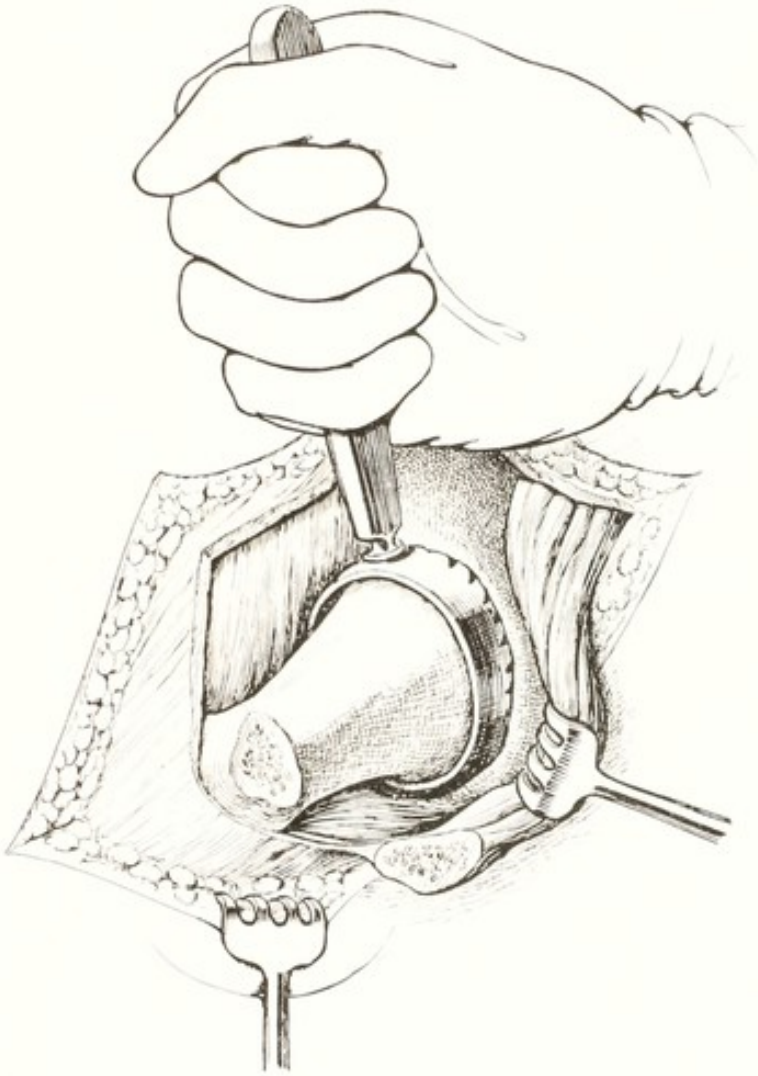


FIG. 668.—Shaping and sounding the new formed acetabulum with author's convex hip-shaper, while the assistant presses the femoral head into the smooth concave side of the shaper by pressing on the knee.

Arthroplasty of the Hip.—(*a*) *Author's Technic.*—The patient should be placed upon a traction table. Sprengel-Smith-Peterson incision (Amer. Jour. Orth. Surg., Vol. xv, p. 592) affords such wonderful exposure that it is *the* incision for all arthrodeses and arthroplasties of the hip. The incision begins at a point about 4 inches below the anterior-superior iliac spine, is carried along the outer border of the sartorius muscle, upward to the anterior spine, thence backward, following the iliac crest. The gluteal muscles are detached and reflected *subperiosteally* from the wing of the ilium downward *en masse*, thus giving a wide exposure of the hip-joint.

By means of carver's gouges, the femur is separated from the acetabulum,

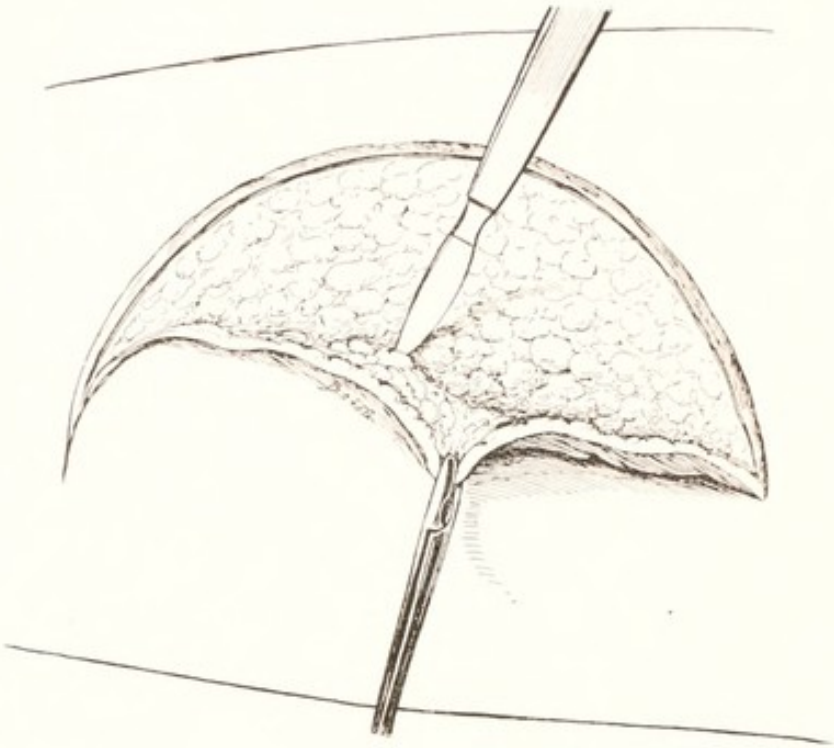


FIG. 669.—Dissection of skin away from subcutaneous fat. Half the subcutaneous layer of fat is left adherent to the fascia lata.

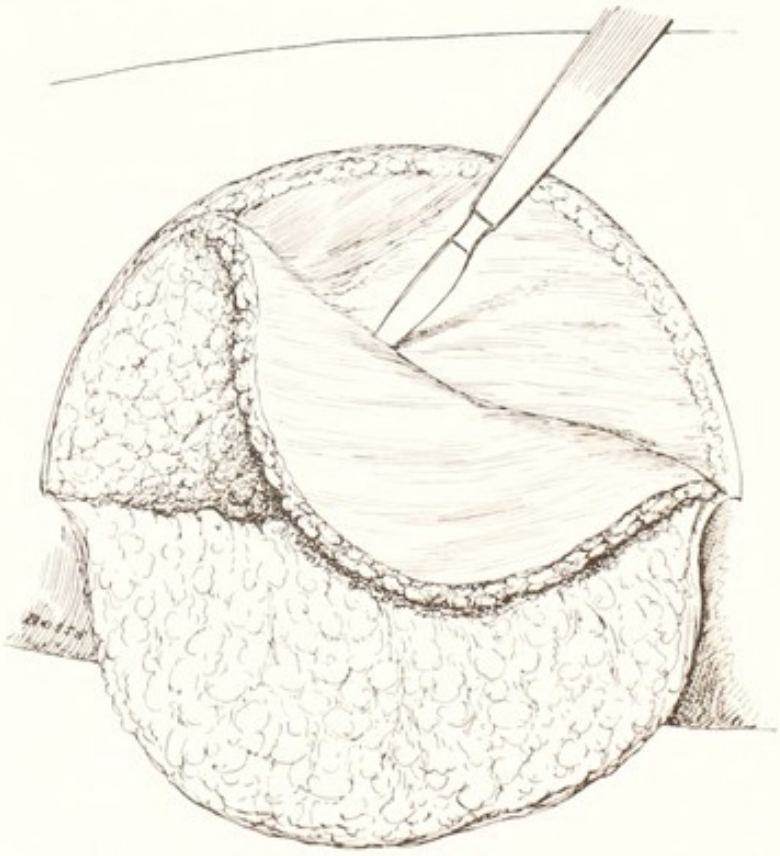


FIG. 670.—Flap of fascia and fat being freed from underlying muscles of thigh.

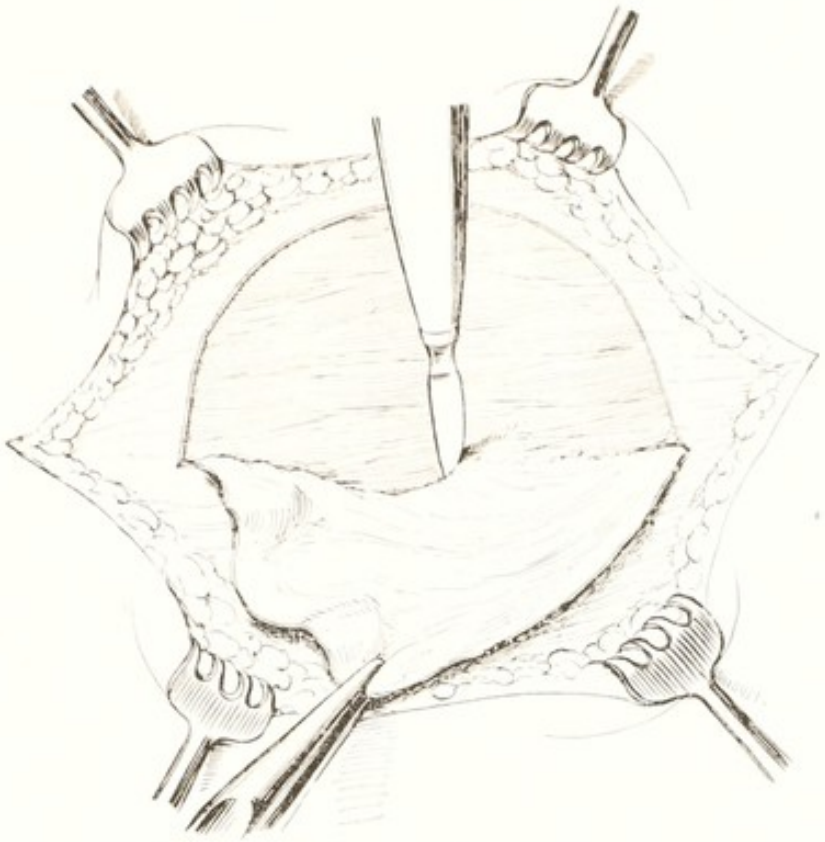


FIG. 671.—Improper method of dissecting-out a fascial transplant. By this method no fat is left adherent to fascia.

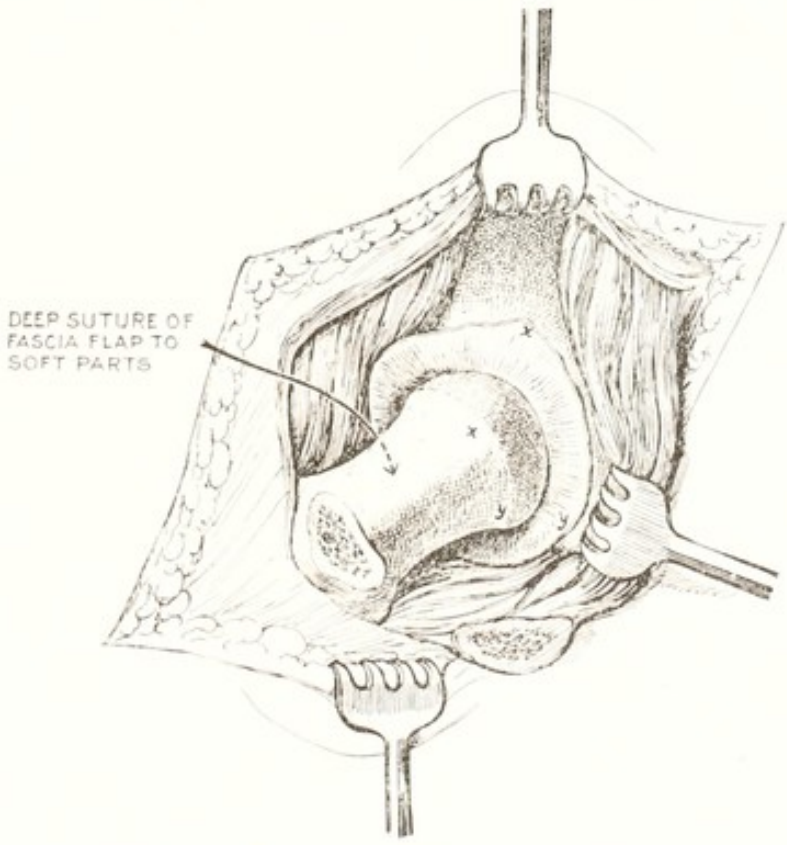


FIG. 672.—Arthroplasty of hip-joint. Fascial- and fat-transplant in place.

care being taken to so make the bone incision that a rounded femoral head and a corresponding acetabular cavity of considerable depth are shaped. The author has found the various carver's gouges and chisels of great service in his plastic bone work, especially in arthroplasties. The large variety of cutting edges and curvatures of the chisel or gouge shafts enables the surgeon to select the proper tool for almost any emergency.

After the general contours of the joint are thus blocked out, the surfaces are merely smoothed and transformed into regular convex and concave surfaces by means of the author's arthroplastic hip rasps (Figs. 667 and 668). The smoothness of these joint surfaces is most important, and therefore the work should be done carefully. The concave and convex rasps are placed in between the femoral head and the acetabulum, and these surfaces smoothed and shaped by a to-and-fro motion of the handle, in the manner of a spoke

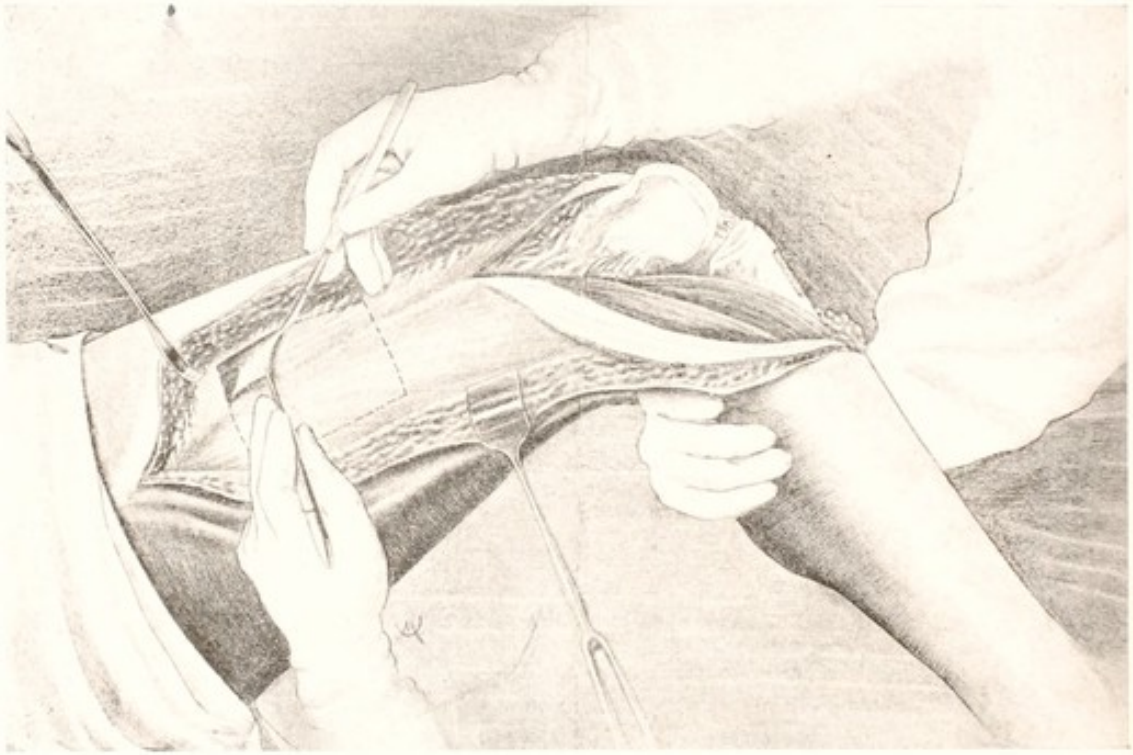


FIG. 673.—Arthroplasty of the knee-joint (After Putti.) Demonstrating Putti's technic. Extensive anterolateral incision beginning just below tubercle of tibia extending upward to outer aspect of thigh. Tubercle of tibia chiselled loose and ligamentum patellæ turned upward, exposing completely region of the knee-joint. Generous amount of bone is removed in shaping the knee-joint. Fascial-fat transplant obtained through upper end of incision.

of a wheel. The tools will execute this work faster if an assistant pushes upward on the patient's knee. These instruments enable the surgeon to shape accurately the inner portion of the joint which cannot be seen or gotten at by any ordinary instrument.

The next step is to apply traction to the limb, to separate the head from the acetabulum, so that the bone particles can be washed out by means of a glass cannula connected with a fountain of saline over the table, and to allow the easy insertion of the fascial flap, about to be obtained from the thigh, lower down. A circular skin incision is made on the outer side of the thigh, midway between the wound and the knee, and a quadrilateral piece of fascia lata with as much fat as is obtainable on both sides and about 4 inches long by $3\frac{1}{2}$ wide (adult) is secured. The subcutaneous layer of fat is

cleaved in equal halves—one-half being left attached to the skin and the other half to the graft which is subsequently to be removed. With a small curved needle, stay sutures are placed in what are to be the two inner corners, and the fascial graft is drawn in and pushed into the inner confines of the new joint by some instrument as far as possible between the new joint surfaces. Additional sutures are then placed about the periphery of the graft. The fascia is carefully approximated by a continuous suture of No. 1 chromic catgut skin, by plain catgut No. 1. Dressings and stickers are applied to hip. With limb in moderate abduction, a plaster-of-Paris spica is applied from above the costal margins on opposite side to toes, with stickers coming out through

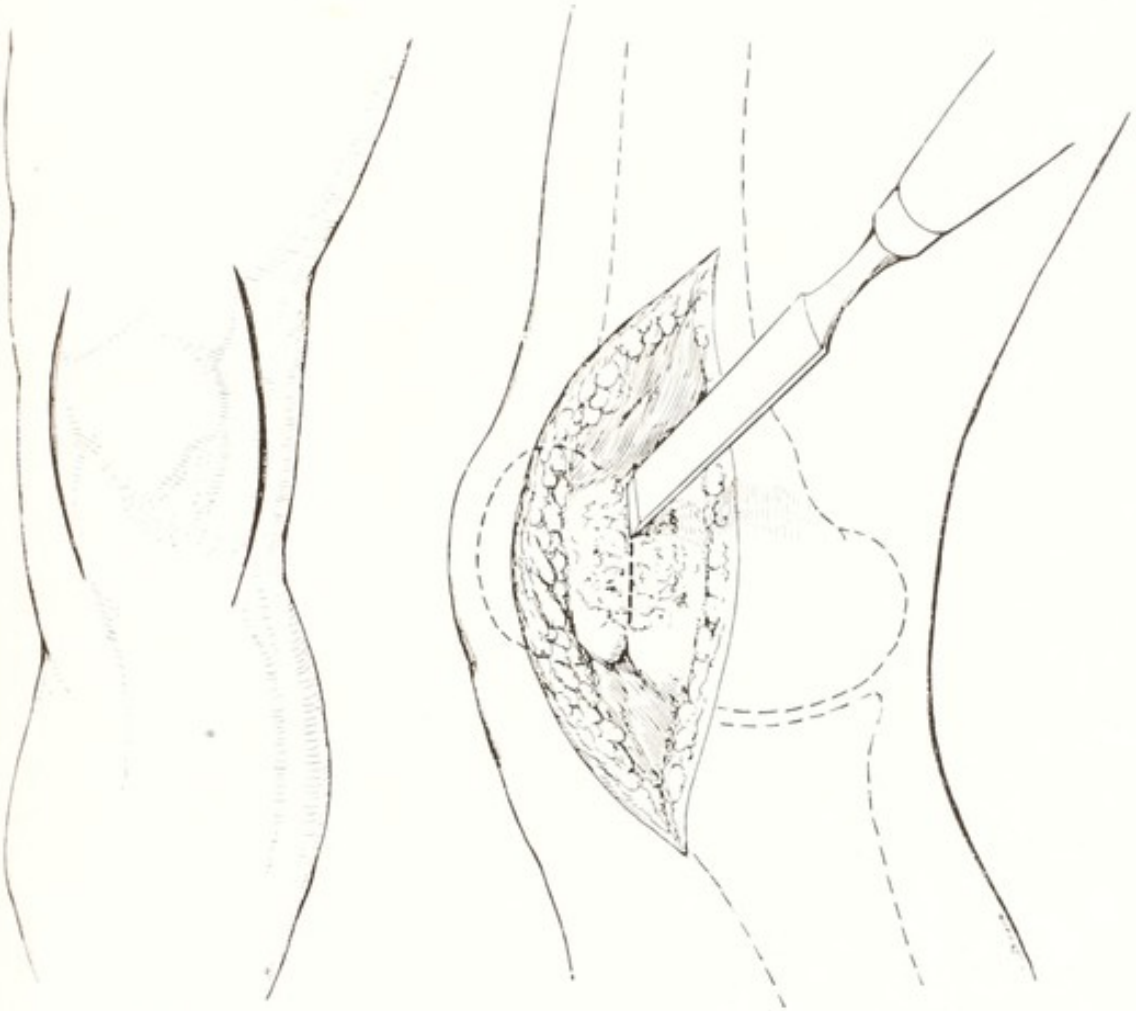


FIG. 674. FIG. 675.

FIG. 674.—Bony ankylosis of patella to femoral condyles. Two curved skin incisions on either side of patella for the double purpose of freeing patella and inserting free fascial-flap for arthroplasty.

FIG. 675.—Internal surface of right knee. Patella being freed from femoral condyles by osteotome.

above ankle. Fifteen to 20 pounds of traction with pulley and weight is maintained for six weeks or until a Taylor traction brace, or Thomas knee-brace is applied and locomotion with crutches is allowed. This brace should be continued for at least three months before weight-bearing is permitted. Traction is most necessary and should be applied before the patient comes out from under the influence of the anesthetic, because of the devitalization and crushing effect upon the fascial graft from the involuntary contraction of the powerful thigh muscles.

(*b*) Through an incision 6 inches long, following the anterior border of the great trochanter, beginning 1 inch below the anterior superior iliac spine, Nélaton exposes and splits the capsule longitudinally, and with a broad osteotome divides the femoral neck close to the pelvis. After excavating the acetabulum into a concave surface, he rounds off the divided neck to fit this cavity. Between these new articulating surfaces, a layer of muscle is interposed. The muscular flap is obtained by dividing the rectus femoris 4 inches below its origin and fixing the upper end in the new acetabular cavity by catgut sutures. The neck of the femur is immobilized in proper

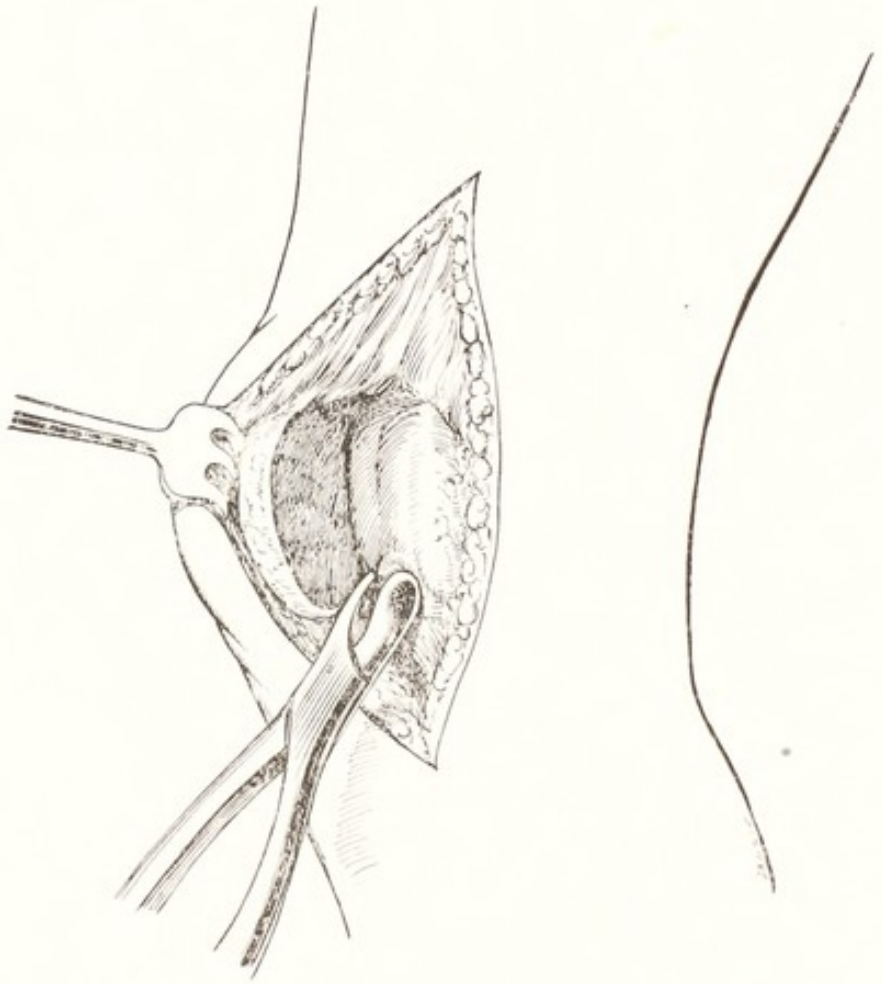


FIG. 676.—Internal surface of right knee. Patella having been freed from condyles, the osteophytes are removed and surface of condyles made smooth with rongeur and curet.

position until the wound heals, when exercises are promptly begun. If inversion prevents the anterior incision, external approach may be employed and the muscle flap obtained from one of the gluteal muscles.

(*c*) Murphy (Jour. A. M. A., June 31, 1905) attempts to remodel the ankylosed joint with fascia and fat, instead of muscle (Nélaton) interposed between the ends of the bones.

A goblet-shaped incision is employed, the trochanter occupying its center, and the open end measuring 5 inches. Vertically, the incision extends from a point 4 inches above to a point 2 inches below the trochanter. This flap is dissected upward and the great trochanter severed at its attachment to the femur. The ankylosed femur is separated from the acetabulum so that in cutting it away a rounded bony surface is left upon its head, and

the cotyloid cavity subsequently deepened by means of Murphy's reamer. The fascia lata is then separated from the deep surface of the goblet-shaped flap, made to line the new acetabular cavity (its apex being used to cover over the head of the femur), and fixed in position with catgut sutures. After manipulating the femoral head into the deepened acetabulum, the severed



FIG. 677.—Semicircular skin incision on outer aspect of thigh for purpose of obtaining fascial- and fat-flap from fascia lata. It is wise to obtain the fascial-flap at some distance from the joint in order to avoid the danger of adhesions about the site of its removal and the possible interference with joint motion.

trochanter is secured in position, the skin closed, and the limb immobilized in extension until the parts are healed, when movements are commenced.

4. *Knee.*—If the knee is ankylosed in flexion deformity, it is, according to the author's viewpoint, a far more rational procedure to perform a linear osteotomy just above the femoral condyles, or to remove a wedge at the site of ankylosis, with or without the insertion of the bone-graft, and with or without tenotomy of the hamstrings, than it is to attempt an arthroplasty. Arthroplasty of the knee is rarely more than partially successful, a knee

with only 5 to 10 degrees of flexion is a painful member and a hindrance to proper walking. The technic is, however, described for the sake of completeness (Fig. 673).

Technic.—A tourniquet is applied about the region of the midthigh. The patella is bisected after Jones' method (see Chapter XV), the lateral ligaments of the knee severed, and bony union between patella and femoral condyles severed with a sharp osteotome. The thickened capsule is divided in a posterior direction on either side. The tibia and femur are separated by forced flexion or with an osteotome. The entire capsule, lateral ligaments, and peri-articular tissue, according to Murphy, should be removed (except from the posterior margin) from both the tibia and the femur, down to their

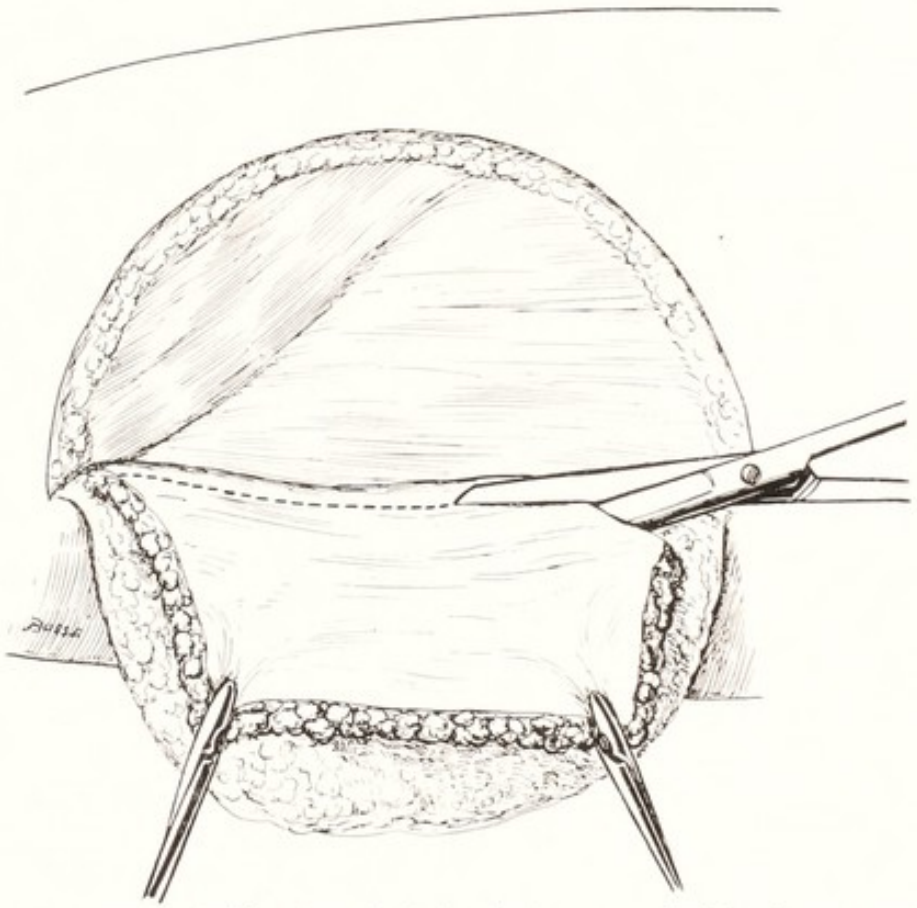


FIG. 678.—Fat- and fascial-flap from fascia lata being removed with scissors preparatory to its insertion between patella and femoral condyles.

attachments to the bones. The free fascial flap (obtained in the manner already described) is turned in between the bones and the entire articular surface of the femur covered with it, its free border coming well up on the shaft of the bone, and is then sutured to the periosteum with interrupted sutures of No. 1 chromicized catgut. The fatty surface of the flap is preferably turned toward the tibia.

In an attempt to restore motion to a stiffened knee, Murphy advocated the following procedure:

With bleeding controlled by a tourniquet, a long external incision is made from a point 6 inches above, to a point 3 inches below the knee-joint.

A second incision of 4 inches is made vertically over the inner side of the joint. The lateral ligaments are divided and removed. The ankylosis is broken down, the patella lifted from the femur with a chisel, and the femur

separated from the tibia with chisel or saw. The lower end of the femur is made convex, the head of the tibia, concave. A flap of muscle and fascia, with the base downward, is detached from the outer surface of the vastus externus. The flap should be so patterned that it extends laterally the whole width of the joint and anteroposteriorly covers the entire raw osseous surface. It is then fastened in place with interrupted catgut sutures. A smaller accessory flap is in like manner placed between patella and femur. The limb is kept rigid and extended for one week; at the end of that time massage and manipulation must be begun.

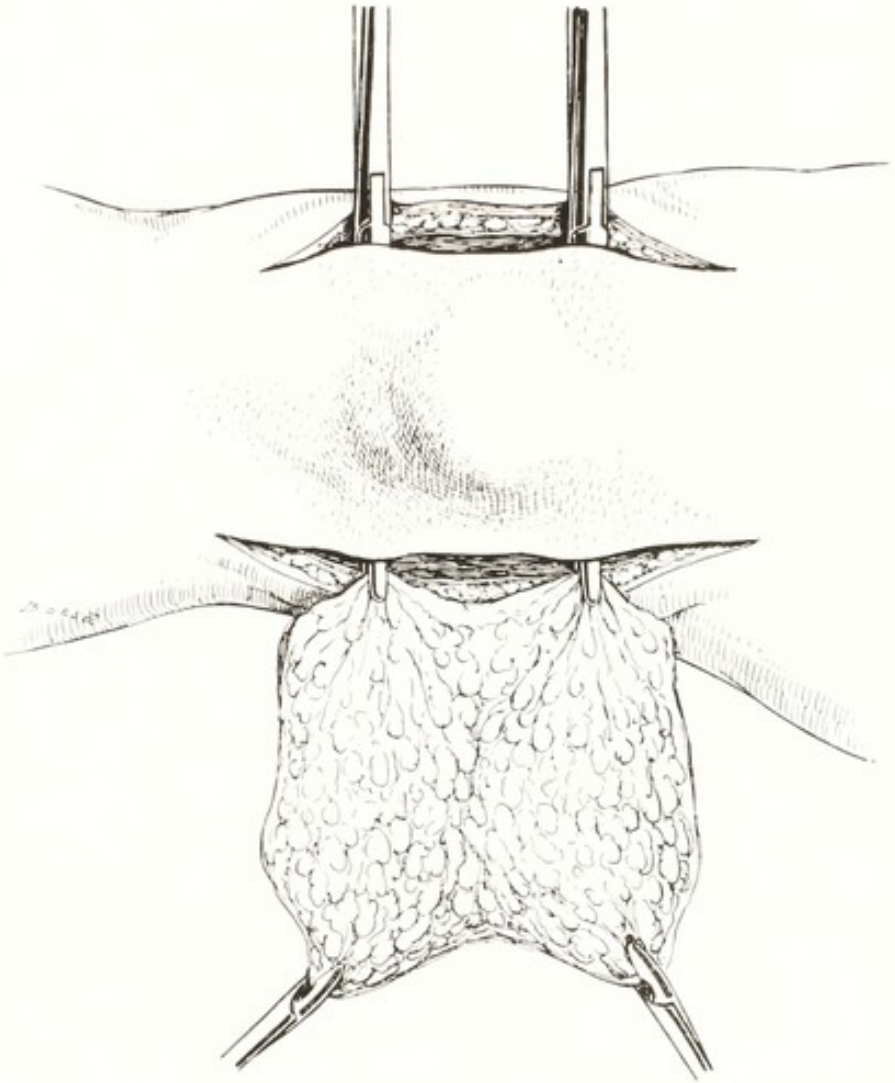


FIG. 679.—Inserting fat- and fascial-flap between patella and femoral condyles, the fatty surface anteriorly. Pair of small hemostats on each corner of flap.

5. *Ankylosis between Patella and Femur.*—This untoward event is not an uncommon complication of the degenerative type of arthritis, as a result of which the patella becomes firmly bound down to the condyles, with consequent great limitation of motion.

Technic of Arthroplasty (Figs. 674 to 681).—Long vertical incisions are made on each side of the patella, and the latter is separated by an osteotome from the condyles. The anterior surface of the condyles and the posterior surface of the patella are smoothed off with gouge and rongeur, and a free fascial flap (obtained as previously described) is drawn in between the two structures, its fatty surface toward the condyles, and sutured by its four

corners to the periosteum of the lower end of the femur and the upper end of the tibia. The knee is put up in the extended position, in a plaster-of-Paris dressing for ten to fourteen days, with weight extension applied, after which manipulation is begun (gently at first) and continued several times a day for six to eight weeks.

6. *Shoulder.*—Partial or fibrous ankylosis of the shoulder is most frequently caused by a fall with contusion of the joint, followed by effusion and, later, the formation of intra-articular adhesions. The treatment after the acute symptoms have subsided consists of repeated systematic manipulations, under anesthesia if necessary, with massage, baking, faradism, etc., in the

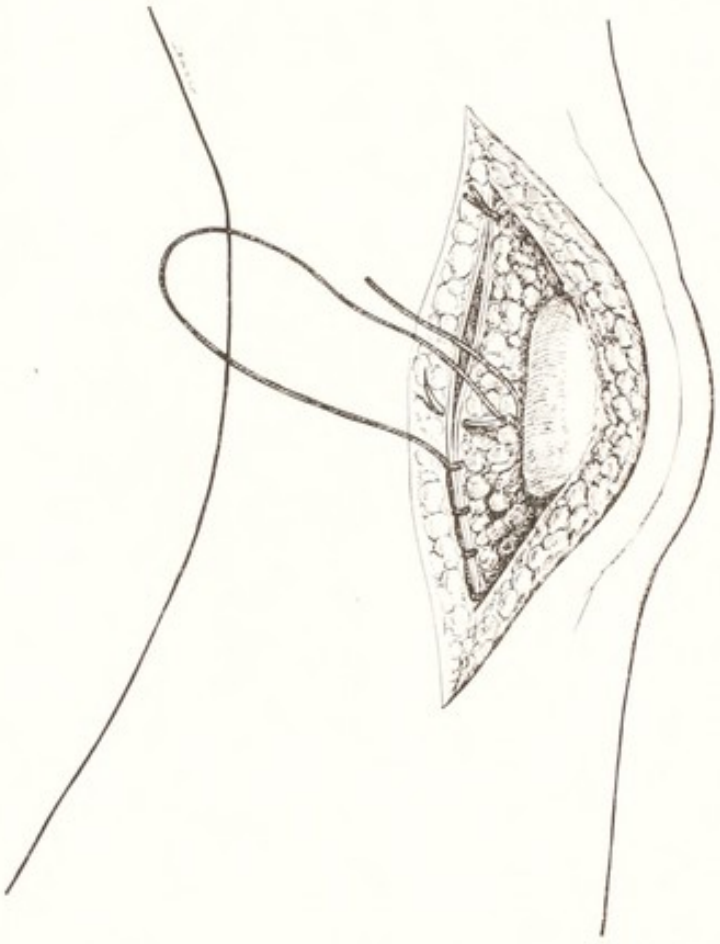


FIG. 680.—Fascial transplant sewed to soft structures about denuded portion of femur.

intervals of manipulative treatment. A fracture extending into the joint from the scapula or the humerus usually causes a greater degree of ankylosis, but even these cases, if given thorough treatment as described above, often enjoy complete restoration of joint motion.

If fracture of the surgical or anatomical neck with dislocation of the head of the humerus occurs, radiography is absolutely indispensable as the basis of judicious treatment. If the main vessel of the limb is compressed (evidenced by absence of the radial pulse), operation is advisable for readjustment of the fragments or removal of the head.

Bony ankylosis of the shoulder is better let alone if the arm is in good position, *i.e.*, with the scapula parallel with the posterior wall of the thorax and the arm at right angles with the trunk so that the patient can reach the mouth and the hair, inasmuch as movements of the scapula on the thorax under these conditions usually give a sufficiently useful range of motion to the upper extremity.

Arthroplasty of the shoulder, wrist, and ankle are so rarely performed that the reader is referred to special monographs for a description of these procedures.

7. *Joint Transplantation.*—Lexer, in 1908, described 2 cases in which ankylosis was overcome by transplantation of the entire knee-joint.

The region of the joint is exposed by an anterior curved incision. The soft parts are separated laterally from the synostosis and the latter is excised. With the limb extended, there now exists an interval of about 1 to 2 inches between the tibia and the femur. An entire knee-joint to fill this gap is obtained from a freshly amputated limb and accurately fitted into place and fixed in position. The ligamentum patellæ is re-united and the skin incision closed. It is evident that the field of usefulness of this operation is a very narrow one.

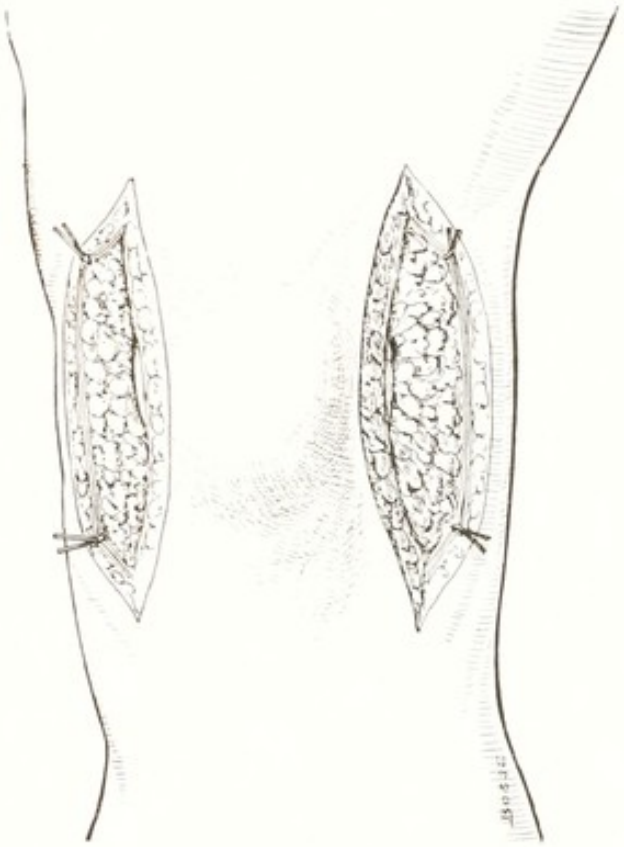


FIG. 681.—Final stay sutures holding fascial transplant.

REFERENCES

ALLISON AND BROOKS: "Ankylosis, an Experimental Study." Surg., Gyn. and Obst., 568–581, November, 1914.

ALLISON AND BROOKS: "The Mobilization of Ankylosed Joints." Surg., Gyn. and Obst., vii, 645, 1913.

HOFFA, A.: Orthop. Chir., 1902; Stüttgart: F. Enko, ed. iv, pp. 55–56.

NICHOLS AND RICHARDSON: "Arthritis Deformans." Jour. Med. Research, xx, 140, 1909.

AXHAUSEN AND PELS: "Exp. Beitr. z. Genese d. arth. Deform." Deutsche. Zeitschr. f. Chir., cx.

KROH, F.: "Exp. Arthritis Deformans." Deutsche Zeitschr. f. Chir., 1909, xcix, 425.

SUMITA: Arch. f. klin. Chir., xcix, 775, 1913.

OSGOOD, R. B.: "The End Results of Attempts to Mobilize Stiffened Joints." Surg., Gyn. and Obst., 664–66, December, 1913.

PAYR: Arch. f. klin. Chir., xcix, No. 3, 1912.

BAER: Am. Jour. Orth. Surg., August 1, 1909.

MURPHY: Jour. Am. Med. Ass'n, May 20 and 27, 1905.

NEFF: Surg. Gyn. and Obst., November, 1912.
TAYLOR, R. T.: Surg., Gyn. and Obst., April, 1912; Penna. Med. Jour., January, 1913.
HELFERICH: Arch. f. klin. Chir., xlviii, 864, 1894.
GLUCK: Verhandl. d. deutsch. Gesellsch. f. Chir., 1902.
CHLUMSKY: Wien. klin. Wochenschr., 1902; Zentralbl. f. Chir., 1900.
HOFFA: Zentralbl. f. Chir., No. 23, 1904.
BAER, W. S.: Am. Jour. Orth. Surg., vii, 1.
KIRSCHNER: Beitr. z. klin. Chir., 1900, lxv, 472; Verhandl. d. deutsch, Gesell. f. Chir., 1911.
LEDDERHOSE: Deutsche Zeitschr. f. Chir., xxxvii, 1893.
DAVIS: Johns Hop. Hosp. Bull., October, 1911.
NEFF: Surg., Gyn. and Obst., xv, 529, 1912.
HOFFA: Lehrbuch d. Orthop. Chir., Stüttgart; p. 33, 1902.

CHAPTER XXIX

PLASTER-OF-PARIS TECHNIC

I. THE PLASTER-OF-PARIS BANDAGE

The reason for the very limited use of plaster-of-Paris bandages in private practice as compared with their extensive use in dispensary and hospital practice is undoubtedly to be found in the fact that those in the market are almost invariably lacking in the essentials of efficiency.

Instead of crinolin, many of these plaster-of-Paris bandages are made of some unsized material; or, if crinolin is used, it is of too fine a mesh and wound too tight. Furthermore, these bandages usually contain too much plaster, and therefore when an attempt is made to saturate them the water is unable to gain access to the interior of the bandage and fully to saturate the plaster, in consequence of which dry lumps are left which interfere with the uniform setting of the plaster.

Again, the plaster-of-Paris is frequently of inferior quality and the bandage is not hermetically sealed. Because of the hygroscopic nature of the plaster, it takes up moisture, "cakes," and the process of setting is effectually prevented.

Plaster-of-Paris hardens by a process of crystallization. If moisture-ladened air is allowed to gain access to the bandage, those particles of plaster which are more hygroscopic than others will crystallize prematurely, producing gritty particles in the plaster, which can be easily recognized by rolling a specimen between the fingers. When such a bandage is in the process of application, it hardens slowly and irregularly, and solidifies unequally—this is a great disadvantage, because it is frequently imperative to maintain correction of a deformity from the outset, without delay, and to be able to properly mould the plaster so as to increase coaptation pressure to prevent relapse of the deformity or a recurrence of the displacement of fragments in the case of a malunited fracture, before the patient is transferred from the operating room to his bed.

II. MATERIALS

(*a*) **Plaster-of-Paris.**—The plaster-of-Paris should be that used by dentists, of very superior quality, and rapidly setting. (That manufactured by the S. S. White Dental Company has been found by long experience to be the best.) It is packed in air-tight tin pails to prevent hydration from the air. It may be said in passing that to further prevent hydration, the pails should be stored in the intervals between use in dry localities, and when in use the hand introduced into the pail should be perfectly dry.

It will occasionally be found that because of some accident during the process of manufacture or from a break in the hermetic seal, a particular specimen of this plaster will not harden properly. Such a specimen should either be returned at once to the manufacturers, or put through a slow baking process, about to be described, for the purpose of dehydration.

When this hermetically sealed dental plaster is used, the addition of salt to the water of immersion is not only superfluous but is an undesirable procedure, because it causes the plaster to become brittle. Moreover, the method usually followed in clinics of measuring the salt by the "handful" is most inaccurate, as is also the method of measuring the water of immersion by the "pailful," "half-pailful," etc.

When the plaster-of-Paris conforms to the specifications noted above, it will be found that the dressing, after three or four layers of bandage have been applied, will harden with sufficient rapidity so that it produces a good splint effect before the application of the final layers has been completed.

(*b*) **Crinolin.**—Although a number of different fabrics have been used as material for impregnation with plaster-of-Paris (gauze, dextrin gauze, flannel, etc.) it has been found that crinolin (gauze sized with some stiffening substance) is by far the most satisfactory for this purpose. An unsized bandage is worthless in this connection, while crinolin of too fine a mesh is unsatisfactory because a superfluous amount of plaster is left in the bandage when it is rolled, causing it to set too rapidly and to become too brittle. A bandage containing too much sizing is open to the objection that the excess of sizing material prevents the plaster from setting. The mesh should number 28 × 32 threads to the square inch.

The crinolin which many of our largest clinics have found by experience to be the most satisfactory, is the hospital crinolin mesh H, manufactured by the H. B. Claflin Corporation. It comes in 12-yard bolts, which should be divided in halves, each 6 yards long by 1 yard wide. Each half is then torn longitudinally into strips 3 inches and 5 inches wide, respectively. In his own practice the author has found these to be the only two sizes required.

III. METHOD OF PREPARING AND STORING PLASTER-OF-PARIS BANDAGES

After the bolt of crinolin has been divided into two equal portions, each 6 yards in length, the selvage is removed by tearing, and roller bandages of 3- and 5-inch widths are produced by tearing the half bolt lengths longitudinally. After winding these strips into loose rolls, the ravellings on the edges are removed by rubbing the point of a pair of scissors over the ends and pulling away the ravellings thus dislodged. (Crinolin should never be *cut* with knife or scissors unless cut obliquely, after having been rolled, as taught by Major Maddock in the Orthopedic Annex of the United States Army Medical School, because of the difficulty of always following between the same longitudinal threads and thus avoiding short ravellings which cannot be removed on account of the uneven cut edge.)

Impregnation of the Crinolin Bandage with Plaster.—This is best done by placing a pile of plaster upon a smooth broad board (such as a bread board) and drawing the crinolin bandage through it. The bandage is held to the left of the pile, slowly unrolled, and dragged through the edge of the pile of plaster. While the bandage is being drawn through, the plaster is rubbed by hand thoroughly into the meshes—the *meshes should be rubbed just full, and no more.* No additional plaster should be sprinkled on the bandage, and care should be taken that the latter is not wound too tight.

Storing.—The completed plaster-of-Paris bandage is wrapped in a single layer of paraffin paper which is impervious to moisture, and secured with an elastic band, or, for lack of this material, in two or three layers of newspaper or wrapping paper, and packed in tin pails with accurately fitting covers.

(The tins pails in which the plaster comes serve well for this purpose.) The pails should be kept in the driest place available. Plaster-of-Paris, whether loose or in bandages, should never be stored in a basement. If for any reason the air-tight seal of the pail becomes broken and the plaster fails to harden well and quickly, it may be possible to restore it by placing the tin container, with the cover off, in a *very* slow oven for a period of several hours, after which the cover is replaced and the container set away in a dry place.

IV. PLASTER-OF-PARIS "STRENGTHENERS"

In addition to the ordinary roller form of plaster-of-Paris bandage, the so-called "strengtheners" are of much value when used at points of great mechanical stress, *e.g.*, at the groin, in the case of the spica. These are made precisely like the ordinary plaster-of-Paris bandage, with the exception that instead of being rolled they are reduplicated into 2-foot lengths of 9 thicknesses, *i.e.*, a bandage of 6 yards (18 feet) is folded in 2-foot lengths of 9 thicknesses. These 9 folds are then loosely rolled up, an elastic band put about each, and they are either placed in a separate container, or, if put in the same tin with the roller bandages, they are wrapped in a specially colored paper for purposes of identification.

Instead of plaster-of-Paris "strengtheners," *metal* is sometimes used for this purpose, tin, zinc, or sheet iron, although the author prefers the plaster "strengtheners" except in the rare instances in which unusual strength is required or when a cast has been weakened by fenestration.

V. REQUIREMENTS OF A PLASTER-OF-PARIS BANDAGE

The crinolin should be of such quality that in applying the bandage it can be made to smoothly conform to the irregularities of the part to which it is being applied. When in the hands of a surgeon who is a master of plaster-of-Paris technic, it should respond readily to every fold in the fitting process, without wrinkling.

The bandage should be so wound and so impregnated with plaster that when properly immersed in water it will become immediately saturated and, during the process of application, will not "telescope." If too tightly wound and containing too much plaster, it will become "gummy" with dry spots from uneven penetration of the water; if too loosely wound, it will "telescope," *i.e.*, the center pushes out of one end, is flat, awkward of application, and does not take the form of a roller bandage. As has been said, the strongest and most efficient bandage is one that contains just enough plaster to fill the meshes of the crinolin and no more.

The plaster should harden with sufficient rapidity so that when the surgeon has completed the final layers, the bandage will be of such consistency as to give good splint support and yet be malleable enough to withstand moulding and stay "put."

VI. PLASTER-OF-PARIS TECHNIC

(*a*) **Padding.**—Several materials have been used as padding, cotton sheet wadding, stockinet, flannel, all of which are acceptable. The author prefers to use sheet wadding, purchased in large rolls and torn into strips varying from 4 to 12 inches in width, and rolled into bandages. One advantage of cotton wadding is that it yields to Stillé's cutter in removing the cast in a way that the other materials do not. Emphasis should be put on the

importance of the *even* application of this sheet wadding, due regard being paid to the protection of all superficially placed bony prominences, at the same time preserving its even distribution throughout the rest of the limb. Another advantage is, that on account of its yielding properties, it never furnishes a constricting edge to cause distal swelling of the limb. The author prefers to hold the wound dressing (postoperatively or otherwise) by means of the sheet wadding bandage, rather than by applying a gauze bandage directly over the dressing, as practised by some surgeons, because the general swelling of the limb from exudate after any operation may cause the edge of the gauze bandage to become taut and to act as a local constricting band, causing further swelling of the limb distal to that point.

(*b*) **Saturation of the Plaster-of-Paris Bandage.**—Tepid water is ordinarily used, always in a container (preferably a pail) of sufficient depth so that with the bandages standing on end they will be entirely submerged. The higher the temperature of the water (within certain limits) the quicker the plaster hardens. The wrapper, if it is permeable to water, may be left on or removed, as preferred; the author prefers its removal. The bandage is placed on end in the water and allowed to remain standing until air-bubbles have ceased to rise, when it is ready for use; time is no guide.to the completion of saturation, the absence of air-bubbles being the criterion.

Attempts to hold or to squeeze the bandage while it is submerged, with the idea of making it absorb water more rapidly, cause agglutination of the ends of the bandage and prevent the water from penetrating to its center.

After removing the bandage from the water, it should be held by each end, with the object of preventing so far as possible the escape of the fluid plaster. It should then be *very gently* wrung out by a half turn of the bandage, so that when handed to the surgeon it is in the shape of a flattened roll with about 6 inches unrolled. The saturated bandage should never be squeezed in the center or vigorously wrung, because thereby too much plaster is lost and frequently the bandage is telescoped.

"Strengtheners" are saturated in the same way as the roller bandages above described.

(*c*) **Application of the Plaster-of-Paris Bandage.**—It is difficult to give clear and comprehensive directions for applying an ideal plaster-of-Paris bandage. Dexterity can be acquired only by actual experience.

The best method is to allow about 6 to 8 inches of the bandage to be unrolled in advance of its actual application. Great care should be taken to have the bandage smooth, without wrinkles, and with its first layers so placed that slight, even compression is exerted throughout the extent of the splint. The plaster should be *constantly* rubbed in during the application.

The limb is first entirely and evenly bandaged with two or three thicknesses, this insures a more uniform bandage and promotes more rapid hardening, since it gives a larger area for drying. It is difficult to state exactly how many layers should be applied in the average case; the quality of the plaster, the rapidity of drying, the character of the lesion, and the mechanical stress that will come upon the splint, largely determine this. Roughly estimated, the average plaster-of-Paris dressing, when completed, consists of 6 to 10 thicknesses, but the splint should always be made as light as safety will permit.

The "strengtheners," above described may always be used to strengthen that part of the splint on which increased stress is to come, thus avoiding a generalized increase of bulk and weight of the cast; incidentally, the use of "strengtheners" lessens the time of the technic.

In the case of a prolonged application, the water should be changed at

frequent intervals, since it becomes saturated with plaster and hence thickened and fails to penetrate the bandages readily. The surgeon should be careful to mould the plaster about the bony prominences, and be on the alert to increase his coaptation effect at the proper time, before the plaster becomes too hard.

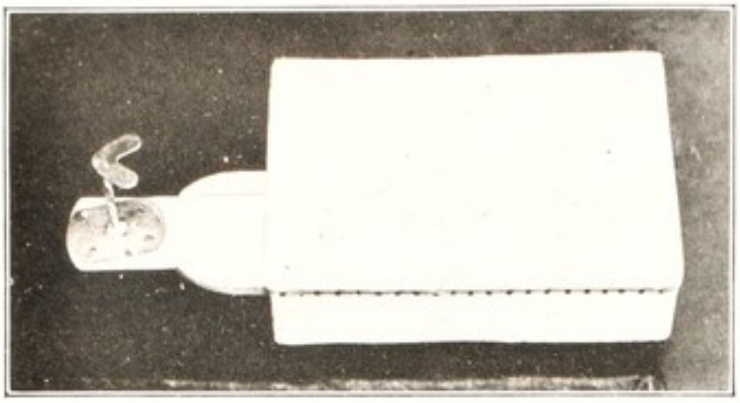


FIG. 682.—Adjustable hip and shoulder rest used at the hospital for ruptured and crippled. (Taylor.)

Rubbing in dry plaster or plaster cream on the exterior of the dressing hastens hardening and gives a smoother surface.

When it is necessary to maintain the plaster in position for a long time, to keep it clean, particularly about the fenestra, and free from contamination and saturation by discharges, varnishing the cast is an excellent practice.

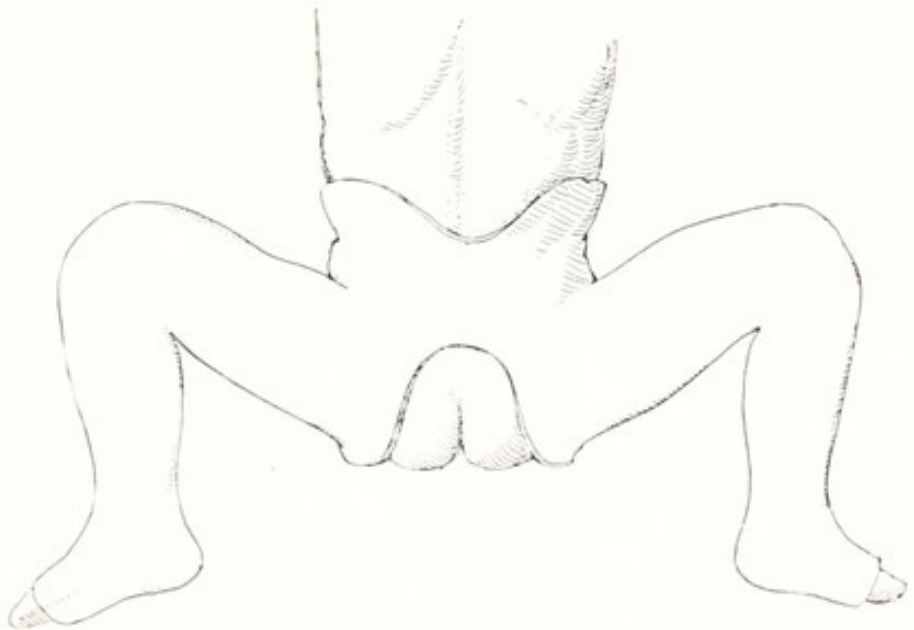
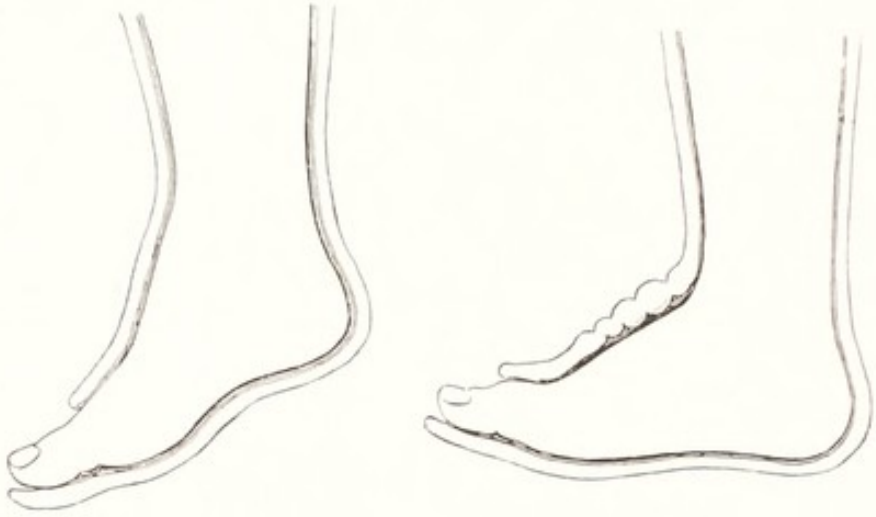


FIG. 683.—Moulded double long plaster-of-Paris spica for double congenital dislocation of the hip. (After Calot.)

It is advisable to turn down a cuff of the sheet wadding over the edges of the cast at its extremities when it has been partially applied, so that the remaining portion of the cast can be placed over it; this not only serves to hold the cotton at the edge, to secure its padding effect, but also to prevent the patient from dislodging or pulling out the cotton at this point. If it is

necessary to trim the cast, the production of a cuff should be delayed until the trimming has been completed, when one or two layers of the plaster-of-Paris bandage may be added for this purpose.



a *b*

FIG. 684.—*a*, Application of plaster-of-Paris with the foot in equinus, which should always be avoided in putting up fractures, etc.; *b*, demonstrates disadvantage of attempting to correct plaster after it has begun to harden. The foot should be held in the correct position from the beginning of application of the plaster to avoid wrinkling of plaster over the dorsum of the foot and ankle.

In cases in which large fenestra are to be cut, it may be necessary to strengthen the dressing at those points by means of metal bridges incorporated in the plaster and carried over the fenestra.

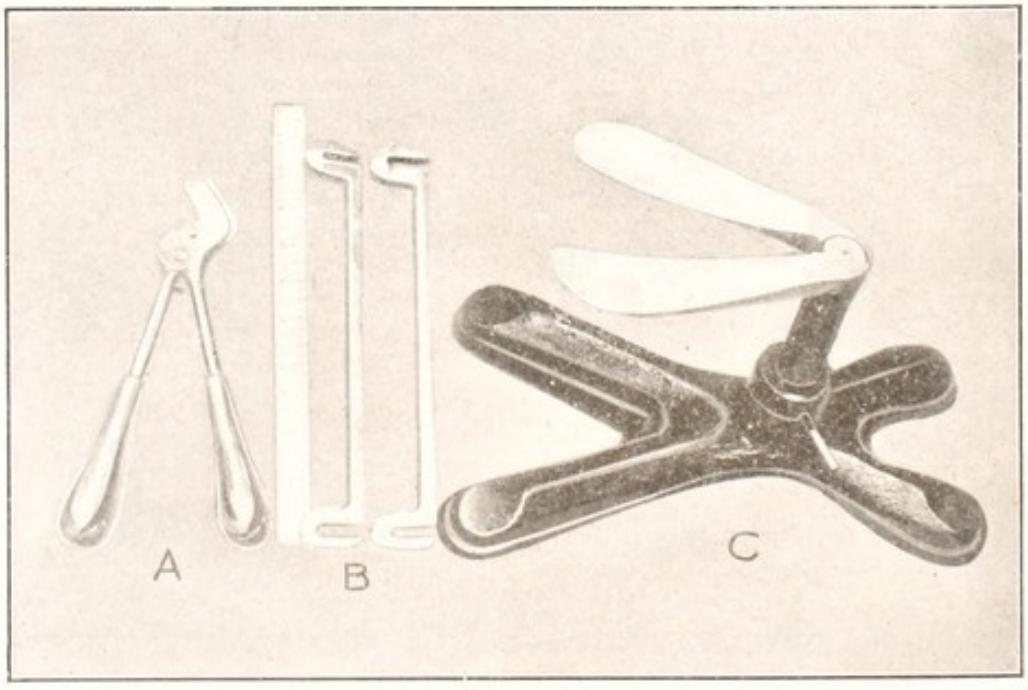


FIG. 685.—A, Stillé's plaster cutter. B, Hooks for bending steel bars. C, Schultze's hip-rest. (Taylor.)

Where traction as well as fixation is required, moleskin stickers, or whatever traction straps are used, are placed upon the limb at the desired points,

emerging at the lower angles through openings made during the course of application. (In the case of the lower extremity, at a point 2 or 3 inches above the malleoli, a spreader being applied below the foot and weights attached in the usual manner.)

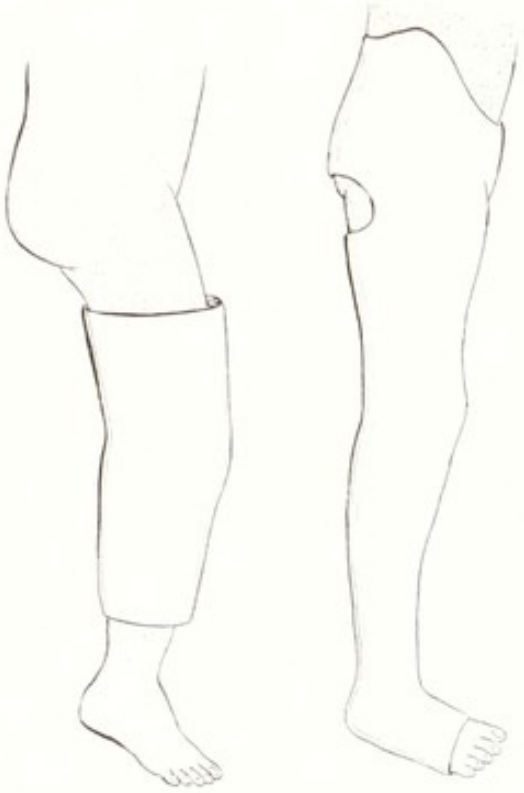


FIG. 686.—The proper (*b*) and the improper (*a*) method of applying plaster-of-Paris dressings to the knee-joint. In *a* the leverage action is too short and, furthermore, fixation effect is lost because of the thick muscles of the thigh.

Plaster dressings well applied and of good material will last many weeks or months, in fact the author has removed plaster-of-Paris jackets that have been in place for five years.

As a rule, the potency of a plaster-of-Paris dressing, is due largely to its leverage action, and it should therefore be sufficiently long to allow this

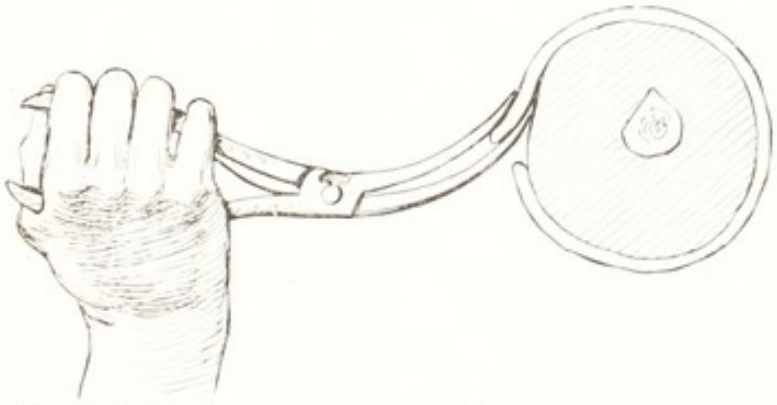


FIG. 687.—The removal of a plaster splint after it has been spread as shown in Fig. 688.

factor full value, in the case of a lesion of the knee-joint, the cast should always extend from the groin to the ankle or toes; in the femur, a spica over the pelvis. The author emphasizes this point because he frequently observes many plaster dressings on such cases that extend only to the midleg or mid-

thigh; it is needless to say that such splints are useless in these cases (Fig. 686).

VII. ACCESSORIES TO PLASTER-OF-PARIS BANDAGES

(*a*) **Jury-masts.**—In cases of cervical Pott's disease or other lesions of the cervical spine where fixation support is required, a jury-mast or chin-cup may be incorporated in the last layers of the plaster jacket. No other special means of retaining the apparatus in the jacket is necessary.

(*b*) **Metal bridges** to span a fenestrum have been mentioned already, as have also (*c*) metal strengtheners.

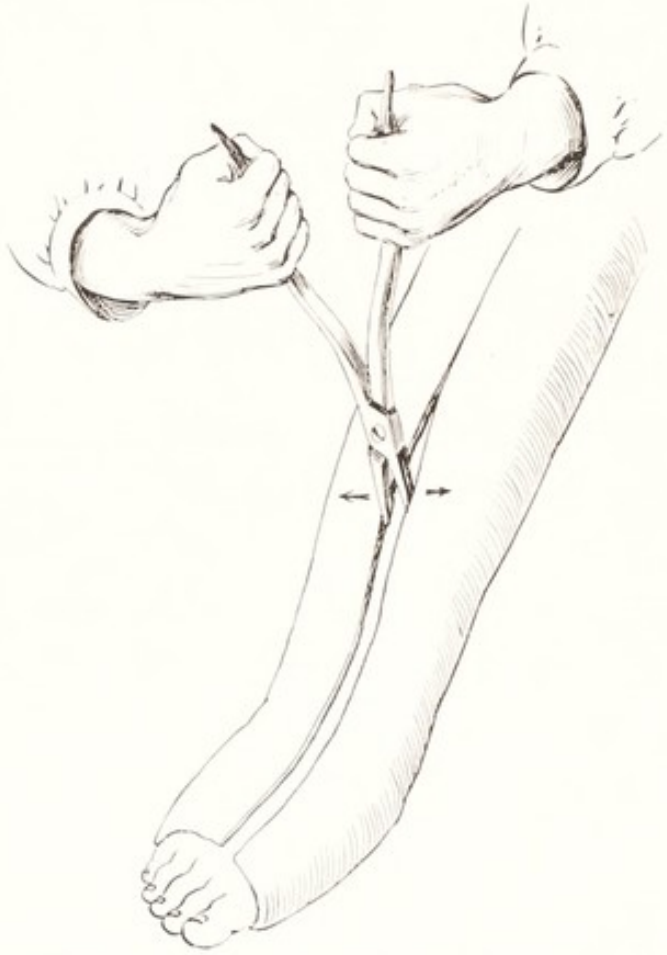


FIG. 688.—Plaster spreader. After the plaster is cut with a Stillé's cutter or the author's motor plaster cutter, it is then spread with this instrument.

VIII. REMOVAL OF A PLASTER-OF-PARIS SPLINT

In the author's experience, this is best done by a Stillé cutter (Fig. 685). If this is not accessible, a saw or a heavy jack-knife serves the purpose. To soften the plaster along the line of incision, vinegar can be used after the surface to be cut has been well scarified with a knife. Hot water also serves the same purpose. (Experiments are now being made to perfect a satisfactory motor-driven plaster cutter.) Having cut the gutter, the dressing is spread with a special clamp as shown in Fig. 688.

In the case of the lower limb, it is best to cut along the outer margin of the foot behind the external malleolus and up the external surface of the leg, rather than along the instep and inner surface of the thigh, where the plaster is usually thinner and hugs the limb more closely. In removing a cast which has been applied for postoperative fixation, the field of operation would be

carefully avoided. The same rules apply to the removal of the plaster-of-Paris spica, in that one should avoid the thicker portion of the bandage at the groin where the portions from thigh and pelvis cross each other. The best method for removing the spica is to cut up the inner surface of the leg as far as the perineum, thence over the abdomen.

If it is desired to make a removable plaster corset, the dressing is cut from the symphysis up the midline of the abdomen and thorax to the sternal notch, then sprung off the trunk and the hooks and eyes and the covering of the corset applied, so that it can be laced together like an ordinary corset.

If the cast is to be re-applied, as anterior and posterior splints, it, of course, has to be split up the inside as well as the outside of the limb.

REFERENCES

MEISENBACH, R. O.: "A Study of Plaster-of-Paris Bandages." Am. Jour. Orthop. Surg., July, 1906.

HOFFA: Orthopädische Chirurgie. (Fünfte Auflage.)

LÄNG: Deutsche Zeitschr. f. Chir., Leipzig, i, 126, 1872.

HERMAN: Wein. Med. Presse, vi, 654, 1865.

FRÄNKEL, B.: "Einiger über Gips." Berl. Klin. Wchnschr., iii, 179, 1866.

GOLDTHWAIT: "Some Practical Hints in the Use of Plaster-of-Paris Bandages." Boston Med. & Surg. Jour., cxxiv, 4061, 1891.

GIBNEY, V. P.: International Clinics, Phila., iv, 244, 1893.

RUGH, J. T.: American Journal of Orthopedics, ii, 107, 1905.

RUGH, J. T.: Philadelphia Polyclinic, vii, 191, 1898.

PHELPS, A. M.: Am. Orthop. Ass'n, (Trans.) vii, 459, 1895.

WHITE, J. W.: "Taking Impressions."

WILCOX, H. A.: "Practical Details in the Preparation of Plaster-of-Paris Bandages." Philadelphia Polyclinic, ii, 31–36, 1893.

DAWSON, W. W.: "Plaster in Surgery." Clinic, Cin., xiii, 217, 1877.

STEELE, A. J.: Trans. Am. Orthop. Ass'n, v, 71.

WEAVER, W. J.: Philadelphia Medical Times, viii, 149, 1878.

DONKIN, C.: London Lancet, ii, 947, 1881.

MACEWEN: Glasgow Med. Jour., xi, 224, 1879.

WARE, MARTIN W.: "Plaster-of-Paris and How to Use it."

STERN, W. G.: "Plaster-of-Paris. The Effects of Various Substances upon Its Rate of Setting and the Subsequent Strength and Durability." Am. Jour. Orth. Surg., iv, 352, 1907.

RYERSON, E. W.: "A Simple Apparatus for the Application of Plaster Jackets in Dorsal Recumbency." Am. Jour. Orthop. Surg., iv, 4, 1907.

RUGH, J. T.: "Report of Experiments to Determine Whether Plaster-of-Paris Contracts or Expands in Setting." Am. Jour. Orthop. Surg., ii, 107.

FREIBERG, A. H.: "A Suggestion for the Improvement of Plaster-of-Paris Technique." Am. Jour. Orthop. Surg., vii, 227, 1909.

SOUTTER, R.: "The Plaster Swathe." Am. Jour. Orthop. Surg., viii, 732, 1911.

BLODGETT, N. E.: "Remarks on the Use of Plaster-of-Paris in Surgery; with Demonstrations." Detroit Med. Jour., p. 241, 1908.

ALLISON, N.: "A Description of Apparatus for the Application of Plaster-of-Paris Bandages." Am. Jour. Orth. Surg., vii, 699, 1909.

FESSIER, J.: "Ueber Erstarrende Verbande Besonders Gipsverbande mit Drahtnetzeinlage." Archiv. f. Orth., iii, 65, 1905.

GOCHT, H.: "Zur Behandlung des Schiefhalses, Combinirter Zug-Gips-Verband." Zeitschrift f. Orth. Chir., xiii, 173.

MOORE, J. E.: "The Use of Plaster-of-Paris in Surgery." Northwest. Lancet, xiii, 201, 1893.

KELSEY, C. A.: "Plaster-of-Paris Casts." St. Paul Med. Jour., iv, 503, 1902.

GEIST, E. S.: "Plaster-of-Paris Casts." Journal-Lancet, Minneapolis, March 1, 1913.

CHAPTER XXX

MILITARY AND INDUSTRIAL RECONSTRUCTION SURGERY[1]

Reconstruction surgery is to-day, above all, the subject of the hour. New conditions are occurring all the time, and new environments are being added to those under which the surgeon formerly worked. Hence it is not easy, at this time, to write a chapter on military surgery; nor is the time yet ripe to write exhaustively on any subject pertaining to military medicine or surgery, though a vast amount of surgical experience and literature has been accumulated in the four years of Pan-European War, with thirty millions of men actively engaged in their world record carnage, including ninety thousand medical men, whose work and observations extend over many thousand miles of the most varied front. Not until peace has been established for sometime and the professional mind has had opportunity to thoroughly digest all the statistical evidence, will the real facts be shown in their true light.

The surgery of war does not vary widely from the surgery of peace. The military surgeon must be "a specialist in surgical adaptability and compromise." Orthopedic work as applied to civilian and industrial cases is very broad and varied in character. It has to do not only with bones and joints, but with tendons, muscles, nerves, ligaments, fascia, etc. The competent military surgeon is required to meet all these various conditions as in civil life. They are all the more likely to occur under the stress and strain and overwork in the trenches than anywhere else, and in addition to these conditions the surgeon has been required to manage a variety of conditions that originate only in war. For this work he must be equipped with the most exact knowledge of anatomy, and the physiology of function.

A very large percentage of bone, joint, nerve, tendon, spinal, and extremity lesions results in the orthopedic service being by far the largest of the army medical services. Lieutenant Colonel Starr, chief of the Orthopedic Surgical Service of the Canadian Army, reports that 75 to 85 per cent. of all surgical cases returning to Canada from the battle front are orthopedic, according to the classification of the United States, Canadian, and British Army medical departments. A large percentage of these wounds consist of compound, comminuted fractures of long bones, involving usually a considerable loss of bone substance, a varying number of which requires a bone-graft operation for their restoration. Dr. Downer (Military Surgeon, Sept., 1917) states that "in the little town of Czarskoe-Celo (Russia) . . . . . there are 130 hospitals, and perhaps 150 cases of ununited fractures all going begging for an operation," because of lack of proper instruments and technic on the part of surgeons.

Keen states that the recent great war surpassed all other wars in five principal respects:

(1) Huge numbers; (2) new weapons, artillery, gas, etc; (3) rapid means of transportation; (4) rampant infection; (5) conquest of infection

[1]A considerable part of this chapter has been compiled from the report of the Orthopedic Division of the Surgeon-General's Office and from Mayer's "Orthopedic Treatment of Gunshot Injuries." Credit is also due Lieutenants Sybenga and Treichler for roentgenograms and photographs.

by antiseptics and by new methods; in two respects great progress has been made, *i.e.*; (1) development of war orthopedic surgery and training of the disabled soldier; (2) reconstruction surgery of the face and jaw by co-operation of dentist and surgeon.

Four Methods of Treating Wounds at the Front.—(1) The ordinary method of incision, drainage, and packing with plain or iodoform gauze, antiseptics, balsamine, etc., exactly as practised in civil life.

2. The physiological or hypertonic saline method, as directed by Sir Almroth Wright.

3. The Dakin-Carrel method.

4. The method of excising wounds.

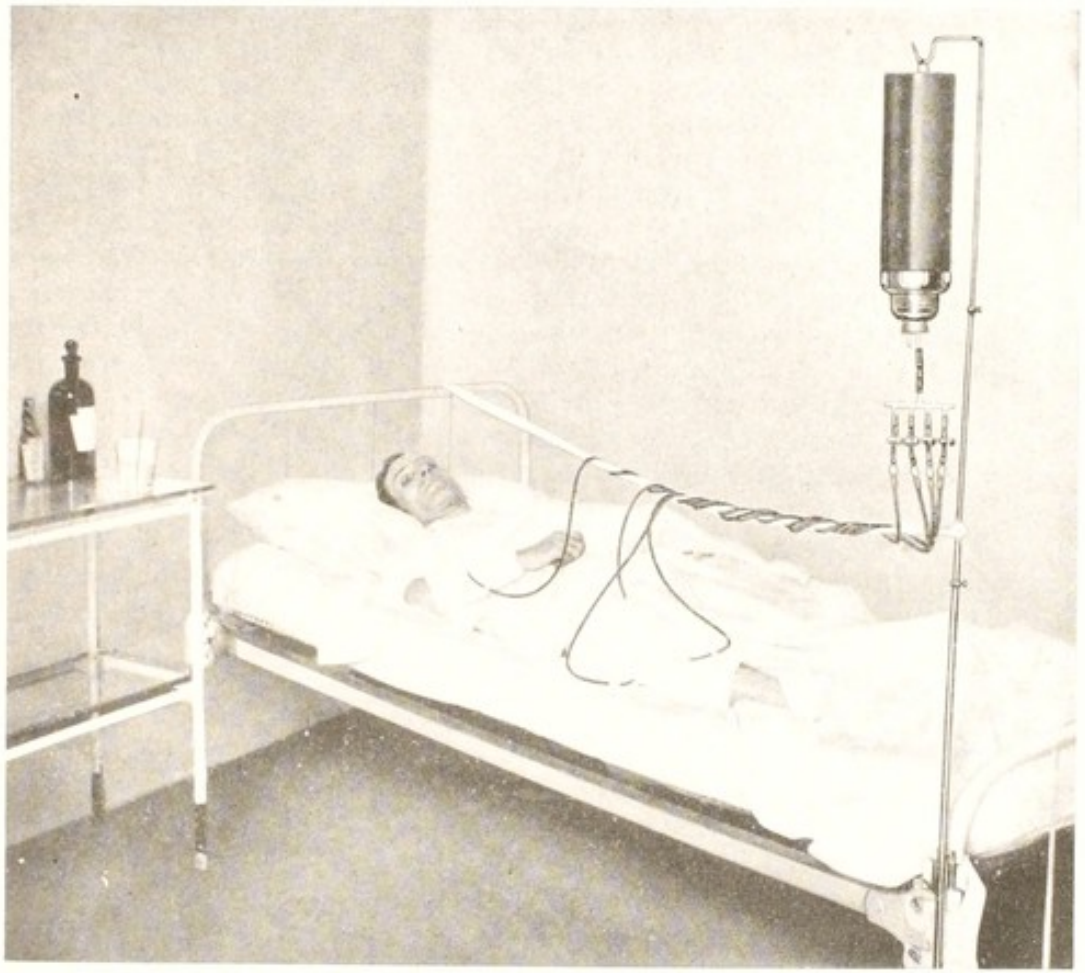


FIG. 689.—Apparatus for instillation of Carrel-Dakin solution. (Albee and Pettinger.)

Lyle believes that the fourth method "in the hands of trained and experienced men, gives the most brilliant results, and this often in places where one would least expect it, for example, in the joints. The method calls for good judgment, the early reception of the patient, and the retention of the patient under the care of the operator for a long period." If infection occurs, the Carrel method should be instituted at once. Whatever method is used, immediate extraction as far as possible of all foreign bodies, projectiles, clothing, etc., was practised at the ambulance at the front by the best men.

Dichloramin-T (Toluene-parasulphondichloramin).—Because of the irritation of the skin and the fact that when in contact with the wound exudates the Carrel-Dakin solution loses its chlorin in one hour, or even less, and therefore becomes inert, and the fact that it is necessary to keep the weak

hypochlorite solutions in constant contact with all surfaces of the wound, Dakin (H. D. Dakin, W. E. Lee, J. E. Sweet, B. M. Hendrix, and R. G. LeConte: "A Report of the Use of Dichloramin-T (toluene-parasulphondichloramin) in the Treatment of Infected Wounds," Jour. Am. Med. Ass'n, July 7, 1917, lxix, 27–30; also Surg., Gyn. and Obst., Jan., 1918) has suggested using dichloramin-T, a synthetic chloramin which corresponds to the germicidal chloramin formed when the nascent chlorin of the hypochlorites comes in contact with the wound exudates. It is best to employ the synthetic chloramin dissolved in chlorcosane and when in this state it causes no irritation to the skin and can be used in 5 per cent., and even in 10 per cent. strengths. Its germicidal action continues for eighteen to twenty-four hours and therefore the dressing need be done only once a day. The advantages of dichloramin-T over the Carrel-Dakin solution are (*a*) that it requires a simpler technic, (*b*) dependent drainage can be secured, (*c*) there is great saving of material and of the time expended on the individual case, while the greatest advantage of all is (*d*) its applicability to lesions in a limb immobilized in plaster-of-Paris dressings, since it obviates the use of irrigation and the attendant danger of saturating the splint-padding and plaster and therefore does not invalidate the fixation.

At the Pennsylvania Hospital, in Philadelphia, the results of treatment as reported by Dakin and his colleagues, promise great advances over those secured by any former method of wound sterilization. In 160 unselected cases of industrial accidents treated by the Dakin-Carrel method, the cases were discharged in one-third of the time required by former methods. In 82 similar unselected cases treated in the same clinic, by the dichloramin-T in oil method, they were discharged in 16.3 per cent. less time than by the Dakin-Carrel method.

Technic.—Dichloramin-T is to be used, as has been said, in strengths varying from 2 to 10 per cent. (from 20 to 40 times the mass of germicide ever present in the usable concentrations of hypochlorites) dissolved in chlorcosane, in order that the germicide may be slowly liberated over a period of eighteen to twenty-four hours instead of thirty minutes to one hour, as in the case of the hypochlorite solutions. (For the technic of preparing the solution, see current chemical journals, and the writings of Dakin and others.)

After careful surgical preparation of the wound at the primary dressing and the excision of all foci of infection and of devitalized tissues, the solution is applied on surface wounds with an atomizer in the form of a spray. In the case of deep wounds, the cavities are filled with the liquid. In the presence of dependent drainage, the lower opening is temporarily closed with gauze and the cavity is then filled with the oil. It is necessary to apply the oil only once in twenty-four hours, the wounds being covered with only a few layers of gauze, to avoid absorption of the oil by the dressings.

For technic of Carrel-Dakin method the reader is referred to works on that subject.

DEVELOPMENTS OF THE WORLD WAR

In studying the various methods and results obtained in England and France, from the ambulances at the front to the special hospitals in the zone of the interior, one is especially impressed with the following:

1. The efficacy of typhoid vaccination (against typhoid bacillus, alpha and betaparatyphoid) and the antiluetic serum.

2. The paramount importance of the briefest possible time elapsing between the reception of the wound and its surgical treatment.

3. The great importance of preserving all loose fragments or spicules of bone, whether free or attached, in compound comminuted fractures.

4. The importance of and the degree to which the co-operation between the dentist and the surgeon has developed during the present war. Also the large number of gunshot injuries of the jaw.

5. The treatment of wounds by irrigation according to the Carrel-Dakin, dichloramin-T method, or by excision.

6. The development of various types of transportation and fixation apparatus.

At the close of our Civil War the maimed veterans "were received as heroes, banqueted and fêted, provided with artificial limbs, consigned to public charity, and all too soon permitted to drift into the almost hopeless battle for livelihood in a world that promptly forgot their heroic deeds." In the present era, every country must approach this great problem in an entirely different manner. It is as much the duty of the state to prepare the returning crippled soldier for the competition of gaining a livelihood in civil life as it is to furnish him the proper surgical treatment. This is generally recognized now by the leading nations, and in many instances men who have suffered the loss of an arm or a leg or have sustained severe functional impairment, have been able, on account of the training provided, to earn a better living than they did before they went into the trenches and this has been brought about through the instrumentality of the reconstruction center more than any other influence.

Every reconstruction hospital, military or civilian, should be equipped with apparatus to carry out active and passive mechanotherapy, treatment by faradic, static, high tension, and galvanic currents, vibration, baking, hydrotherapy, massage, gymnastics, out-door exercises, and curative workshop. Work in the last named, if properly selected and graduated, has a very high psychic value and affords the best means of restoring muscles to activity. Men wounded and disabled become depressed by suffering and an exaggeration of apprehension of their incapacity; they become downcast and believe that they will never again become self-supporting. The sooner efforts are made to get the men out of this psychic state, the better; and the best means to accomplish this is the curative workshop and the re-educational school. Men who are anxious to become independent are at the same time so depressed that they see no escape from a life-long dependence upon a pension or in a soldier's home. It would be rare for the disabled individual civilian or soldier to have sufficient initiative to lead him to re-educate himself for a different trade or occupation.

Administration and Control.—Experience has shown that the residential type of re-educational school, with the soldier inmates still under military control yields the best results. In France, it has been found that it is best for the director of a center of re-education to be a surgeon possessing special knowledge as to the functional limitations of disabled men. The advice of the so-called technician or mechanician in the choice of the particular occupation for an individual soldier is very important. The psychological and economic factors may be of more importance than the physical infirmity of the man under discussion.

One of the principal advantages of curative workshops located in the reconstruction hospital is that they allow the surgeon and the vocational teacher an early opportunity of observing the patient's aptitudes and physical disabilities and consequently facilitate an early and appropriate choice of occupation. The early creation of a correct outlook and the spirit of

cheerful life in the patients are among the most important influences of the curative workshop and functional re-education.

In many of the English orthopedic centers or American reconstruction hospitals large workshops are provided for woodworking, forge work, and splint-making as well as repair shops, artificial limb shops, etc. Large numbers of patients work regularly. The object of these shops is fourfold: first, to keep the men mentally occupied and thus obviate the tendency to introspection. It is well known that the subject of a long-standing disability is apt to become depressed and the victim of his sympathizing friends. He does not do well physically because he is in a non-receptive psychological state. If he works, he is usually happy.

Second, work provides one of the best means for passive and active motion and massage.

Third, work keeps a man at his task, or goes far to teach him a new one.

Fourth, the product of the shops supplies many needs of the hospitals.

The following two conditions are to be avoided: first, a soldier with a wounded or sensitive hand constantly tends to save that hand and use the well one, and therefore gains nothing as far as local therapeusis is concerned. Second, the tendency of the executive of the hospital is to aim to get as large a production from the shop as is possible, irrespective of the curative influence. Therefore, a foreman is very likely to put a man on the job that he can do best, regardless of the curative effect. A medical supervisor should be in constant attendance, and prescribe the work for each individual case.

The men should be kept under military control until they are well established in their work at some factory, farm, etc. Hospitals, which are costly to build and maintain, should be relieved of convalescents just as soon as their lesions will permit (*i.e.*, when treatment offers no further relief).

The so-called "Command Depots" of the English partially solved this problem. These stations were large camps where the men were kept under military discipline, did what work they could, and were protected from the strain and competition of active life. These camps were well suited for certain types of cases which needed no special treatment. Some of the Command Depots supplied some of the treatment, such as baths, massage, electricity, etc.

The processes by which a disabled soldier is treated and returned to his home may be arranged under the following heads (modified from Major Todd):

1. Active medical and surgical treatment.
2. Functional re-education.
3. The equipment with and re-education in the use of artificial appliances
4. Professional and vocational re-education.
5. The re-establishment of the soldier in civilian life.

Experience has demonstrated that men whose legs have been amputated can work at almost any trade or occupation. If the amputation has been through the thigh however, standing for long periods of time is difficult. Loss of the left leg is especially troublesome to carpenters and shoemakers. On the other hand intensive or scientific farming is well adapted to men with amputated or disabled arms. Clerical work is suitable for men who have amputated or disabled arms or legs.

The file and plane are very useful in the functional re-education of the upper extremities. The plane is especially serviceable in educating a left hand to take the place of the right hand which has been lost.

Courses in primary education must be provided in all such centers so that

men who are deficient in that grade may be given a chance to acquire a knowledge of reading, writing and arithmetic. At Colonia, N. J., the work and progress of the men is recorded and followed carefully by means of a thorough system of workshop record-books and reports, in order to make certain that the individual men are being benefited by the instruction which they receive and also to confirm the wisdom of the choice of occupation.

It is important when a man has completed his re-education in his chosen occupation that he be given a certificate to that effect and as to his capacity. An active employment bureau is of the greatest service in placing these men as soon as they leave the institution, for if they do not find employment immediately they are likely to become discouraged and resigned to exist in idleness on their pensions or in some soldiers' home.

PHYSICAL REHABILITATION

Treatment, functional and professional re-education and not the provision of artificial limbs and braces, are complementary processes. They should

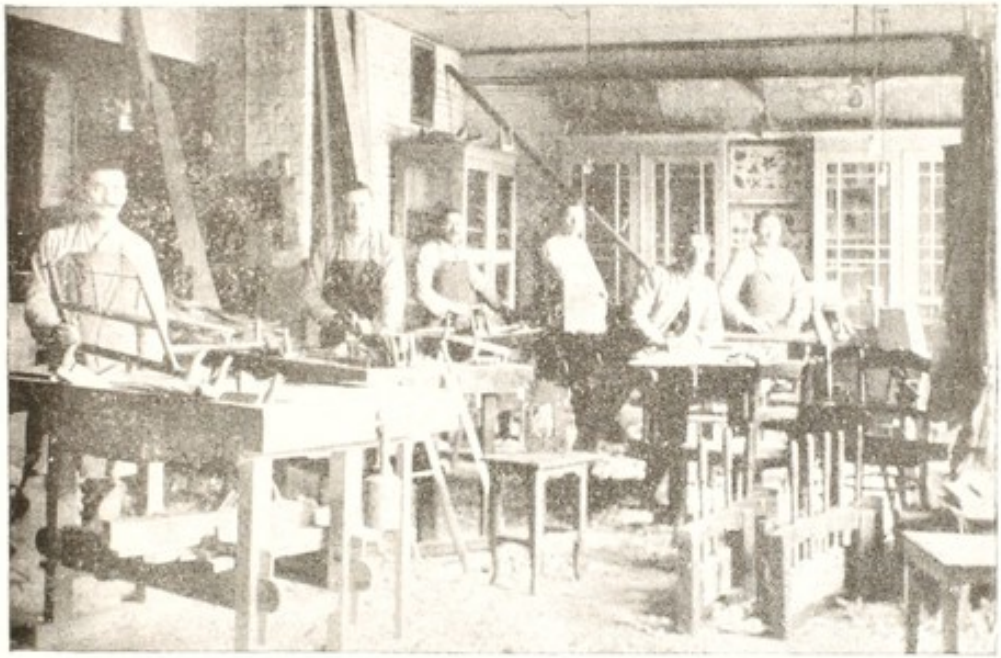


FIG. 690.—The carpenter shop. Work of this type is invaluable not only as a form of physiotherapy for patients suffering from injuries to the shoulder, elbow and hand, but also as psychotherapy. The patient at the extreme left for instance, was suffering from marked neurasthenic symptoms due to the exertion and psychical strain of the war. His condition improved remarkably within a short time after he was allowed to begin carpenter work. (Mayer.)

all be instituted and carried out as soon as possible, and in many instances they are best carried out simultaneously, consequently in the same center.

Return of Soldiers.—It is beyond discussion that it is best from the soldier's standpoint as well as from the economic and administrative point of view, that all men who are incapacitated for further military service should be returned to their own country (in our case, the United States) as soon as the transportation can be accomplished without injurious effect on their condition.

Massage and manipulation should be employed at all stages of treatment as a preliminary to surgical operations for the purpose of loosening scars

and rendering the required operative procedures easier and less extensive. As pointed out by Jones, the preliminary massage is very often of great diagnostic or prognostic value, since it may excite inflammatory reaction in an old gunshot injury and thus reveal that the tissue still contains some lurking infection and that it is not safe to operate so soon. Massage may also be used after manipulative procedures, such as the breaking-up of adhesions, to relieve swelling and alleviate pain. In orthopedic practice, one of the most important functions of massage is to aid in maintaining circulation and nutrition in muscles atrophied on account of disease or injury and thus help the re-establishment of normal function.

On the other hand, muscles of extremities atrophied from disease on account of injury to a peripheral nerve or damaged by prolonged suppuration are often devitalized, and their metabolism is so low that vigorous massage or over-stimulation by electricity exhausts, rather than strengthens them. When certain selected muscle groups are affected, electric baths may only excite the innervated group, and lead to deformity, instead of restoring power to the weak muscles. Therefore, it is imperative that the mechanotherapeutic department (including massage) should be under the direction of an experienced medical officer in constant consultation with the orthopedic surgeon in charge of the case under treatment.

The thousands of crippled and disabled men resulting from war constitute one of the largest costs of war. In past wars such soldiers have been indemnified for their injuries (at best most inadequately) by admission to an old soldiers' home or by pensions. Thus idleness and dependence have been stimulated, largely on account of these forced conditions, and as a result the public conception of the adult cripple has been that he is lazy, worthless, intemperate, and ill-mannered, all of which are too often true.

It is now believed that an excellent solution of these problems has been evolved in the curative workshops, trade and vocational schools, where the re-education of the cripple takes place and he is enabled, much to the increase of his own pleasure in life and the relief of the State economically, to become again self-supporting and self-respecting.

Vocational Re-education.—(1) A choice of vocation should be reached by a commission to consist of an orthopedic surgeon, a teacher or one familiar with sociological problems, and a technician. All should have experience in practical re-education. In each individual case, the decision should rest upon a thorough medical examination from the point of view of anatomical, physiological, mental and clinical qualifications. Each subject should be questioned carefully in reference to his education, former work or trade, tastes and aptitudes, future plans and responsibilities, and economic status. The individual himself, with the guidance of the mature judgment of the commission, should choose his new vocation after he has been taken on visits of inspection to the various workshops and departments of the vocational school. He should be especially guided by the surgeon, who must decide again whether the practice of his former vocation is compatible with his physical infirmities and his mental capabilities.

(2) Further, trades and vocations to be taught should be such as are remunerative in normal times as well as in war times. The manufacture of articles not stable and which are only temporarily salable, should not be included. The trades should be such as do not require long periods of training, except when the individual has a good foundation and it seems desirable for him to specialize in some branch of the industry which he formerly practised. The needs and possibilities of his locality should also be taken into consideration. The manufacture of artificial limbs and the various ortho-

pedic appliances is especially suitable, partly because this work may be used to build the way to many occupations and because of the large variety of tools and machines used in their manufacture. In this instance three birds are killed with one stone, in that at the same time the soldier's physical and mental conditions are improved, he is being re-educated for some future trade, and in producing needed appliances for himself and his fellow soldiers he is helping to relieve his country of that much economical burden. Again, the psychic value of such training is most valuable.

Each reconstruction hospital or center should include as large a variety of vocations as possible, so as not to unduly increase the labor supply in any occupation, and also to allow each individual to select what he is best fitted for. As far as possible, the training should be directed toward the preparation of foremen, overseers, and superintendents. Care should be exercised to prevent the men from being continued in too elementary work, and as far as possible the instruction should utilize the utmost physical and intellectual powers of each individual. A soldier who has lost the use of his legs may be trained for an occupation at which he can work while seated; the man deprived of an arm is re-educated for an occupation in which the remaining arm and two legs are sufficient.

The author found medical men in both England and France almost unanimously sceptical of passive mechanotherapy and insisting upon the value of active muscular movements brought about by the initiation of the patient himself in the curative workshop or elsewhere. Massage and heat are very valuable therapeutic adjuncts to the voluntary movements.

THE AMPUTATED AND THE ARTIFICIAL LIMB

The management of the amputated and the manufacture and fitting of artificial limbs and education in their use are most important problems. In France alone there are some *fifty thousand* persons with amputated extremities. It has been estimated that artificial appliances of some kind will be required by about 1 per cent. of all the wounded. It has been granted in Europe that the State must supply and keep in repair any artificial appliance necessary for the rehabilitation of a disabled soldier. The statistics of the French army show that the relation of loss of the lower extremity to that of the upper extremity is three to two. The proportion of disabling injuries not resulting in amputation is the reverse of this. The reason for this has been found to lie in the fact that when a man received even a very severe mangling injury to the arm he was able to walk back to the dressing station where he received treatment which prevented infection and saved his arm.

"Little attention has been given by surgeons to the fitting of artificial limbs. As a rule, the surgeon rarely sees his patient after the healing of the wound, but turns him over, usually without supervision, to the care of the artificial limb maker. Hence the surgeon loses one of the most valuable means of control in the perfection of his technic and frequently errs in comparatively simple details which a knowledge of the fundamental points of the artificial limb maker's art would enable him to avoid. It seems wise, therefore, to call attention to those points in the technic of amputations which have a direct bearing on the fitting and wearing of a substitute.

"In war, as is well known, amputations must usually be performed under conditions which exceed the most adverse in civil life. During an active engagement decision must be quickly made: the wounded are suffering from

shock and often from exhaustion, and the chances of infection are multiplied to the highest degree.

"The questions of when to amputate, at what point it should be done, what type of amputation should be chosen and whether the incision can with safety be closed are obviously matters of the most vital importance to the individual and also determine whether his after-care and the fitting of the artificial limb are to be easy or difficult. It is admitted that in the first months of the war, when conditions were particularly unfavorable and infection ran rampant, amputations were sometimes performed carelessly and stumps left open that could with safety have been closed.

"The question of amputation is, therefore, one of the most serious problems the army surgeon must face and one that calls particularly for calmness under stress and for the exercise of the most sound surgical judgment. When the requirements necessary to conserve the safety of the patient have been met, the sole remaining consideration is to be given to securing the stump which will best meet the demands made upon it by the artificial limb." (From Office of the Surgeon General, U. S. Army. The Division of Military Orthopedic Surgery.)

End-bearing Stumps

"The importance of securing an end-bearing stump in the lower extremity is not sufficiently recognized. The usefulness of a successful Syme, Pirogoff or Gritti-Stokes has long been known. Yet with these exceptions artificial legs are designed by the makers to take the weight on the ischial tuberosity when the amputation is above the knee, and laterally on the tuberosities of the tibia when it is below, and little or no attempt at end-bearing is made. The possibility of securing an end-bearing stump in a large proportion of cases has, however, been clearly demonstrated, and it is highly desirable that the surgeon and the artificial limb maker should co-operate to achieve it; for it is obvious that the transference of even a part of the weight to the end of the stump will conduce to greater comfort and improved function.

"The chief responsibility rests, however, upon the surgeon, since the prerequisites for end-bearing are a good stump and early functional use."

Treatment of the Amputated.—The usual amputation operation at the battle front is a simple oval or circular amputation, executed as rapidly as possible, with little thought of any result other than saving the patient's life.

Relation of Technic to Amputation.—It is apparent that the choice of procedure in the various steps of amputation will depend on (1) the presence or probability of infection, (2) the general condition of the patient and (3) the local circumstances under which the operation is to be performed.

When all conditions are favorable, that technic may be chosen in each step which experience has shown is likely to give the most useful stump. This is one in which—(1) the scar is so placed as not to be exposed to pressure, (2) the soft parts are sufficiently voluminous to be freely movable over the end of the bone but not redundant, (3) the divided muscles and fascia are united over the bone end, (4) the nerve-ends are not hypersensitive, and (5) the end of the bone is smooth and rounded.

In the presence of or the probability of infection, long flaps are contraindicated because of the lowered resistance following the impairment of circulation incident to their formation. Hence it is recommended by the interallied surgical conference that amputation for infection should be flapless or with short flaps held apart. Furthermore, it is obvious that the periosteum and bone should be treated in the simplest manner possible, by transverse division in the same plane.

Placement of Scar.—In the leg, amputation by circular incision results in terminal cicatrices which have every defect of situation, shape and adherence; on this point all surgeons are agreed. When flaps are not contraindicated, therefore they should be made of unequal length so that the resulting scar will fall where the terminal and lateral surfaces meet.

In the arm pressure is exerted laterally and not on the end of the stump; hence here the scar, with the exception to be noted, should be terminal. Amputation by the circular method or by short, equal anteroposterior flaps is therefore preferable, except in the case of the wrist, where a palmar flap gives an excellent stump.

When the incision is left open, whether the circular method be used or the one with short flaps, extension must very soon be applied to the skin to overcome retraction and thus limit the size of the resulting scar.

Attention to Soft Parts.—The comfort with which the appliance is worn and the freedom with which it is used are influenced to no small degree by the condition of the terminal soft parts. Adherence of the skin to the bone is most undesirable and is a frequent cause of re-amputation.

For this reason it is desirable, whenever possible to suture the muscles and the deep fascia. Silk should not be used. The tissues should be of sufficient bulk to move freely over the end of the bone. Redundancy should, however, be avoided as in this case the skin is apt to become excoriated from rubbing against the walls of the socket.

Treatment of the Nerve-ends.—Pain in the stump is one of the most common annoyances of the amputated and in a large percentage of cases is due to trouble with the ends of the nerve. In every amputation, therefore, the greatest pains should be taken in the division of the nerves. The nerve should be drawn down strongly, out of its sheath, and an inch or more removed. Various additions to the technic have been suggested to still further protect against overgrowth of the end; a modification of the fish-tail method of Ritter is recommended as meeting the indications most simply and effectively.

Treatment of the Bone.—To meet the requirements of the artificial limb, especially if end-bearing is sought, the bone must be smooth and rounded.

Clinical results seem to indicate, however, that the aperiosteal method (Bunge) is more likely to give an end-bearing stump, even in the presence of infection. In this method, 1 cm. of the periosteum is removed from the end of the bone, and the marrow cureted out for the same distance. Care must be taken not to remove too much of either the periosteum or the marrow in order to avoid danger of a localized osteomyelitis in the end of the shaft. The osteoplastic method seems to offer an ideal technic, but is obviously unsuited to any other than ideal conditions.

Relation to the Site of Amputation.—While as a general rule, amputation should be performed at the lowest possible level, yet this is not always the case. In some instances, a higher point is made desirable by anatomical conditions or by the requirements of the artificial limb. As an example of the former may be cited amputation through the tarsus, in which sooner or later a position of equinus is likely to result and walking becomes difficult or impossible. Although the retention of the bony enlargement of the proximal portion of the joints is of decided advantage in retaining the artificial limb in position, yet the best type of appliance requires several inches for the joint mechanism, so that if this were used in the case of disarticulation, it would result in making that segment of the limb longer. It is usually regarded

as preferable, therefore, to amputate at a sufficient distance above the joint to allow the necessary room for the artificial limb joint mechanism.

Upper Extremity.—In the hand it is generally recognized that the importance of preserving as much as possible of the thumb and fingers needs hardly to be emphasized. A thumb or part of a thumb together with some portion of fingers or hand to which it can be opposed, is more useful than any artificial contrivance which can be fitted (Fig. 701). In this region irregular operations, trimming, removal of splinters of bone or sequestra, etc., are likely to give better functional results than any set amputation. At the wrist, there is a decided advantage in disarticulation, on account of the better preservation of the forces of pronation and supination, which are now being used to activate the artificial hand. Moreover, in this case it is easier to put the necessary mechanism below the wrist. A further advantage in amputation at this point is that the enlargement of the wrist is a decided aid in holding the artificial arm in position.

In the forearm, amputation in the lower part of the middle third gives a good and useful stump, and while the circulation in the lower third of the stump is often poor, yet the better preservation of the power of pronation and supination that is secured by amputating as near the wrist as possible makes this site desirable; to insure freedom of these movements, every precaution should be taken at the time of the operation to guard against union of the ends of the bones by osseous or fibrous adhesions. Above the middle of the forearm it becomes of increasing importance, the nearer the elbow is approached, to save every fraction of an inch possible. When the stump is less than 3 inches, great difficulty is experienced in preventing it from slipping out of the socket, owing particularly to the action of the biceps tendon during flexion of the elbow, and with the short stump there is also naturally a decided loss of leverage. "If it is impossible to get a forearm stump extending at least an inch and a half below the insertion of the tendon of the biceps, amputation above the condyles of the humerus is to be preferred" (Mayer).

In the upper extremity the lowest point at which amputation is desirable is just above the condyles (about 2 inches above the center of the joint); the reasons for this are similar to those already discussed. From this point the longer the stump the better. Above the middle of the upper arm the surgeon must utilize every surgical expedient to save all the length possible; the power to control an artificial arm diminishes to an alarming degree with each loss of even a slight portion of bone. But little can be expected from a stump in which the bone extends less than two inches below the axillary fold. Since a terminal or even an adherent scar is not particularly objectionable in the upper extremity, owing to the pressure being exerted laterally, skin-grafting (usually inadvisable in a leg stump) may be employed to cover defects, rather than a re-amputation performed. Moreover, in some cases, "a good deal can be gained by removing wholly or in part the folds of the axilla, that is, the pectoralis major and the teres minor. This has been done with good results and seems to be an operation worth doing in suitable cases." It is always advisable to retain any portion of the upper end of the humerus, even if only the head, rather than to remove it (as is necessary under similar conditions in the thigh), since the appliance is fitted much more easily when the glenoid cavity is filled.

Lower Extremity.—In the foot it is undesirable to save a solitary toe, even the great toe. Amputation just back of the heads of the metatarsal bones, in front of the attachment of the tibiales and peronei, may be fitted so as to give a useful foot; but amputation through the tarsus, back of the

muscular attachments just mentioned, is usually unsatisfactory, as sooner or later a condition of equinus is likely to result from contraction of the unopposed calf muscles and walking becomes difficult or impossible.

At the ankle a satisfactory end-bearing stump is usually secured by Syme's amputation, in which the bones are divided just above the joint line and at right angles to the long axis of the tibia. The Syme is preferable to the Pirogoff, as it gives more room for an ankle-joint mechanism and avoids the difficulty frequently encountered in keeping the end of the os calcis in position.

In the lower leg the middle third is generally considered the most favorable site; many artificial limb makers prefer amputation at the middle of the leg to any amputation back of the toes. With proper surgical precautions and a good modern artificial limb, end-bearing should often be secured and the gait should be practically normal. The fibula should always be cut an inch shorter than the tibia and the sharp point of the tibial crest should be removed in the usual manner. The lower third is not so favorable; the tibia is smaller at this point and not as satisfactory for end-bearing, and circulatory disturbances are not infrequent. In the upper third a very short stump, of course, gives poor leverage but fair results are sometimes obtained with as little as 2 inches of bone. However, a stump as short as this is usually inadvisable, as it will ordinarily have to be fitted with the older type of knee-bearing leg with the tibial stump bent to a right angle; this has the sole advantage of direct weight-bearing which can usually be secured by amputation at the lower end of the femur, and possesses all the disadvantages incident to artificial knee-joint construction.

In the thigh the best amputation is, of course, one just above the condyles; when conditions permit, the patella may with advantage be utilized to cover the end of the femur. (The preservation of a part of the condyles, with the patella imbedded in them, is favored by some limb makers, as it enables the weight of the apparatus to be borne by the bulb end of the leg itself.) Above this point all the length possible should be saved, since the possibility of end-bearing decreases rapidly as the upper limit of usefulness as regards leverage is approached. A stump in which the bone is less than 3 inches, measured from the pubis, is of little value, and exarticulation is preferable. The linea aspera requires attention in the same manner as the crest of the tibia.

To avoid shock, subtrochanteric or intratrochanteric amputation may be first performed by the flapless or short flap method, and the removal of the end of the bone may be left for a later period.

It is now possible to fit an exarticulation of the hip with a very satisfactory appliance; in some cases the gait is even better than with the shorter stumps.

When these patients with a limb already amputated reach the reconstructional center, their further treatment should fall into the hands of some one versed not merely in surgical technic but in orthopedic principles, and above all, in the application of artificial limbs. The practice of turning the patient over to the manufacturer of artificial limbs as soon as the amputation wound has healed, is frequently responsible for much unnecessary suffering and many instances of poor function. Only by rational harmonizing of surgical technic and orthopedic treatment with the brace maker's art, can satisfactory results be achieved.

Preliminary Treatment of the Stump.—When the amputation wound is still unhealed, it frequently occurs that by the time the patient has reached the base hospital the loose sutures applied at the time of the primary am-

putation have torn out, the skin-flaps have retracted, and a large granulating area lies exposed. Attempts must be made to prevent further retraction of the skin. This is best done by applying a piece of stockinet to the stump after first painting it with some adhesive mixture, such as one of the preparations of mastic or Heussner's glue. The free ends of the stockinet projecting below the stump are gathered together with a stout cord, which, passing over a pulley, serves for the attachment of a suitable weight (3 to 10 pounds). To bandage the wound, the cord is loosened and the edges of this stockinet are turned backward so as to expose the granulating area. In many cases where the skin has not already become adherent, this method suffices to coapt the skin edges; when much retraction has already taken place and the skin has become adherent to the deeper structures, it merely prevents further retraction, until it is safe to perform secondary removal of all the projecting bone or a typical re-amputation.

The Care of the Stump.—Proper care of the stump is indicated broadly for two reasons: (1) to secure ultimately the maximum degree of usefulness, and (2) to minimize the difficulties associated with the first attempts at using an artificial limb and thus avoid discouragement of the maimed. Freedom from sensitiveness to pressure is the chief qualification of a good stump and is the measure of its capability for end-bearing. This is mainly dependent on the absence of swelling and congestion of the soft parts, and, above all, of exostoses on the bearing surface of the bone. It is evident, therefore, that those measures must be used which will hasten absorption and prevent the formation of exostoses or limit their location to less harmful areas. In addition to the measures usually employed for such purposes, namely, elevation of the part, bandaging, massage, hydrotherapy, electric light baths and electricity, particular emphasis must be laid on the benefit derived from early functional use; carefully graduated pressure on the end of the bone helps to give it a smooth and rounded shape and limits the formation of exostoses to the less harmful locations at the sides. Hence early functional use is the second prerequisite for end-bearing; the most careful surgical technic may be of no avail if the proper care of the stump is not begun at the earliest possible moment. This undoubtedly is the explanation of the fact that artificial limb makers are not, as a rule, enthusiastic about the possibilities of end-bearing; the cases reach them too late for anything further to be gained in this direction, so that unless the surgeon has prepared the stump for end-bearing by early institution and persistent use of the necessary measures, end-bearing will be possible only in exceptional cases.

Muscular weakness and limitation of motion are two of the chief causes of discouragement in learning the use of an artificial limb: considerable strength is obviously required to manipulate it satisfactorily. The demand is naturally greater with the shorter stumps and is still further increased if joint stiffness is present. When a contracture has been allowed to develop, this may make the use of an artificial limb difficult or impossible, as for example, in amputation of the thigh the stump tends to become slightly flexed and abducted, and this may easily become sufficient to prevent the use of an artificial leg until it has been overcome. The preservation of the full range of motion of the joint above the site of amputation is therefore of particular importance. The incentive to movement of the part is absent and hence limitation of motion develops more rapidly and is usually difficult to overcome, particularly in the case of a short stump, owing to the poor leverage afforded. Contractures must, therefore, be guarded against from the first and movements of the joints must be begun just as soon as the condition of the incision per-

mits and persisted in until the full range of mobility in all directions is assured (Fig. 692).

Routine for Proper Stump Treatment.—To meet all indications the plan of treatment must be systematic. While the incision is healing, at each dressing the stump should be moved to the full limit in the opposite direction to that in which a contracture is likely to develop. In forearm stumps, movement should be carried out in supination and extension; in upper arm amputations, in upward and backward motion; in the lower leg, in extension and in thigh amputations, in extension (securing hyperextension) and adduction. It is usually advisable to keep all the stumps elevated while the patient is recumbent and therefore particular attention should be directed to thigh amputations, because this site favors flexion contracture; to counteract

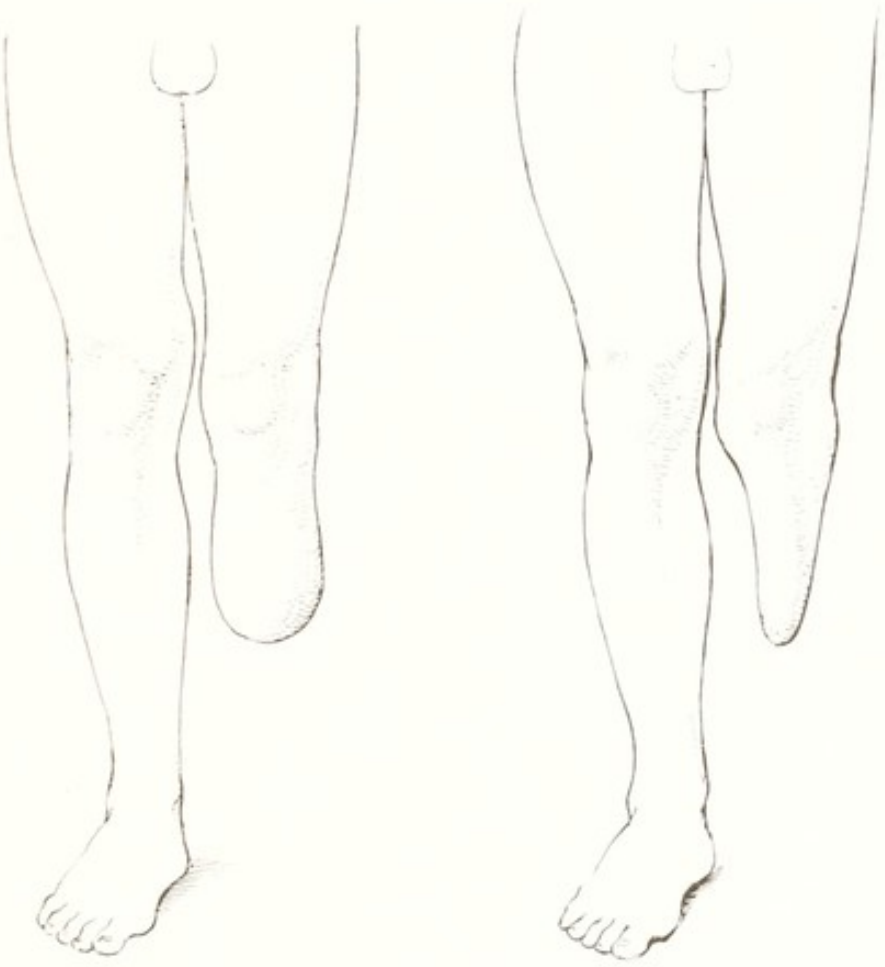


FIG. 691.—Stump before and after shrinkage and hardening.

this tendency, it is recommended that once or twice each day the pillow be removed from under the stump and placed under the buttock, thus allowing the stump to drop into hyperextension. Further advantage should be taken of the position in which the stump is dressed, in order to guard against the tendency to contracture. Thus, in forearm stumps, where supination is hardest to control, the dressing should be applied so as to maintain the bones in this position. When the incision has had to be left open, movement of the joint in the other directions, also, should be added as soon as conditions permit.

As soon as the wound is healed, or practically healed, and while the patient is still confined to the bed, the following routine (modified from Hirsch) is begun:

1. *Massage.*—The stump should be massaged for a period varying from ten to thirty minutes, once or twice a day, according to its size and position. The region of the incision should naturally be avoided for the first few minutes, and care should be taken not to make undue tension on the fresh scar. As rapidly as the tolerance of the stump will permit, the depth and the force of the massage should be increased up to the full normal limits.

2. *Bandaging.*—After the massage, the stump should be redressed with a cotton dressing, bandaged snugly in place, or, if it is well healed, a bias flannel bandage alone should be used. The latter, when properly applied in several layers, gives a firm, even pressure.

3. *Pressure Exercise.*—The patient is directed to press the end of the bandaged stump against a cushion, placed in the bed or against a frame. This must be begun with care, pressure being made at first for only several minutes at four- or five-hour intervals; if there is no unfavorable reaction, it should be increased gradually up to five or ten minutes every two hours, and then every hour.

4. *Movements.*—After each pressure-exercise, active movements of the stump are to be made in all directions, to the full limits of the joint motions, for three to five minutes. Later, some form of resistance movements may be added to advantage, in order still further to build up the strength of the muscles controlling the stump and thus make easier the early use of the artificial limb.

5. *Baths, etc.*—Hydrotherapy in the form of hot packs or warm baths, or electric light baths are to be used as indicated to improve the circulation and hasten absorption. The contrast bath is particularly valuable, the rapid dilatation and contraction of the blood-vessels which it produces causing marked improvement in the local vascular and nervous tones; the simplest method of application consists in the use of two buckets, the stump being plunged for five or ten minutes first into the hot water and then into cold, as rapidly as the patient can change it.

When the patient is able to leave the bed, the measures just outlined are to be continued, but in the case of leg amputations the pressure exercise is to be discontinued as described and direct weight-bearing on the stump begun. A stool of the proper height and a cushion are provided and the patient, supporting himself with his hands, allows at first only a little weight to rest upon the bandaged stump; the amount of weight borne and the time are then gradually increased, in a manner similar to that used in the pressure exercise in bed, until the entire weight can be taken on the stump. The patient may then carefully begin to hammer on the stool with the end of the stump, in imitation of the pounding which takes place in walking with an artificial limb provided for end-bearing. As soon as the patient can stand alone for a long time without getting tired, and with no other support than that needed to balance himself, a temporary leg, properly adapted for end-bearing, may be fitted and walking begun, crutches being used guardedly and dispensed with as soon as possible. For a long time, however, the patient should continue to practice standing on the bare stump on a hard surface three times a day.

The value of the end-bearing is generally admitted. The measures suggested, both with respect to the amputation and the case of the stump, are simple and have borne the test of clinical experience. The presence of long continued infection seriously delays institution of proper after-treatment, yet much good may still be expected even when begun late, and there will be a large number in which the routine may be

followed from the first. The ideal cases will obviously be those requiring re-amputation, which will naturally be deferred until entirely favorable conditions can be secured and which may, therefore, be performed solely with regard to the requirements of the artificial limb. Even when the attempt to secure end-bearing is unsuccessful, rigid adherence to the routine just described is still to be insisted on; the improved conditions of the stump, the greater freedom from pain and the avoidance of much of the discomfort usually associated with the early use of an artificial limb are more than sufficient to repay one for the additional trouble.

Systematic Examination of Range of Motion.—The joint motion should be tested by the surgeon at regular intervals, particularly in bedridden infected cases, in order to be certain that the full range is retained. At the elbow, in addition to verifying the presence of complete flexion and extension, the freedom of rotation of the radial head must be determined, particularly with reference to outward rotation (supination); the value of the movements of pronation and supination in activating the artificial hand, will depend upon the degree possible of attainment, the loss of even a few degrees making a great difference. Of the movements of the shoulder girdle (upward, downward, forward, backward, and circumduction), the upward and backward ones are the most important; these may easily be tested with the patient lying at the edge of the bed or turned on the opposite side. At the knee it is well to remember that there are normally a few degrees of recurvation. In testing the hip, the presence or absence of flexion deformity may be determined (following the method used in hip disease) by fully flexing the opposite thigh on the trunk, the stump rising from the bed when contracture exists, or with the patient lying on the face, the degree of hyperextension may be determined (again as in the similar test used in hip disease) by lifting the stump with one hand while holding down the buttock with the other; in testing the amount of adduction, movement of the pelvis should be controlled with one hand, while the other manipulates the stump.

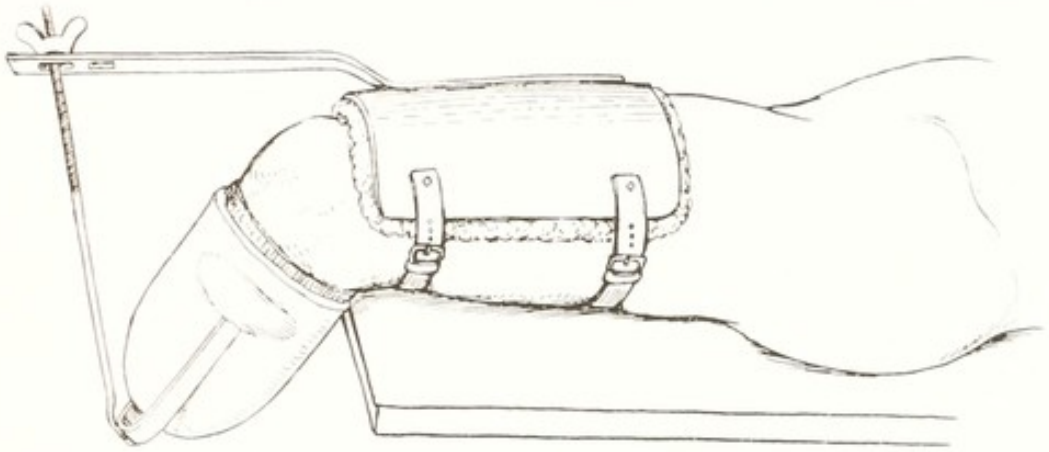


FIG. 692.—Apparatus for correcting flexion deformity at knee in amputation of the lower leg. (After Ducroquet.)

Contractures.—Care must be taken to prevent the development of contractures. The most frequent mistake in this regard is in the case of patients with amputations of the thigh or of the calf several inches below the knee. The nurse, in her effort to make the patient comfortable, places a pillow underneath the stump, thus flexing the thigh at the hip or flexing the knee. This error, usually unnoticed at the time, results in flexion contractures the significance of which is not appreciated until the first fitting of the artificial limb. Then the brace maker tells the surgeon that something is wrong, and

that he cannot make the artificial limb fit correctly. As a consequence a long period of treatment is required to lengthen the contracted tissues until the free range of motion has again been acquired (Fig. 692).

The same principle emphasized in the treatment of injuries to the muscles, should be applied to the amputated; the position of the limb should be such as to prevent the overaction of the strong muscles at the expense of the weaker. Thus, at the hip and at the knee, every effort must be made to prevent the strong flexors from overcoming the action of their weaker antagonists. At the shoulder, the strong adductors must not be allowed to contract at the expense of the abductors.

Affections of the Stump.—*Sinuses.*—Persistent sinuses are an occasional source of annoyance. They are a hindrance to the proper use of the measures necessary for the care of the stump and delay the fitting of the artificial limb. Necrosis of bone is naturally by far the most common cause; as is well known, sinuses due to this cause may close temporarily and even remain closed for several weeks. In addition to other diagnostic methods, radiographic examination is most helpful; should a sequestrum be disclosed, its removal is, of course, called for. In old sinuses the possibility of specific disease will naturally always be considered. Occasionally sinuses are due to foreign bodies, as for example, to retained silk—a suture and ligature material which should not be used in this work.

Ulceration.—Ulceration of the skin of the stump is sometimes troublesome. The common cause, in the stump itself, is poor circulation (most often seen at the lower third of both arm and leg) and this is favored by general debility, constitutional disease and intemperance; when there is too great tension on the scar, due to too short flaps, it is likely to break down and an ulcer apt to form. Ulceration is more common, however, after the use of the artificial limb has been begun and is then usually caused by a poorly fitting socket which allows friction or causes unequal pressure; in some cases also it results from the circulation to the end of the stump being cut off by a socket which is too tight around the top.

Painful Stump.—Painful or sensitive stumps constitute one of the chief sources of difficulty in the satisfactory adjustment and use of the artificial limb. The cause may be in the soft tissues, the nerves or the bone. In the soft tissues, atrophy may be so extreme as to leave the bone insufficiently protected, or the pain may be caused by an adherent scar with defective nutrition. Both of these causes are avoided by the use of the proper after-treatment. In the nerves, pressure from scar formation or overgrowth of the nerve-end are not now so common as formerly, since greater care is usually given to this part of the technic of amputation. Cases which do not yield to ordinary measures will require re-operation, the compressed nerve being dissected free or the bulbous end treated by the method already recommended. By far the most common causes of pain are found in the bone itself; these are exostoses, ostitis or periostitis, and small areas of osteomyelitis. To determine the exact source of the trouble is often difficult and may tax all the ingenuity and patience of the examiner; an *x*-ray examination of the bone should always be made in such cases and the possibility of specific disease carefully considered."

Re-amputations.—The surgeon should not be too hasty in deciding that re-amputation is necessary. The presence of scar tissue over the end of the stump does not necessarily mean a poor stump, although it is, of course, preferable to have a normal skin covering. The indications for re-amputations are: (1) Projection of the bone beyond the granulation tissue; (2) persistent ulceration of the stump owing to the thinness of the epithelial covering;

(3) a fixed contraction of the short stump in such a position as to render application of the artificial limb impossible; (4) in rare instances, for painful neuromata which yield to no other form of treatment. A conical stump is in itself no indication for re-amputation, since it may, if properly exercised, develop excellent functional capacity.

A discharging sinus due to the presence of a sequestrum or foreign body, necessitates operative removal (easily accomplished through a small incision) but this operation is in no way analogous to that of re-amputation.

Whenever possible, re-amputation should be avoided, since it invariably necessitates shortening the stump. This means loss of power, since the longer the stump, the more accurate its coaptation to the artificial limb and the more effective its action. Of course, if the stump is a long one, with the site of the amputation just above the ankle at the knee, an inch or two can be sacrificed without appreciable diminution of power.

This principle of maintaining the maximal length of the limb does not minimize the importance of securing, whenever possible, a weight-bearing stump. If the stump can be rendered capable of supporting the body-weight, the problem of fitting the artificial limb is rendered much simpler. To this end, certain osteoplastic operations are of great value and should be performed wherever feasible. In a class by themselves stand the Pirogoff and Gritti amputations. Both these procedures are excellent examples of the physiological methods, and when properly executed invariably give good results. Of course, an important condition for the success of all osteoplastic operations is an absolutely aseptic field. When this cannot be had, these operations are contra-indicated.

In the calf, when the stump is a long one, so that several inches can be sacrificed with comparatively little loss of power, the Bier osteoplastic method usually results in a weight-bearing stump. When this operation is not feasible, it matters little whether the so-called aperiosteal technic is followed or the periosteum is left adherent to the bone stump. Irrespective of the treatment of the periosteum, it will be found that in some cases bony spurs develop, while in others they do not.

In all cases of amputation of the calf, the fibula should be divided at least $\frac{1}{2}$ inch above the level of the tibia.

Mayer has found the following technic to give good results in cases where the Bier osteoplastic method is contra-indicated. The skin flaps are planned so that the anterior is long enough to cover the inferior surface of the stump. The muscle flap, on the contrary, is taken from the posterior aspect of the calf, since the fleshy gastrocnemius and soleus furnish the best covering for the cut surface of the tibia. The muscles are attached to the periosteum by strong sutures anterior to the weight-bearing surface. As the skin suture lies posterior, there is no suture line subjected to pressure when the artificial limb is applied.

In amputations of the thigh, where the Gritti is not applicable, the Bier method may be followed, provided the stump is sufficiently long.

In patients with a femoral stump not more than 2 or 3 inches long, the presence of abduction or flexion contracture renders the application of the artificial limb impossible. The problem in these cases is solved most simply by disarticulation of the femur at the hip. Nothing is lost, since the stump is too short to control the artificial limb, and much is gained in the ease of application of the artificial limb.

For amputation of the upper limb, the question of weight-bearing plays no rôle whatsoever. The stump should invariably be left as long as possible, and re-amputation performed only when there is urgent indication.

Kinetic Stumps.—Vanghetti and later Ceci attempted the utilization of the latent muscular force of the stump by freeing the tendons or muscle bellies in such a way as to enclose them with skin flaps. These flaps could then be moved by voluntary muscular contraction of the patient's stump. During the last three years the method has been modified by Sauerbruch (until recently Professor of Surgery at the University of Zurich) and its technic developed so that it may be regarded as a perfected surgical procedure. Instead of the original Vanghetti technic a much simpler method has been adopted. After freeing a skin flap of appropriate size, a tunnel is bored through the muscle belly and widened sufficiently to admit the skin flap which has been sutured to form an epithelial lined tube. A simple skin plastic completes the operation. The canal is kept patent by means of a rubber drainage tube or ivory peg, and as soon as possible active exercise of the muscle is begun (see Figs. 723 to 726).

Excellent though the operative results are, the practical benefit to the patient has thus far been slight, owing to the difficulty in constructing a prosthesis capable of utilizing the muscular force placed at its disposal. If this mechanical procedure can be solved, the Vanghetti procedure will constitute an important advance in our methods of treating the amputated.

The Education of the Stump.—Even before the wound has healed, the physician must begin treating the stump with a view of developing its function. The muscles should be massaged and the patient should be encouraged to move the limb. As soon as the wound has healed, more vigorous measures may be adopted. The stump should then be bathed daily with cold water, and in addition to the massage, graduated exercises should be performed. These consist of simple movements, flexion, extension, abduction, adduction, and rotation, against the resistance of a weight running over a pulley, or of the hand of a trained masseur. Bandaging the stump firmly helps remove fat and reduce the edema. To assist the hardening process leading to weight-bearing function, the patient should learn to rest the end of the stump against a chair or stool of suitable height. At first the chair is thickly padded; gradually the padding is removed, until the patient is able to bear his weight on the bare wood. He then begins to hammer with the end of the stump against the support, since a certain amount of this pounding motion is incidental to walking with an artificial limb. This treatment should, of course, be carefully graduated, otherwise the stump tends to become irritated, instead of hardened.

The greatest educator of the stump is, however, the artificial limb itself: therefore, it should be applied as soon as possible. The use of a crutch for the amputated is an indication of inadequate treatment. The early use of an artificial limb presents one great difficulty: the stump is still swollen, a large amount of fatty tissue is still present, and the muscles are usually flabby. With time, the stump changes its shape so markedly that the artificial limb, which fitted accurately when first applied, is no longer suitable. If this has been made of leather or wood, great expense has been involved, and the value of early training of the stump seems to have been outbalanced by the economic waste of time and material involved in the construction of an artificial limb, whose period of usefulness has been so short. Owing to this difficulty, the provisional or temporary prosthesis has been evolved.

The evolution of these provisional limbs has been most interesting. To Mommsen belongs the credit of evolving what is, the most practical and efficient provisional artificial limb. Assume that the patient has been amputated 6 inches below the knee. An exact plaster impression is taken of the stump by enveloping it with a plaster-of-Paris bandage. The plaster

should not be thicker than one-sixteenth of an inch. While it is hardening, the operator should carefully mould the plaster to the tuberosity of the tibia since this bony projection forms the chief weight-bearing area. The head of the fibula and the femur are not subjected to pressure, since experience has shown that they are not adapted to weight-bearing. The plaster negative is then turned over to the brace maker, who makes the corresponding foot, steel supports, knee-joint, and thigh piece, just as though he were making an artificial limb for a patient whose stump had assumed its final definite form. The one difference between the final prosthesis and this provisional one, lies in the fact that the plaster shell has been substituted for the usual leather socket. The steel uprights are firmly fixed to the plaster by means of two rivets and a series of bandages soaked in a mixture of plaster-of-Paris and bone glue. In other words, the patient is given at once the same type of artificial limb which he is to wear after the stump has attained its constant shape. During the stump's transition period, the plaster negative can be changed whenever necessary, since the cost is minimal and the labor involved comparatively slight.

For amputations of the thigh, the technic is similar. In these cases, the surgeon must lay stress upon accurate moulding of the tuberosity of the ischium, since this bone is to bear the weight of the patient's body.

When the stump has, after many months, assumed a form which no longer changes, then leather is substituted for the plaster-of-Paris, and the patient is equipped with a finished prosthesis.

Types of Artificial Limbs for the Lower Extremities.—It would far exceed the limits of this chapter were even mention to be made of the thousands of different varieties of artificial limbs designed for amputations of the lower extremities that have been devised during preceding centuries or which are now on the market.

From a study of about 50 different men, Mayer comes to the following conclusions: (1) For amputations of the thigh, it is important to distinguish between those stumps which are weight-bearing and those which are not. In the latter case, the success or failure of the artificial limb depends upon an accurate fit at the ischial tuberosity. Most brace makers fail to realize that the tuberosity does not slant from above downward and forward but in the reverse direction, namely, from below, upward and forward. This upward inclination, be it ever so slight, must be taken into account. The usual type of support given by the brace maker does not conform to this anatomical fact, but slants from above downward and forward, so that the patient slips downward on the support and almost invariably suffers pain anteriorly, near the pubic bone. The result is that the stump is rotated externally, and the artificial limb does not fit.

In addition to the tuberosity of the ischium, the adductor muscles are capable of bearing great weight when they have been properly hardened. The pubic bone, however, cannot stand pressure and must be left free. The gluteal muscles and the vasti also help to support the body-weight.

When the stump is short, a pelvic girdle with a strong joint at the level of the top of the trochanter is necessary; whereas in the long stumps, the pelvic band and trochanteric joint are unnecessary. In patients with marked atrophy of the muscles, unable to balance themselves securely upon their stump, the trochanter joint should allow flexion and extension only, since the pelvis would drop toward the opposite side of the body, were abduction permitted.

In applying the steel uprights which support the body, or, in case of a wooden limb, in joining the thigh piece with the calf, it is advisable to give

the calf about 5 degrees of genu valgum position. This adds markedly to the stability of the artificial limb.

The type of knee-joint used does not, as far as Mayer can observe, play an important rôle. In general, the simpler the mechanism the more effective. Complicated screws, ratchets, or springs add merely to the likelihood of breakage, and to the cost of keeping the limb in order. Besides, for the majority of patients who live at a distance from industrial centers, where brace makers are to be found, the entire construction of the limb should be so simple as to permit the wearer himself to make the necessary repairs. In one European hospital there is an admirable custom of giving each amputated patient a three weeks' course in the brace maker's shop, and discharge from the hospital is dependent upon ability to repair his own prosthesis there.

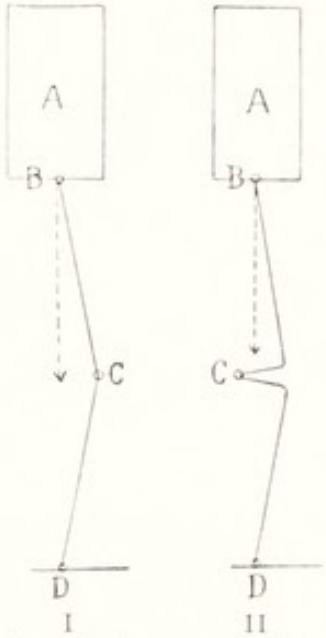


FIG. 693.—Diagrams illustrating the importance of posterior displacement of the knee joint of the artificial limb. A. Body; B. hip; C. knee joint; D. ankle. In Fig. I, the axis of the artificial joint corresponds in position to the anatomical. A slight degree of flexion brings the body weight posterior to the axis and, as is evident from the figure, further flexion must result. For the patient this position of the axis causes insecurity since the least degree of flexion is almost certain to cause him to fall. In Fig. II, the axis of the artificial limb has been displaced posteriorly. The body weight, represented by the dotted line, now falls anterior to C (the axis) and tends to lock the knee instead of producing further flexion. (Mayer.)

An essential in the mechanical construction of the joint is the location of its axis posterior to the center of gravity of the anatomical joint. If this demand is not complied with, the patient loses all sense of security, because the artificial leg tends to bend at the knee under the patient's weight. If the mechanical joint lies posterior to the normal, then the body-weight tends to lock the joint as is seen by reference to the diagram (see Fig. 693).

(2) For amputation of the calf, the type of limb depends upon the length of the stump. If it is short, less than one-half of the length of the calf, there must invariably be a thigh piece and a knee-joint. If it is long, these may be dispensed with, if the stump is capable of weight-bearing.

As already indicated, when the stump is not capable of weight-bearing, the artificial limb must be moulded to grasp the tuberosity of the tibia firmly, not the condyles of the femur as is usually taught. The patella tendon also is capable of weight-bearing, as may be learned by observing any patient who has worn an artificial limb for many years.



FIG. 694.



FIG. 695.

FIG. 694.—Apparatus to replace the knee strap used by the cobbler. This simple device enables the shoemaker who has lost a leg to work without inconvenience.

FIG. 695.—A chair designed for patients suffering from an ankylosis of the left hip. (Biesalski model.) (Mayer.)



FIG. 696.—Case of American soldier who lost completely the four fingers and adjoining metacarpal bones of his left hand at Château Thierry. The left photograph shows the only remaining digit, the thumb, fully extended. On the right the thumb is shown fully flexed.

Note the absence of any opposing surface for contact with the thumb, as a result of which nothing can be grasped and held. To overcome this difficulty, the author decided to resort, so far as he knows, to an original procedure consisting in synthetically grafting on a stationary opposing finger. The first operative step is shown in the next figure.

(This is one of two similar cases on which plastic operations for restoration of function of hand were performed successfully by author at about the same time at U. S. Army General Hospital No. 3, Colonia, N. J.)

The ankle-joint, like the knee, should be of the simplest type, allowing merely flexion and extension. In addition to the ankle-joint, there should be one corresponding to the metatarsophalangeal junction.

Types of Artificial Limbs for Amputations of the Upper Extremity.—The problem of dealing with amputations of the upper extremity is far more difficult than is the case with amputations of the lower limbs: the latter have merely to carry the body, but the former has a great variety of functions to perform. Depending upon the nature of these functions, and also to a great extent upon the site of the amputation, the artificial limb must vary from one case to another. Thus, an artificial limb which might be of value to a lawyer or business man, would be of little use to the farmer or mechanic; and of two farmers, one with amputation of the forearm and the other with an



FIG. 697.—Same case as Fig. 696. Showing first operation in tissue transplantation. A rectangular flap of skin and subcutaneous tissue was turned up from the chest wall and sutured into the form of a finger. Its end was approximated to the edges of an incision made over and down to the distal surface of the os magnum, by the Italian flap method. A pedicle (indicated by arrow) was left attached to the chest wall to supply nourishment to the newly implanted parts, until circulation with the hand should be thoroughly established. (See Fig. 700.)

amputation above the elbow, the one would have to be equipped with a type of limb markedly differing from that supplied the other. There is no artificial limb applicable to all cases.

1. *Types of Artificial Limbs Designed for Amputations of the Forearm.*—"For the farmer and artisan, a simple and effective prosthesis has been designed by August Keller. Amputated himself, some nine years ago, he constructed an artificial limb of the simplest materials, so well adapted to the needs of the farmer that the amputated scarcely note the handicap under which they are compelled to work. Keller's device consists of a leather socket cuff reinforced by two longitudinal steel bars, held in place by a figure-of-8 strap which passes just above the elbow. The handpiece, made of wood, may be removed from a socket, if desired. Inserted into the wooden handpiece are three strong steel hooks. These are not adjustable. They aid the patient in two ways: first, small objects, such as pencil or

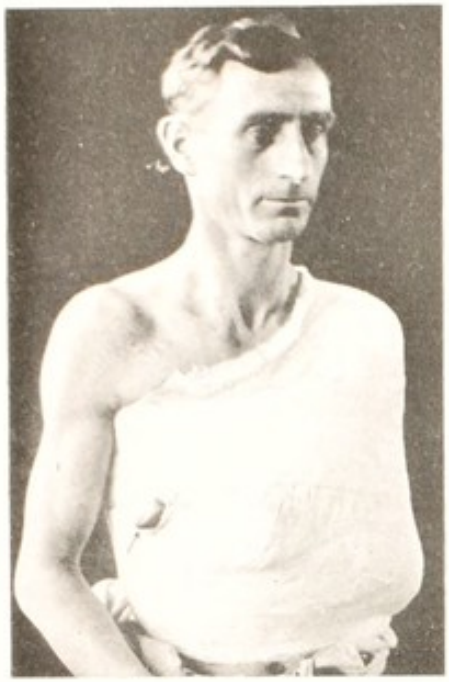


FIG. 698.



FIG. 699.

FIG. 698.—Same case as Fig. 696. The hand was immobilized firmly in place over right chest by a plaster-of-Paris shoulder spica. The thumb was left projecting for purpose of determining the circulation of the limb. This cast was removed four weeks after operation and the finger was then cut loose from chest wall. The second operative step, consisting in the implantation of the bone-graft, is illustrated in the radiogram, Fig. 699.

FIG. 699.—Same case as Fig. 700. Radiogram of left hand with grafted finger, showing implantation of 2 tibial bone-grafts. In this operative step the boneless finger, cut loose from the chest wall, was first tunneled by means of a scalpel and a wedge-shaped mortise was made in the distal-radial surface of the os magnum with an osteotome. Into this mortise a wedge-ended tibial graft, 3 inches long and about $\frac{3}{8}$ inch wide, consisting of the full thickness of periosteum, cortex and as much marrow as could be obtained, was firmly driven, in the position shown in the figure. A sliver graft (indicated by arrow) was affixed along the ulnar side of graft No. 1, for purposes of "bone-seed," or increased osteogenesis. The skin was closed with interrupted silk sutures.

This radiogram was taken four weeks after the implantation of the tibial grafts which have now become firmly united to the bones of the hand.

Note the amount of bony extremity originally absent in the hand and the resulting loss of function, to restore which the synthetic transplantation of tissues was undertaken.

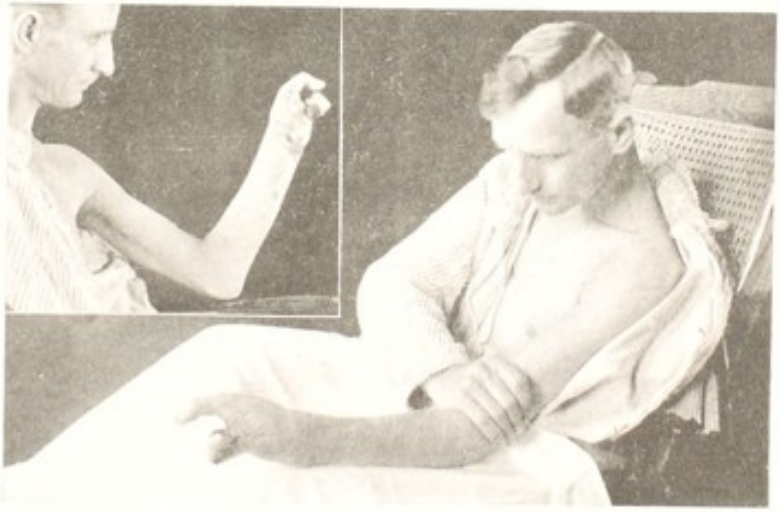


FIG. 700.—Same case as Fig. 696. Showing the grafted finger five weeks after the last operation. The lower photograph shows the thumb fully extended. In the upper view the thumb is shown flexed and in apposition with the new finger.

knife, can be inserted between them; second, they furnish the leverage for larger instruments. To hold these latter firmly in place, a leather strap attached to the anterior portion of the apparatus is made to take a double turn about the handle of the article used and then, passing backward



FIG. 701.—New finger six weeks after last operation. As shown in the photograph, the patient is now able to grasp and hold objects with his thumb and grafted finger.

By providing an opposing surface for contact with the thumb, the helpless stump, shown in the first figure of this series (page 1015) has been converted into a useful member capable of performing most of the necessary functions of a hand.



FIG. 702.—Same case as Fig. 696. The patient uses both hands in the natural manipulation of knife and fork.

between the hooks, is fixed to the posterior aspect by means of a steel pin."

A large number of other ingenious contrivances has been evolved to replace the fingers. These consist of hooks, rings, clamps, and holders designed for special articles, such as knife, fork, spoon, pen or pencil, knitting needle, etc.

For the business or professional man, a more suitable type is the ingenious limb designed by Carnes. In this, the mechanism is far more complicated, and the cost therefore is proportionately greater. Despite the deli-



FIG 703.—Same case as Fig. 696. This photograph shows the cooperation of the two members in an act requiring strength and dexterity.

cate mechanism, however, it is capable of standing the usual amount of wear and tear, and a break of any constituent part can readily be replaced. The essential feature of the arm is the voluntary control of motion of the fingers and of the wrist by means of hands which become shortened or length-



FIG. 704.—The Keller artificial hand. Keller at work with his spade. (Mayer.)

ened by motion of the elbow-joint. The arm requires considerable practice before the technic of its use can be acquired. To give a patient such an artificial limb and expect him to be able to use it at once is as illogical

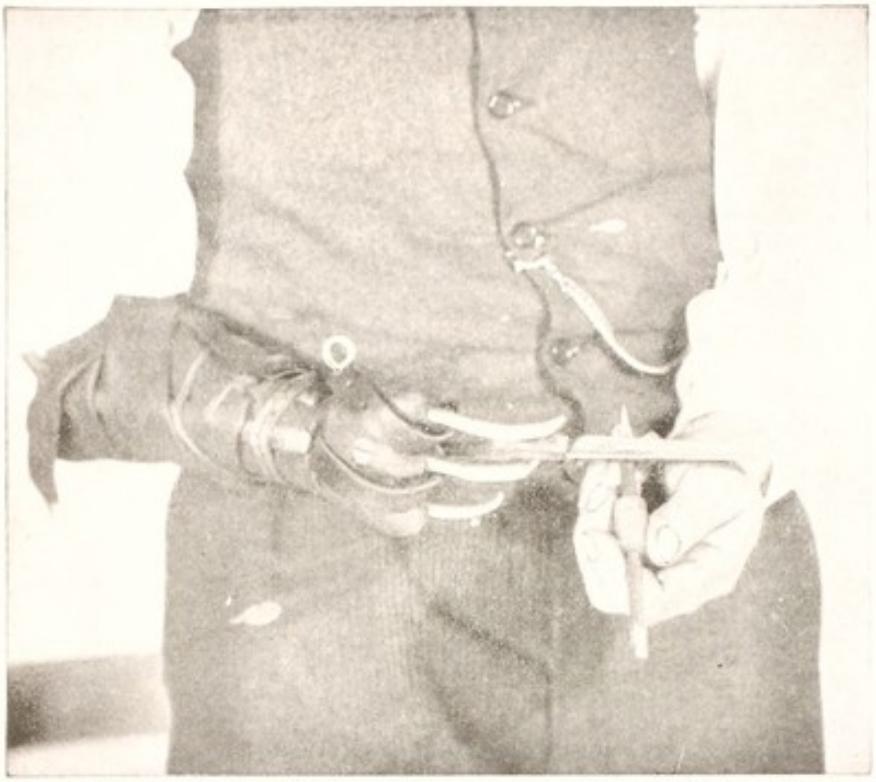


FIG. 705.—The Keller artificial hand. The picture illustrates Keller's method of inserting a small knife, with which he is sharpening his pencil. Note also the piece of cork attached to the pencil. This enables him to grip the pencil between the claws and to write with it. The lower arm socket is held firmly in place by a broad strap which makes a figure-of-eight turn about the elbow. (Mayer.)



FIG. 706.—The Keller artificial hand. For aesthetic purposes Keller draws a glove over the hooks. This he terms his "Sunday" hand. (Mayer.)

as presenting a man with a violin and telling him to play upon it. When, however, its use has been mastered, it gives surprisingly good results. The mode of attachment of the artificial limb to the stump is of importance. The hinge-joint at the elbow with an upper arm cuff—the usual type in the brace maker's shop—should not be employed, since it gives no opportunity for pronation and supination. A simpler and far more advantageous method of attachment is the figure-of-8 strap, which passes just above the condyles of the humerus and crossing the posterior surface of the humerus, descends again over the anterior surface.

2. *Types of Limb Designed for Disarticulation of the Elbow or Amputations of the Upper Arm.*—The classical type of limb is a useless encumbrance, and is almost always relegated to the garret by an intelligent patient. To be of any assistance to its wearer, the prosthesis must—even more than in the case of that for the forearm amputation—be particularly designed for the special work to be performed.

Of course, it must be remembered that the artificial hand plays the rôle of assistant to the sound arm.



FIG. 707.—The Keller artificial hand. The hand attachment can be removed, permitting the insertion of various instruments. In this instance a hammer has been inserted, which Keller is able to use with the same dexterity as a normal individual. (Mayer.)

Another valuable type of limb is devised purely for working purposes, and must be supplemented by another limb which hides the defect. It consists of a broad padded metal ring which fits over the shoulder and is held firmly in place by straps passing around the body. To this ring is attached a second, which, running on ball-bearing, has perfect freedom of rotation on the first ring. To the second are attached steel uprights which run parallel with the stump and terminate at the level of the elbow in a circular disk to which can be attached various instruments useful to the carpenter. The stump is bound firmly to the steel uprights by means of straps, and, owing to the ball-bearing joint at the shoulder, the wearer has almost the normal range of motion. A little ingenuity in devising the tools to be inserted into disks enables the amputated to do even the most delicate kind of carpentry work. One tool suffices to grasp the screw of the screw-and-bit; another grasps the nail so that the uninjured hand is free to hammer; another is designed to hold the chisel, etc.

The Carnes limb already described in speaking of amputations of the forearm, is also applicable to amputations of the upper arm. The motor power is then derived from the movements of the shoulders. The difficulty in learning to use the limb is increased when the amputation lies above the elbow. Nor is it particularly well suited to the artisan. For esthetic purposes, however, it is probably the most ingenious device which can be secured.

The shorter the upper arm stump, the more difficult the attachment of the prosthesis, and the more difficult it is to render the stump capable of doing its fair share of work. As a rule, it is almost impossible to train a patient with a stump less than 4 inches long to be an independent farmer

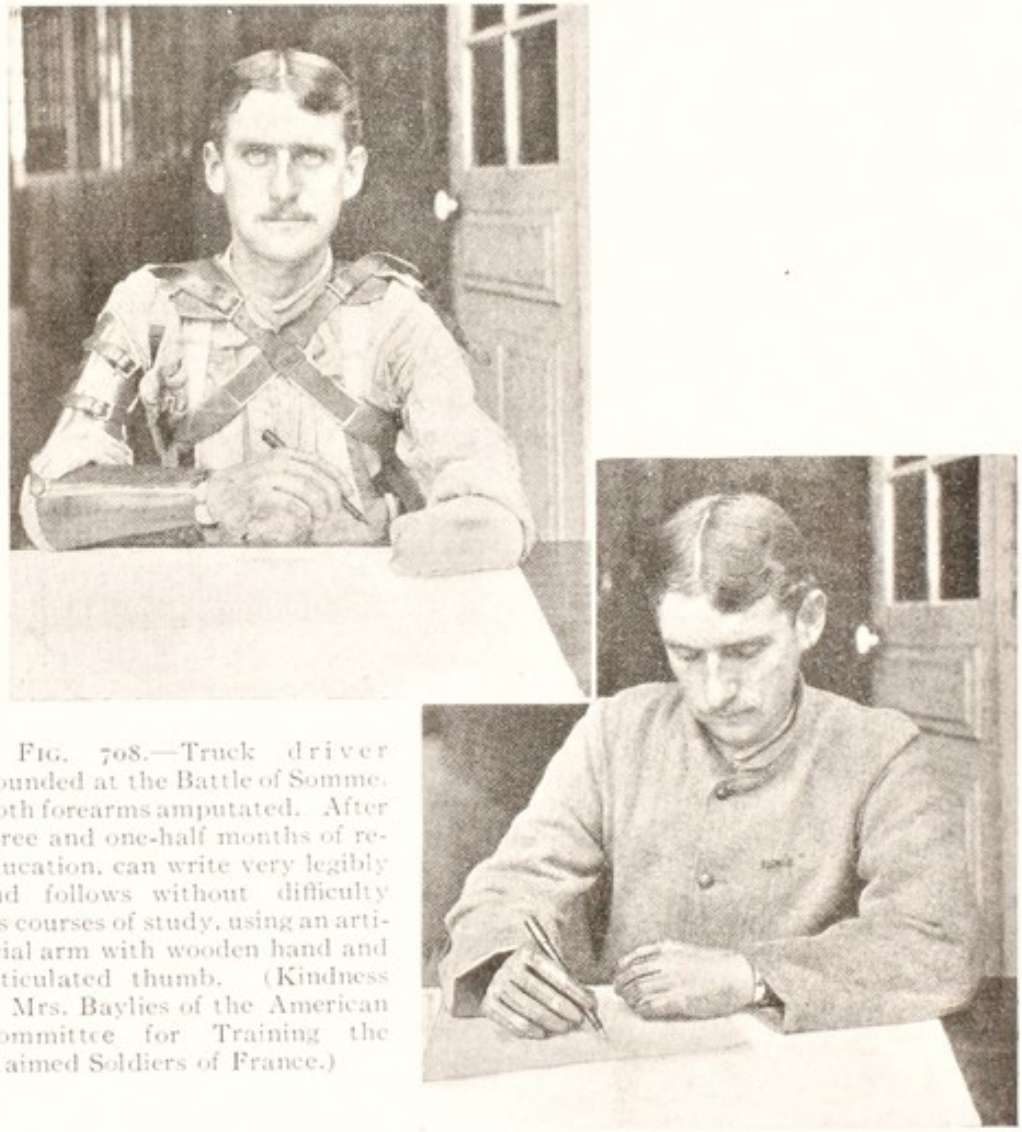


FIG. 708.—Truck driver wounded at the Battle of Somme. Both forearms amputated. After three and one-half months of re-education, can write very legibly and follows without difficulty his courses of study, using an artificial arm with wooden hand and articulated thumb. (Kindness of Mrs. Baylies of the American Committee for Training the Maimed Soldiers of France.)

or artisan. An exception is pictured in Figs. 714 and 715. Despite the short upper arm stump, this young boy was able to work skilfully in a machine shop. The prosthesis shows the excellent shoulder device designed by Riedinger. As a rule the patient with the short upper arm stump can be made capable of doing higher garden work or, in suitable instances, he can be trained to work at a factory machine. For this latter purpose close co-operation is necessary between the physician, a machinist, and the manager of the factory.

Even when the entire limb has been disarticulated at the shoulder, a prosthesis can be applied with distinct benefit to the wearer. The artificial



FIG. 709.



FIG. 710.

FIG. 709.—Judge Corley's apparatus for helping the man who has lost both hands to button his own collar. (Mayer.)

FIG. 710.—Locksmith wounded in Argonne. Left forearm amputated. After ten months of training at Maison Blanche, is able to work again at his former trade as well as before, has become foreman at the school, earning ten francs a day. (Kindness of Mrs. Baylies of the American Committee for Training the Maimed Soldiers of France.)



FIG. 711.—Gardeners of Horticultural Section at Maison Blanche. One with left arm amputated; two with right leg amputated. (Kindness of Mrs. Baylies of the American Committee for Training the Maimed Soldiers of France.)

limb is controlled by the swing of the body, and enables the amputated to wield a broom, to rake, etc.

The Life of the Amputated

Care of the stump and the application of the artificial limb constitute only two of the numerous problems which confront the physician in the care of the amputated. Particularly in the case of those who have lost a hand,

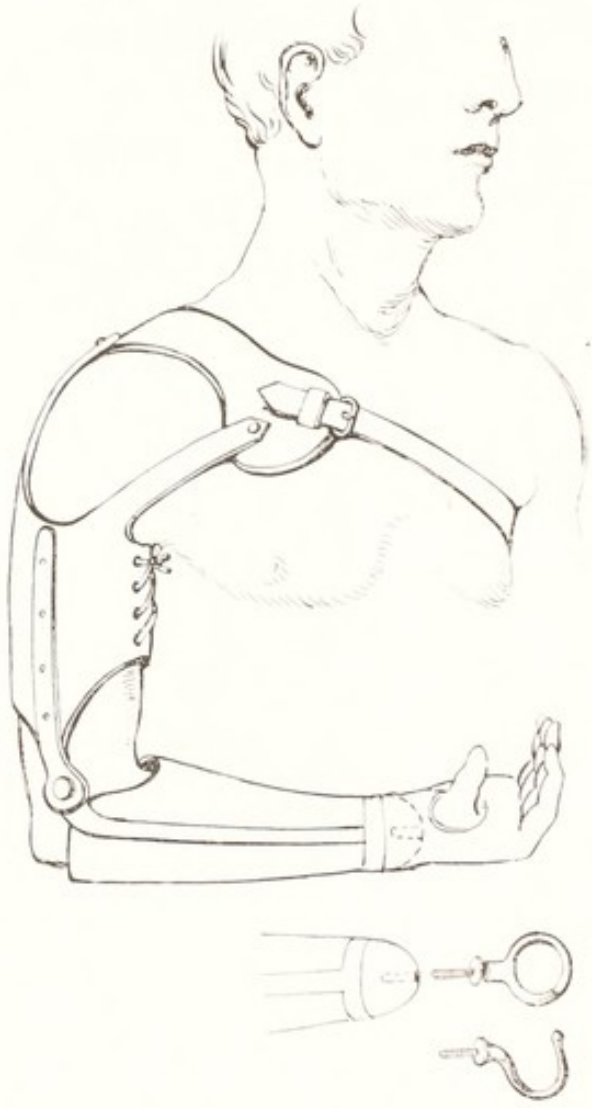


Fig. 712.—Artificial arm with interchangeable holding devices. (After Ducroquet.)

the entire mode of life must be modified. Nothing can be done as it was previously done, and the simplest actions of everyday life must be relearned, especially such functions as dressing and undressing, washing the hand and face, lacing the shoes, eating, writing, etc.

This training in proficiency, combined with the wholesome cheeriness of physician and instructor, does more than anything else to overcome the depression under which most of the patients are laboring, and fits them for the next important step in rendering them useful citizens of their community, namely, specialized training of the stump for the particular purposes for which it is to be used. For this, of course, the men must be divided into groups depending upon the type of amputation and the nature of the work. In

helping the patient decide what work he is fitted for, the physician should have as consultants a staff of technical assistants versed in the details of all the handicrafts. Experience has shown that amputations of the forearm and of the upper arm if not more than 2 or 3 inches above the elbow, do not debar a man from becoming a carpenter, a farmer, or some type of mechanician. Of course, those possessing an elbow-joint have a great advantage over those amputated above the elbow. When the amputation has occurred near the shoulder-joint, it is foolish to attempt training a man for these branches. He should then be taught some handicraft allied to his previous occupation. Thus, the carpenter should be taught sufficient mechanical drawing and building construction to enable him to act as foreman; or if he is not sufficiently well educated to assume this responsibility he can be taught to be a

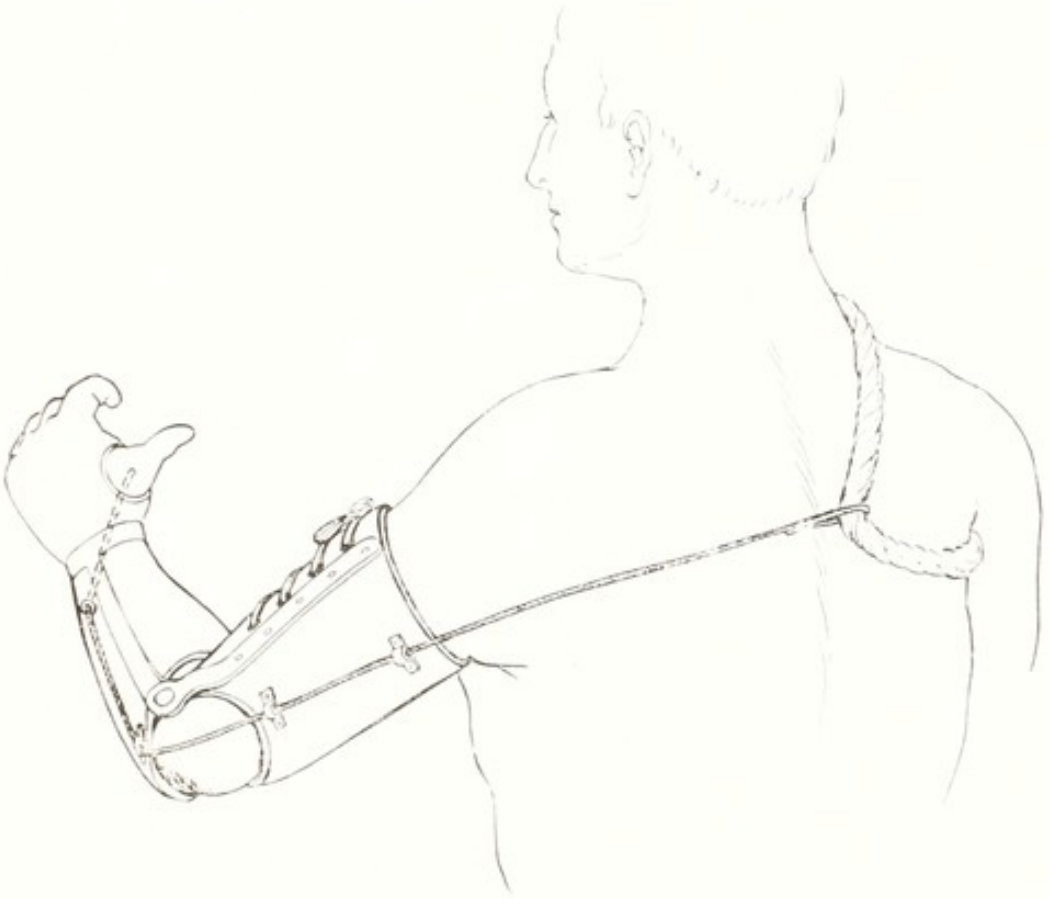


FIG. 713.—Apparatus for amputation of the middle portion of the arm. Shows method of actuating the thumb by muscles of opposite shoulder. (After Ducroquet.)

piano polisher. In this occupation, practically all the work is done with a sweeping motion of one arm; the other hand is used simply to hold the varnish or other polishing substance, a function which is quite as well filled by a small tray placed near the worker.

While the artificial limb can be used to advantage in many instances, for many men the stump itself is the best prosthesis. This applies particularly to a moderately long forearm stump. This can be used for filing, almost as effectively as the normal hand; for hammering, the handle is gripped in the elbow between the upper arm and the stump. At the turning lathe, the stump can easily be trained to turn the adjusting swivel. In learning to use the stump it is of great assistance to have an amputated man himself act as instructor.

Those suffering amputation of a lower limb do not require the same specialized training. All they need is the proper stump treatment and the application of a well-fitting prosthesis to render them fit to return to their



FIG. 714.



FIG. 715.

FIG. 714.—Patient of Riedinger with very short upper arm stump. (Mayer.)

FIG. 715.—The same patient as in Fig. 714, equipped with a Riedinger prosthesis. Note the broad circular pad which closely surrounds the shoulder and serves as support for the leather socket which is attached to it by a strong joint, permitting motion in all directions. (Mayer.)

community. With rare exceptions, they are able to return to their previous occupations. The exceptions are the cases of double amputation or amputa-



FIG. 716.—The mechanic's tools employed by the patient shown in Fig. 715. These are inserted into the slot at the lower end of the forearm piece and fastened firmly in place by a turn of the screw. (Mayer.)

tion near the hip in cases of men who previously did hard manual labor. They must be taught a trade which allows them to be seated most of the time.

Far and away the most difficult problem presented in the care of the amputated is that of those who have lost both hands. Providing the stumps

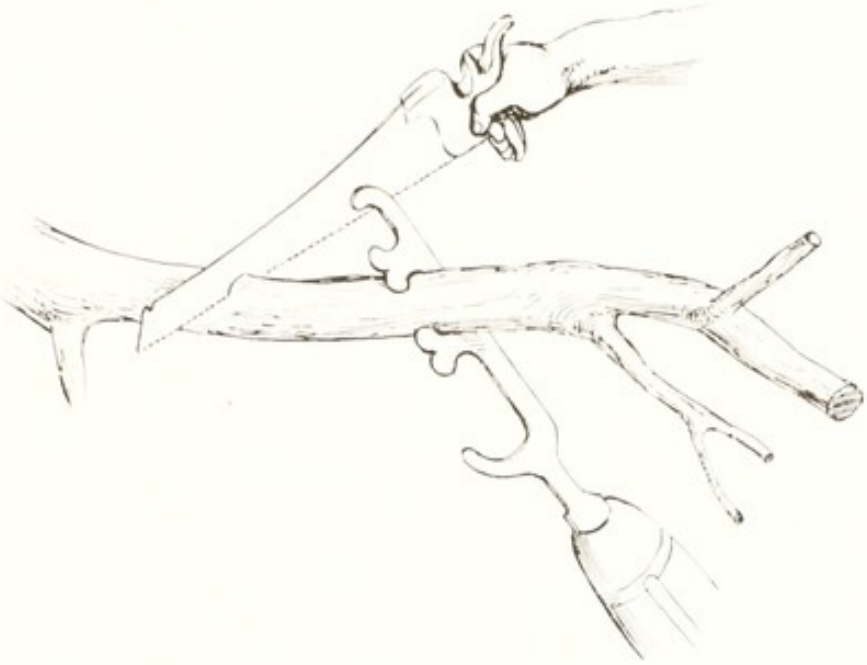


FIG. 717.—Method of holding any object such as a branch of a tree.

are sufficiently long to allow them to be approximated, the loss is not as tragic as it at first appears. In Fig. 730 is shown one of the teachers of the

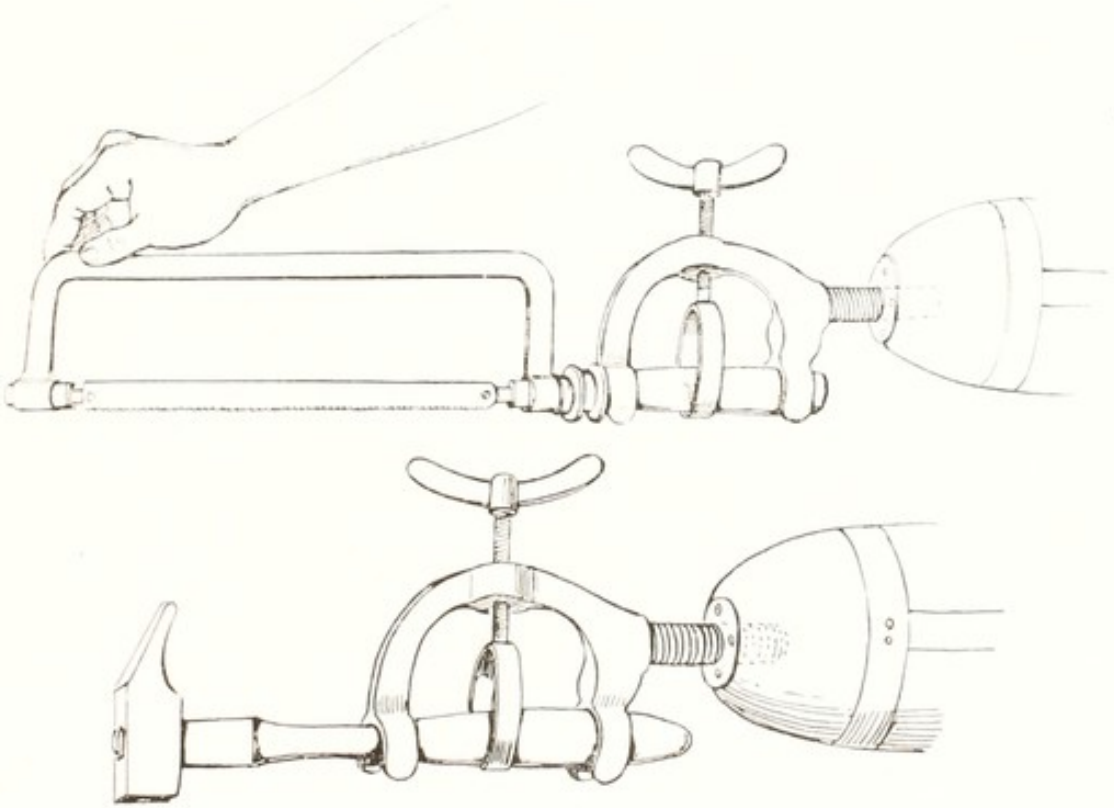


FIG. 718.—Artificial arm with special holding device for tools. (After Ducroquet.)

crippled children's home already referred to. He is seen in the act of buttoning his collar by means of a button hook held between the two stumps. This

man had learned to dress himself alone, to eat with delicacy and grace, to write a perfect hand with more than the normal speed, and had passed the

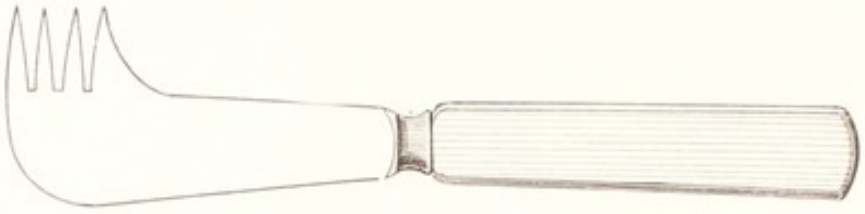


FIG. 719.—A combination of knife and fork for the one-armed. (Mayer.)

examinations qualifying him as a licensed teacher. He did all this without the use of artificial limbs.

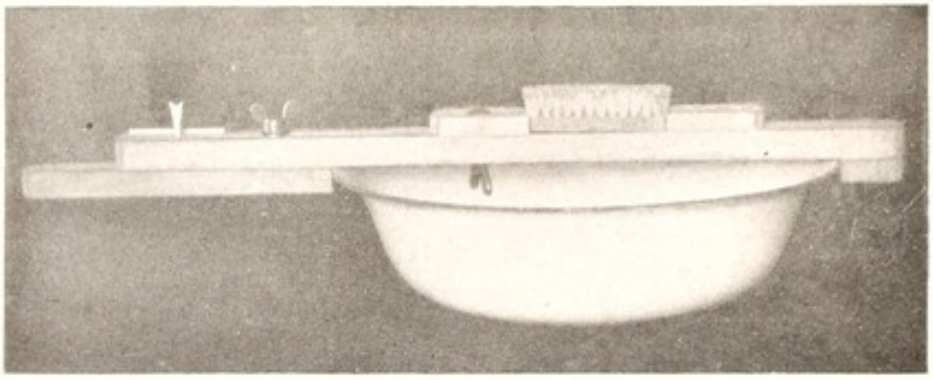


FIG. 720.—A simple toilet arrangement for the one-arm soldier. To permit proper cleansing of the hand, a scrubbing brush and a nail file are fastened firmly to the board which rests on the basin. (Mayer.)

When, however, the stumps are so short that they cannot be brought together, an artificial limb must be applied, and for these probably none



FIG. 721.—Badly mutilated hands of a patient, who in civil life had been a butcher. To enable him to grasp his knives, a clay impression of the grip of his right hand was taken and the handles of the knives correspondingly carved. See Fig. 722. (Mayer.)

is equal to the Carnes' limb, since with sufficient training it enables the wearer to become a reasonably independent being, whereas without it, he is abso-

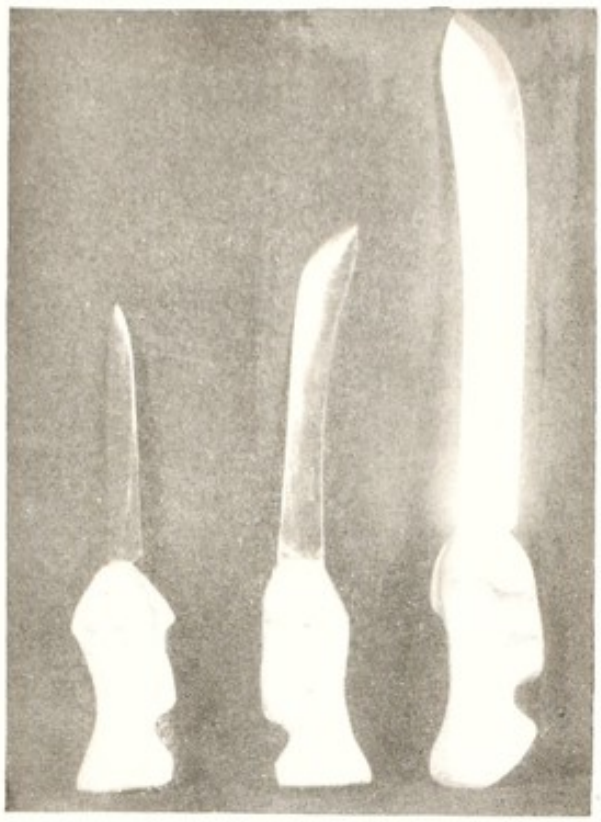


FIG. 722.—Butchers' knives, carved so as to permit their effective handling by the patient depicted in Fig. 721. (Mayer.)



FIG. 723.—The Sauerbruch method of producing a kinetic stump. First step of operation. A tunnel has been bored through the biceps muscle. A skin flap has been freed and is being sewed about a piece of rubber tubing with the epithelial surface turned inward. (Mayer.)

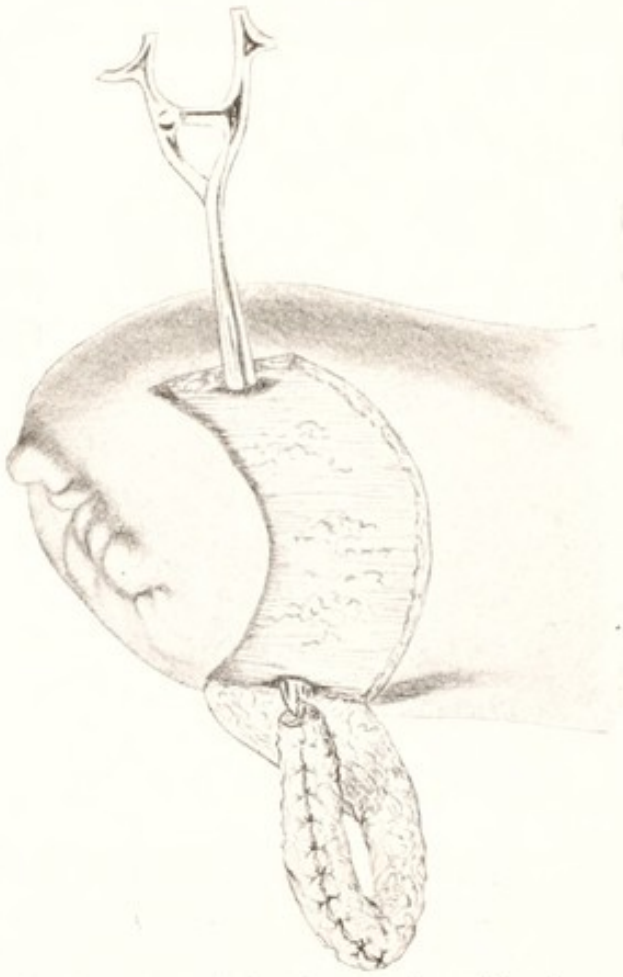


FIG. 724.—The Sauerbruch method of producing a kinetic stump. Second step of operation. The epithelial-lined tube is being drawn through the channel in the muscle. (Mayer.)

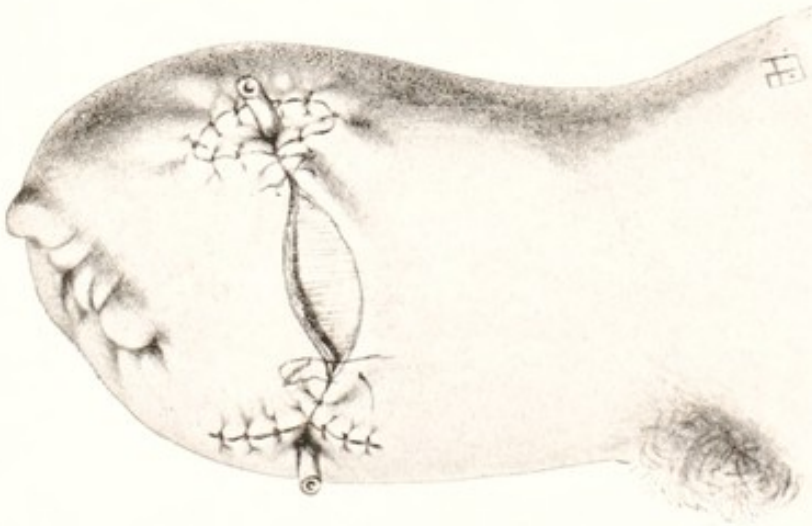


FIG. 725.—The Sauerbruch method of producing a kinetic stump. Third step of operation. The operation is completed by uniting the skin edges as shown in the illustration. The canal is kept patent by running a piece of rubber tubing or an ivory peg through it. (Mayer.)

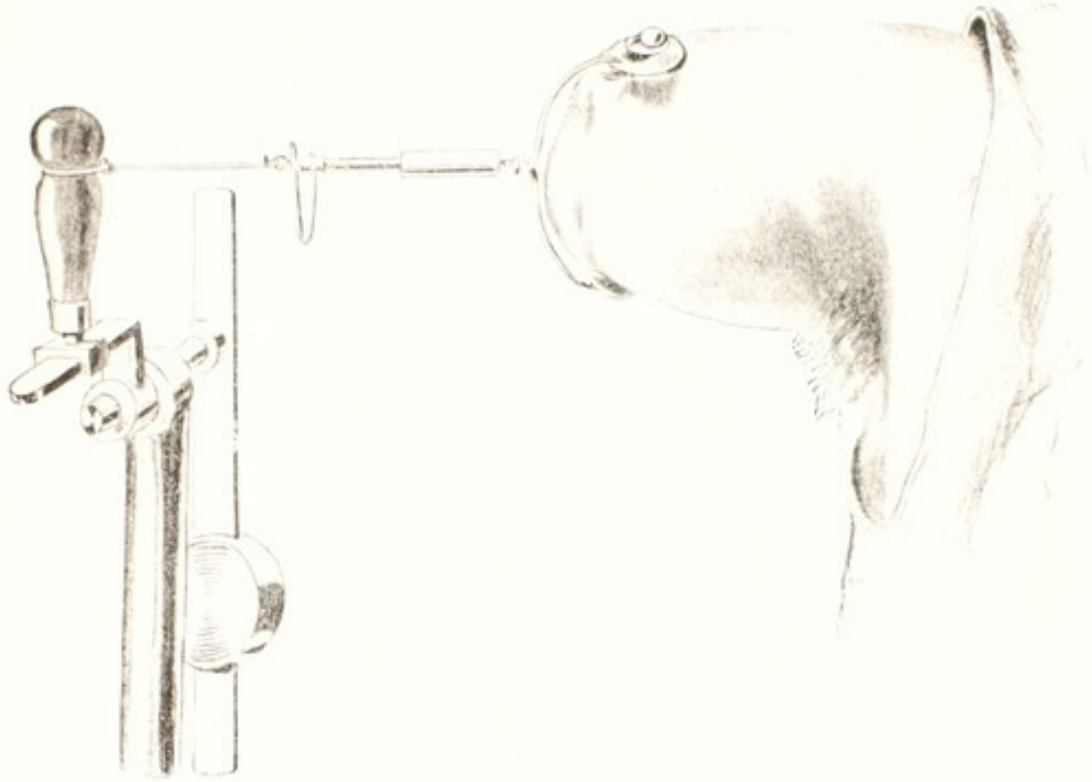


FIG. 726.—The Sauerbruch method of producing a kinetic stump. The after-treatment. To exercise the muscle through which the channel has been bored, the ivory peg running through it is attached to a pedulum apparatus. The patient can by a voluntary contraction of the muscle cause the ivory peg to move upward and thus move the lever of the apparatus. By regulating the length of the pendulum the exercises can be graduated to meet the increasing muscular power of the patient. (Mayer.)



FIG. 727.

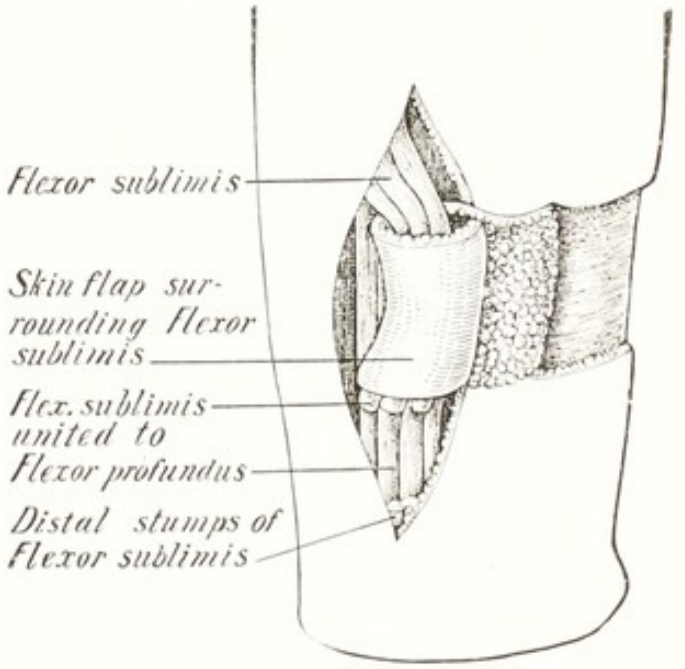


FIG. 728.

FIG. 727.—Cinematic apparatus and method of preparing forearm so that muscle pull is transmitted to artificial arm. (Binnie.)

FIG. 728.—Cinematic amputation through lower third of forearm. A pedicled cuff of skin is placed about the elevated flexor sublimis tendons, its fat surface next to the tendons, its cutaneous surface external. The rest of the skin incisions are closed. In three weeks time the skin pedicle is separated, leaving a skin loop with active tendons inside. To this loop is attached a traction cord, its distal end connected with the artificial hand and fingers. (Binnie.)



FIG. 729.—Result of cinematic amputation. (De Francesco.)

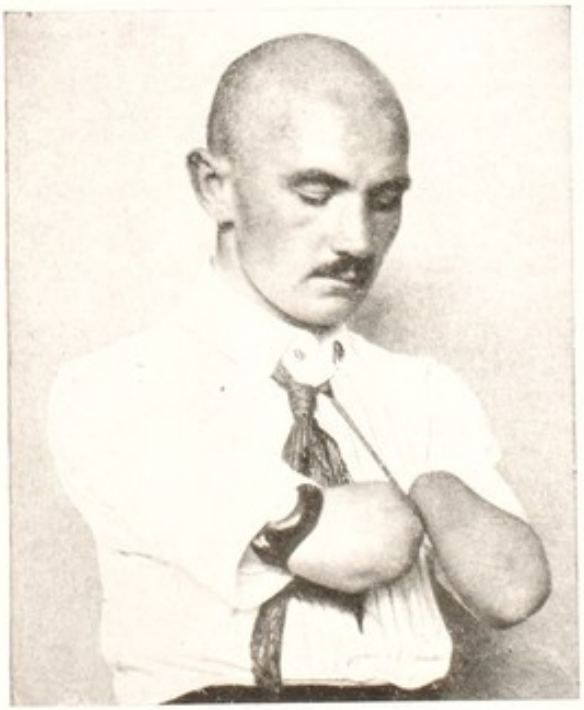


FIG. 730.—A teacher, both of whose hands had been amputated when six years old. He had learned to be absolutely independent and had passed his examination entitling him to a teacher's license. Without artificial limb he could dress himself (the illustration shows him in the act of buttoning his collar), shave, eat with grace and assurance, write an unusually legible hand with more than normal rapidity, travel long distances alone, carry a suit case and pay his fares, just as the normal individual would. All this was done by careful education of the stump, which in his case had acquired almost the same sensitiveness as the tips of the fingers. (Mayer.)

lutely helpless. The double amputated require a school all to themselves, specially devised clothing with snaphooks instead of buttons, trousers devised to fit directly to a vest, etc."

Experience has proved that it is best to employ the simplest artificial limb, and that the aim should be to replace not the anatomical but the physiological loss. The artificial arms supplied by the French Government are of two types: (1) Moulded leather arm-piece and wooden hand, with movable thumb for which other fittings can be substituted, such as a hook or ring, etc. At the elbow of the first arm there is a joint allowing flexion and rotation. At the wrist, a pair of jaws is attached by a ball-and-socket joint. All these joints can be locked in any position. The powerful jaws are designed so that they will hold tools of almost any character. The jaws can be detached and the conventional wooden hand can be substituted. (2) A steel arm designed by Professor Amar.

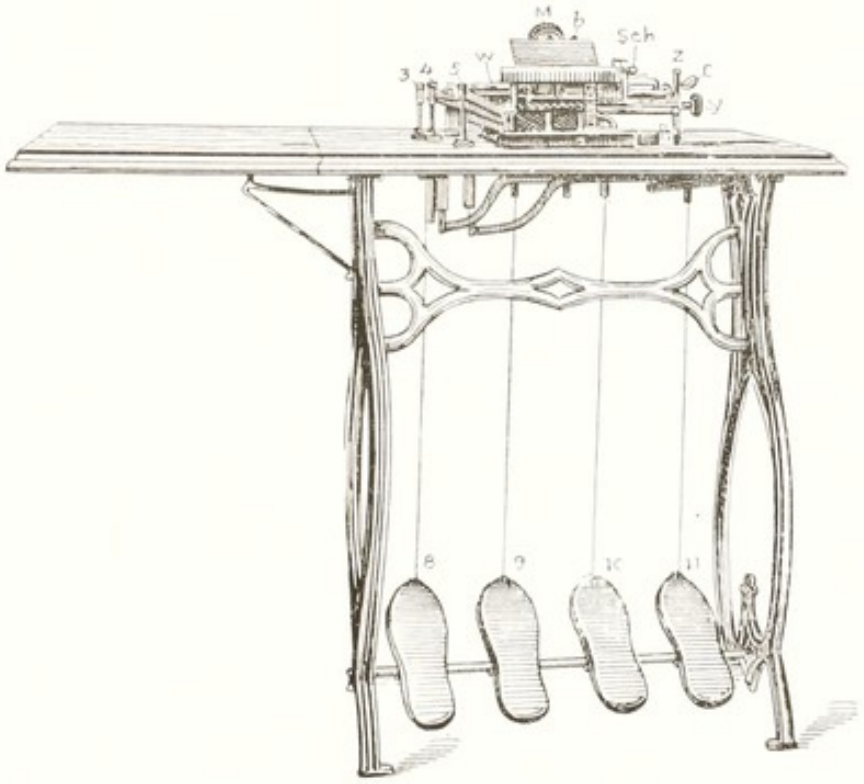


FIG. 731.—A modified typewriter for the one-armed. The pedals are connected with the spacer and shift key. (Mayer.)

The second prosthesis is made of thin sheet steel and includes a hand with artificial fingers which are actuated through the means of a cable by movements of the shoulder or the chest, less often the latter. It possesses an especial advantage for those engaged in light occupations.

ARTIFICIAL LEGS

Legs made of wood fiber or leather have been in use in France and England. As a rule, men who have become dependent upon an artificial limb are supplied with two, so that they will always have one in reserve if the limb in habitual use becomes worn or broken. It has been decided in France that the State must keep the limbs in repair as well as supply them, and it has seemed best to pay the possessor of the limb about one-tenth of its original cost annually, he to renew the limb when it is worn out. The life of an

artificial limb is short, about three years for a leather one if it is properly looked after, otherwise it may last only one year.

GUNSHOT INJURIES OF BONES AND JOINTS (see also Chapter XVII)

It was very striking to the author, in studying compound comminuted fractures and non-union, while in France and also as chief of the Surgical

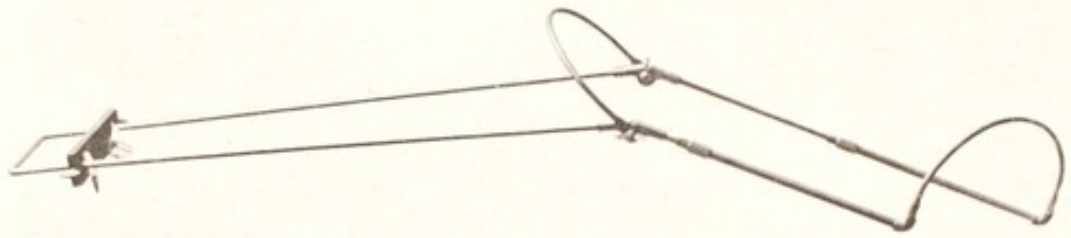


FIG. 732.—Butler splint. An adjustable splint especially valuable in military practice as it furnishes the surgeon all the modifications of the Hodgen or Blake splint (as to right, left, various sizes, etc.) in one brace. The position in this figure is that of a right Hodgen with spreader at knee thrown forward. This brace was devised by S. C. T. Butler of New York and is of especial value when used in conjunction with the Balkan frame or or transportation.

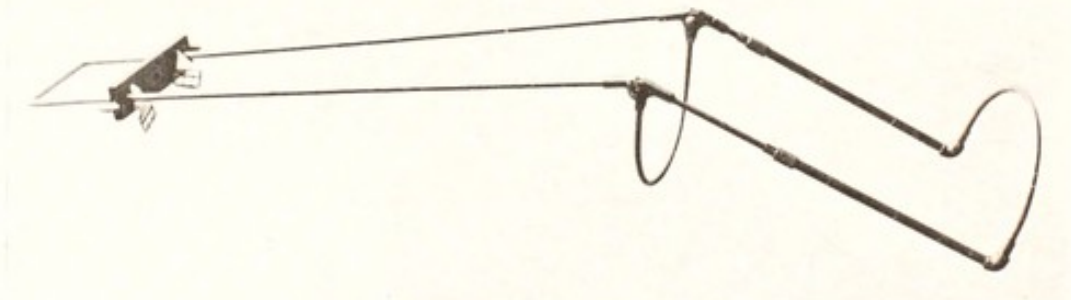


FIG. 733.—Butler splint. Here the position of a left Hodgen has been obtained by shifting the relative position of the tubes; the near tube has been pulled away from, the far one pushed toward the center of the splint. Any desired position is rigidly maintained by a friction lock which is easily loosened by pushing the metal cuff with a spiral motion toward the center of the splint and tightened by the reverse motion. In this instance an additional width of one inch at the knee has been obtained by unscrewing the joint locks and placing the spreader inside instead of outside the joints. The spreader may be placed either above or below and in the latter position, is much more convenient in cases where wounds of the anterior surface of the knee are present.

It may be noted here that the thigh "length" may be increased by drawing both tubes away from the knee-joint, and also that the thigh "width" may be made wider or narrower by altering the relative position of the sliding tubes. The width is greatest when the tubes are the same distance from the knee-joints.

Service at U. S. Army General Hospital No. 3, Colonia, N. J., to note that where all loose bone fragments were removed and the ends of the main fragments were squared and smoothed off, delayed union or failure of union occurred; or where the ends of shattered bones, such as the upper end of the



FIG. 734.

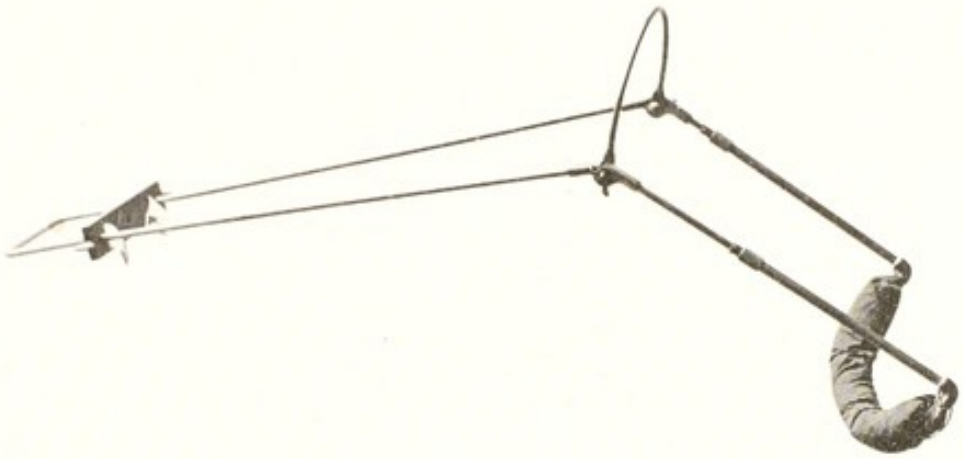


FIG. 735.

FIGS. 734, 735.—Butler splint. To use the apparatus as a straight or Blake splint, it is only necessary to pull off the tube section, turn it over, and replace it on the rods. A left or right Blake splint is obtained in the same way as described above for Hodgen's splint. A cushion of rubber cloth is laced on, as in this position the semicircular rod rests well up against the tuberosity of the ischium.

The spreader at the knee-joint is not absolutely essential when the splint is used straight, but gives additional support and is ready for use in case, at a later date, it seems advisable to bend the knee (Fig. 735). In the bent position the spreader is essential to insure strength.

The extension bar at the foot slides readily along the splint and may be fixed in any desired position by means of the set screws at the sides. To the buckles are attached the extension bands (mole skin, etc.) that have been fastened to the limb, and a knotted cord passed through the center hole runs over a pulley at the foot of the bed and is attached to the extension weights.

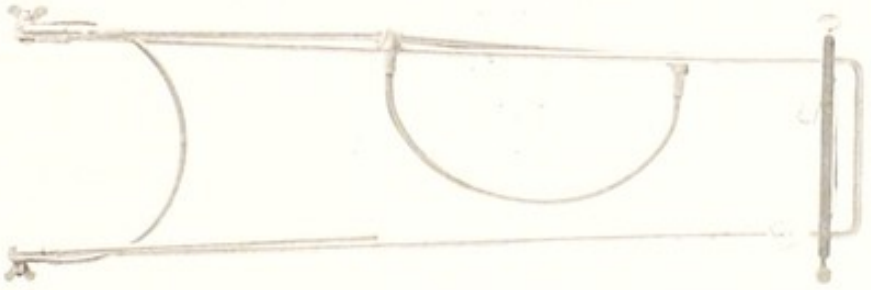


FIG. 736.—Butler splint. This figure illustrates the splint folded and ready for storage or transportation.

humerus, were resected, flail limbs resulted, which were practically useless. In other cases, when the wounds were thoroughly cleaned and drainage was established with tubes, etc., and the bone fragments were saved, the results were markedly better. Provided that the fragments and spicules were not removed, there seemed to be almost no limit to the amount of shattering which might be followed by a complete re-establishment of the shaft.

"When bone is struck, the bullet spreads and by this means is enabled to impart a great deal of its energy to the bone fragments, and these in their onward flight act as projectiles themselves, and tear and lacerate the tissues



FIG. 737.

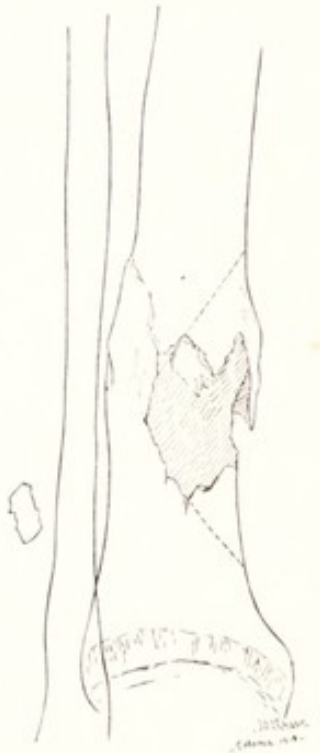


FIG. 738.

FIG. 737.—Anterior posterior view of lower third of tibia, demonstrating pocket with osteomyelitis and sequestrum from machine gun bullet, battle Château Thierry. The arrows in the radiogram indicate shelving bone. For treatment, see Fig. 738.

FIG. 738.—Diagramatic drawing made from the roentgenogram, Fig. 737, to demonstrate a fundamental mechanical principle in the treatment of bone cavities in osteomyelitis, especially after gunshot injuries.

All shelving or overhanging bony walls should be removed along the dotted lines, as indicated in this figure. In order that there may be no pockets to harbor infection, the cavity should be so shaped that the overlying soft parts will drop into it. If this is not possible, a fat transplant should be inserted in suitable cases.

in the neighborhood." The fragmentation caused by the bullet in such cases is often extensive.

Great emphasis should be placed upon the danger of attempting a plastic procedure (such as bone-grafting or arthroplastic operations) within a period of months after the skin has become thoroughly healed; the working rule should be about three to six months.

Recent wars have shown that the destructive effect upon bones of mantled bullets, such as the Mauser, varies in relation to (1) the distance or range, (2) the character of the bone, and (3) the angle at which the bone is struck.

1. **Distance or Range.**—Speaking generally, the shorter the range, the more extensive and severer is the bone destruction. It may be stated that the greater the velocity of the bullet, the greater its destruction. Theories to the contrary have been put forward, based on the assumption that a bullet travelling at high velocity is more apt to perforate than produce shattering



FIG. 739. FIG. 740. FIG. 741.

FIG. 739.—Loss of 7 inches of tibia from osteomyelitis. Duration two years.

FIG. 740.—Same case as Fig. 739. Eight weeks after the insertion of a graft 10 inches long to span a hiatus of over 7 inches and inlaid into the proximal and distal tibial fragments. Union of graft to host fragments of tibia is firm.

FIG. 741.—Same case as Figs. 739, 740. Eighteen months after the insertion of the graft. Remarkable hypertrophy of the graft is shown also increased density of the tibial fragments. The marrow cavity already developed especially in upper end of graft is striking.

of the bone. The lateral expansive or explosive effect of a bullet in all tissues is increased by its velocity. Bone injuries produced by a regulation bullet within a range of fifty yards resemble very closely those caused by a true expanding or explosive bullet. Large portions of bone may be shot away, and there may be very extensive comminution and pulverization, with resulting injuries to the surrounding soft parts.

2. **Character of Bone.**—The more dense and compact the bone, the more extensively it becomes shattered and comminuted in all but very long ranges. The tibia may be shattered and pulverized, when at the same distance a bone of lighter structure, such as the ulna, presents a fracture with little shattering. Again, hard cortical bone may be badly comminuted at the same range that cancellous bone may be perforated without being fractured; the latter usually occurs, however, in portions of bones that are thick, as the lower end of the femur, and not where they are slender, as the lower end of the fibula or humerus, which usually become split. The patella, carpus, and tarsus also are apt to be simply drilled by a penetrating bullet.

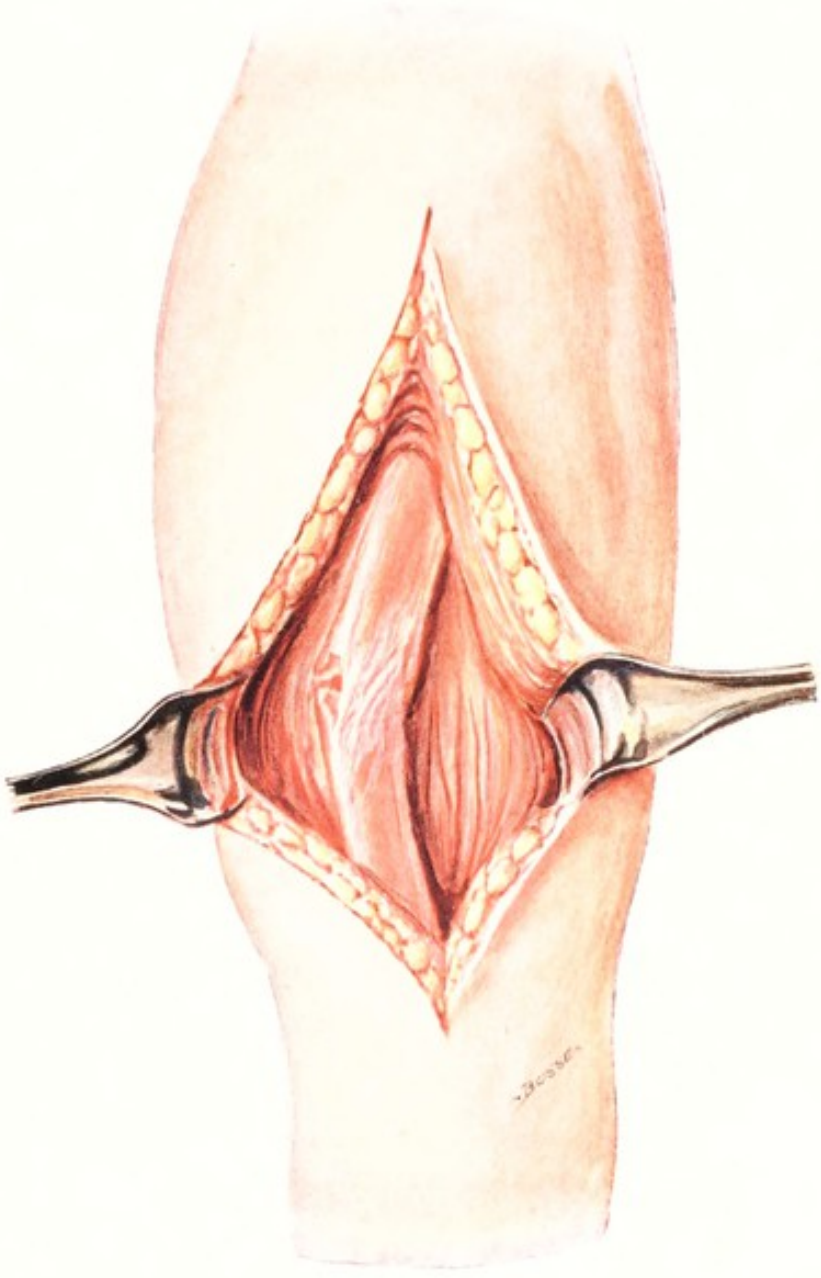
3. **Angle of Impact.**—Contrasted with the characteristics of bone wounds described under headings (1) and (2) produced by bullets hitting full, are



FIG. 742.—This case was wounded at Château Thierry by machine gun bullet. The radiographs show loss of bone at central portion of ulna, with non-union.

those striking a glancing blow and simply cutting a superficial groove in the bone or causing a simple transverse fracture. This may even occur in a dense part of the bone, such as the femur, and at short range. If the bullet passes in an oblique and longitudinal direction through the shaft of a large bone, it will produce a more shattering effect, even at very long ranges.

Transverse fractures are very rare, splintering with extreme obliquity of the fracture being the rule. In addition to the splintering, there is a varying amount of pulverization of the bone in most cases, and this is one of the chief characteristics of injuries caused by high velocity, hard mantled bullets, compared with the old soft and low velocity projectiles. The scattering of pulverized bone into the soft tissues surrounding the wound is a matter of considerable importance in planning and executing the treatment. If suppuration occurs, multiple sinuses may form and persist for long periods of time. They may close and open again even after the lapse of months or years.



Same case as Fig. 742, showing actual pathology found. The bone hiatus had filled with soft tissue.

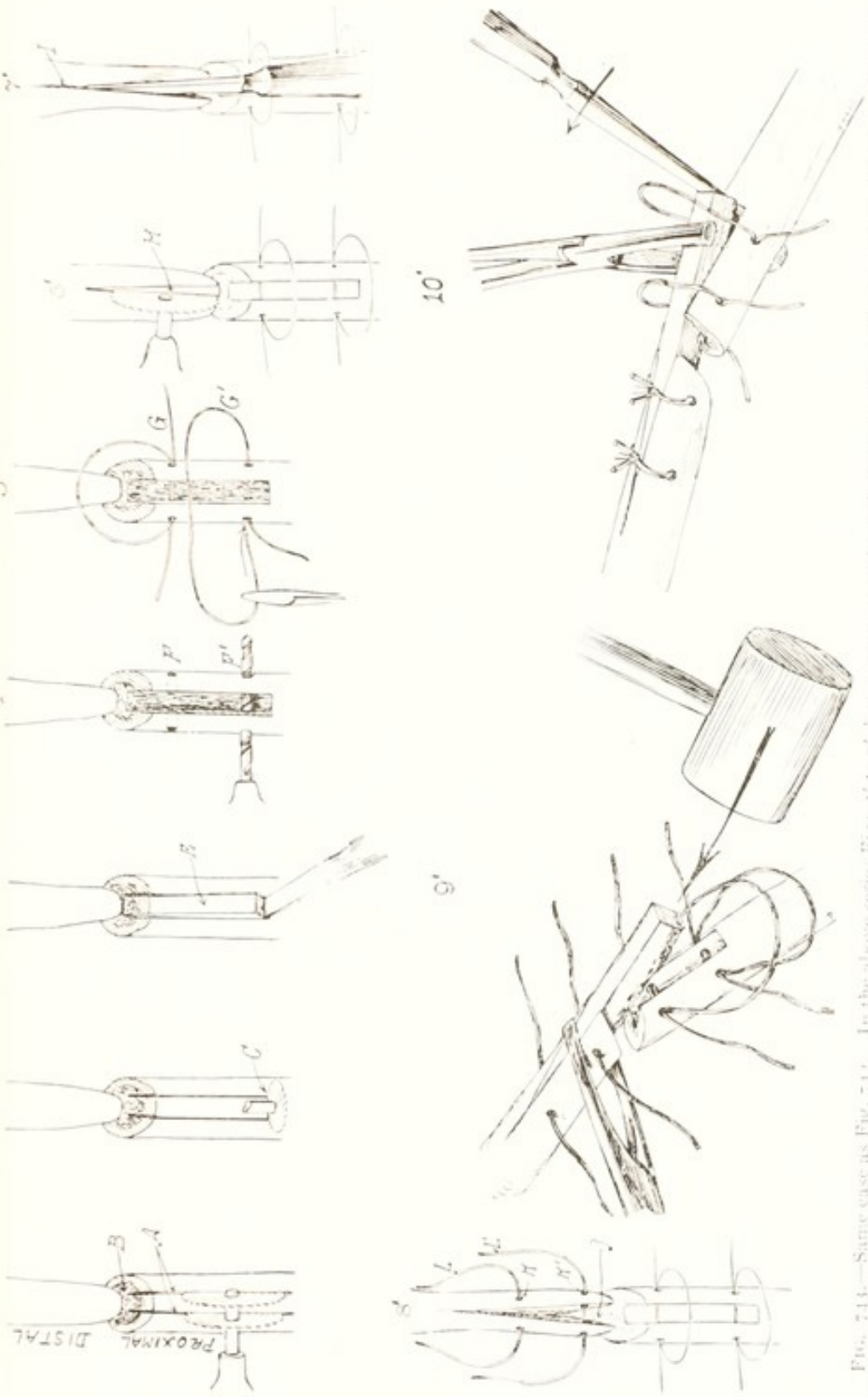


FIG. 744.—Same case as Fig. 742. In the above series (Figs. 1' to 9') demonstrate steps in author's technic in such cases where the end of the bone fragment (distal or upper fragment in this case) is conical in shape, and too small in diameter to receive the usual inlay graft which is shown in the proximal or lower fragment in these drawings. (For discussion of this technic, see Chapters XVI and XVII.)

A wedge-shaped piece of cortex, *H*, is removed from the upper fragment. A split at end of wedge cavity may or may not be made by means of a thin osteotome, as shown at *I*. If the fragment is small in diameter and osteoporotic, as is usual in these cases, the bone may be bent on both sides of the cavity in the region of *I* and the wedge cavity enlarged by driving a wedge-ended graft of larger diameter into it, as demonstrated in steps No. 6', 7', 8'.—In this step the wedge end of the graft is firmly immobilized in the distal or upper fragment by means of kangaroo tendon. The other end of the graft is then forced into the proximal fragment by means of a strong clamp at the same time that the graft is being levered endwise by means of a narrow osteotome, the object being two-fold: first, to restore as far as possible the length of the ulna, and secondly, to bring end stress upon the graft as a stimulus to bone growth. (These drawings were made with distal fragment of ulna uppermost because of position of arm during operation.)

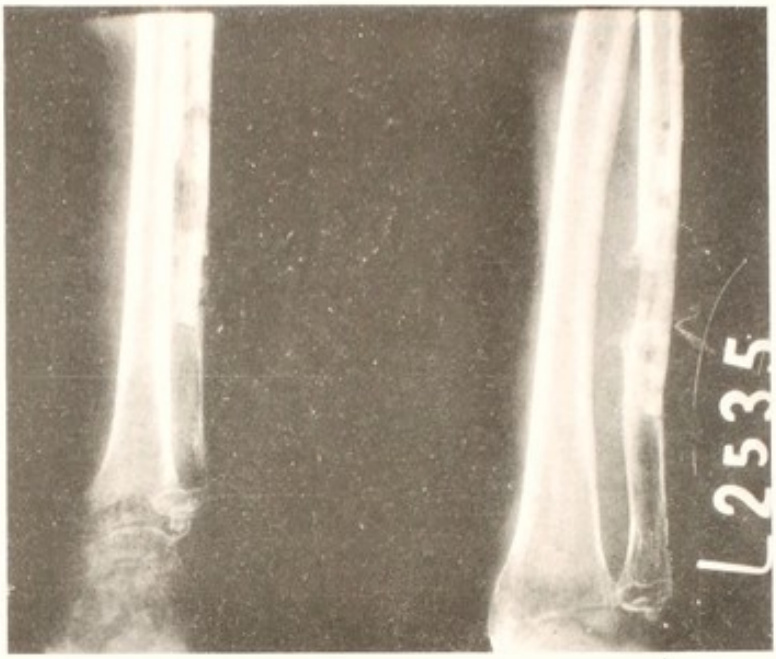


FIG. 744.—Same case as Fig. 742, three months after restoration of loss of ulna by inlay graft from tibia. This case was operated on by author at U. S. Army General Hospital No. 3, Colonia, N. J., four months after being wounded and two months after wound was healed. Restoration of function is complete.

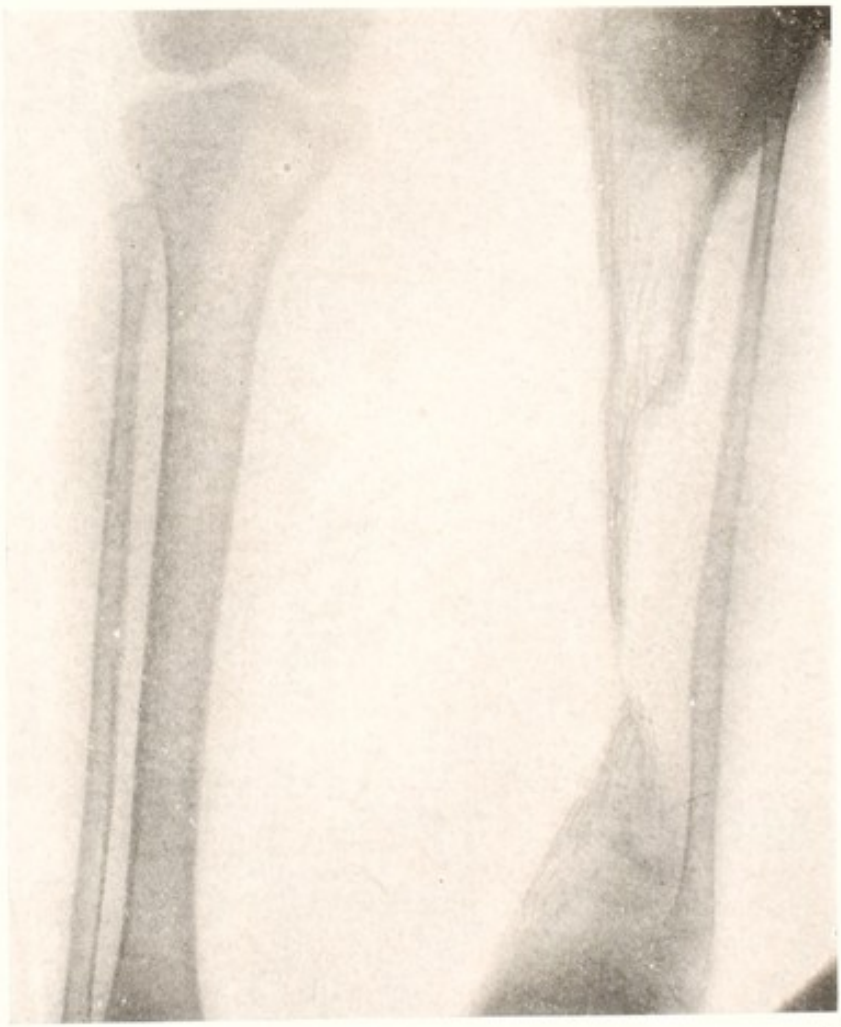


FIG. 745.—Absence of central portion of tibia from old osteomyelitis.

Conclusions of Martin and Petrie (British Journal Surgery, October, 1917). —(1) From the surface of a divided or fractured bone exposed to infection, bacteria may penetrate to the deeper parts.



FIG. 746.—Same case as Fig. 745, one year after insertion of graft. The upper tibial fragment was split with motor saw and the upper end of the graft, being made with wedge end, was inserted into saw-cut cleft at *A*. The lower end was inlaid by author's usual technic at *B*.

2. In an untreated fracture, bacterial penetration is apparently unlimited.

3. If the dead bone on the surface of the fracture is removed early, penetration is much reduced, and may not occur at all.

4. Penetration, particularly of anërobes, is greatly increased by reduction of the circulation through the injured bone.

5. Penetration is increased by obstruction to drainage, either of the bone or of the soft parts.

6. The order of frequency and power of penetration of the bacteria found is: (1) Streptococcus; (2) Staphylococcus; (3) Anërobes; (4) B. coli.

7. The rate of penetration is at its maximum during the first few days.

8. In the material examined, no difference in reaction to penetration has been noted between cancellous bone and the marrow of the shaft.

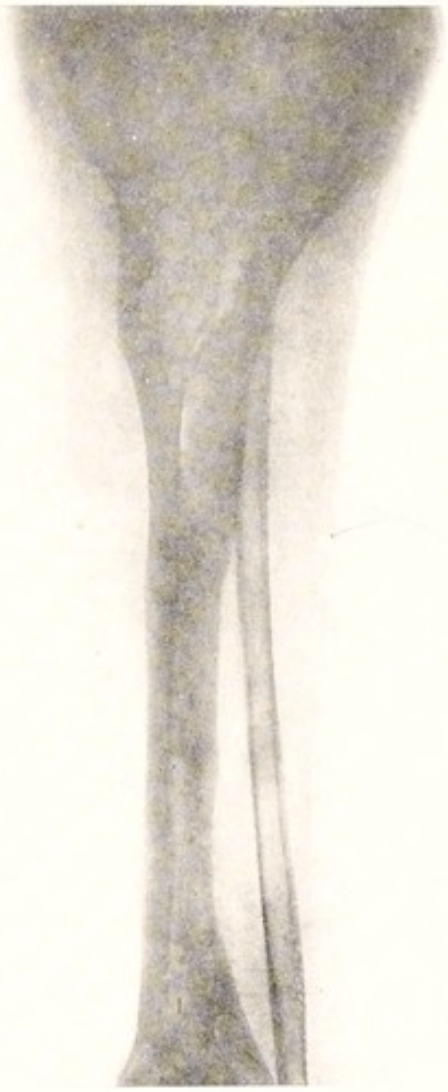


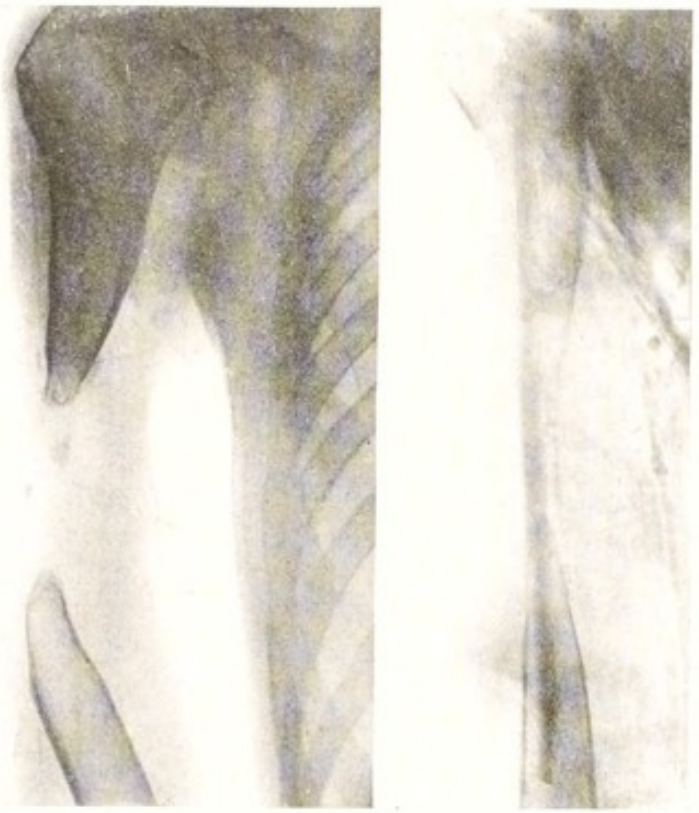
FIG. 747.—Same case as Figs. 745 and 746 demonstrating complete restoration of diameters of tibia two years after implantation of a graft, obtained from the opposite tibia.

9. Bruising—an invariable accompaniment of projectile fracture—does not appear to facilitate bacterial penetration if the surface layer of débris is removed and drainage established.

10. In a septic fissure, growth of bacteria is progressive, and may lead to infection of a distant part, for example, a joint. Dissemination of infection throughout a bone takes place by penetration from its walls.

Faulty alignment of fractured long bones is a frequent cause of disability. On account of a mistaken conception, bony fragments are often allowed to remain in a faulty position during the entire period through which most compound-fracture wounds pass, because it has been thought that an attempt

to correct the alignment at this time would increase the patient's suffering, interfere seriously with the healing of the wound, or lead to spreading of the infection. Just the opposite obtains. Proper alignment obliterates pockets in the soft tissues about the fragment ends, in which pus or infected material collects, favors drainage, and if the fragments are firmly immobilized the wound heals much more kindly and the surgeon can dress it more easily and more comfortably to the patient. Again, the reduction of the fracture by open operation or otherwise is much easier during the first few weeks after injury, and is usually very difficult after malunion. In the beginning, the reduction of the deformity involves no additional risk if the proper time is selected, that is, as soon as the temperature has dropped, because the wound



a *b*

FIG. 748.—*a*, Loss of 4 inches of central portion of humerus from compound comminuted infected fracture. Ends of bones are shown to be conical, with thinned cortex with osteoporosis, six months after the injury. *b*, Same case five weeks after the implantation of a tibial graft 9 inches in length with small fragmented grafts ("bone-seed") placed beside it at the humeral hiatus for the purpose of hastening osteogenesis.

must be cleaned out anyway. Later, the danger of lighting up fresh infection is nearly as great, and therefore a delay of many months must occur before correction can be accomplished.

TREATMENT OF FRACTURES AND INJURIES TO JOINTS

"The method of fixation must comply with the following requirements:

"1. It must prevent shortening and hold the fragments.

"2. It must be adapted to the transfer of the patient from the front to the base hospital.

"3. It must allow free access to the wound, not only for dressing and inspection but for incision in case of abscess formation.

"4. The materials used must be such as will allow their ready transfer.

"It is self-evident that no one splint can meet the requirements of the many types of fractures, and also that in many instances a variety of methods can be employed with equal effectiveness. In all cases, however, it is essential that the surgeon should have sufficient mechanical skill to appreciate the

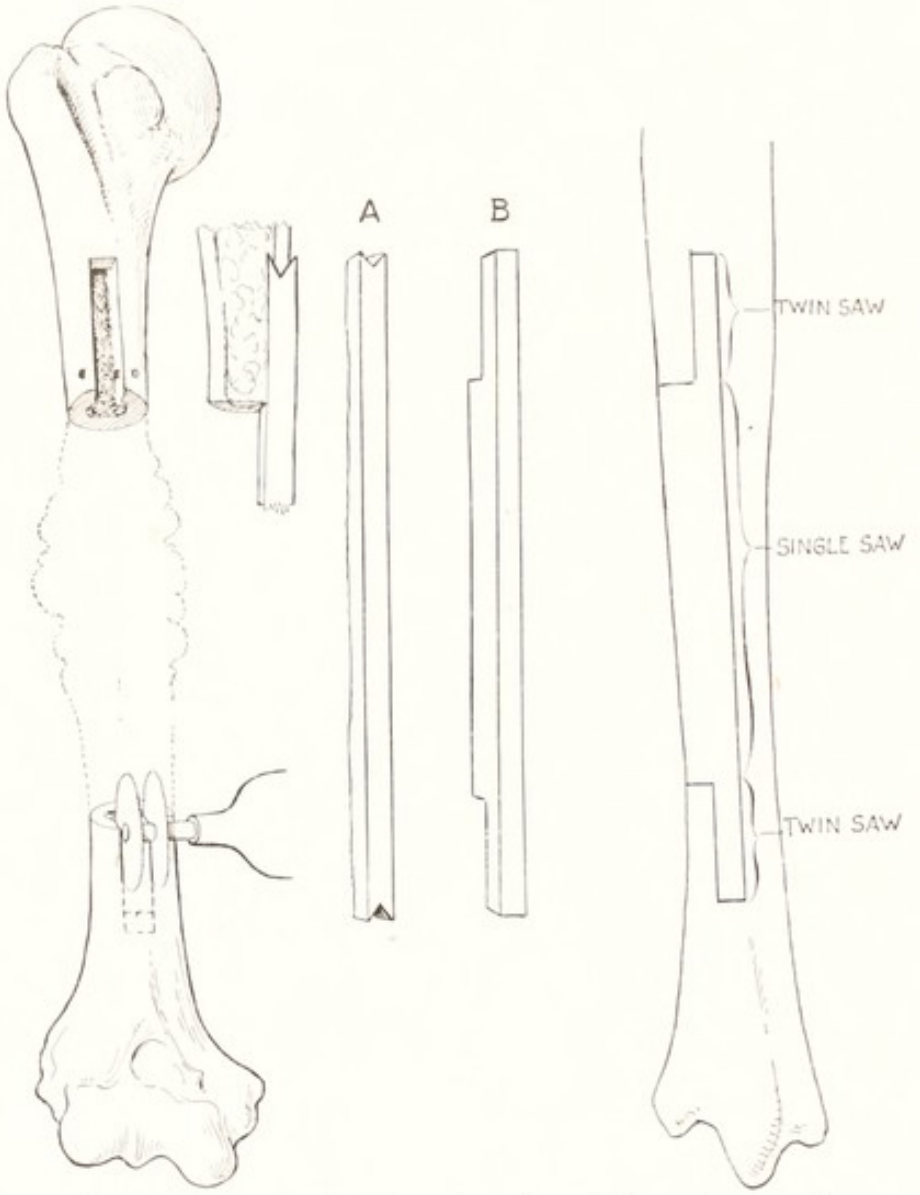


FIG. 749.—Inlay technic for the insertion of a tibial graft after the resection of a portion of the shaft of a long bone. The prevention of the limb shortening may be accomplished in two ways, either by a tongue and grooved joint as indicated at *A* or by shaping the graft so that it is larger in diameter where it spans the bone hiatus and has mechanical shoulders at either end, as indicated by *B*, which is mapped out in the periosteum of the anterior internal surface of the tibia. The latter technic is preferable. (See drawing to the right.) The tibia is the source of the graft.

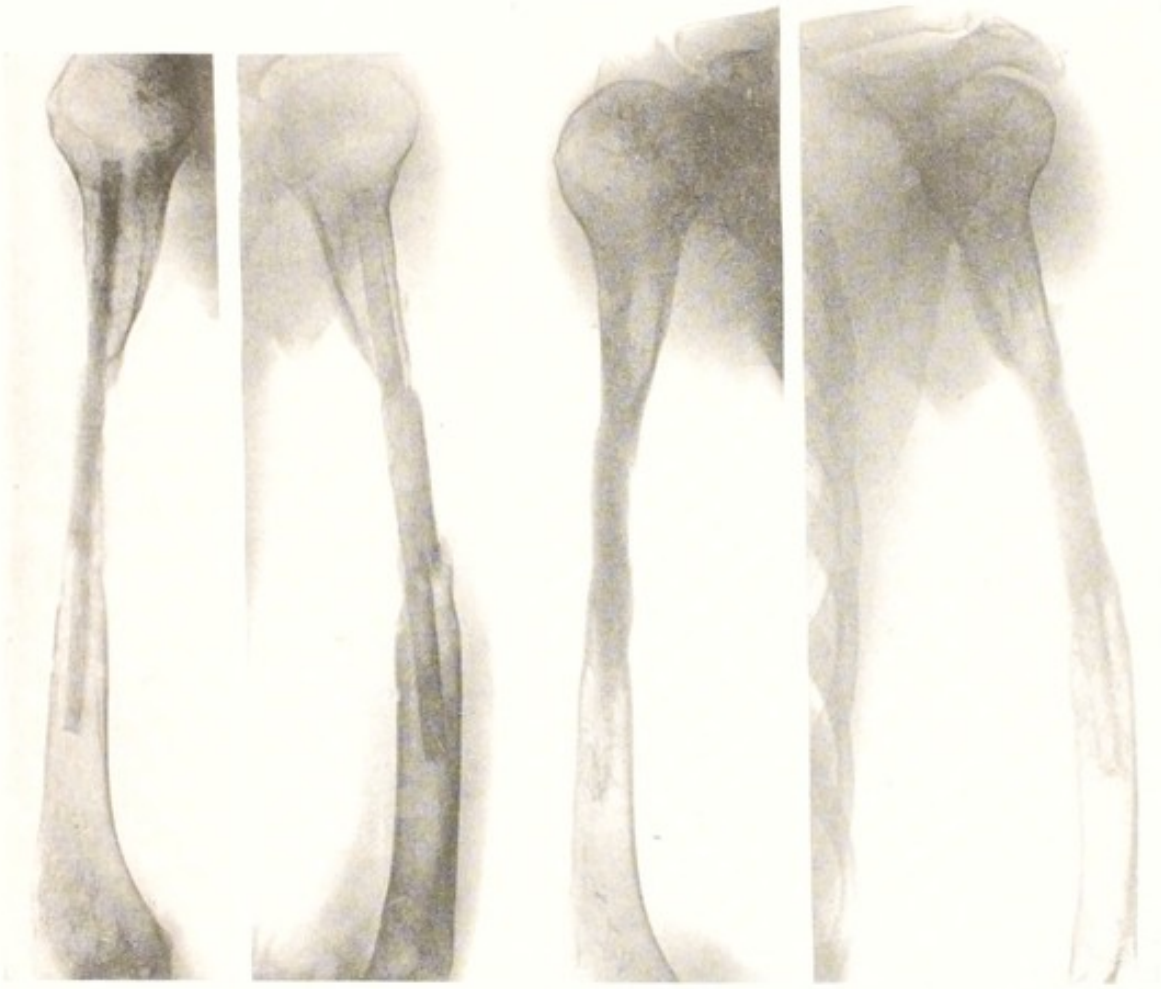
nature of the problem confronting him, and sufficient ingenuity to adapt the method to meet the demands of the individual patient" (Mayer).

The problem confronting the surgeon in extensive compound comminuted fractures of long bones is to reduce and maintain the fragments in alignment, and as far as possible to preserve the length of the limb.

The position of neutral muscle-pull and the Balkan bed-frame, have proved

most useful in the accomplishment of these objects (see Chapters XVII and XVIII).

Balkan Bed-frame.—The following dimensions are given by Blake: 36 inches (91 cm.) between the lower ends of the uprights (external measurement); 24 inches (60 cm.) between the upper ends, which gives about 32 inches (80 cm.) for the length of the lower cross-bar, which crosses at the level of the upper surface of the mattress. Each upright is 6 1/2 feet (2 meters) in height, and the upper transverse bars measure 3 1/4 feet (1 meter)



a *b* *c* *d*

FIG. 750.—Same case as Fig. 748. These four figures show progressive bone-growth. *a*, Three months after implantation of graft, showing increase of diameter. *b*, Four months; *c* and *d*, Six months after implantation of graft, showing inlaid portions of graft adapting themselves to their environment, taking on the character of the humerus, while the graft at the hiatus is assuming the anatomical features (tubular shape, marrow cavity, etc.) of its host bone.

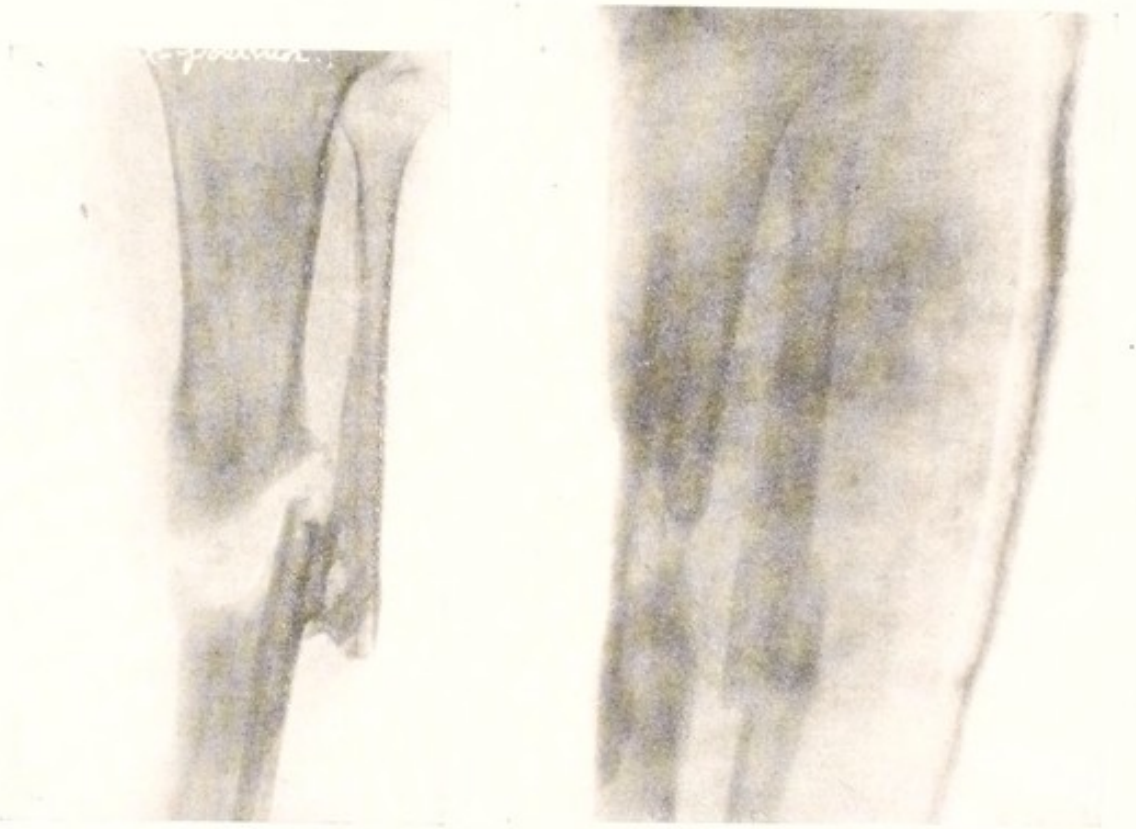
and are notched at intervals on each end to receive the longitudinal bars and permit adjustment.

The best wood for the frame is soft, white pine without knots, since pine does not easily split and screws are easily inserted. In an emergency, however, any wood may be used. With the pine, it has been found that strips of wood 2 1/2 inches (5 cm.) wide and 1/2 inch (21 mm.) thick, are sufficient for the uprights, and for the lower transverse bars, while the upper transverse bars and the longitudinal ones require a width of 3 inches (6 cm.). The longitudinal bars are 8 1/2 feet (2 meters or 65 cm.) long, and

pass beyond the head of the frame to allow suspension of weights by pulleys at the foot and head of the bed. Both ends are notched at intervals to allow adjustment for individual cases.

The trolley is suspended on a rod by means of common pulleys which are fastened to the wood by screws. This allows the patient to move longitudinally, as when sitting up, because the trolley with the suspension pulley attached glides easily on the rod.

Ordinary suspension weights are used. If they are placed above the patient, it is best, in order to avoid accidents, to place them in a strong bag closed with draw-strings. In cases of the upper extremity, these may be supplemented by buckshot, so as to graduate more delicately the amount of weight needed.



a *b*

FIG. 751.—*a*. Loss of $1\frac{1}{2}$ inches of shaft of tibia as result of compound comminuted infected fracture.

b. Four months after operation. Complete restoration of defect by bone-graft.

Extension strips may be made of mole-skin or, as in France, muslin strips may be fastened to the skin by means of Heussner's glue (colophane). This glue does not slip, nor does it irritate the skin. It holds for two to three weeks or until the skin desquamates. Before using the glue, the skin should be prepared with alcohol or ether.

In cases of fracture of the upper end of the femur, where the position of abduction and flexion is desired, an extra bar is fastened to the footboard uprights at the desired height and with the pulley end extending to the right or left beyond the upright at the proper distance to obtain the desired amount of abduction. In the same way, the frame which is universally adjustable, can be arranged to secure abduction of the arm.

UNUNITED FRACTURE OF THE LOWER JAW WITH OR WITHOUT LOSS OF BONE SUBSTANCE

The methods of trench fighting in the recent war, resulting in the exposure of the upper part of the body, have greatly increased the percentage of wounds involving the head (especially the lower jaw), and the destructive effects of the modern projectiles, including shells, bullets, shrapnel,



FIG. 752.—Loss of the central portion of the metacarpal of the index-finger from osteomyelitis, no periosteal regeneration after one year. Absent bone shaft restored by bone-graft. (See Fig. 755.)

and hand grenades, have filled hospitals with cases of which many are rare and unusual. Their complex nature, involving extensive loss of the maxillæ and soft parts of the face, has opened up a field of procedure where the plastic bone surgeon and the dental surgeon must come into close co-operation; the advantages thus gained have been amply demonstrated.

It will be impossible in this volume to describe the various dental orthopedic splints used for securing immobilization in ununited fractures of

the lower jaw, with or without loss of bone substance: for these the reader is referred to works on dentistry.

The author wishes to emphasize the importance and necessity of the co-operation of the specially trained dentist and surgeon in the management of these most difficult cases. However, in a large number of cases of non-union, both with and without loss of bone substance, the author, by the use of his motor bone engine and the inlay technic and a strong graft obtained from the tibia, has been able to so firmly fix the fragments as not to need the dental splint, facial supports, etc. In cases where contractures have occurred, however, such as loss of substance in the region of the symphysis with approxi-



FIG. 753.—Illustrates technic in case of which Figs. 752 and 755 are röntgenograms.

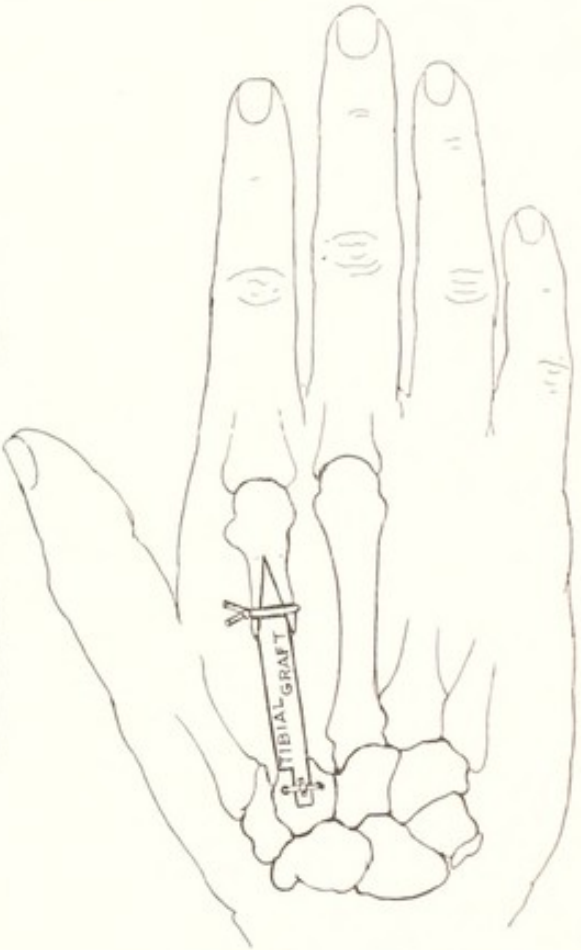


FIG. 754.—Illustrates completion of technic with tibial graft held in place with kangaroo tendon.

mation of the two halves of the mandible and narrowing of the arch, much time and effort may have to be devoted to the correction of the deformities and the re-establishment of the normal occlusion of the remaining teeth of the two jaws before the insertion of the bone-graft.

The accompanying *x*-ray diagrams and photographs, with legends, together with Chapters XVI and XVII, illustrate the bone technic.

INJURIES TO THE NERVES

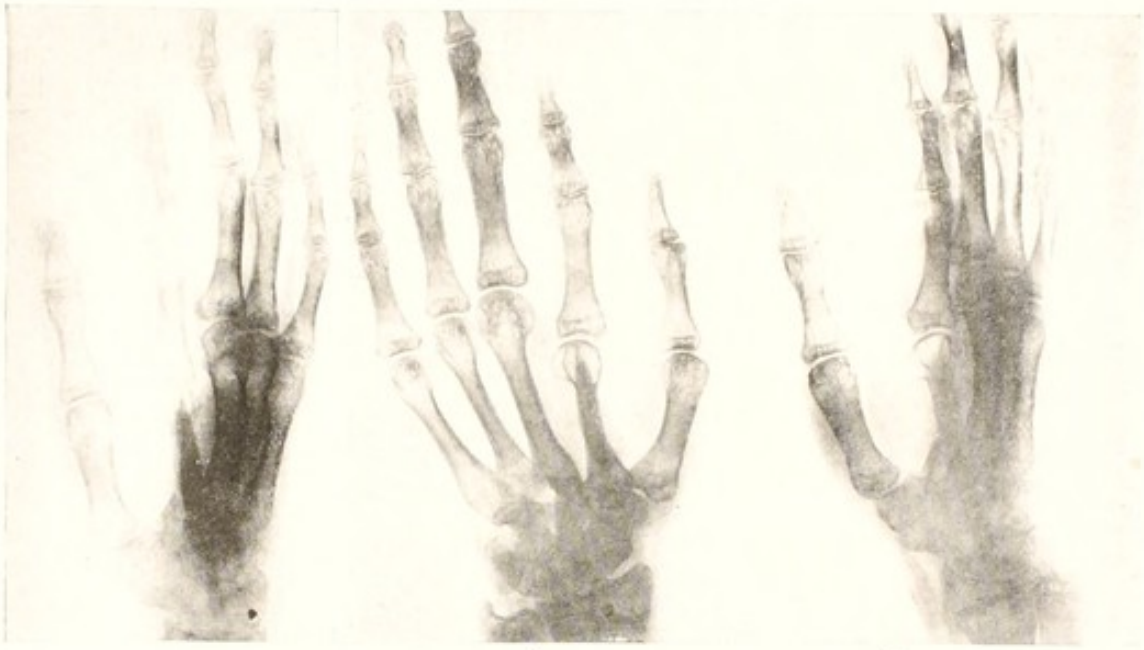
No surgical problem is more complex than that presented by injuries to nerves, and by the consequent deformities which result from the

non-balancing of muscle control. The degree of injury varies within wide limits. The nerve may be intrinsically damaged beyond hope of repair; it may be enmeshed in the cicatrices resulting from the injury or from exuberant callus formation. It is uncommon in gunshot cases for the nerve



FIG. 755.—Same case as Fig. 752, after missing portion of metacarpal bone has been restored by author with a tibial graft. See Fig. 754 for diagram of technic.

to be the only structure involved. A varying number of the muscles which it innervates may be more or less severely injured, ranging from partial to complete destruction. The joint or joints which the nerves and muscles control may be ankylosed or limited in motion from adhesions or cicatricial



a *b* *c*

FIG. 756.—Same case shown in Figs. 752, 755. *a*, Shows graft six weeks after implantation; *b* and *c*, anteroposterior and lateral views, three months after implantation.

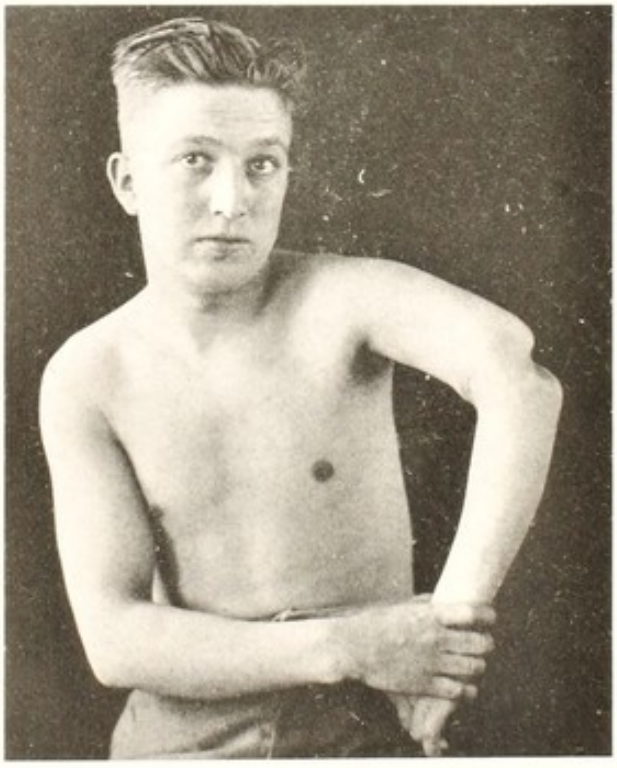


FIG. 757.—This case, wounded at Cantigny by machine-gun bullet, was operated on seven months later, two months after the wound had healed. The photograph, which was taken before the plastic operation, shows laxity of left arm due to loss of substance in shaft of humerus. Note that the elbow has dropped below the distal end of the proximal fragment.

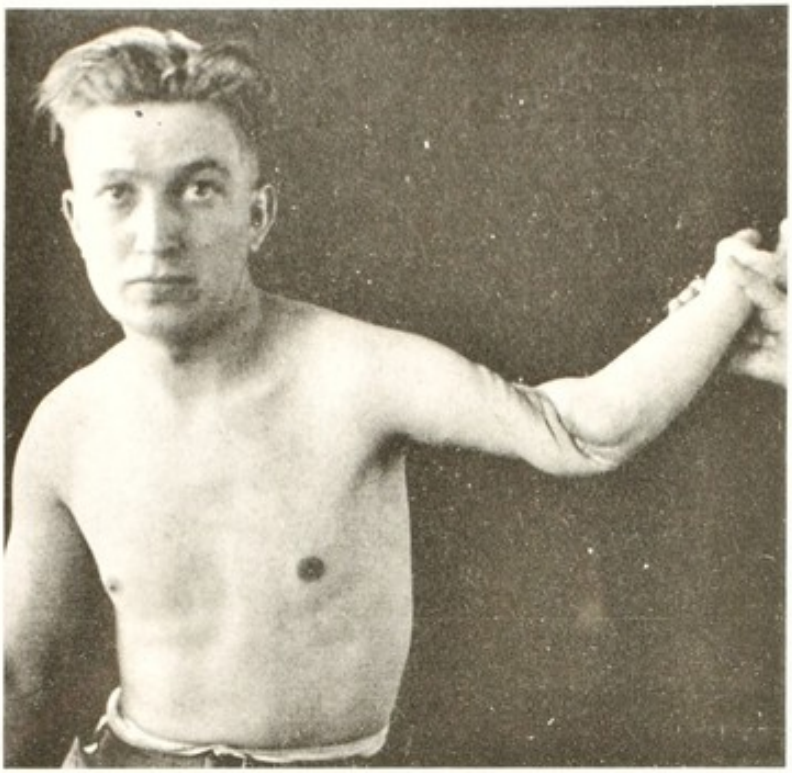


FIG. 758.—Same case as Fig. 757, showing half-turn of forearm and elbow on proxima fragment of humerus.



FIG. 759.—Same case as Fig. 757. Posture of left arm demonstrates extreme flail condition due to boneless state.

tissue in the skin or peri-arthritic structures; the muscles or tendons themselves may be involved by adhesions or cicatrices, and thus their motion and function may be seriously impaired.

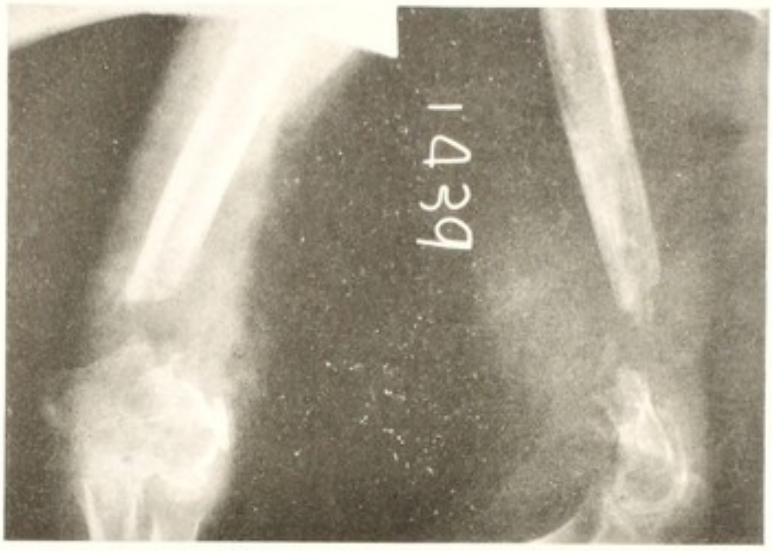


FIG. 760.—Same case as Fig. 757. The röntgenogram shows loss of about 1½ inches of the shaft of the humerus.

In view of the above, it is not necessary to emphasize the fact that in many of these complicated nerve lesions the surgical and mechanical capabilities of the surgeon are drawn upon to the utmost.



FIG. 761.—Same case as Fig. 757, showing author's method of immobilizing fractures of humerus. In this case the dressing was allowed to remain on for eight weeks.

Lesions of the peripheral nerves complicate a large percentage of gunshot injuries to the extremities, and no examination of a wounded soldier is com-

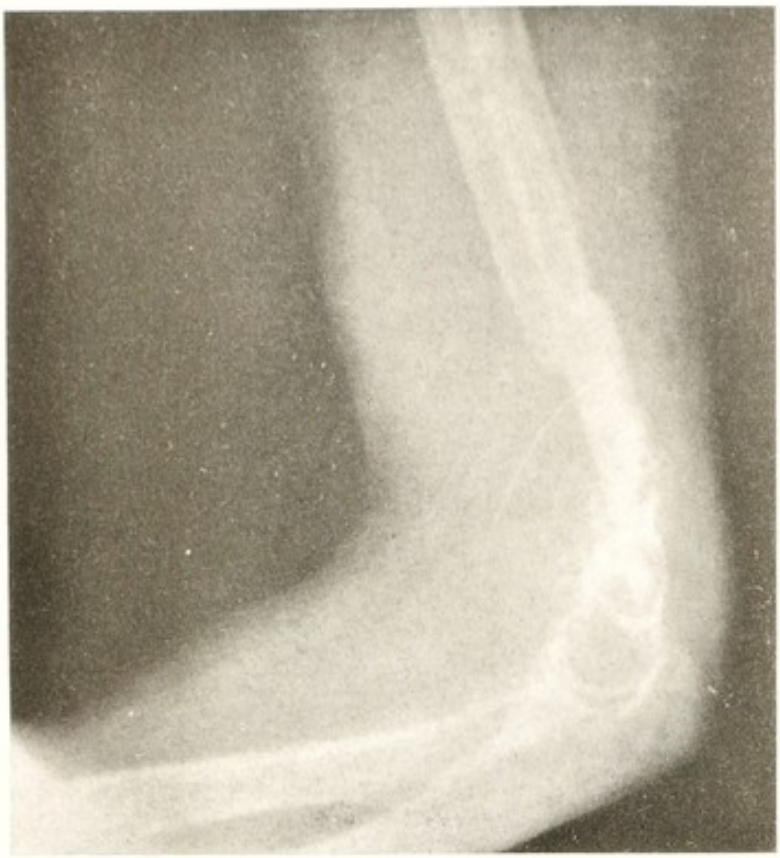


FIG. 762.—Same case as Fig. 757. The radiogram shows tibial bone-graft of humerus firmly united in position ten weeks after operation.



FIG. 763.—Same case as Fig. 757, ten weeks after operation. Note stability of arm from union of graft. Such a posture was impossible before operation, as shown by preceding figures.



FIG. 764.—Non-union of body of inferior maxilla with loss of about 1 inch. Tibial inlay, inserted six weeks prior to this radiogram, resulted in firm union.

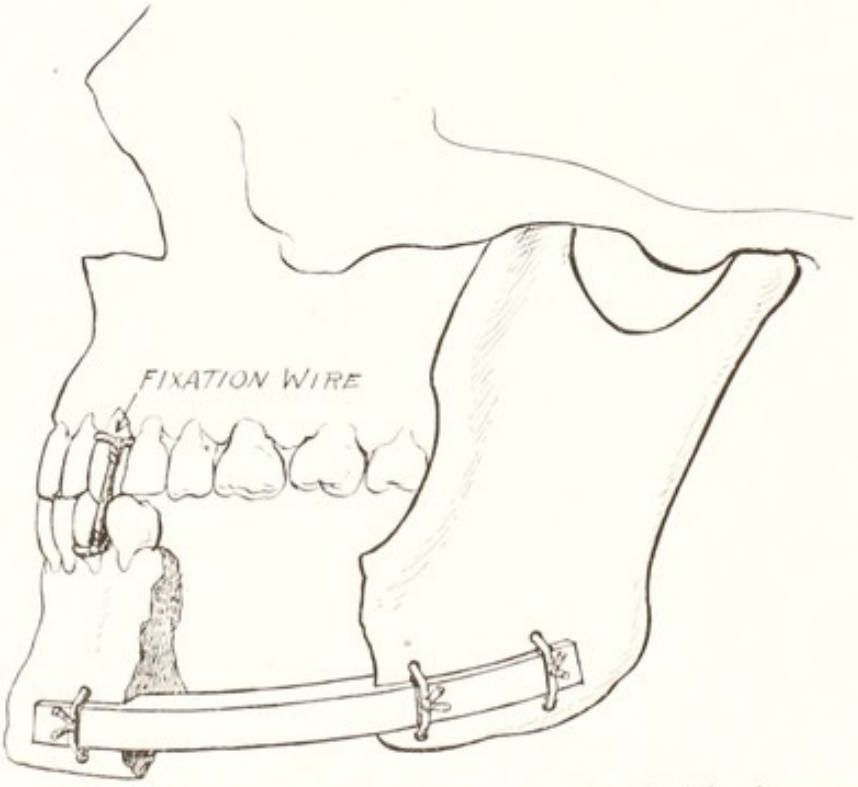


FIG. 765.—Diagram of a fractured lower jaw illustrating the inlay bone-graft in place imbedded in the gutter cut in both fragments by the twin motor saws. The graft has been procured from the antero-internal surface of the tibia cut by the twin motor saws adjusted at the same distance apart as when cutting the gutter in the jaw fragments. Note the drill holes and that the graft is fixed in place by kangaroo sutures.

plete unless the surgeon tests the function of the nerves which may have been injured. This neurological examination was important even at the front,

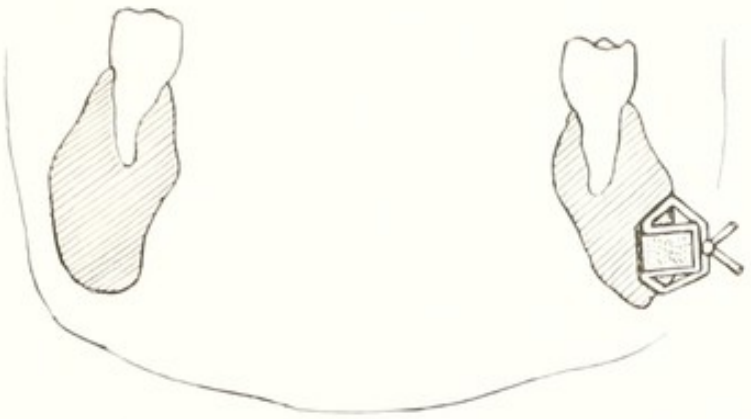


FIG. 766.—Diagram showing a cross-section of the inlay bone-graft implanted for a fracture of the lower jaw with or without loss of bone substance and showing the method of securing the graft in position by the kangaroo-tendon suture passed through the drill holes and over the graft holding it securely in position.

since the treatment of the nerve injury should begin as soon as the patient reaches the hospital. A splint for the nerve is frequently fully as important as a splint for the fractured bone; and just as the bone injury must be



FIG. 767.—Case referred by Dr. Johnson, of Buffalo.

The arrows indicate loss of the body of the lower jaw from the symphysis almost to the angle on account of removal for malignancy one year before.

In between the arrows are fragments of a rib graft which was inserted about six months before.

The rib is not a favorable source of graft material in cases in which mechanical stress is borne because on account of its frail structure it breaks up as it did in this case and results in failure.

treated at the front, so, too, should the nerve injury be properly cared for without delay.

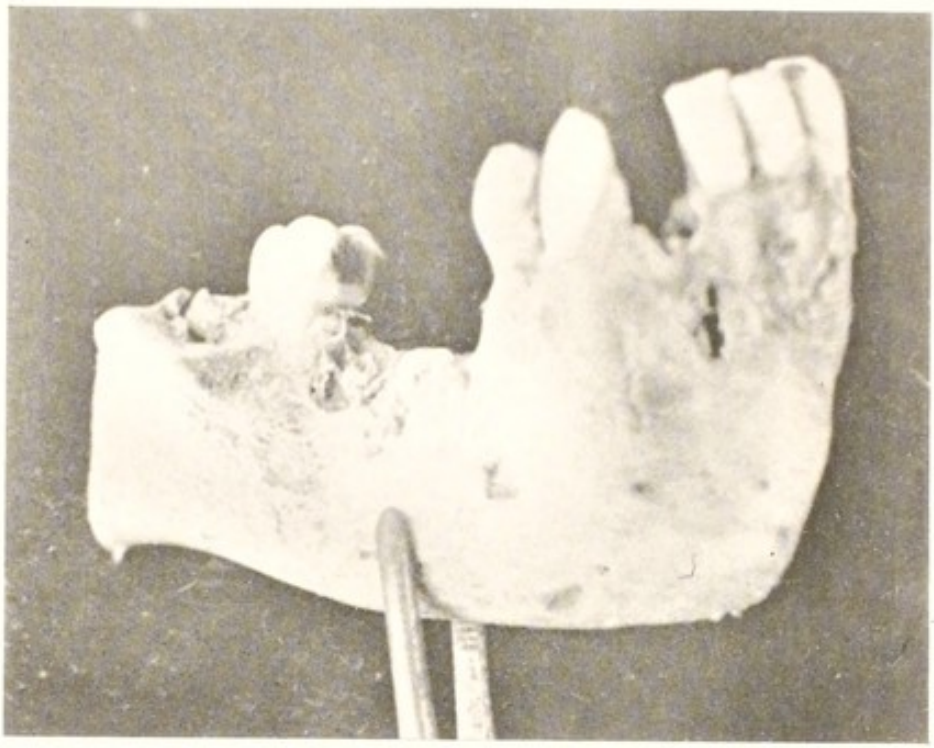


FIG. 768.—Same case as Fig. 767. Portion of lower jaw removed for sarcoma. Excised portion extended from symphysis in front nearly to the angle posteriorly.

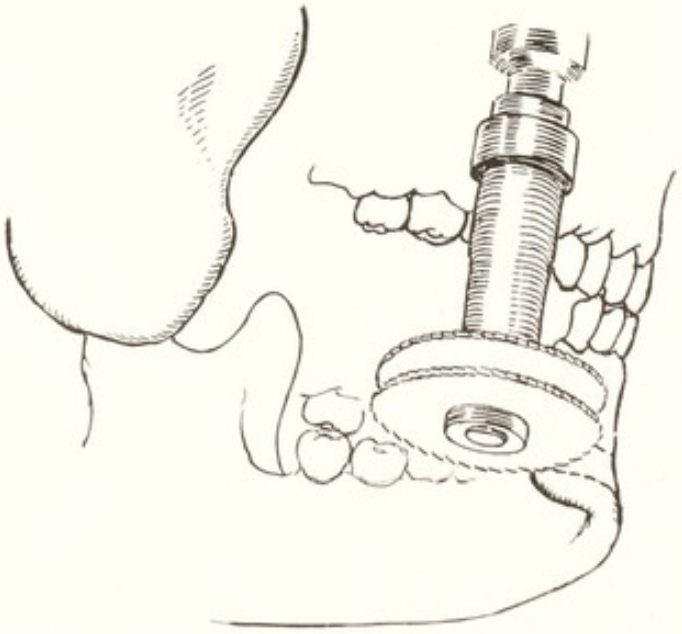


FIG. 769.—Drawing to illustrate inlay technic employed in case of Fig. 767. The groove for tibial inlay is being prepared at symphysis by twin saw.

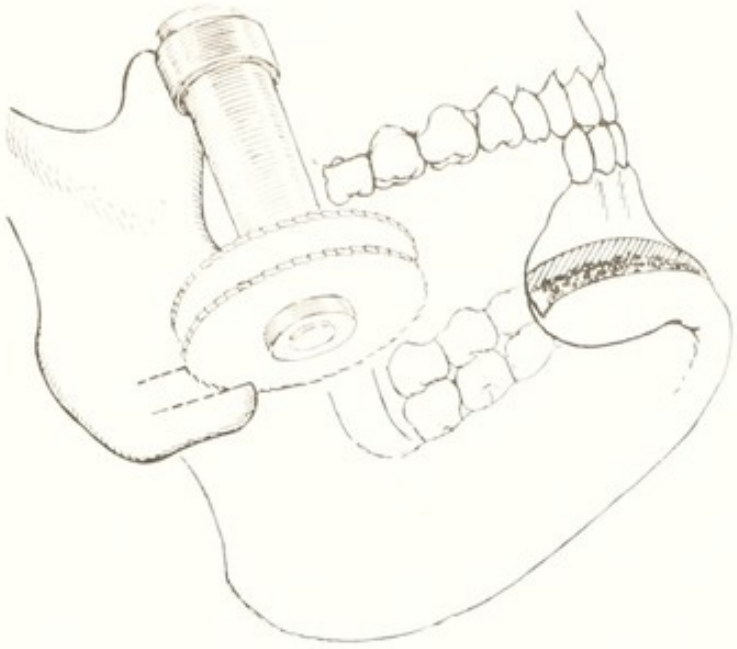


FIG. 770.—Groove being formed in posterior fragment in same case shown in Fig. 767. The bone is usually so hard in these jaw cases that it resists cutting with hand-tools such as osteotome and gouge, and it is necessary to employ motor-driven burrs and drills to remove the bone between the initial saw-cuts. The motor-engine is indispensible for this work. Pattern of proposed graft obtained by bending probe to conform to gutters.

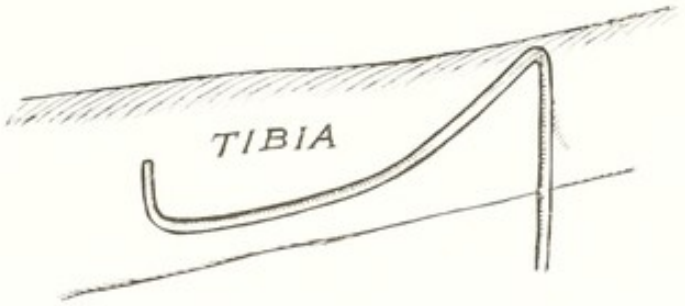


FIG. 771.—Pattern of desired graft in case of Figs. 767 and 768 transferred to tibia by flexible probe. Pattern outlined on tibia by incising periosteum with point of scalpel.

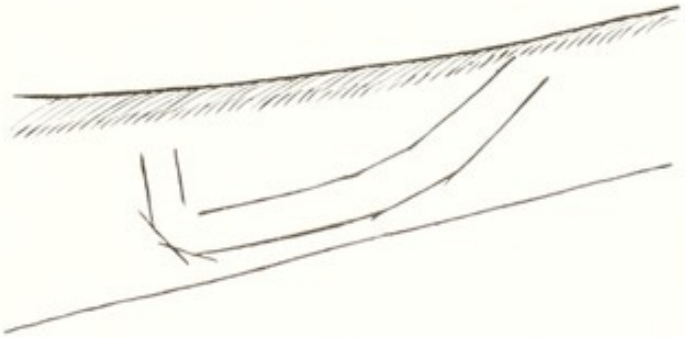


FIG. 772.—Shows cuts of rotary saw in tibia following pattern outlined in Fig. 771.

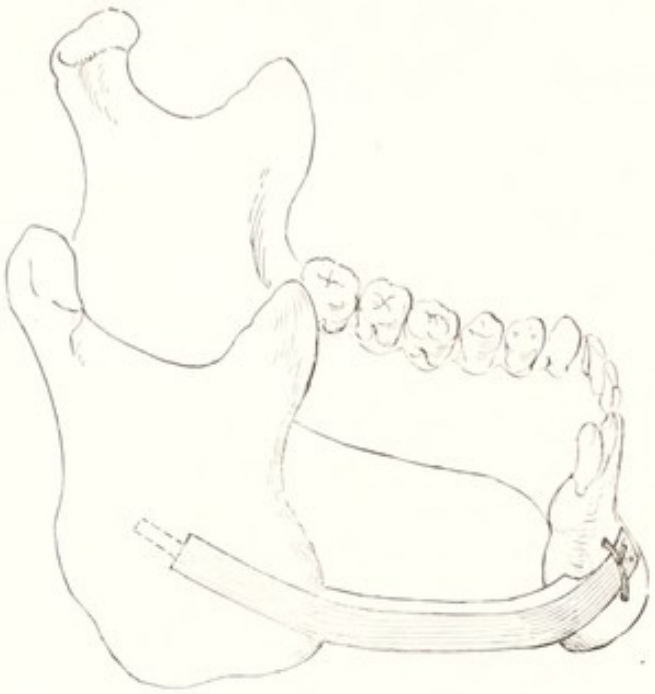
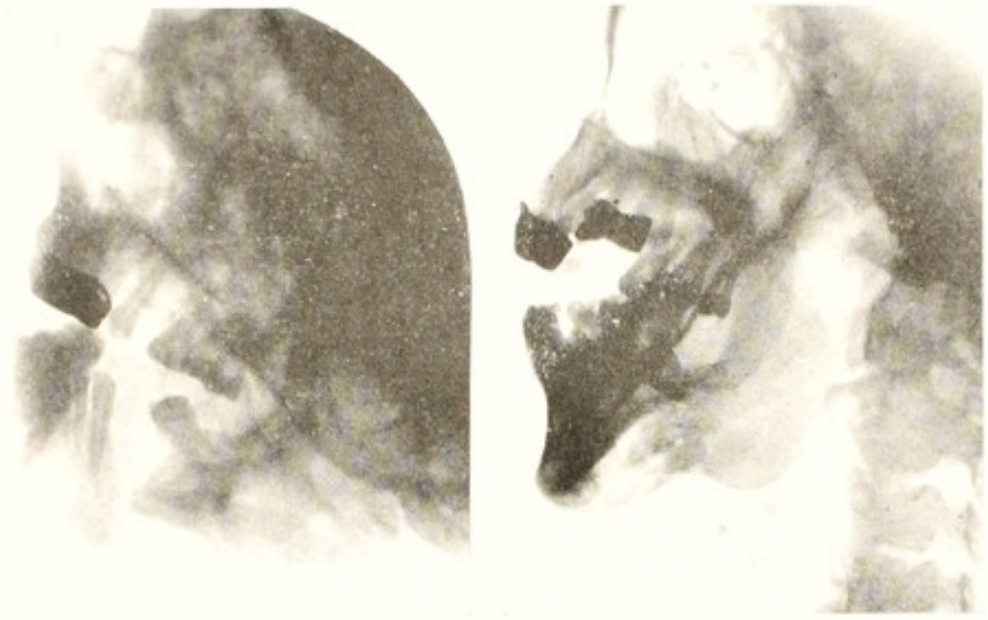


FIG. 773.—Bone-graft in position spanning the hiatus in the lower jaw. (The artist has shown the kangaroo-tendon fixation ligature at symphysis but has failed to indicate the one in the posterior fragment.) The extreme posterior end of the graft is so shaped that it is driven into the marrow space between the cortical tables at this point—this does not interfere with the inlay technic and increases fixation.



FIG. 774.—Same case as Fig. 767. The arrows indicate two grafts obtained from the antero-internal surface of the tibia and inserted at two operations by the inlay method with restoration of the jaw.



a *b*

FIG. 775.—*a*. Ununited fracture of the body of the inferior maxilla with loss of over 1 inch.

b. *X*-ray three months after insertion of author's inlay tibial graft. Complete union and consolidation has occurred with perfect function.



FIG. 776.—Entire inferior maxilla from angle on one side to angle on the other, together with the overlying soft parts swept away by a fragment of an exploding cannon. Photograph taken soon after injury. On account of loss of so large a part of lower jaw and lower lip patient was unable to phonate. Tongue was later drawn down to an extreme degree by the contractured tissues.

Relative Frequency of Injury to the Different Peripheral Nerves

The following table, by Captain J. R. White, R. A. M. C., shows the actual and relative frequency of injury of the different peripheral nerves in a series of 50 cases:

	Per cent.
Ulnar nerve	24.6
Musculospiral nerve and branches	17.0
Great sciatic nerve and branches	17.0
Median nerve	10.8
Brachial plexus	10.8
Internal cutaneous nerve	9.2
Musculocutaneous nerve (arm)	4.6
Cauda equina	3.0
Spinal accessory nerve	1.5
Cervical plexus (great auricular and small occipital nerves)	1.5



Fig. 777.—Same case shown in Fig. 776 after soft parts were drawn from side of neck and jaw to restore loss of soft structures in middle line. This plastic work often requires five or six operations to accomplish all that is possible in drawing forward skin and soft structures from sides of face and neck.

Suture of Nerves

In the suture of nerves, certain fundamental principles must be borne in mind: First, contractures of all peri-arthritic structures, such as skin, muscles, fascia, joint-capsules, etc., must be corrected; second, all joints must be freed from adhesions and free motion must be restored in the joint threatened with stiffness; third, it is most important that the paralyzed muscle be retained at all times in a position of relaxation, not even once allowing the relaxed muscles to be stretched during massage or the readjustment of appliances.

The fundamental principles in this type of cases do not differ from those in anterior poliomyelitis, viz.: (1) if all mechanical obstructions to the free excursion of muscles are not overcome, the muscles cannot be expected to functionate. Their stiffness is not due to the nerve lesion alone, but to



a *b* *c*

FIG. 778.—*a*. Author's case (same as Fig. 776) where the whole anterior part of lower jaw from angle on one side to angle on the other side was carried away with all of the soft parts of the chin by a fragment of an exploding cannon.

A large flap of skin and subcutaneous tissue has been turned up onto the chin; the pedicle is seen in Figs. *a* and *b*.

b, *c*. The fixation plaster including the upper arm and the forearm in the region of the elbow and the top of the head above the ears is shown. It is essential that the pedicle be left intact and not severed until three weeks has elapsed.

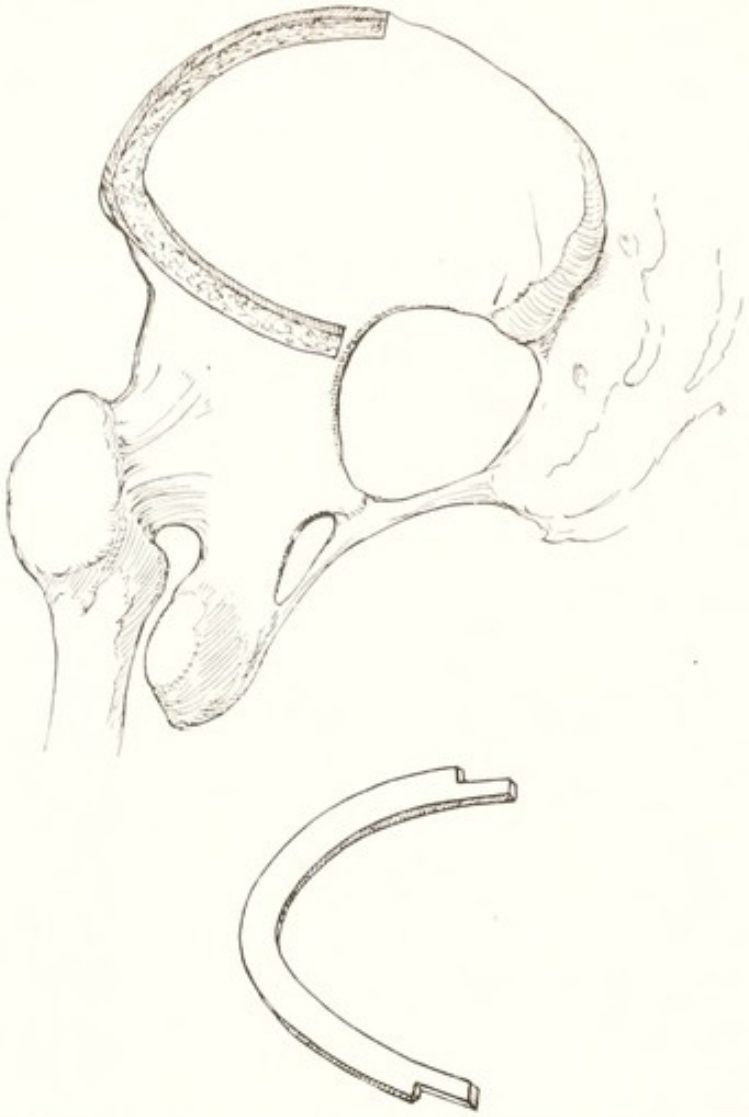


FIG. 779.—Bone-graft for restoring lower jaw and site of its removal from ilium. This graft is used to repair defects of jaw in such cases as shown in Fig. 776. The author has found that, in a very large percentage of cases involving loss of substance of the lower jaw occurring in his experience in France and in civil life, the tibia is adequate in its dimensions to furnish grafts for satisfactory repair. However, in cases such as the one shown in Figs. 768 to 776, where large portions of both sides of the jaw are lost, the ilium has to be utilized to obtain grafts with the necessarily marked curvature.

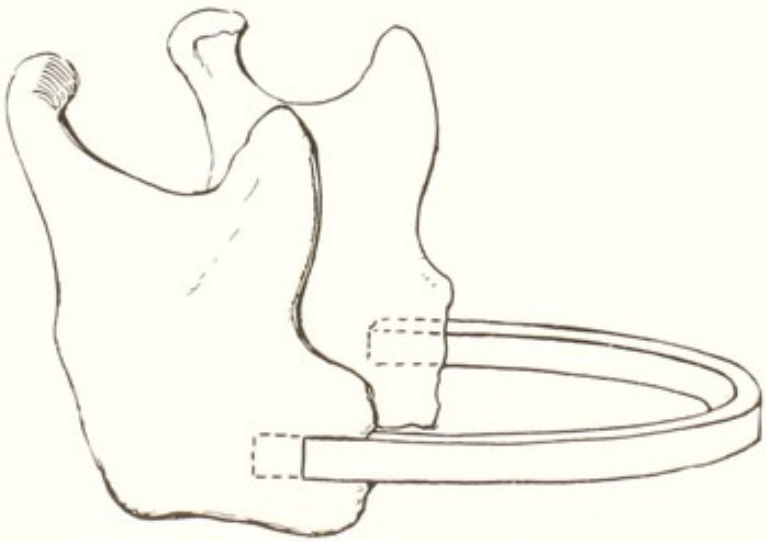


FIG. 780.—Diagram of graft from ilium shown in Fig. 779 in place.

the results of trauma and sepsis of the muscle, fascia, tendons, blood-vessels, and ligaments about the joints. (2) The restoration of nerve function is sure to fail if the joint, which its muscles control, is markedly limited in motion or ankylosed.

Fundamental principles are often lost sight of in cases of musculospiral nerve involvement, and the patients are allowed to go about with the wrist and hand in a position of marked dropped-wrist. As pointed out by Jones, a similar error is made in the case of suture of the external popliteal nerve,



FIG. 781.—Same case as Figs. 776 to 780 after a large area of skin and subcutaneous tissue had been transplanted from upper surface of shoulder to the chin, and an extensive u-shaped graft from the side of the ilium inlaid for the restoration of the whole anterior portion of the jaw from the angle on one side to the angle on the other.

The object of the soft tissue transplantation was two-fold: (1) to furnish sufficient soft tissue in which to later embed the iliac bone-graft, and (2) for its cosmetic results. False teeth will still further improve the cosmetic result. At this writing it is too early for this.

Dr. Kennedy the prosthetic dentist very kindly cooperated in this case and supported the jaw fragments internally by a vulcanite plate.

when the foot is allowed to drop into equinus and remain in that position, or sometimes the nerve suture may be done while the tendo Achillis is markedly shortened, thus holding the foot constantly in the equinus position. It is most important that in such cases the foot be held constantly at right angles with the leg during the entire period of convalescence. Unless the joint (including the muscles, tendons, etc.) is capable of motion, it is absurd to hope for good function, even though successful nerve suture has been accomplished. For the same reason, it is urgent that the patient should as soon as possible

begin to use the limb in every way. In the case of locomotion and the use of the lower extremities, the weaker or paralyzed muscles should be protected from overstretching or strain, while function is allowed. The surgeon must be prepared to recognize the difference between a muscle unable to contract owing to destruction of its nerve supply, and a muscle unable to respond to the will because the muscle itself is overstretched. The latter condition is very likely to occur from long-continued drop-wrist, where the wrist extensors have been temporarily paralyzed.

One of the most interesting and important features of war surgery is nerve injuries without the classical symptoms which have formerly been supposed to correspond.

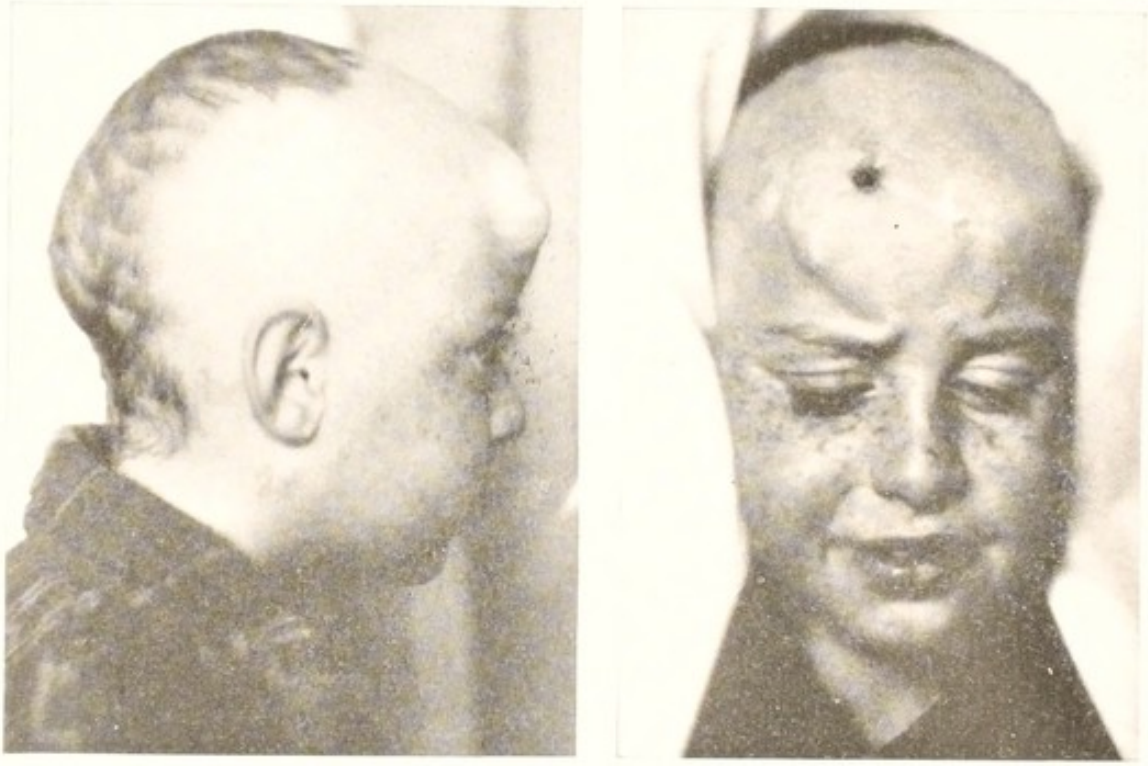


FIG. 782.—Case with loss of both tables of right frontal bone over an area 1¾ × ¾ inch, with pronounced hernia cerebri. This area was exposed by V-shaped incision with its convexity to the right and posteriorly so that resulting scar would be in the hair-covered region of the scalp.

Previous to the recent war, much of our knowledge of the clinical side of nerve injuries dates from the work of Weir Mitchell during the Civil War. Many revisions, however, will have to be made from the numerous experiences of the world war.

Summary of Captain J. R. White, R. A. M. C.—(1) Signs rapidly and easily noticed or elicited that suggest the presence of nerve injury.

(*a*) The presence of muscular wasting, as compared with the opposite side.

(*b*) Abnormal position of a limb or segment of a limb, such as *main en griffe*, drop-wrist, genu valgum, and various forms of talipes. Such position may be due to one or more of the following factors: action of gravity, contraction or contracture of unparalyzed antagonistic muscles, contracture of scar tissue, contracture due to myositis of traumatic, septic, or ischemic origin, the last two classes being independent of the actual nerve injury, but due to the same cause, viz.: the entrance of the foreign body.

(*c*) Abnormal limitation of mobility of joints, due to conditions similar to those causing abnormal position of a limb.

(*d*) Presence of tenderness along the course of nerve trunks.

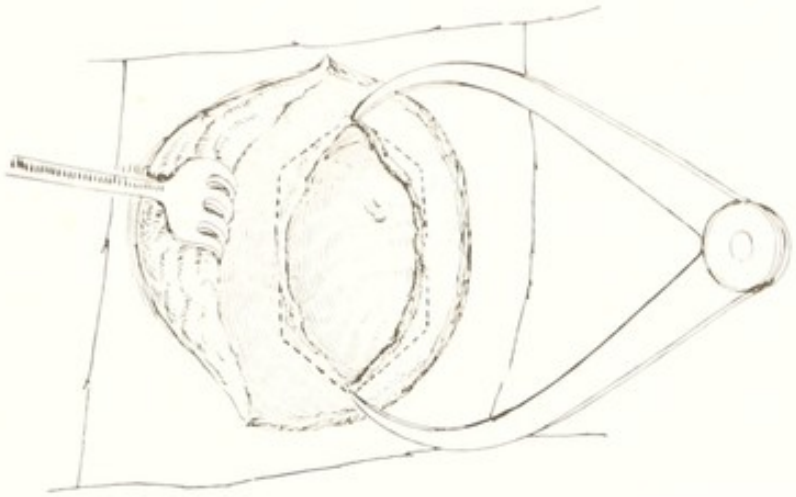


FIG. 783.—Same case as shown in Fig. 782, after the bone-defect has been exposed. Dotted lines about the margins of the defect indicate the bevelled saw-cuts which were made to allow perfect inlay of the bevelled-edged graft.

2. Signs and symptoms that require longer and more careful investigation, and that directly result from the cessation or diminution of the passage of impulses, afferent and efferent, along the nerve trunk.

Afferent (sensory) changes (tested with the eyes bandaged).

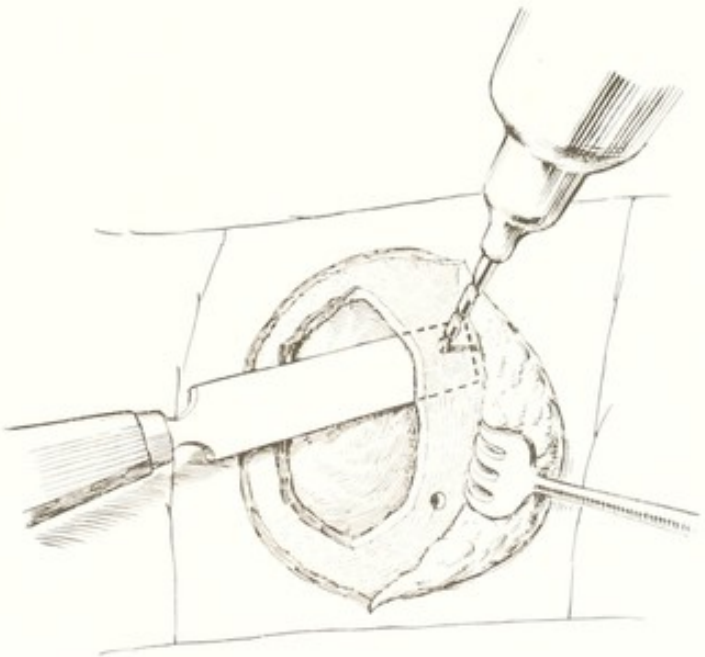


FIG. 784.—Same case shown in Fig. 782 with holes being drilled with motor drill for fixation ligatures of kangaroo tendon at margins of the bone-defect for the purpose of holding the graft in place.

(*a*) Epicritic sensibility, tested by light cotton wool stroking that causes no deformation of the surface of the skin, after shaving the suspected area.

(*b*) Protopathic sensibility, tested with pinpricks; the presence of an area in which it is lost or increased (hyperalgesia).

(*c*) The relation in size and position of the areas of loss in (*a*) and (*b*).

(*d*) Deep sensibility, tested by deep pressure: the area of its loss.

(*e*) The presence or absence of joint sense.

(*f*) The presence or absence of shooting pains and paresthesia: their distribution.

Efferent changes.

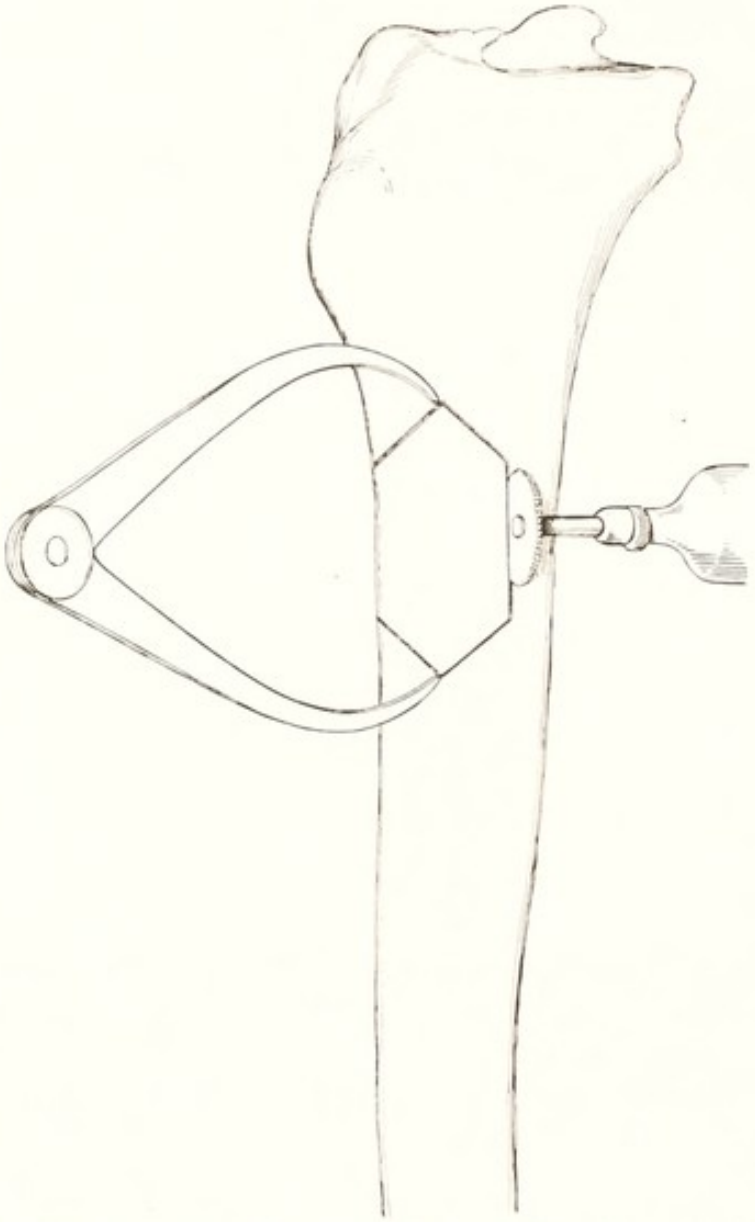


Fig. 785.—Same case shown in Fig. 782. Pattern of graft having been outlined in antero-internal surface of tibia, and its dimensions exactly determined by measurement with calipers, the graft is removed with the small single saw.

(*a*) The determination of the presence or absence of voluntary contraction of individual muscles: actually watching or feeling the suspected muscles contract or harden is a much less fallacious method than merely testing the power to perform specified movements of joints.

(*b*) The determination of the presence or absence of involuntary contraction of unstriped muscle, by noting such points as local cyanosis of a paralyzed part, due to vasomotor paralysis; pupillary changes in lesions of the third

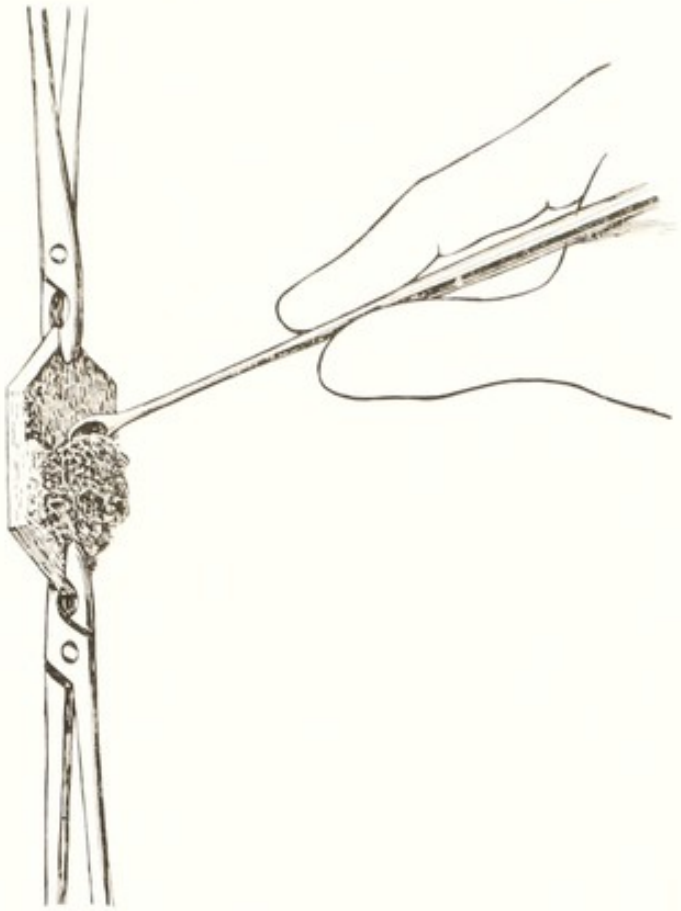


FIG. 786.—Same case shown in Fig. 782. Graft held with hemostats while marrow substance and endosteum is being carefully removed with a sharp curet. This is done to avoid excessive bone-growth from the inferior surface of the graft which is to lie in contact with the dura mater.



FIG. 787.



FIG. 788.

FIG. 787.—Same case as shown in Fig. 783. Graft, cleared of its marrow and endosteum, is being notched with motor-saw nearly through its thickness, to permit of its being bent to the curved contour of the skull. (See Fig. 788.)

FIG. 788.—Bone-graft shown in Fig. 787 being tested as to its flexibility before being placed in the cranial defect.

sympathetic and first dorsal nerve; pilomotor paralysis; bladder and rectal disturbances.

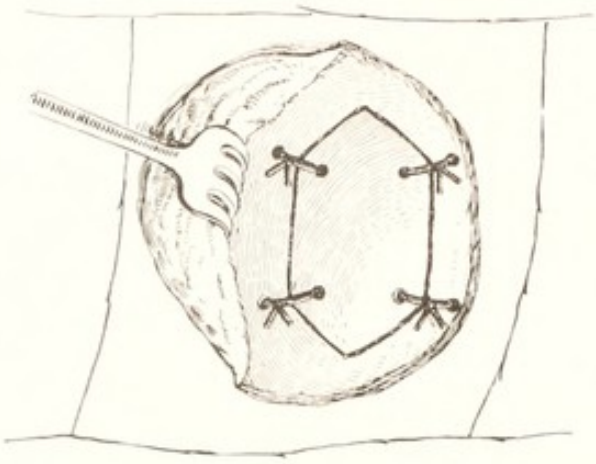


FIG. 789.—Graft shown in Fig. 788 held in place by kangaroo fixation ligatures.

(*c*) Secretory changes: increase or decrease in the secretion of sweat. Very often the area of cutaneous sensory loss may be estimated at a glance as corresponding fairly closely with the area of dryness of the skin supplied



FIG. 790.—Anteroposterior view of case shown in Figs. 782 to 789, three months after insertion of bevelled inlay graft. Attention is directed to the fact that the graft is adapting itself to its environment and is assuming the anatomical characteristics of the skull in which it is embedded and is not sharply defined.

by the affected nerve. In cases of incomplete physiological lesion, this area will often show increased sweating.

(*d*) Trophic changes: trophic ulcers and blisters; wasting of finger pulps; presence of delayed desquamation over the area of sensory loss, often showing the boundaries of this area at a glance.



FIG. 791.—Lateral view of same case as in Fig. 790. Bone-graft is shown consolidated with skull.

(*e*) Changes in the electrical reaction of the paralyzed muscles: (1) their reaction to faradism; (2) their reaction to galvanism, especially noting

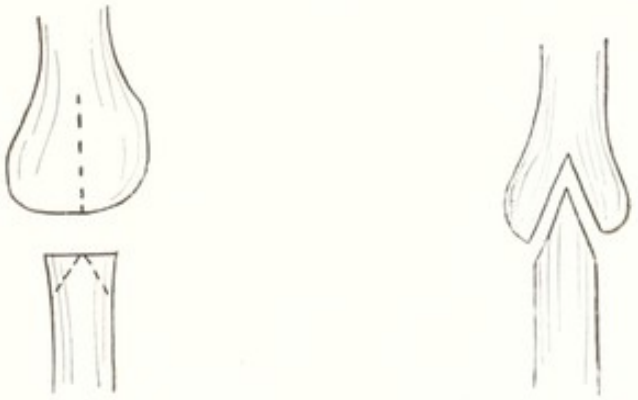


FIG. 792.—Method of approximating nerve ends for suture. (Binnie.)

the relation between cathodal closing stimulation and anodal closing stimulation, and the character of the consequent contraction.

Mayer, from an extensive experience in the recent war, has arranged the following symptoms of injury to the more important nerves:

Symptoms of Injury to the Peripheral Nerves

1. **Musculospiral Nerve.**—The patient is unable to extend the hand at the wrist, to extend the proximal phalanx of the four fingers, or to extend the thumb. Extension of the distal two phalanges of the fingers is possible, owing to the action of the interossei and lumbricales which insert into the extensor tendon just proximal to the first interphalangeal joint. Supination is weakened and, in cases of injuries to the musculospiral near the axilla, extension of the elbow is also weakened. Total paralysis of the triceps occurs only as the greatest rarity, because that branch of the inner head known as the ulnar collateral pursues a separate course and is therefore not exposed to the injury produced by the projectile which has injured the parent trunk.

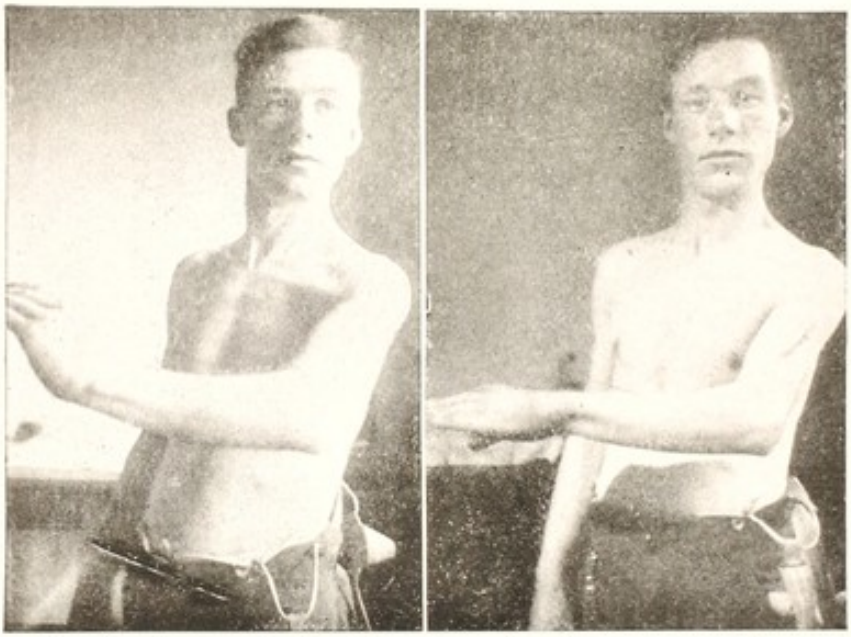


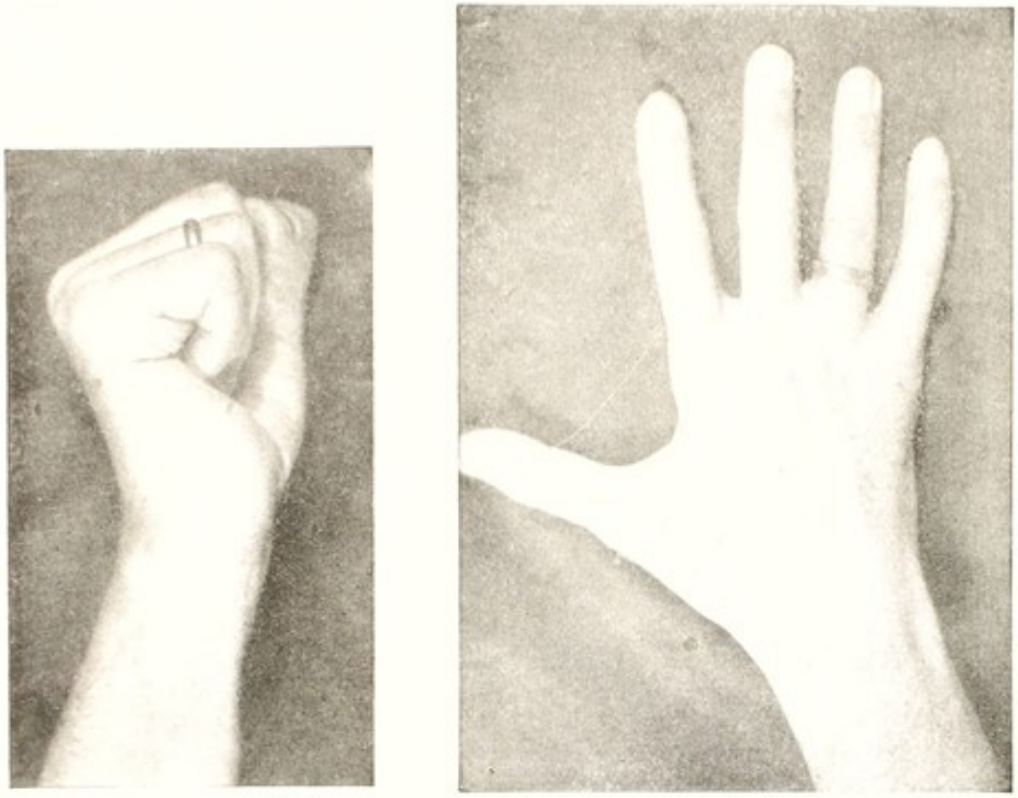
Fig. 793.—Result of transplanting the external saphenous nerve for a 4-inch gap in the course of the musculospiral. The photographs were taken six months after the operation. (Mayer.)

The sensory disturbance varies markedly from case to case. In not one instance did Mayer observe anesthesia corresponding to the distribution of the sensory branches of the nerve, that is, over the distribution of the thumb, second, third, or half of the four finger. Usually the anesthetic area is not larger than a fifty-cent piece and located on the dorsum of the hand near the base of the thumb. Very often, however, even the most careful tests fail to reveal any sensory disturbance whatever.

2. **Ulnar Nerve.**—"Injuries to this nerve are peculiarly variable in the extent of the motor symptoms. In some cases there is a very marked interference with the flexion of the fingers; in other instances, there is no appreciable disturbance except a slight weakening of the fourth and fifth fingers. The only motor symptom which is constantly found is the inability to spread the fingers wide apart, due to the paralysis of the interossei. In contrast to the variability of the motor symptoms, is the constancy of the sensory disturbance. There is regularly anesthesia over the entire little finger, the ulnar half of the fourth finger, and the ulnar border of the hand. In cases where the injury to the nerve occurs a short distance above the wrist, the anesthetic area is present only on the palmar surface, owing

to the fact that the dorsal sensory branch leaves the nerve some few inches above the annular ligament, and is therefore spared by the projectile.

"Immediately after the injury there is no tendency to deformity. Gradually, however, in the majority of the untreated cases, a contraction of the



a *b*

FIG. 794.—Two photographs illustrating the effect of transplanting the dorsal sensory branch of the ulnar nerve to bridge a gap in the parent trunk, one and one-half years subsequent to the operation. *a*, To show the absence of atrophy of the hypothenar muscles. *b*, The power of spreading the fingers apart and the absence of atrophy of the interossei. There was anesthesia of the dorsum of the little finger and ulnar border of the hand but normal sensation over the palmar surface, indicating the growth of sensory fibers along the transplanted nerve. (Mayer.)

fourth and fifth fingers occurs. This was so marked in a number of patients referred to Mayer that the nails of the affected fingers were cutting into the palms and the patients were clamoring for amputation. The flexion contracture of the fourth and fifth fingers is a paralytic phenomenon peculiar

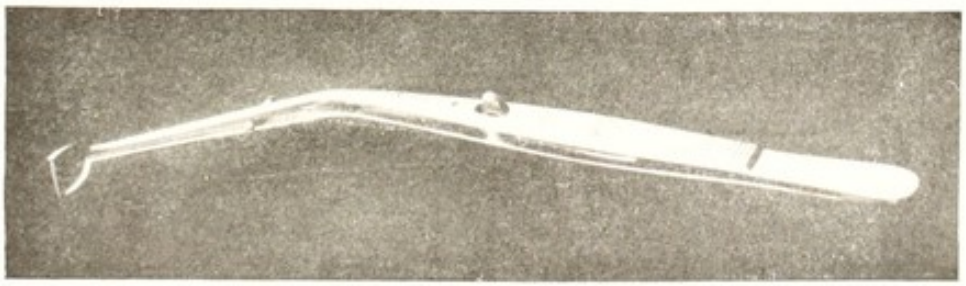


FIG. 795.—The stirrup forceps for nerve operations. (Mayer.)

to the ulnar nerve, due to scar tissue formation in the flexor muscles and their consequent shrinking, but this explanation, as well as others, is purely hypothetical. The later cases of ulnar paralysis are also characterized by the marked atrophy of the interossei and of the muscles of the thenar and hypothenar eminences.

"3. **Median Nerve.**—There is regularly a marked interference with the flexion of the fingers, particularly of the thumb, index, and middle fingers. Flexion of the wrist is possible owing to the action of the strong flexor carpi ulnaris. As a rule, the sensory disturbance corresponds accurately to the distribution of the nerve and is found over the thumb, index, middle, and radial half of the ring fingers on the palmar surface. A portion of the palm on the radial half is also anesthetic.

"Although the pronating muscles are also paralyzed by a lesion of the nerve occurring above the elbow, great care must be exercised in testing their function, since an agile patient can almost always, by a clever use of the brachioradialis, swing his arm from the supinated position into the pronated. To prevent this vicarious action of the brachioradialis (supinator longus), the patient's arm must be twisted so that the dorsum faces toward the ceiling, not with the thumb toward the inner side, but with the elbow bent so that the thumb points away from the body. In this position, pronation must overcome the weight of the arm, whereas in other positions the weight of the arm assists in pronation.

"4. **Musculocutaneous.**—There is a weakness of flexion of the elbow but not a complete paralysis, owing to the presence of the non-paralyzed muscles which spring from the internal and external condyles of the humerus (pronator radii teres, flexor carpi radialis, brachioradialis, extensor carpi radialis longus and brevis). Sensory disturbances are usually not to be found, owing to the overlapping of other nerves.

"5. **Circumflex.**—There is a paralysis of the deltoid and of the teres minor. The latter is difficult to diagnose, but paralysis of the deltoid prevents the full abduction of the arm. The action of the supraspinatus combined with that of the trapezius suffices to abduct the arm to 90 degrees; for the complete abduction, however, the deltoid is essential. Sensory disturbance is not constant.

"For some peculiar reason, isolated injuries to this nerve are seldom seen in military surgery. Stewart and Evans, in their series of cases, report not a single injury to this nerve.

"6. **Brachial Plexus.**—Injuries are quite frequent, either from wounds above the clavicle or in the axilla. The arm hangs absolutely helpless by the side, there is complete anesthesia of the hand, forearm, and usually of a portion of the upper arm. Depending upon the site of the injury, there may or may not be involvement of the pectoral muscles and of the serratus magnus. In case the latter is involved, the patient shows the characteristic winged scapula deformity.

"7. **Great Sciatic.**—Even in those cases where the injury occurs near the sacroiliac foramen the flexors are not completely paralyzed, because a number of branches to the hamstrings are given off from the nerve immediately after it leaves the pelvis. The foot is completely paralyzed in all cases, and is anesthetic except in a small area on the inner aspect supplied by the internal saphenous nerve.

"When the injury occurs in the middle third of the thigh, there is no perceptible weakening of the hamstring muscles.

"8. **External Popliteal.**—Dorsal movement of the foot (dorsal flexion) and eversion are impossible, owing to the paralysis of the tibialis anticus, extensor proprius hallucis, extensor longus digitorum, and the peronei. The anesthetic area covers the entire dorsum of the foot and of the toes.

"9. **Musculocutaneous** (of the Calf).—Eversion of the foot is weakened but not inhibited, owing to the fact that the extensor longus digitorum and the peroneus tertius, both supplied by the anterior tibial nerve, also act

as evertors. The anesthetic area covers the dorsum of the foot and of the toes, except the contiguous surfaces of the great and second toes.

"10. **Anterior Tibial.**—Dorsal flexion of the foot is impossible. There is an anesthetic area of the contiguous areas on the great and second toes, as indicated above.

"11. **Internal Popliteal.**—The symptoms vary, depending upon the site of the injury. If this occurs above the point where the branches to the gastrocnemius leave the nerve (near the upper limit of the popliteal fossa), the plantar motion of the foot is impossible. If below this point, the foot can be brought into a position of equinus, but the motion is weakened and flexion of the toes is impossible. The anesthetic area is the same in both instances, and covers the sole of the foot.

"12. **Posterior Tibial.**—There is a normal action of the Achilles tendon, pulling the foot into the equinus position, but owing to the paralysis of the flexor longus hallucis and flexor longus digitorum the toes cannot be flexed. Adduction is possible despite the paralysis of the tibialis posticus, owing to the action of the tibialis anticus and of the Achilles tendon. For a consideration of other nerves, rarely injured the reader is referred to neurological text-books."

The Immediate Treatment of Nerve Injuries

General Principles.—If the physician is to prevent the development of deformity, maintain the maximum muscular tone, and create the most favorable opportunity for recovery, the treatment of traumatic injuries of nerves should begin immediately after their occurrence. The principle enunciated many years ago by Hugh Owen Thomas and constantly emphasized by Sir Robert Jones, must invariably receive the consideration of the surgeon. This teaching of Thomas maintains, that when a muscle, temporarily paralyzed, is constantly subjected to undue strain by a position of the limb which puts its fibers continually on the stretch, the muscle itself degenerates and even when the nerve recovers the muscle will fail to respond to the volition of the individual.

"Thus, for instance, in the case of musculospiral paralysis due to pressure on the nerve either during narcosis or in deep sleep, the nerve injury will be repaired within six weeks. If, immediately after the paralysis has occurred, the hand be properly splinted, so as to relax the fibers of the paralyzed extensors, the patient will be able to control his muscles as soon as the nerve paths have regained their normal conductive powers.

"If, however, the hand be allowed to dangle during the period of nerve recovery, the patient will be unable to extend the hand voluntarily because the overstretched muscle fibers fail to respond to the nerve impulses. In the nerve lesions of modern military surgery the same rule applies as in those cases seen in time of peace. In every instance of musculospiral paralysis or of injury to the anterior tibial nerve, it is absolutely essential to splint the limb in such a way as will relax the affected muscles. In the case of the ulnar nerve, other factors must be considered, so that it is not safe to give a general rule applicable to all nerves. In some instances the surgeon must consider the tendency to deformity or contracture and adjust his splint so as to prevent either from developing.

"Recently, it has been maintained that the union of a divided nerve can be furthered by splinting the limb in such a position as to bring the nerve ends as near together as possible. Thus, in division of the median nerve near the elbow, the arm should be flexed; while in division of the internal popliteal nerve, the leg should be flexed on the thigh.

Immediate Treatment of Injuries to Individual Nerves

"1. **Musculospiral.**—A light splint of plaster-of-Paris, or of metal or leather, so applied as to hold the hand and thumb fully extended and reaching to the first interphalangeal joint, should be applied in every instance. The two distal phalanges need not be extended, since owing to the action of the interossei the patient has them under voluntary control. The little additional freedom given by leaving these two joints free is a great convenience to the patient, who would otherwise have a completely helpless hand.

"Mayer emphasizes the necessity of extending the thumb—the distal phalanx as well as the proximal—since the extensors of these phalanges are supplied by the musculospiral alone. In using the moulded plaster-of-Paris splint, the lower end should be made sufficiently broad to hold the thumb in this extended position.

"2. **Ulnar Nerve.**—In the case of the ulnar nerve, there is no tendency to overstretching of the paralyzed muscles. On the contrary, that portion of the flexor profundus muscle supplied by the ulnar nerve frequently undergoes a shrinkage, producing contracture of the fourth and fifth fingers. The splint should be so applied as to prevent this contracture by keeping the fingers straight. It is easily made of plaster, wood, or cardboard.

"3. **Paralysis of the Median Nerve.**—Here there is little danger of overstretching the paralyzed muscles, since they are much more powerful than the corresponding extensors. Unlike the ulnar nerve, however, there is little or no tendency to contracture, so that there is no necessity for a hand splint. If the injury lies near the elbow, a splint holding the forearm flexed may promote union.

"4. **Musculocutaneous.**—A light dorsal moulded plaster-of-Paris splint, or two pieces of leather held together at an angle of 70 degrees, should be applied to hold the forearm sharply flexed upon the upper arm, to relax the paralyzed flexors.

"5. **Circumflex.**—The arm must be held abducted. In addition to the methods already given for injuries to the shoulder-joint, the simple splint shown in Fig. 801 gives excellent service. A piece of cotton flannel reaching from the iliac crest to the axilla and then forward to the elbow is measured off. Its width should be twice that of the plaster-of-Paris bandages which are to be used to form the splint (the 6-inch size is the best). The bandages, after being immersed in water, are rolled backward and forward on the table so as to form two layers, each about one-sixteenth of an inch thick and corresponding in length to the strip of cotton flannel already prepared. Meanwhile, the surgeon has bent a strip of malleable iron, about 10 inches long, to form a right angle. This is placed between the two layers of plaster-of-Paris, and the whole is enveloped by the two layers of cotton flannel. The plaster splint is applied to the body and arm, and is fastened in place securely by a gauze bandage. After it has hardened, additional strips of webbing can be sewed to the cotton flannel to obviate the necessity of gauze bandages.

"6. **Brachial Plexus.**—The arm must be kept abducted, the elbow flexed, and the hand extended. This is best done by a modification of the abduction splint shown in Fig. 801.

"7. **Sciatic Nerve.**—The foot should be held at a right angle to the calf since, owing to the comparative weakness of the extensor muscles, a pes equinus will rapidly develop unless these measures are taken to prevent it.

"8. **External Popliteal.**—A splint is used, as in the case of injury to the sciatic nerve.

"9. **Internal Popliteal.**—The foot should be splinted in moderate equinus position.

"10. **Musculocutaneous.**—The splint should be applied to hold the foot in moderate eversion (about 50 degrees beyond the neutral position). As the peronei are plantar flexors, it is not advisable to splint in the position of equinus for fear of developing a contraction of the Achilles tendon.

"11. **Posterior Tibial.**—Owing to the preservation of the nerves to the gastrocnemius and soleus, a splint is of no particular assistance in this type of injury.

In addition to splinting the extremity in the approved position, massage of the paralyzed muscles and electrical stimulation should be instituted as soon as feasible."

THE TREATMENT OF NERVE INJURIES

Every measure should be taken to keep the paralyzed muscles in condition of maximal tone by massage and electrical stimulation. Galvanic, faradic, and high frequency currents can all be applied with excellent effect. This portion of the work should be controlled by an experienced technician. The custom of turning over this branch of therapy to a half trained assistant cannot be too strongly condemned. Electrotherapy, in particular, requires the most careful anatomical and technical training, if it is to be anything except a therapeutic placebo.

Primary nerve suture is seldom possible after a gunshot injury, since in almost all instances of extensive laceration the danger of infection constitutes a contra-indication. In all instances the operator must try to assure this intimate union between the axones whose continuity has been interrupted by the projectile.

The exact method applicable to the case depends upon the nature of the pathological process which is found at the operation.

If the nerve is seen to be merely traumatized or pressed upon by a bone fragment or scar tissue, nothing should be done except to remove the external cause of the pressure. Should this be due to scar tissue, some means must be taken to prevent its recurrence. This is best done by changing the position of the nerve from the area where scar tissue is likely to develop into one where it is surrounded by normal healthy muscles. As a rule, this is readily done by securing the muscles which normally are superficial to the nerve in such a fashion as to bring them deep to the nerve, that is, interpose the nerve between them and the scar tissue. If this should be impossible, as, for instance, in the case of the external popliteal nerve where it rounds the head of the fibula, the nerve should be ensheathed in fascia, if the infection has been controlled. The surgeon may be confronted by the question of whether to operate or wait for the spontaneous return of function in the injured nerve. On this subject there is the greatest difference of opinion among men of experience. Some maintain that the operation should be performed as soon as the operative field is reasonably aseptic; others claim that by postponing the operation for five or six months a great proportion of nerve injuries recover without operative interference. The following practical rules of guidance have been adopted by Mayer.

1. When the symptoms of a nerve lesion are progressive, operate at once.
2. If the symptoms are regressive, do not operate.
3. In cases where there is no change whatever in the extent of the paralysis, or of the sensory symptoms, wait until the wound has healed and then determine, on the basis of the anatomical course of the nerve and the direction of

the bullet, whether there is a strong probability that the nerve has been directly injured by the passage of the bullet. If so, operate; if not, wait still longer.

The operative treatment of nerve injuries depends upon a knowledge of the physiological processes involved in nerve regeneration whatever differences there may be in the present attitude of physiologists and neurologists toward this question, whether the regeneration is due entirely to the downward growth of the axis-cylinder processes from the proximal stump into the distal.

4. If a small nodule of scar tissue is still felt within the nerve, indicating its partial division by the projectile, this area should be examined and the corresponding axis cylinder processes united by fine perineural stitches. In these cases the prognosis is particularly good, since it is easy to secure appropriate apposition.

5. If scar tissue is generally present throughout the nerve, two courses are open, dependent upon the degree of development of scar tissue. If a small quantity is present, by careful dissection this can be removed from within the substance of the nerve without disturbing the continuity of the nerve bundles. This operation is known as internal neurolysis. If, however, extensive scar tissue formation is present, completely interrupting the course of the axones, the area must be entirely excised and a suture of the nerve must be performed.

6. When a nerve has been completely divided, there is nothing to be done except nerve suture. In performing this delicate operation no surgeon of the present day has a right to urge his method dogmatically since the present status of nerve suture is an uncertain one. We do not know whether or not the perineural stitch advocated by most men is preferable to the transneural stitch advocated by such authorities as Wilms and Sherran; also there is an excellent probability that some other method of nerve suture may be introduced superior to either of these. Certain it is that the results of nerve suture by our present methods are none too good.

Under all circumstances, sufficient of the injured nerve must be excised to render healthy axis-cylinder processes visible. The cross-section of the healthy nerve is quite characteristic. The individual nerve bundles stand out as white, sharply circumscribed areas separated by intervening bands of connective tissue containing the nutrient vessels. Hemorrhage from the proximal stump is profuse, and should be controlled in the case of a large nerve by ligature of the spurting vessel and in the case of the small nerve, by the application of pledgets of cotton saturated with adrenalin. A suture cannot be attempted until the hemorrhage has been controlled, since the presence of hematoma between the nerve ends endangers the success of the operation.

Excision of a sufficient amount of the nerve frequently renders it difficult to unite the two ends. Flexion of the limb helps to bridge the gap; in the case of the median nerve, 2 inches can readily be overcome; in the case of the sciatic, $3\frac{1}{2}$ or even 4 inches. When the gap is too great proximal degeneration is a danger and nerve transplantation should be resorted to. Traction may also be exerted on the nerve stumps without much danger, although no great force should be applied to the proximal stump, since, according to Warrington, too much tension causes a degeneration of the anterior horn cells. To assist in approximating the stumps, it is advisable to place traction sutures about a quarter of an inch from the cut surface of the nerve. These are best inserted before the scar tissue has been excised, so that the healthy cross-section of the nerve should be exposed to

the air for as short a time as possible. The sutures are inserted by taking two longitudinal bites of perineurium to each of the nerve stumps and so placed that when the assistant grasps the two sutures attached to the proximal and a second assistant grasps the two attached to the distal stump, traction upon them will bring the nerve ends in apposition. The perineural stitch which Mayer usually employs is very fine silk; the needle passes in about one-sixteenth of an inch from the cut perineural surface, emerges between the perineurium and the nerve trunk, passes into the other stump at this same plane, and emerges again one-sixteenth of an inch from the cut edge. The suture is tied at once, and if properly inserted should produce no inversion of the perineurium but a very slight eversion. As few sutures as possible should be inserted, consistent with accurate approximation of the perineurium on all sides. It must be remembered that the more stitches inserted, the greater the danger of scar tissue formation. Particular care must be exercised not to tear the nerve fibers. If the nerve is once lacerated by clumsy handling, it is practically impossible to insert a successful suture. When the perineural stitches have been inserted (usually 3 or 4 for the median or musculospiral, 6 to 8 for the sciatic), the traction sutures are removed.

The transneural stitch differs radically from the perineural in that the needle is carried directly through the entire thickness of the nerve, without regard for the nerve bundles. Its advocates claim comparatively little traumatization of the nerve paths, and the great advantage of more accurate apposition. Certain it is that the perineural stitch does not give absolute approximation, since the nerve fibers within the perineurium retract a little when the nerve is subjected to marked tension, and thus a small intraneural gap is left, even when an external view shows perfect approximation of the perineurium. In the case of a large nerve, such as the sciatic, it is advisable to combine the perineural stitch with the transneural, so as to overcome the gap between the nerve ends. In instances where it is impossible to approximate the nerve ends because of extensive loss of substance, some bridging method must be followed.

The method which Mayer follows is based upon the physiological fact that the essential factor in nerve regeneration is an intimate union of the axones of the proximal stump with those of the distal. That the latter are degenerated does not seem to be of significance. Accordingly, he has transplanted segments of other nerves of the body to fill in the gap between the ends of the divided nerve. For this purpose it would, of course, be impossible to use a motor trunk without producing paralysis, and he has therefore utilized the sensory nerves, in the arm, the radial or internal cutaneous; in the foot, the external saphenous. Since the cross-section of these sensory nerves is seldom equal to that of the trunk which is to be bridged, it is usually necessary to construct a cable of appropriate diameter by employing multiple segments (2 to 8) of the sensory nerve.

The technic is as follows: sensory nerve is laid bare for a sufficient extent, depending upon the number of segments which must be utilized to give a cross-section corresponding to that of the injured nerve. It is freed from its bed, completely divided at one end, and then doubled on itself to form a loop slightly longer than the gap to be bridged. At the closed end of the loop, the nerve is again divided, except on one side, where the perineurium is maintained intact. This step of the operation requires some practice, but is perfectly feasible. Two fine perineural stitches are taken, holding the first segment in intimate contact with the second at its upper and lower extremities. The nerve is then further lifted out of its bed

so that a third segment, corresponding in length to the first two, can be measured off and sutured to these. In a similar way, a fourth or fifth segment can be united to the preceding. For this, Kirby silk and the finest needles, such as those used in arterial suture, can be employed. The nerve cable thus constructed is implanted into the gap between the ends of the divided nerve and held in place by the typical perineural suture.

Of course, in all nerve operations, the general principles of minimal traumatization must be rigidly adhered to. Never grasp the nerve roughly with forceps; always lift it gently by the perineurium; never allow it to dry; never free it unnecessarily from the surrounding tissue. The operation should be performed without the Esmarch bandage, to be sure that no postoperative hemorrhage occurs.

Operative Exposure of the Nerve.—As a rule with practically no exceptions, no attempt should be made to expose the nerve at the point of injury, since it is here embedded in scar tissue and frequently is so degenerated as to be unrecognizable. It is much simpler to expose it above and below the lesion, and then work toward this central point. To find the nerve quickly and accurately it is necessary to have exact anatomical knowledge of the course of the nerve, with especial reference to the muscular cleavage planes.

1. *Musculospiral Nerve.*—This is readily found near the bend of the elbow by a longitudinal incision along the inner margin of the brachioradialis muscle (supinator longus). The incision is deepened between the brachioradialis internally and the brachialis anticus externally. The nerve is found between these two muscles. Care must be taken not to confuse it with the musculocutaneous nerve, which lies near the musculospiral at this point, although on a more superficial plane. They are readily distinguished by following the nerves upward, when the musculocutaneous is seen to emerge from between the brachialis anticus and the biceps, whereas the musculospiral passes backward.

It is difficult to locate the musculospiral as it passes back of the humerus, since it is here very deep under the muscles and there is no certain guide to its position. It is, however, readily found in the upper portion of its course by bluntly separating the long head of the triceps from the external head. Therefore, in injuries to the musculospiral, it is well to expose it at this point and at the elbow, and follow the nerve upward and downward to the point of injury.

Of the two branches of the musculospiral nerve, the radial and posterior interosseous, only the former has surgical significance, since the posterior interosseous divides into numerous fine filaments at such a high point that its suture is seldom, if ever, feasible. The radial nerve can be used with great advantage for transplantation purposes, since its loss occasions little or no disturbance of sensation. It can be found by retracting the brachioradialis muscle (supinator longus) toward the radial side.

2. *Median Nerve.*—In the upper arm, this is easy to identify because of its immediate relation to the brachial artery. No surgical significance attaches to the crossing of the nerve and artery, so frequently emphasized in anatomical text-books, since the two structures are so intimately associated that the least traction with the forceps brings the nerve to the inner or outer side of the vessel. At the elbow, the nerve lies almost directly in the midline and is exposed by dividing the semilunar expansion of the biceps to the inner portion of the deep fascia (lacertus fibrosus), when it is found passing into the forearm between the two heads of the pronator radii teres. The deep head of the muscle separates the nerve from the ulnar artery. About one inch

above the elbow the branch to the pronator radii teres and flexor carpi radialis emerges from the parent trunk, care should be taken not to injure it.

At the wrist, the nerve is found just to the ulnar side of the flexor carpi radialis tendon. It passes beneath the annular ligament just to the ulnar side of the flexor sublimis tendon to the index-finger.

3. *Ulnar Nerve.*—This lies about one-quarter of an inch posterior to the brachial artery in the upper half of the arm, and then passes backward to its well known groove behind the internal condyle of the humerus. Throughout most of its course it lies posterior to the fascial septum separating the anterior from the posterior group of muscles.

For a short distance below the elbow, it is difficult to find the nerve because it is buried in the fibers of the flexor carpi ulnaris; but in the lower two-thirds of the forearm it is easily discovered by using the flexor carpi ulnaris as a guide, the nerve lies just to the radial side of this muscle and its tendon. About 4 or 5 inches above the wrist the dorsal sensory branch passes backward: this branch is of significance for transplantation purposes in case it becomes necessary to bridge a gap between the ends of the divided nerve.

4. *Radial Nerve.*—This is of significance only for transplantation purposes and is found by retracting the brachioradialis muscle (supinator longus) toward the radial side.

5. *Musculocutaneous.*—The emergence of this nerve between the brachialis anticus and the biceps near the bend of the elbow has already been referred to in describing the musculospiral nerve. The upper portion of the nerve is laid bare by separating the coracobrachialis from the short head of the biceps.

6. *Internal Cutaneous.*—Like the radial, this is of significance for transplantation purposes, particularly when bridging a gap in the ulnar or median nerve in the upper arm. Its position varies somewhat, but it is usually found between the ulnar and the median nerves.

7. *The Circumflex Nerve.*—Operative exposure of this nerve is very seldom necessary in military surgery. The lower end of the brachial plexus has to be exposed by upward retraction of the pectoralis major.

8. *The Brachial Plexus.*—Ample operative exposure is given only by a long incision running from a point four inches above the clavicle to the axilla. The clavicle is divided by a Gigli saw, and the two ends are retracted. Great care must be exercised when freeing the plexus from the great vessels, and the operation should never be undertaken except by a surgeon experienced in vascular technic.

9. *Sciatic Nerve.*—When exposure near the sacrosciatic foramen is necessary, the best incision runs from the midline of the thigh at the lower border of the gluteus maximus over to the trochanter and upward, with a sweep toward the midline near the upper border of the muscle (see also Chapter XIV). The skin and muscle flap is retracted inward, giving free exposure of the upper portion of the nerve. Some hemorrhage is encountered in dividing the fibers of the muscle near the trochanter but much less than were the muscle divided directly in the course of the nerve.

In laying bare the sciatic in the thigh, the relation of the long head of the biceps muscle is of great importance. It is to be recalled that this portion of the muscle has its origin from the tuberosity of the ischium, in common with some of the hamstring muscles, and that therefore its course must be a slanting one from within outward. It crosses the nerve in the upper third of the thigh. Above this point of crossing the muscle should be drawn to the inner side in order to expose the nerve; below this point, it should be

drawn to the outer side. Adherence to this rule will save the operator much inconvenience.

10. *Internal Popliteal Nerve.*—An incision directly in the mid line of the popliteal fossa lays the nerve bare. Like the sciatic, it is almost always embedded in a fatty envelope, even in thin individuals and should therefore be sought where the operator sees the adipose tissue between the muscles.

The two important branches to the gastrocnemius pass off from the nerve near the upper end of the popliteal fossa, and should always be carefully identified, so as to avoid injury.

11. *Posterior Tibial.*—In the lower two-thirds of the leg, the nerve is best exposed by an incision on the mesial aspect, following the lower border of the soleus muscle and the Achilles tendon. The Achilles tendon and the muscular mass consisting of soleus and gastrocnemius are retracted outward, baring the deep layer of the fascia. When this is incised, the nerve is found lying directly beneath it.

In the upper third of the calf, this incision cannot be employed, since the nerve lies too near the midline. It is exposed by a median incision which is deepened through the fibers of the gastrocnemius and soleus.

12. *External Popliteal Nerve.*—The tendon of the biceps serves as a guide for this nerve. The relation of the two structures is not always exactly the same, since in some individuals the tendon overlaps the nerve, whereas in others a gap of a quarter of an inch may separate them.

13. *Anterior Tibial.*—This nerve is found by exposing the outer border of the tibialis anticus muscle. Near the ankle, the extensor proprius hallucis lies on its outer side; nearer the knee, the extensor longus digitorum. A large branch to the tibialis anticus muscle passes off almost immediately after the separation of the external popliteal nerve into its terminal branches.

14. *Musculocutaneous Nerve.*—This lies directly in the substance of the peroneus longus. The sensory portion emerges from the fascia in the lower third of the leg near the septum which separates the peroneal muscles from the anterior extensors.

15. *External Saphenous Nerve.*—The significance of this nerve lies in its value for transplantation purposes. It is found directly in the middle of the calf in immediate association with the external saphenous vein, which frequently lies directly over the nerve, hiding it from the view of the inexperienced operator.

Postoperative Treatment.—Subsequent to the operation, the treatment as practised before should be continued, that is, the extremity should be properly splinted and the paralyzed muscles should be given daily massage and electrical stimulation. Whenever possible, the patient should be allowed to use the extremity, since in this way the circulation is best kept normal.

It is advisable to keep the patient under observation until the muscles have recovered their power. If, for economic, military, or social reasons it is impossible for the patient to remain in the hospital, he may be allowed to go about his work, reporting daily for the necessary treatment and for examination.

Prognosis.—Concussion and contusion of the nerve yield rapidly to nonoperative treatment. Scar tissue formation external to the nerve, without interruption to the continuity of the nerve fibers, is easily removed, and return of function should occur in approximately 100 per cent. of the cases. Endoneural scar formation, on the other hand, does not yield so readily to treatment; when but slightly developed, so that the internal neurolysis can be practised, the prognosis is more favorable than in those instances

where, owing to extensive scar tissue development excision of the neuroma is necessary, with subsequent nerve suture. When the projectile has injured only a part of the nerve, excision without complete division of the nerve gives excellent results in the majority of cases, because of the accuracy with which the nerve ends can be brought into apposition.

When complete nerve division has occurred, cure results, as far as can be judged from reliable statistics, in not more than 40 per cent. of the cases. This poor result, though partly due to the technical difficulties associated with the secondary nerve suture, undoubtedly indicates the need for careful experimental work to improve the present operative technic.

STABILIZING PROCEDURES (See also Chapter XXI)

Before resorting to stabilizing operations, such as arthrodesis, the surgeon should make certain that the paralysis of the controlling muscles is not temporary, such as would result from overstretching. The only reliable way to determine this point is to put such muscles in a relaxed state and maintain this relaxation constantly for a period of four to six months. Electrical reactions are not reliable for obtaining this information.

TENDON TRANSPLANTATION IN GENERAL (See also Chapter XXI)

Injuries of Nerves

In cases where muscle balance has been destroyed by a nerve injured beyond repair, tendon transplantation, with or without arthrodesis or bone transplantation, frequently offers a solution of the problem.

Tendon Transplantation in Nerve Injuries of the Upper Extremity.—In cases where the musculospiral nerve is irreparably damaged, the resulting deformity is a drop-wrist, with loss of extension of the fingers and wrist. The unopposed action of the flexors causes the fingers to contract into the palm of the hand, and the hand becomes useless. The following procedures are indicated.

The flexor carpi radialis and the flexor carpi ulnaris are transplanted into the tendons of the paralyzed extensor communis digitorum, and the extensor longus pollicis; the pronator teres may also be transplanted into the extensor carpi radialis longus and brevis.

Transplantation of the Pronator Teres and the Radial and Ulnar Flexors into the Extensors of the Fingers and Thumb.—*Operative Technic.*—"With the forearm midway between pronation and supination, an incision is made along the radial border of the forearm in its middle third. Under cover of the tendon of the supinator longus, the pronator teres is found at its insertion into the outer border of the radius. From this it is detached, and it is then inserted into the tendons of the extensor carpi radialis longus and brevis, which lie closely applied to it on the dorsal surface. A horseshoe incision, with the convexity resting on the back of the carpus and its two straight sides extending along the radial and ulnar borders, is then made. Through the lateral aspects of this incision, the tendons of the flexor carpi ulnaris and radialis are identified and detached from their insertions, as near the carpus as possible. The tendons are brought around the ulna and radius respectively in very slanting fashion, and are then attached to the extensors of the finger and thumb, the carpi ulnaris being attached to the tendons of the three inner fingers, and the flexor carpi radialis to those of the thumb and index-finger" (Jones).

The author always employs over-and-over sutures of fine kangaroo in anchoring tendons, because this type of suture avoids knots, and is absorbable.

WOUNDS OF MEDIAN AND ULNAR NERVES

It should be appreciated that the repair of extensive injuries to the median and ulnar nerves is much easier and more feasible than in musculospiral or extensive popliteal nerve injuries, because by flexing the elbow a hiatus of 2 inches or more can be closed; in the case of the ulnar nerve, by displacing it anteriorly and then flexing the elbow, an equal hiatus can be overcome. In these nerves, end-to-end suture is much easier than in almost any other nerve, therefore it is rarely necessary to resort to the other alternative of tendon transplantation when these nerves suffer extensive injuries.

On the ulnar side of the forearm the only suitable muscles not supplied by the median nerve are the flexor carpi ulnaris and the ulnar side of the flexor profundus digitorum.

Technic of transplantation of the tendons of the radial side of the *flexor profundus digitorum* into those of the *ulnar side* of the same muscle; the tendons of the *flexor sublimis digitorum* into those of the *flexor carpi ulnaris*, and the tendon of the *extensor carpi radialis longior* into the *flexor longus pollicis*, in *paralysis* of the *median nerve*. "A curved incision is made, convexity downward, with the apex just above the anterior annular ligament of the wrist. After retracting the flexor sublimis tendons, the outer two tendons of the flexor profundus are inserted into the two active inner tendons of the same muscle. The flexor ulnaris is then divided close to its insertion and between the two portions of the split ends of the tendons of the flexor sublimis, and the four tendons are inserted. The tendon of the extensor carpi radialis longior is now found at the outer border of the incision, and, after division is inserted into the tendon of the flexor longus pollicis round the outer border of the radius" (Jones).

Tendon Transplantation in Complete Paralysis of the Ulnar Nerve.—The operative technic is very simple. The two tendons of the ulnar side of the flexor profundus digitorum are transplanted into the two on the radial side; the palmaris longus, into the tendon of the flexor carpi ulnaris.

Postoperative Treatment.—It is important to keep the hand constantly in dorsiflexion for a period of five to six weeks. When the grafted muscles are sufficiently strong to elevate the hands and fingers muscle training, "in co-ordination and balanced movement," should be instituted. But even then the hand should not be allowed to remain in palmar flexion while the patient is asleep, because of the tendency of the flexors to shorten. A splint holding the hand in dorsiflexion should be worn each night for a period of several weeks.

GUNSHOT INJURIES OF THE LOWER LIMB

In gunshot injuries to nerves of the lower extremity, the surgical measures to overcome contractures, to rebalance muscle control by tendon transplantation, and to stabilize the extremity by plastic procedures, such as arthrodesis, bone transplantation, etc., have been described in Chapter XXI, on the "Treatment of Infantile Paralysis." In destruction of the anterior crural nerve, the quadriceps group of muscles is the principle one involved, and the transplantation of the biceps or sartorius into the patella is the treatment of choice. A brace with a lock at the knee to hold the leg in extension while walking and to allow flexion when unlocked, can be applied

as an alternative, or the extension catch may be substituted by an extension spring. One of these braces will have to be worn permanently, unless transplantation is done.

Destruction of External Popliteal Nerve.—The muscles paralyzed are the anterior tibial and peronei groups, which allow the foot to drop into a position of equinus and varus by gravity, weight-bearing, and unbalanced muscle control. Such cases are not favorable to tendon transplantation because there is no muscle suitable for transplantation. When only one branch of this nerve has been destroyed, rebalancing of the foot can be accomplished by splitting the anterior tibial tendon and inserting its outer half into the upper surface of the cuboid or into the base of the fifth metatarsal bone. In such a case, the author prefers to remove with the half of the tendon a piece of its bony insertion into the internal cuneiform which is inlaid subperiosteally with the tendon end. If the tibialis anticus muscle is involved, the peroneus longus can be transplanted in its place.

Tendon Fixation.—When the tendons have been so extensively damaged that muscles cannot be transferred, tendon fixation offers a means of maintaining correction of deformity and stabilizing the limb, and at the same time allows useful mobility. The object is to utilize selected tendons. (whose muscles have been completely paralyzed), as ligaments to hold the paralyzed foot in a corrected position. There is a large variety of such procedures, and they allow the ingenious surgeon to work out his mechanical problems in endless ways.

Destruction of the External Popliteal Nerve with Drop-foot.—"Two small incisions are made along the course of the peroneus longus tendon. The first is placed over the tendon just before it turns around the outer border of the foot on to the sole, and the other about 3 to 4 inches above the tip of the external malleolus. The tendon is now divided through this upper incision and the lower freed portion is then pulled out of its sheath through the lower opening, while its normal attachment to the sole remains undisturbed.

"An incision, 2 to 3 inches above the tip of the external malleolus is made just externally to the anterior border of the tibia at the divided lower portion of the peroneus longus. The tendon is passed up from the lower incision to this new one. In its new course the tendon sheath passes under the anterior annular ligament, but if this cannot be done it may be passed in the deep fascial layer.

"The periosteum is now raised from the anterior aspect of the tibia and a deep groove is made in the base; the tightly pulled tendon whose outer surface has previously been roughened, is then laid in the groove" (Jones).

The author differs with Jones in his method of fixing the tendon. The bone is drilled on each side of the gutter by means of the motor-drill, and the tendon is held in place by means of kangaroo tendon. The periosteum is then drawn over it by means of interrupted sutures of No. 0 chromic catgut.

If desirable, the tendon of the tibialis anticus muscle can be severed, roughened, and inserted with the peroneus tendon in the same groove; or, if preferred, these tendons may be inserted into a large drill hole in the anterior surface of the tibia, instead of into the above mentioned groove. Jones uses a very simple device to prevent toe-drop, by fixing the boot at right angles by means of a leather tongue fixed to the toe-cap and with a leather strap around the upper part of the boot just above the ankle. This method or a suitable brace should be applied for a few months after the original plaster of Paris has been removed. (See Fig. 408.)

Destruction of Sciatic Nerve.—When the whole sciatic nerve has been destroyed high up in the thigh, a total paralysis of the muscles controlling the foot and of certain muscles of the knee results. Such cases are best treated by means of specially devised braces controlling the foot and ankle. It is believed with Jones that it is a great mistake to amputate such limbs. They can be controlled by means of various efficient braces and are better and much less troublesome than artificial limbs. In no branch of surgery are the ingenuity and versatility of the surgeon more taxed than in these instances, not only in the plastic procedures required to accomplish the satisfactory suturing of the damaged nerves, but in the event of failure there are satisfactory alternatives, namely, the many combinations of tendon transplantation when active contractile muscles are available. If tendon transplantation procedures are not feasible, there still remain available stabilizing operations, such as various operative procedures to secure tendon fixation, arthrodesis, or the use of the bone-graft. Many times, also, the treatment involves planning and devising special braces which are to be used temporarily before or after operation, or permanently as a supplement to the result obtained by the various operations.

INJURIES TO TENDONS, AND TENDON OPERATIONS

In military practice the tendons most frequently injured are those of the hand and fingers. As a rule, the projectile traversing the hand splinters one of the metacarpal bones and divides one or both groups of tendons. The infantry projectile seldom does damage to the tendons of more than one finger unless its course happens to be oblique. Shell fragments, however, usually produce much more extensive destruction. When both flexors and extensors have been injured, there is little to be done except to immobilize in the midposition. If either flexor or extensor has suffered an isolated injury, the hand and fingers should be so splinted as to relax the tension upon the injured tendon and afford the maximal opportunity for contact between the tendon ends. It is rarely possible to perform a direct tendon suture, owing to the infection which usually accompanies the injury.

These injuries to tendons, however, constitute only a minor field in tendon surgery. A far wider scope is given by those paralytic conditions in which, owing to the impracticability of nerve operations, tendon transplantations should be executed to restore the normal muscle balance. Although the chief field for the application of these operations is in the treatment of the residual paralysis of anterior poliomyelitis, they are also applicable in those paralyses resulting from gunshot injuries which are not amenable to nerve suture or neurolysis. Thus, a lesion of the anterior tibial nerve just after it has branched from the parent trunk can seldom, if ever, be cured by operation on the nerve, since the numerous fine muscular branches given off at this level cannot be found in the scar tissue. So, too, a lesion of the posterior interosseous nerve does not lend itself to direct operative treatment. Under these conditions, tendon transplantations are indicated. (For the further consideration of this subject and the technic of tendon transplantation, see Treatment of Infantile Paralysis, Chapter XXI).

Flatfoot in the Soldier.—The only point about flatfoot in the soldier here necessary to be mentioned is that it is a frequent ailment in every army and that it demands the most careful consideration. There is at present no orthopedic condition which will diminish the efficiency of the army more than this. Because supports are not permitted to the soldier on duty, exercises and shoe alterations are more frequently employed in the army.

(For the diagnosis, pathology, and treatment of this condition, see Chapter XXIII on the Foot.)

Painful Heels.—The heel seems to be a very vulnerable spot in the soldier's foot, and he frequently complains of discomfort from this source. The causes may be enumerated under the following headings: (1) Spurs and sensitive bursæ under the os calcis from toxemia or trauma; (2) periostitis or ostitis from direct trauma; (3) strain or injury about the insertion of the tendo Achillis.

1. The spur on the os calcis is located almost always at the insertion of the plantar fascia or tendo Achillis. When in the latter location, there are no associated symptoms; those in the plantar fascia may not produce symptoms. Symptomless spurs may become troublesome after stone bruises from jumping into the trenches or after a long march. (For operative technic of removal, see Chapter XXIII on the Foot.)

2. *Periostitis and Ostitis.*—These conditions often originate from traumatism of the periosteum by jumping or falling from a height. They may also be associated with local crushing of the bony cortex. In this event, the symptoms may be due to bony irregularities on the weight-bearing surface of the os calcis.

Treatment.—Palliative treatment, as a rule, does not answer in such cases. If pronounced bony irregularities are felt, it is best to turn down the soft tissues of heel and remove thoroughly the bony prominences. A soldier with a severe fracture of the astragalus is rarely again fit for service.

INJURIES OF THE KNEE-JOINT IN MILITARY SERVICE

The knee-joint is the most vulnerable joint of the body, and every type of injury may occur in military service, from the slightest sprain to the severest gunshot wound. Sir Robert Jones has found the following conditions frequently:

(1) Simple sprain of a lateral ligament, usually the internal. (2) Slipping of the semilunar cartilage. (3) Nipping of the infrapatellar pad of fat.

Any or all of these injuries may be produced by a twist or fall which at first does not seem serious. All of these cases are associated with fluid in the joint, and in all the patient complains of increasing or recurring disability after the lesion, unless it has been recognized and treated in the first instance.

1. **Sprain of the Internal Lateral Ligament.**—Sprain of this ligament is associated with pain and tenderness, from pressure over its attachments. The patient complains of pain on the inner side of the knee. There are no signs or symptoms elsewhere in or about the knee. Stress in the direction of producing knock-knee and external rotation interferes seriously with recovery from this lesion.

Treatment.—The patient should be immediately put to bed and the limb placed in a plaster-of-Paris splint reaching from the toes to the groin, and so moulded as to remove stress from this ligament. This splint should be continued for a period of five weeks at least, after which the inside of the knee should be strapped with basket strapping of adhesive. The inner side of the heel and ball of the shoe should be raised one-fourth of an inch in adults, thus materially relieving the ligament from strain during locomotion.

Second and Third Types.—The internal injuries of the knee-joint encountered in military practice vary within wide limits, *i.e.*, from a slight sprain of the attachments of the semilunar cartilages to a fracture of the spine of the tibia associated with a complete rupture of the crucial ligaments. The first condition is difficult to differentiate at first from a simple sprain. It is

immediately obvious, however, that the second condition is a most serious lesion. It is of the utmost importance that a military surgeon should be able to make a differential diagnosis between the various knee lesions encountered in military service.

POSITION OF ELECTION FOR ANKYLOSED JOINTS RESULTING FROM GUNSHOT INJURIES

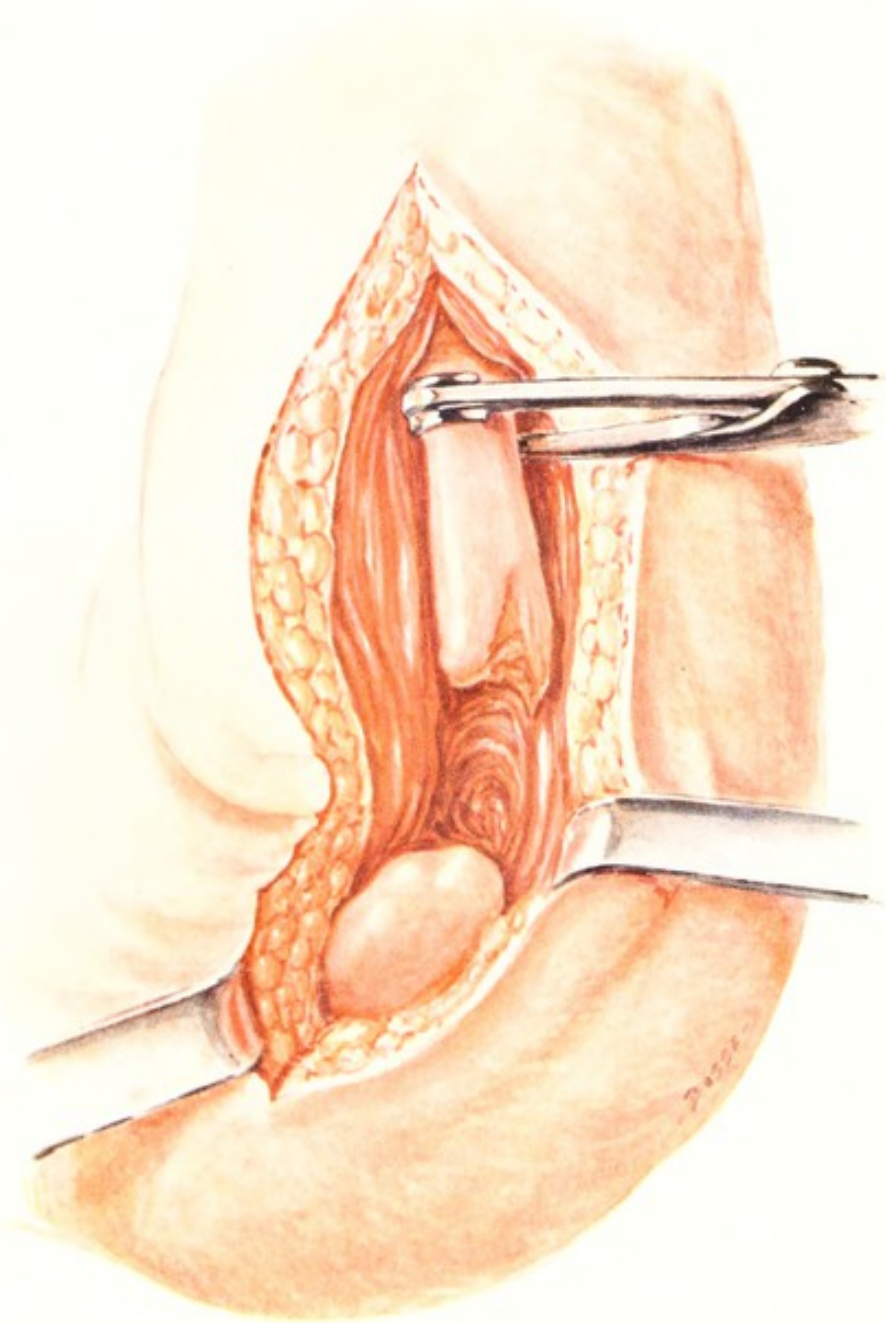
In many instances injuries occur to joints after gunshot wounds which must inevitably end in bony ankylosis. These joints, many times, are not suitable for excision or arthroplasty for mobility, therefore the position in which they are allowed to ankylose should be considered carefully from the beginning, and the maintenance of this position must be provided for. This



FIG. 796.—This case, an officer, was wounded at Ourcq River by fragments of a high explosive shell. Operated on by author at U. S. Army General Hospital No. 3, Colonia, N. J., four and one-half months after he was wounded and seven weeks after the wound had healed. The röntgenogram shows loss of about 3½ inches of the upper end of the humerus including the entire head, resulting in a flail arm and almost complete loss of motion of upper arm at shoulder. Fig. 802 demonstrates the restoration of loss of bone by tibial bone-grafts.

is especially true of the shoulder, elbow, and wrists. The author had occasion while in France during the recent war and as chief Surgeon at U. S. Army General Hospital No. 3 to observe many cases where extensive resection had been done early and the limbs, especially the arm at the shoulder, were useless and flail. In such instances, the question immediately arose; how should they be ankylosed, and in what position? In most instances it was to restore loss of bone by a graft.

Shoulder-joint.—*Position.*—The upper arm should be elevated to about 45 degrees and rotated with the forearm at right angles, so that the thumb comes on the tip of the nose, while the forearm is in semi-pronation and the palm of the hand directed toward the opposite side. The



Same case as Fig. 796. Superior view, showing actual pathology.

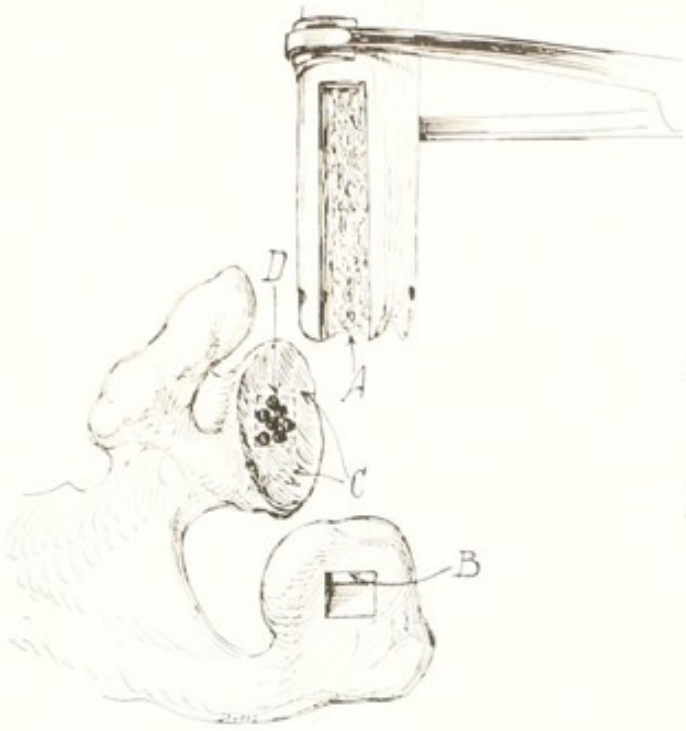


FIG. 797.

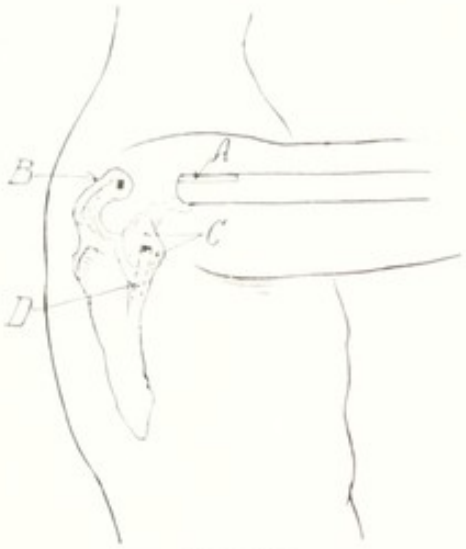


FIG. 798.

FIG. 797.—Same case as Fig. 796. Superior view, showing groove, A, in humerus, mortise, B, in acromion, glenoid cavity denuded of cartilage, C, and mortise in glenoid body, D.

FIG. 798.—Same case as Fig. 796. Lateral view, showing relation of humerus to scapula, with patient in upright posture.

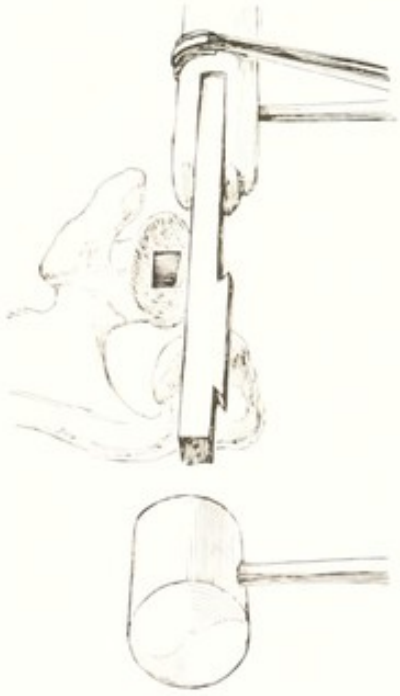


FIG. 799.

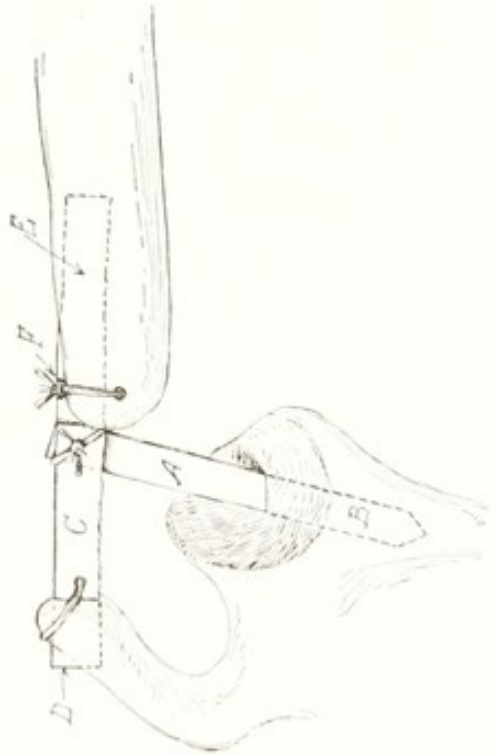


FIG. 800.

FIG. 799.—Same case as Fig. 796. This drawing demonstrates the contour of the graft and the method of insertion into the groove in the humerus. The diameter of the graft at its left end has been increased for two purposes: first, for increased strength, and secondly, to form "shoulders" which will impinge against the acromion process and the upper end of the humerus, thus preventing later shortening of the arm from muscular contraction.

FIG. 800.—Same case as Figs. 796 and 802, showing bone-grafts in place and fixed by means of kangaroo tendons.

upper arm is fixed in this position, preferably by a plaster-of-Paris shoulder spica, while the scapula rests in its normal neutral position against the bony thorax.

Rationale.—If the shoulder should become ankylosed with the arm in this position, the hand can be brought easily to the hair, to the necktie, and the mouth, and the patient will be able to pick up articles with ease. It should be emphasized that the arm ought never be allowed to hang by the side during the period of probable ankylosis of the shoulder, because the functional result in such a case is bound to be very unsatisfactory. The upper arm should never be allowed to ankylose at the shoulder in a posture of right angle-lateral inclination with the body, as in this case the arm could not be brought to the side. If already in this position, correction by osteotomy is indicated.



FIG. 801.—Same case as Fig. 796.—This photograph illustrates the relation of arm to scapula and thorax which was secured by ankylosing the humerus and scapula by means of a graft (as shown in Fig. 802), thus allowing the scapulararthoracic motion to compensate for the loss of motion in the shoulder.

Elbow-joint.—In determining the position of the elbow, one should consider the peculiar requirements of the patient, the greater number would choose fixation at a little less than a right angle. The position usually met with, that is, an angle of 130 degrees, is not satisfactory. When both elbows are flail and to be ankylosed, it is best to ankylose one at an angle of 100 to 120 degrees and the other at 60 to 80 degrees.

Rationale.—The extremity with the ankylosis at less than a right angle, allows the patient to reach the mouth and hair, reach across the table, and button his clothing. The other arm when ankylosed at a greater angle, supplements this.

Forearm.—*Position.*—If pronation and supination are lost, the forearm should be fixed in semipronation.

Rationale.—In appearance this position of the hand is much to be pre-

ferred and the hand is more generally useful for eating, manual labor, dressing, etc.

Wrist-joint.—*Position.*—All injuries and conditions at the wrist-joint should be treated with the wrist in dorsiflexion. This cannot be too strongly emphasized. It is indicated not only when ankylosis is expected, but even when limitation of motion is feared. The frequent and awkward deformity of palmar flexion occurs when no splint is used or when a straight splint is applied: this position always greatly impairs the function of the hand.

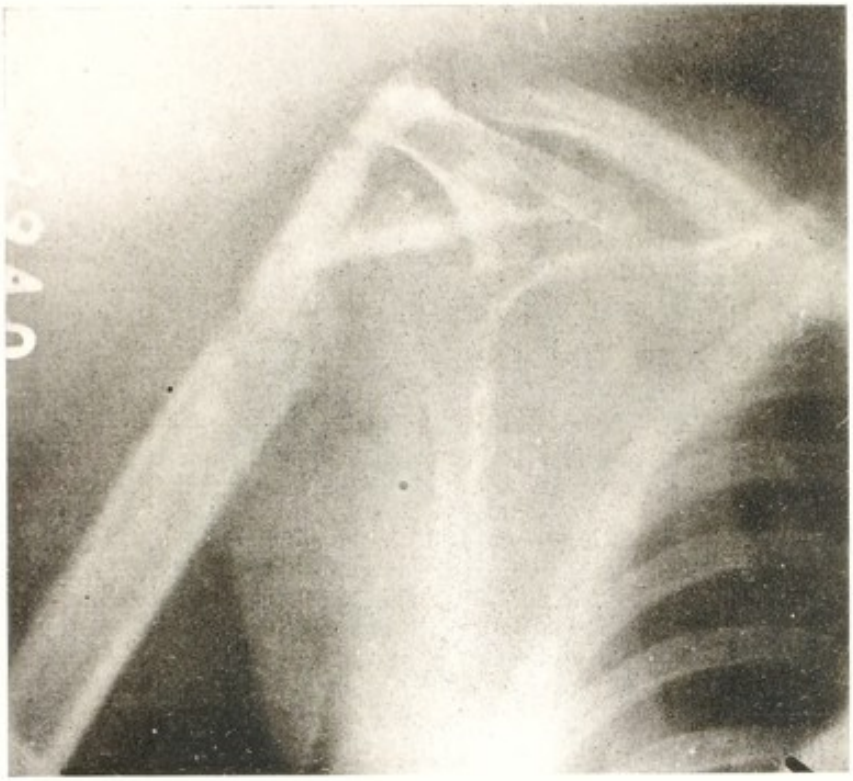


FIG. 802.—Same case as Fig. 796. This röntgenogram demonstrates the restoration of loss of bone by two tibial grafts, eight weeks after the operation. Graft No. 1 was inlaid into the shaft of the humerus and mortised into the acromion process. Graft No. 2 was mortised into the glenoid body of scapula and contacted with graft No. 1 and the upper end of the humerus fragment. (For technic, see Figs. 797 to 800.)

The arm was placed in such relation to the scapula that the powerful thoracic muscles controlling this bone might move it and in a large measure restore its loss of function by causing the scapularthoracic motion to be compensatory for loss of shoulder motion of the arm. During the union of the grafts the arm was held by a plaster-of-Paris shoulder spica in an elevated anterior posture so that later scapularthoracic motion would bring the hand to the hair, mouth and neck. (For posture of arm, see Fig. 801.)

In similar cases where the head of humerus is gone and where the shoulder muscles are still capable of functionating, motion of the shoulders has been restored by replacing head of humerus by the head and upper portion of the fibula.

Rationale.—The grasp of the fingers is correspondingly diminished as the palmar flexion is increased. The flexors overbalance the extensors, and as a consequence co-ordinated movements of the fingers are impaired. Dorsiflexion affords the best use of the hand and brings about the proper balance between flexors and extensors. Dorsiflexion at the wrist can be maintained by plaster dressing or the Jones' "cock-up" splint.

Hip-joint.—*Position.*—The limb should preferably be fixed in a position of abduction, sufficient to nearly compensate for bony shortening of the limb with the thigh flexed 10 or 15 degrees, and the foot slightly rotated outward.

Rationale.—The ordinary position of the hip after any irritating condition of the hip-joint is that of flexion, adduction, and internal rotation. This is the deformity we find in all untreated or imperfectly treated hip-joint affections. The posture produces lumbar lordosis and a very awkward limb. If the hip is fixed in the slightly flexed and abducted position, lumbar lordosis and probable consequent backache are avoided, and walking is rendered much easier. If the foot is slightly rotated outward, the ugly lift of the pelvis as the patient rises on the forefoot is prevented. The gait is more natural if the foot is rotated a little inward rather than straight forward.



FIG. 803.—Comminuted fracture of external portion of head of tibia, with loss of substance and marked knock-knee deformity. Although this was a simple fracture, the surgeon, who originally treated this case, removed all fragments; thus taking away the very elements which would have restored the head of the tibia. Bone fragments in all similar cases should be religiously kept.

Knee-joint.—*Position.*—The knee-joint should always be immobilized in a position of 10 to 15 degrees of flexion when there is danger of stiffness or ankylosis.

Rationale.—This position affords a more normal posture and greater ease in climbing stairs or sitting. Sir. Robert Jones' objection to this flexed position, namely that owing to yielding of the fibrous or soft bony union there is danger of marked flexion deformity, is entirely obviated in the author's practice by implantation of an inlay tibial graft which usually brings about immediate firm bony union.

Ankle-joint.—*Position.*—The foot should always be fixed at a right angle with the leg, in a slight varus position.

Rationale.—The common position of equinus causes foot strain and leads to weak-foot or flatfoot. The position of varus insures stronger action of the foot, whereas the valgoid position results in weak action.

Tarsus and metatarsus.—Traumatic and gunshot injuries of the tarsus and metatarsus are likely to lead to the common static deformities, that is, flatness and pronation. To prevent these deformities, the shoe may be elevated on the inside at both ball and heel, or flatfoot supports may be worn. Great conservatism should be observed in treating these cases, and not allowing the patients to get on their feet too early.

Flail-joints.—Flail-joints, as a rule, are best treated by producing bony ankylosis. The author has succeeded in such cases most satisfactorily when using the bone-graft. Occasionally, one sees a flail-hip or similar condition

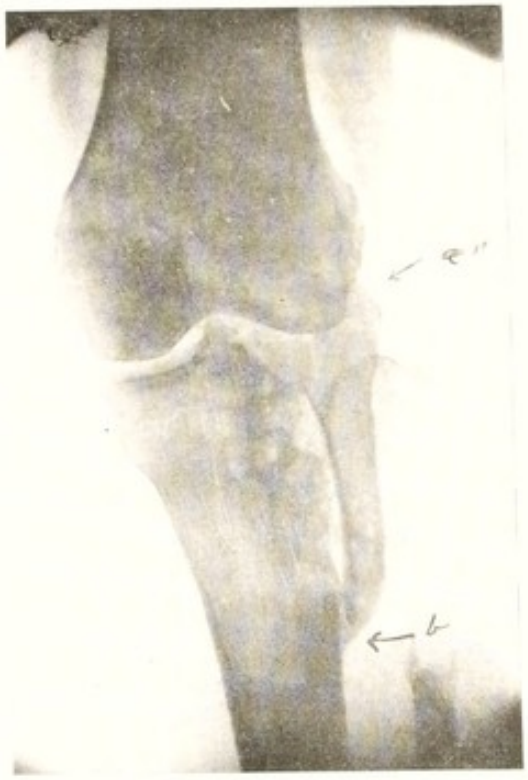


FIG. 804.—Same case as shown in Fig. 803. Loss of outer portion of head of tibia, restored by transplanting 3½ inches of upper end of the fibula. The cartilaginous surface of the head of the fibula was brought at *a* in firm contact with articulating surface of external condyle of femur and held with kangaroo tendon. The leg was put up in plaster-of-Paris in position of slight bow leg. This rontgenogram was made three months after operation.

in some other joint where there is satisfactory painless function with the aid of supporting braces.

REFERENCES

OCHSNER, A. J. AND PERCY, N. M.: "A New Manual of Surgery, Civil and Military." Cleveland Press, Chicago, 808 p. 5th. ed., 1917.

CHURCHMAN, J. W.: "A Group of Injuries in Modern Warfare." Boston M. & S. J., clxxvi, 113–118, 1917.

SILVER, D.: "The Function of Orthopedic Surgery in the Present War." Am. Jour. Orthop. Surg., Boston, xv, 509–511, 1917.

WHITE, J. R.: "Notes on 50 Cases of Injury of the Peripheral Nerves." Brit. Jour. Surg., iv, 607, April, 1917.

MCMURTRIE, D. C.: "The War Cripple." Columbia War Papers, Series 1, No. 1. N. Y. Col. Univ., 1917.

CORBUSIER, H. D.: "The Soldier's Foot." Am. Med., xii, 328–344, May 5, 1917.

ALBEE, F. H., AND PITTENGER, PAUL S.: "Simplification of the Carrel-Dakin Method of Wound Sterilization in Military and Civil Practice." Am. Med., xii, 389–402, May 5, 1917.

ALBEE, F. H.: "Bone-graft Surgery in Present European War with Moving Pictures of Technic." Railway Surg. Jour., Chicago, xxiii, 357–365, 1917.

"The Function of the Military Orthopedic Hospital." N. Y. Med. Jour., cvi, 2–4, 1917.

DUCO, A., AND BLUM, E.: "Guide Pratique du Médecin dans les Expertises, Médico-légales Militaires." Masson et Cie., Paris, 1917.

BABINSKI, J., AND FROMENT, J.: "Hystérie-pithiatisme et troubles nerveue d'ordre reflexe en neurologie de guerre." Masson et Cie., Paris, 1917.

ROUSSY, G., AND L'HERMITTE, J.: "Les Psychonevroses de Guerre." Masson et Cie, Paris, 1917.

BARBARIN, P.: "Manuel de Chirurgie de Guerre a l'usage des Infirmieres." Octave Doin et fils, Paris, 1916.

CAZIN, M.: "Notes cliniques et thérapeutiques de Chirurgie de guerre." A. Maloine et fils, Paris, 1917.

SENCERT, L.: "Les blessures des vaisseaux." Masson et Cie, Paris, 1917.

GRÉGOIRE, F., AND COURCOUX, A.: "Plaies de la plèvre et du poumon." Masson et Cie., Paris, 1917.

OMBRÉDANNE, L., AND LEDOUX-LEBARD, R.: "Localisation et extraction des projectiles." Masson et cie., Paris, 1917.

ABADIE, J.: "Les blessures de l'abdomen." Masson et Cie., Paris, 1916.

BOURGEOIS, H., AND SOURDILLE, M.: "Otites et surdités de guerre." Masson et Cie., Paris, 1917.

CHATELIN, CH., AND DEMARTEL, T.: "Blessures du crâne et du cerveau." Masson et Cie., Paris, 1917.

ATHANASSIO-BENISTY, MME.: "Traitement et restauration des lésions des norfs." Masson et Cie., Paris, 1917.

IMBERT, L., AND REAL, P.: "Les fractures de la machoire inférieure." Masson et Cie., Paris, 1917.

BROCA, A.: "Les séquelles ostéo-articulaires des plaies de guerre." Masson et Cie., Paris, 1916.

BROCA, A., AND DUCROQUET: "La prothèse des amputés en Chirurgie de guerre." Masson et Cie., Paris, 1917.

CARREL, A., AND DEHELLY, G.: "Le traitement des plaies infectées." Masson et Cie., Paris, 1917.

LAGRANGE, F.: "Les fractures de l'orbite par projectiles de guerre." Masson et Cie., Paris, 1917.

ZIMMERN, A., AND PEROL, P.: "Electrodiagnostic de guerre Clinique-conseil de réforme technique et interprétation." Masson et Cie., Paris, 1917.

CAZIN, M.: "La cure solaire des blessures de guerre (Methode Rollier)." A. Maloine et fils, Paris, 1917.

BILLET, H., AND MARTIN, H.: "La pratique Chirurgicale dans la zone de l'avant." Baillière et fils, Paris, 1917.

ALQUIER, P., AND TANTON, J.: "L'appareillage dans les fractures de guerre." Masson et Cie., Paris, 1917.

LEGROS: "L'électrothérapie de guerre. Notions essentielles d'électrothérapie." A. Maloine et fils, Paris, 1916.

DESPLAS, B.: "Anesthésie a la stovaïne en Chirurgie de guerre dans une ambulance de aïeligne." Masson et Cie., Paris, 1917.

DEPAGE, A.: "Ambulance de "L'Ocean." Masson et Cie., Paris, 1917.

CARREL, A., AND DEHELLY, G.: "The Treatment of Infected Wounds." N. Y., Paul B. Hoeber, 1917.

GLYNN, E.: "Microbes and the War." C. Tinling & Co., Liverpool & London, 1916.

JONES, SIR R.: "Notes on Military Orthopedics." Cassell & Co., Ltd., Lond., N. Y., etc., 1917.

FOX, R. F.: "Physical Remedies for Disabled Soldiers." Lond., Baillière, Tindall & Cox, 1917.

HUTT, C. W.: "The Future of the Disabled Soldier." N. Y., Wm. Wood & Co., 1917.

GARTON, G.: "Electrotherapeutics for Military Hospitals." Lond., H. K. Lewis & Co., 1917.

KEEN, W. W.: "The Treatment of War Wounds." Phila., W. Saunders Co., 1917.

RIDDELL, J. S.: "A Manual of Ambulance." Lond., Chas. Griffin & Co., 1913.

GOODWIN, T. H.: "Notes for Army Medical Officers." Phila., Lea & Febiger, 1917.

DAKIN, H. D., AND DUNHAM, E. K.: "A Handbook on Antiseptics." N. Y., The Macmillan Co., 1917.

MUNSON, E. L.: "The Soldier's Foot and the Military Shoe." Menasha, Wis., George Banta Publishing Co., 1917.
FAUNTLEROY, A. M.: "Report on the Medico-military Aspects of the European War." Washington, Gov't Printing Office, 1915.
"War Surgery of the Nervous System." Office of the Surgeon General, War Dep't, Washington, 1917.
GROVES, E. W. H.: "Gunshot Injuries of Bones." Lond., Oxford Univ. Press, 1915.
POWER, D. A.: "Wounds in War. Their Treatment and Results." Lond., Oxford Univ. Press, 1915.
JONES, SIR R.: "Injuries of Joints." Lond., Oxford Univ. Press, 1915.
MURPHY, J. K.: "Wounds of the Thorax in War." Lond., Oxford Univ. Press, 1915.
SQUIRE, J. E.: "Medical Hints for the Use of Medical Officers Temporarily Employed with Troops." Lond., Oxford Univ. Press, 1915.
MORISON, R., AND RICHARDSON, W. G.: "Abdominal Injuries." Lond., Oxford Univ. Press, 1915.
RAWLING, L. B.: "Surgery of the Head." Lond., Oxford Univ. Press, 1915.
DUMAS, J., AND CARREL, ANNE: "Technique of the Irrigation Treatment of Wounded by the Carrel Method." N. Y., P. B. Hoeber, 1917.
EDER, M. D.: "War Shock. The Psychoneuroses in War Psychology and Treatment." Lond., Wm. Heinemann, 1917.
HULL, A., J: "Surgery in War." Lond., J. & A. Churchill, 1916.
PENHALLOW, D. P.: "Military Surgery." Lond., Oxford Univ. Press, 1916.
DELORME, E.: "War Surgery." N. Y., P. B. Hoeber, 1915.
DE FRENELLE, D.: "Techniques des opérations et pansements des plaies de guerre." Paris, Memento Dupuy, 1916.
SMITH, G. E., AND PEAR, T. H.: "Shell Shock and its Lessons." Lond., N. Y., etc., Longmans, Green & Co., 1917.
LAGARDE, L. A.: "Gunshot Injuries." N. Y., Wm. Wood & Co., 2d. ed., 1916.
DAKIN, H. D., LEE, W. E., SWEET, J. E., HENDRIX, B. M., AND LE CONTE, R. G.: "A Report of the Use of Dichloramin-T. (Toluene-parasulphondichloramin) in the Treatment of Infected Wounds." Jour. Am. Med. Ass'n, lxix, No. 1, pp. 27–30, July 7, 1917.
LITTLE, E. M.: Brit. Med. Jour., p. 550, Oct. 28, 1917.
LYLE, H. H. M.: Jour. Am. Med. Ass'n, vol. xviii, p. 1140, 1914.
LITTLE, E. M.: Brit. Med. Jour., p. 550, Oct. 27, 1917.
The Medical Bulletin: Pub. by Am. Red Cross in France, vol. I, No. 1 p. 11, November, 1917.
KELLY, M. F.: Brit. Jour. Surg., p. 676, April 16, 1916.
TUFFER: Brit. Jour. Surg., vol. iv, p. 422, 1916.
Official Memorandum on Amputation: London, March, 1916.
Questionnaire: Association of Artificial Limb Manufacturers of the U. S.
SINCLAIR, M.: "Collection of Fracture Apparatus Used in the British Army." Internat. Conference, May, 1917.
BRYAN, C. W. G.: Jour. R. A. M. C., May, 1916.
MARTIN, E. K., AND PETRIE, G. F.: "A Contribution to the Pathology of Projectile Fracture of Limb Bones." Brit. Jour. Surg., vol. v, No. 18, October, 1917.
FLEMING, A.: "On the Bacteriology of Septic Wounds. Lancet, Lond., Sept. 18, 1915.
ADAMI AND JUDAH: Internat. Ass'n, of Med. Museums, Bull. v, June 1, 1915.
GOLDTHWAIT, J. E.: "The Place of Orthopedic Surgery in War." Am. Jour. Orth. Surg., xv, No. 10, p. 679, October, 1917.
GIBSON, C. L.: Brit. Med. Jour., p. 533, April 28, 1917.

INDEX

Abbott's frame in scoliosis, 417, 419
Abdomen, prominent, in rickets, 644
Abdominal paralysis in infantile paralysis, treatment, 693
Abduction in tuberculosis of hip, estimation of, 198
Abscess, alveolar, as focal infection, 285
  prevention, 294
  Brodie's, 531
  cold, in bone tuberculosis, 35
  dumb-bell, 315
  in bone tuberculosis, 42
  in infectious osteomyelitis, 537
  in joint tuberculosis, 41, 44
  intrapelvic, in sacro-iliac joint affections, treatment, 443
  local, in sacro-iliac joint affections, treatment, 443
  of bones, localized, *x*-ray examination in, 168
  shirt-stud, 315
  subcutaneous, as focus of infection, 285, 287
  submucous, as focus of infection, 285
Absence of fibula, congenital, 914
  bone-graft restoration in, 915–919
  of patella, 903
  of radius, congenital, 903
  of tibia, congenital, 914
  of ulna, congenital, 904
Absorbable ligatures in bone surgery, 19
Accessory sinuses as foci of infection, 285, 286
Acetabulum, cartilaginous lining, 190
  in congenital dislocation of hip, 873
  wandering, 192
Achillobursitis, 867
Achillodynia, 867
Achondroplasia, 658
  x-ray examination in, 174
Acquired syphilis of bones and joints, 306
Acromegaly, 380, 654
  clinical features, 654
  differential diagnosis, 655
  etiology, 654
  pathology, 655
  prognosis, 655
  treatment, 655
  x-ray examination in, 171
Acromion, depression of, osteotomy for, 516
Actinomycosis of bones, 317
  of spine, 375
Adduction in tuberculosis of hip, estimation of, 198
Adductor contraction in spastic paraplegia, treatment, 794
Adenitis in tuberculosis of lower jaw, 279
Adenoids, infected, focal infection from, 286
  prevention, 294
Adhesive plaster straps in flatfoot, 854
  in talipes, 825
Adolescence, kyphosis of, 428
  treatment, 428
Adults, kyphosis of, 428
Alar ligaments of knee, 230
Albee's adjustable twin saw, 182
  arthrodesis in arthritis deformans of hip, 458
  in tuberculosis of hip, 215
    Brackett lateral approach in, 216
    indications for, 215
    Smith-Peterson subperiosteal approach in, 216
    technic, 215
  with bone-graft peg in tuberculosis of shoulder, 272
  electric motor operating outfit, 177
    cutting instruments, 181
    description, 179
    foot switch, 179
    guard with spray, 183
    Hartley-Kenyon method of sterilization, 184
    laminatome, 183
    lathe or dowel instrument, 182
    notched drill, 183
    precautions in use of, 186
    requirements, 178
    rotary cutter, 182
    single saw, 181
    small saw, 183
    technic of using, 185
    twin saw, 181
    twist drills, 183
  fish-pole technic of inserting double wedge-ended inlay graft, 582
  fixation dressing in congenital torticollis, 931
  hip-shapers, 186
  for arthroplasty, 972, 973
  inlay method, 148
  laminatome, 183
  method for osteotomy of humerus to restore external rotation, 803
  of arthroplasty, 965
    obtaining fascial flap in, 965
    of hip, 973
      after-treatment, 977
      dressing after, 977
      fat-fascia transplant in, 976
      smoothing new joint surfaces in, 976
      Sprengel-Smith-Peterson incision for, 973

Albee's method of constructing finger by synthetic graft, 1015–1019
of drainage in acute infectious osteomyelitis, 539
of making plaster cast of flatfoot, 855
of transplanting hamstrings in paralysis of quadriceps extensor cruris, 752
of tying knot in kangaroo tendon, 560, 561
modification of Brackett's circular method of osteotomy of femur, 473
of Bradford frame in scoliosis, 417
of Burrell and Lovett's technic for reefing capsule of shoulder-joint, 514
of Jones' operation for displaced semilunar cartilage, 494
of Roberts' technic for astragalus graft in loss of femoral head and neck, 452
motor bone-jack, 186–189
technic of using, 189
osteotome, 101
patellar bone-graft in tuberculosis of knee, 248
position for immobilization of shoulder after manipulation, 515
reamers, 186
rotary bone-peg sharpener, 607
splint in ischemic myositis, 813
technic for improvisation of external malleolus, 920
for restoration in congenital absence of fibula, 915–919
of lower jaw, 1059–1063
in congenital dislocation of hip, 895–900
advantages, 895
bone-pegs in, 898
Smith-Peterson incision in, 896
talipes equinovarus, 833, 835
in fracture of femoral neck, 602
accurate fit in, 609
after-treatment, 610
driving dowel-peg in place, 610
indications for, 604
method of drilling fragments, 605
obtaining tibial graft, 606
shaping dowel-peg, 607
of humerus with bone loss, 1050–1053
of olecranon, 624
of os calcis, 636
in habitual dislocation of patella, 627–630
in infectious osteomyelitis, 544
in paralytic drop-wrist, 770
equinovarus, 762
Soule's modification, 765
scoliosis, with spinal brace, 422
talipes equinovarus, 837
Soule's modification, 839
in pseudarthrosis, after-treatment, 592
in sacro-iliac joint affections, 438
relaxation, 422
in scoliosis, 422, 424
indications for, 423
mechanics of correction by, 423
in spina bifida, 383
Albee's technic in transverse fracture of patella, 615, 617
double T-shaped graft, 618–622
in tuberculosis of ankle, 261
of hip, 222
of knee, 245
closure of incision, 246
exposure of joint, 246
external fixation after, 246
incision for, 245
placing and securing graft, 246
preparation of graft, 245
removal of articulating surfaces, 246
with cuneiform osteotomy, 253
of lower jaw, 280
of lumbar vertebræ and sacro-iliac joints, 441
of metacarpal bones, 269
of metatarsal bones, 269
of phalanges, 270
of skull bones, 278
of spine, 100
bent-shingle method, 110
closure of wound, 108
contra-indications, 116
elements included in graft, 105
exposure, 100
external support after, 114
general postoperative treatment, 113
immediate postoperative treatment, 113
incision for, 100
indications for operation, 116
inlaying graft, 105
management of convalescence, 113
method of bending graft, 108
operative exposure, 100
preparation of graft-bed, 100
prognosis after, 117
protective dressing after, 108
removal of graft, 102
suturing graft, 108
of wrist, 277
in tuberculous osteitis of ankle, 261
in ununited fractures, 569, 572, 573
advantages, 583
after-treatment, 592
armamentarium for, 573
bone-fragment insertions in graft, 580
contra-indications to, 591
fish-pole graft in, 582
fixation dressing for, 592
in small bones, 579
length of graft in, 578
near joints, 585
obtaining graft for, 576
of clavicle, 592
preparation of patient, 572
tibial graft in, 578
with pseudarthrosis, 578
with wedge cross-section, 581
traction operating table, 552–557
treatment of anterior metatarsalgia, 865

Allyl sulphide in tuberculosis of bones, 59
Alveolar abscess as focal infection, 285
prevention, 294
Ambulatory treatment in tuberculosis of hip, 209
of knee, 238
of spine, 96, 124
of displaced semilunar cartilage, 493
American Orthopedic Association report on treatment of scoliosis, 426
Amphiarthrosis, 38
Amputated, life of, 1024
Amputation at ankle, 1004
at battle-front, 1002
at elbow, artificial limb for, 1021
at knee, apparatus for flexion deformity of stump, 1009
at thigh, 1005
at wrist, 1004
attention to soft parts in, 1003
cinematic, through lower third of forearm, 1031
in tuberculosis of ankle, 265
of hip, 225
of joints, 64
of phalanges, 270
of foot, 1004
of forearm, 1004
artificial limbs for, 1016
of hand, 1004
of leg, artificial limb for, 1014
of limbs, management after, 1001
of lower extremity, 1004
artificial limb for, 1013
leg, 1005
of thigh, artificial limb for, 1013
of toes, intra-uterine, 926
of upper arm, artificial limb for, 1021
extremity, 1004
artificial limbs for, 1016
placement of scar in, 1003
relation of technic to, 1002
to site of, 1003
stump, 1002. See *Stumps*.
treatment of bones in, 1003
of nerve-ends in, 1003
Amyloid infiltration in tuberculosis of spine, 82
Aneurism of bones, 956
Ankle, amputation at, 1004
ankylosis of, position of election, 1090
arthrodesis of, with astragalus, 765
arthrotomy of, 525. See also *Arthrotomy of ankle*.
aspiration of, 526
deformities of, 821
in infantile paralysis, treatment, 722
dislocation of, congenital, 524
drainage of, for suppuration, 527
excision of, for tuberculosis, 264
Kocher's method, 264
Ochsner's method, 264
exercises in infantile paralysis, 704
ligaments of, 258
mediotarsal joints and arthrodesis of, in infantile paralysis, 781
movements, 259
Ankle, operations on, 525
sprain of, 523
chronic, 524
treatment, 523, 524
subluxation of, congenital, 524
synovial membrane of, 259
tenosynovitis of, 524
traumatic affections of, 523
tuberculosis of, 258. See also *Tuberculosis of ankle*.
tuberculous osteitis of, bone-graft fixation in, 261
weak, with flatfoot, 851
x-ray examination, 167
Ankylosis, 960
arthroplasty in, 963. See also *Arthroplasty*.
bony, 960
treatment, 962
cartilaginous, 960
causes, 22
congenital, 961
diagnosis, 962
etiology, 961
fibrous, 960
treatment, 962
from gunshot wounds, position of election for, 1080
in proliferative non-tuberculous arthritis, 961
of ankle, position of election, 1090
of flail-joints, 1091
of hip, 464
arthroplasty for, 465. See also *Arthroplasty*.
bony, 465
fibrous, 464
position of election, 1089
of knee, position of election, 1090
of metatarsus, position of election, 1091
of patella to femur in tuberculosis of knee, 251
of shoulder, position of election, 1080
of tarsus, position of election, 1091
pathology, 961
prognosis, 962
prophylaxis, 961
Anterior curvature of spine, 428. See also *Lordosis*.
Antigens, non-specific protein, in chronic infectious arthritis, 299
Antituberculous serums in tuberculosis of bones, 61
Appendicitis as focal infection, 280
Arch supports in flatfoot, 855
Arches of foot, 847
Arm, artificial, Carnes', 1019
Riedinger's, 1022, 1026
deformities of, acquired, 908
congenital, 903
exercises in infantile paralysis, 714
upper, amputation of, artificial limb for, 1021
permanent inward rotation, correction of, 515
Arthrectomy in tuberculosis of joints, 64
of elbow, extracapsular, 520

Arthritis, backache from, 388
treatment, 389
chronic infectious, 320
Bier's hyperemia in, 298
diet in, 297
eradication of infectious foci in, 297
exercises in, 298
hydrotherapy in, 298
hygienic treatment, 297
medical treatment, 297
non-specific protein antigens in, 299
serum treatment, 298
strengthening body defences in, 297
vaccines in, 298
x-ray examination in, 170
deformans, 320
atrophic type, 321
deformity in, 326
juvenile, Perthés' disease and, differentiation, 462
of hip, 453
arthroplasty in, Baer's method, 459
clinical features, 456
diagnosis, differential, 450
etiology, 454
muscular atrophy in, 455
pathology, 454
prognosis, 456
symptoms, 455
treatment, 457
x-ray examination in, 456
of spine, 379
clinical features, 380
etiology, 379
symptoms, 380
pathological types, 320
Preiser's theory, 331
scoliosis with, 409
degenerative, 330
capsule changes in, 335
changes in epiphysis, 334
clinical features, 338
dislocations in, 335
erosions in, 335
etiology, 330
exposure in etiology, 332
Heberden's nodes in, 332
lipoma arborescens in, 334
luxations in, 335
of sacro-iliac joint, 432
pathology, 332
in relation to clinical symptoms, 336
perichondrial new bone in, 335
prognosis, 338
synovial membrane changes in, 335
traumatism in, 330
treatment, 339
local, of joints, 339
operative, 339
results, 380
Goldthwaite's hypertrophic, 330
gonorrheal, 304
clinical features, 305
diagnosis, 305
empyema articuli in, 304
etiology, 304
from focal infection, 291
Arthritis, gonorrheal, from focal infection, 291
treatment, 296
hydrops articuli in, 304
of hip, 453
of sacro-iliac joint, 432
prognosis, 443
pathology, 304
peri-articular suppuration in, 304
phlegmonous inflammation in, 304
prognosis, 305
serofibrinous synovitis in, 304
treatment, 305
infectious, sacro-iliac, 429
of hip, 450
acute, of infancy, operation for drainage, 487
subacute, 453
of infancy, acute, 313
pneumococcal, 313
proliferative, 321
age in, 325
arthrotomy for, 330
bone changes in, 324
brisement forcé for, 330
capsule changes in, 324
changes in, 321
clinical features, 325
diet in, 328
etiology, 321
gross appearances in, 324
luxations in, 324
non-tuberculous, ankylosis in, 961
onset in, 326
order of joint involvement, 327
pathological process in, 322
pathology in relation to clinical symptoms, 325
peripheral ingrowth of synovial pannus in, 323
pituitary extract in, 328
prognosis, 328
proliferation of epiphyseal endosteum in, 323
of perichondrium of articular cartilage in, 323
serum therapy, 330
symptoms, 327
synovial membrane changes in, 322
tags in, 324
thymus extract in, 329
treatment, 328
local, 329
medicinal, 329
operative, 330
vaccines in, 330
pyogenic, of sacro-iliac joint, 432
rheumatoid, 321
staphylococcal, 311
treatment, 312
streptococcal, 310
treatment, 311
typhoid, 314
rheumatic, 314
septic, 314
Arthrodesis, 760
astragaloscaphoid, for paralytic flatfoot, 761

Arthrodesis in infantile paralysis, 760
of ankle and mediotarsal joints in infantile paralysis, 781
with astragalus, 765
with bone-peg in infantile paralysis, 780
of foot, 760
of hip for arthritis deformans, 458
for tuberculosis, 215. See also *Albee's arthrodesis.*
of shoulder for flail-shoulder, 767
of wrist, 770
regional application, 760
transplantation of tendons with, 741
with bone-graft peg in tuberculosis of shoulder, 272
Arthrodia, 38
Arthropathies, 807
Arthropathy, Charcot's, 331, 803, 807
treatment, 804
Arthroplasty, 963
Albee's technic, 965
for ankylosis, 963
Mac Ausland's technic, 968
of elbow, 966
of hip, 405, 973
Albee's technic, 973
Murphy's method, 978
Nélaton's technic, 978
of knee, 979
Murphy's technic, 980
Putti's technic, 976
of patella and femur, 981
of shoulder, 982
of temporomaxillary joint, 968
for arthritis deformans of hip, Baer's method, 459
for tuberculosis of hip, 224
of knee, 255
history, 963
Arthrotomy in proliferative arthritis, 330
in tuberculosis of joints, 64
of ankle, by anterior external incision, 525
by internal incision, 526
by median incision, 526
by circular incision, 526
by posterior external incision, 525
internal incision, 526
of hip, 486
Brackett's anterior incision for, 486
for congenital dislocation, 894
Murphy's incision for, 486
posterior incision for, 486
of shoulder, 516, 519
anterior incision for, 516
externo-lateral incision for, 519
indications for, 516
interno-lateral incision for, 519
Kocher incision for, 516, 517
posterior incision for, 516, 519
rules for, 516
technic, 516
of wrist, 521
anterior incision for, 521
indications, 521
posterior incision for, 521
radial incision for, 521
Articular cartilage, 28
infection, acute, from focal infection, 290
Articulations. See *Joints.*
Artificial arm, Carnes', 1019
Riedinger's, 1022, 1026
supplied by French Government, 1033
with interchangeable holding devices, 1024
hand, Keller's, 1016
limbs, 1001
for amputations at elbow, 1021
of forearm, 1016
of leg, 1014
of lower extremity, 1016
of thigh, 1013
of upper arm, 1021
for lower extremities, 1013
proper location of axis in, 1014
provisional, 1012
Aspiration of ankle, 526
of elbow, 517, 520
of hip, 486
of knee, 507
of wrist, 523
Astragalectomy in infantile paralysis, 776
in paralytic talipes calcaneovalgus, 776
Astragalonavicular joint of foot, 858
Astragaloscaphoid arthrodesis for paralytic flatfoot, 761
Astragalus, curved cuneiform osteotomy of neck and head in congenital talipes, 830
fracture of, 632
treatment, 633
graft for loss of femoral head and neck in septic arthritis, Albee's modification of Roberts' technic, 451
plastic operation on body, in congenital talipes, 830
resection of, for tuberculosis of tarsus, 267
Ataxia, Friedreich's, 804
scoliosis with, 411
hereditary, 804
Athetosis, bilateral, 791
Atony, muscular, sacro-iliac joint affections from, 430
Atrophy of muscles, from disuse, 21, 819
in tuberculosis of elbow, 274
of knee, 233
Attitude in tuberculosis of spine, 84
Autogenous bone-graft, 142
osteoplasty in tuberculosis of spine, 97
tuberculins in tuberculosis of bones, 60
vaccines in tuberculosis of bones, 58
Avulsion of internal tubercle of tibial spine, 496
of spine of tibia, 496

Bacillus typhosus in infectious osteomyelitis, 530
Back brace in tuberculosis of spine, 123
flat, 428
hollow, 428
round, 428
and hollow, 428
strain, chronic, 388

Backache, chronic, 387
clinical features, 388
etiology, 388
from arthritis, 388
treatment, 389
from traumatism, 388
treatment, 388, 389
of pelvic origin, 388
treatment, 388
symptoms, 388
from defective balance, 388
static, 388
treatment, 389
uterine, 388
Bacteria, transmutability of, in focal infection, 289
Baer's technic for arthroplasty of hip in arthritis deformans, 459
Balkan frame, adjustable, 562, 563, 1045
Ball-and-socket joints, 39
Bandage of stump, 1008
plaster-of-Paris. See *Plaster-of-Paris bandage.*
Bands, accessory, of hip, 191
Barlow's disease, 652
treatment, 653
Bartlett's apparatus for reducing congenital dislocation, of hip 891
Bartow's silk ligaments for paralytic conditions at knee, 506
Baseball-player's finger, 912
Baths for stump, 1008
Beck's bismuth paste in tuberculosis of bones, 62
in tuberculous bone sinuses, 58
Bed-frame, Balkan, 562, 563, 1045
Bed-sores after fracture-dislocation of spine, treatment, 359
Bent-shingle technic in tuberculosis of spine, 110
Bier's hyperemia in chronic infectious arthritis, 298
in tuberculosis of bones, 53
of elbow, 274
of joints, 64
of knee, 239
in tuberculous bone sinuses, 59
osteoplastic re-amputation of leg, 1011
Biesalski-Mayer method of transplanting peroneus longus for tibialis anticus, 750
tibialis anticus for paralysis of pronators of foot, 747
Biesalski's method of tendon transplantation, 735
Bifid spine, 381. See also *Spina bifida.*
Billroth splint in tuberculosis of knee, 252
Binnie's lever in congenital dislocation of hip, 892
Birth paralysis, 797. See also *Obstetrical paralysis.*
Bismuth paste injection in tuberculosis of bones, 62
in tuberculous bone sinuses, 58
Blood-vessels, changes in, in bone tuberculosis, 32
in joint tuberculosis, 40
Boarding in tuberculosis of spine, 87
Bodies, rice, 41
Boiled bone for bone-grafting, 145
Bond's theory, 154
Bone-corpuscles, 28
Bone-graft, astragalus, for loss of femoral head and neck in arthritis, Albee's modification of Roberts' technic, 451
autogenous, 142
in osteitis fibrosa cystica of femur, 949
bridge, from sacrum to wing of ilium, in sacro-iliac joint affections, 438
changes in, 143
contacting of bone elements in, 148
contra-indications to, 161
dowel-peg in fracture of femoral neck, 602
of olecranon, 624
elements included in, 107
factors controlling growth and development, 150
in failure, 143
failures in use of, 143
fixation for paralysis in tuberculosis of spine, 136
in spondylolisthesis, 350
in tuberculosis of ankle, 261
of hip, 222
of spine, 100, 132. See also *Albee's technic.*
of wrist, 277
germ-resisting properties, 588
heteroplastic, 144
homoplastic, 144
fibrous encapsulation in, 144
ilium, in restoration of lower jaw, 1059–1063
importance of periosteal covering in, 155
improvisation of external malleolus, 920
in paralytic drop-wrist, 770
in tuberculosis of skull bones, 279
of spine, 99
indications for, 159
inlay, 148
advantages, 149
after excision of cyst of upper end of femur, 464
for fixation in tuberculous osteitis of knee in adult, 242
for restoration after subperiosteal resection in tuberculosis of lower jaw, 280
for spina bifida, 383
from wing of ilium to spine in tuberculosis of lumbar vertebræ and sacro-iliac joint, 441
in cysts of humerus, 948
in fracture of lower jaw with bone loss, 1054, 1059
in sarcoma of lower jaw with partial removal, 1056
in transverse fracture of patella, 615
in ununited fractures, 569, 572. See also *Albee's technic.*
into joint, in sacro-iliac joint restoration, 440
range of applicability, 150

Bone-graft, inlay, with cuneiform osteotomy, in tuberculosis of knee, 253
intramedullary, 140
in ununited fractures, 582
ivory, 140
Kausch's table of value of materials for, 140
mortise, for paralytic equinovarus, 762
nutrition of, 143
osteoconductive theory, 144
osteogenetic theory, 144
peg, arthrodesis with, in tuberculosis of shoulder, 272
in fracture of os calcis, 636
preservation of, 157, 158
restoration with resection in tuberculosis of metacarpal bones, 269
of metatarsal bones, 269
of phalanges, 270
rhinoplasty by, 309
rôle of, 145
selection of bone for, 154
sliding, in compound fracture of tibia, 590
tibial, in fracture of frontal bone, 1064–1069
of humerus with bone loss, 1050–1053
in tuberculosis of knee, 245
wedge between split halves of scaphoid in congenital talipes, 833, 835
in habitual dislocation of patella, 627–630
in paralytic talipes equinovarus, 839
in pronated flatfoot, 860
remodeling in congenital dislocation of hip, 895–900
with boiled bone, 146
Bone-grafting, bone-seed in, 148
fundamental principles underlying, 142
rules for, 147
Bone-jack, motor, 186–189
technic of using, 189
Bone-marrow, 28, 29
cells, 29
changes in, in tuberculosis, 31
embryonic, 29
in infectious osteomyelitis, 534, 536
myxomatous, 29
red, 29
yellow, 29
Bone-peg arthrodesis in infantile paralysis, 780
Bones, actinomycosis of, 317
affections of, from focal infection, treatment, 295
aneurism of, 956
architecture, laws of, 24
canaliculi, 28
cancellous, 27
changes in, in joint tuberculosis, 40
chondroma of, 938
compact, 27
cortex, in infectious osteomyelitis, 535, 536
cystic appearances, differential *x*-ray diagnosis in, 170
cysts of, 938. See also *Cysts of bones*.
Bones, diseases of, *x*-ray examination in, 167
endothelioma of, 955
excessive malleability, scoliosis from, 408
exostoses of, cancellous, 938
fibrocystic disease of, 938. See also *Fibrocystic disease of bones*.
fibroma of, 938
furunculosis of, 530
gunshot wounds of, 1034. See also *Gunshot wounds*.
hydatid cysts of, 317
hypertrophy of, 154
hysterical affections of, 809
infectious diseases of, 303
injuries to, *x*-ray examination in, 164
interspaces, 28
ivory exostoses of, 937
lamellæ, 28
localized abscess, *x*-ray examination, 168
microscopic anatomy, 28
myeloma of, 955
neoplasms of, 937
benign, 937
malignant, 952
neuromimetic affections of, 809
neuropathic conditions of, 806
newgrowths of, malignant, primary, 952
secondary, 956
x-ray examination in, 169
normal anatomy, 27
osteogenetic power, 22
physics of, 24
posttyphoid lesions, *x*-ray examination in, 168
power of regeneration, 151
sarcoma of, 952. See also *Sarcoma of bones*.
selection of, for graft, 154
shaft, 28
superiority of, over soft tissue as stabilizing and supporting agent, 19
syphilis of, 306
acquired, 306
hereditary, 308
treatment, 309
x-ray examination in, 168, 174
traumatic lesions, *x*-ray examination in, 174
treatment of, in amputation, 1003
tuberculosis of, 26. See also *Tuberculosis of bones*.
tumors of, 937
benign, 937
malignant, 952
typhoid affections, 315. See also *Typhoid bone affections*.
x-ray examination, in children, 171
Bone-sand, 32, 35
Bone-seed in bone-grafting, 148
Bony ankylosis, 960
treatment, 962
outgrowths of foot, 845
Bouton de chemise, 315
Bow-legs. See *Genu varum*.
Brace for flatfoot, 857
Goldthwait, in sacro-iliac joint sprain, 437
in anterior metatarsalgia, 866

Brace in infantile paralysis, 693
in rigid flatfoot, 859
Kleinberg's spinal, for rotation in scoliosis, 420
Knight's, in genu varum, 648
Orr's spinal, for rotation in scoliosis, 419
Osgood's, in sacro-iliac joint sprain, 437
Thomas', in genu valgum, 646
Brachial plexus, infraclavicular lesions of, 802
operative exposure, 1079
supraclavicular lesions, 797
wounds of, contractures following operative treatment, 802
deformities from, 797
from cervical ribs, 801
from exostoses, 801
symptoms, 1072
treatment, 1074
Brachioradialis, transplantation of, in paralysis of flexors of hand and fingers, 757
Brachydactylia, 907
Brackett's anterior incision for arthrotomy of hip, 486
circular osteotomy in tuberculosis of hip, 219
of femur, 472
Albee's modification, 473
lateral approach in arthrodesis of hip, 216
operation for ununited fracture of neck of femur, 611
Bradford and Goldthwaite's genuclast in tuberculosis of knee, 252
Bradford's apparatus for forced extension in congenital dislocation of hip, 892
frame, Albee's modification, for scoliosis, 417
hip-splint in tuberculosis of hip, 211
method in internal rotation in congenital dislocation of hip, 890
Bradford-Whitman frame in tuberculosis of spine, 122, 123
Brain in infantile paralysis, 672
Bratz apparatus for torticollis, 930
Brickner's operation for subacromial bursitis, 510
sign in subacromial bursitis, 509
Brisement forcé for proliferative arthritis, 330
British Government's classification of orthopedic surgical conditions, 17
Medical Association report on treatment of fractures, 567
Brodie's abscess, 531
Bromidrosis of feet, treatment, 844
Bronchiectasis, chronic, as focal infection, 286
Bronchitis, chronic, as focal infection, 286
Bucholz and Osgood's method of recording curvature in scoliosis, 402
Bunge's aperiosteal method of amputation, 1003
Bunion, 860. See also *Hallux valgus*.
Burrell and Lovett's technic for reefing capsule of shoulder-joint, Albee's modification, 514
Bursa, gluteal, operative exposure, 486
subdeltoid, 508
Bursæ of foot, affections of, 867
subacromial, anatomy, 507
pathogenesis, 507
Bursitis, gluteal, 485
iliopsoas, 485
prepatellar, 504
pretibial, 505
subacromial, 507
Brickner's sign in, 509
clinical features, 509
Dawbarn's sign in, 509
diagnosis, 510
etiology, 509
internal rotation in, 509
laceration of tendons in, 509
limitation of abduction in, 509
swelling in, 509
tenderness in, 509
treatment, non-operative, 510
operative, 510
x-ray examination in, 509
subdeltoid, tuberculosis of shoulder and, differentiation, 271
Butler splint, 1034, 1035

Calcaneobursitis, 846, 868
Calcaneocavus in infantile paralysis, treatment, 723
paralytic, Jones' operation for, 777
Calcaneocuboid joint of foot, 858
Caliper convalescent splint in tuberculosis of knee, 239
Calmette's reaction in bone tuberculosis, 44
Calot's correction of deformity in tuberculosis of spine, under anesthesia, 132
grand jacket in tuberculosis of spine, 126
injection treatment in tuberculosis of knee, 239
method in internal rotation in congenital dislocation of hip, 890
of reducing unilateral congenital dislocation of hip, 880–888
retention after, 885
military jacket in tuberculosis of spine, 126
plaster jacket in tuberculosis of spine, 133
Cambium layer of periosteum, 155
Cancellous bone, 27
Cancer of bone, *x*-ray examination in, 169
of hip, 463
of spine, 375
Capsular ligament of hip, 190
of knee, 230
Capsule, joint, 38
Carbuncle as focal infection, 287
Carcinoma. See *Cancer*.
Caries carnosa, 33
of shoulder, 271
sicca, 33, 41
of shoulder, 270
clinical features, 271
Carnes' artificial arm, 1019
Carpal bones of wrist, 276
scaphoid fracture of, 637

Carrel-Dakin method in infectious osteomyelitis, 542
in war wounds, 995
Carriers of infantile paralysis, 687
Carrying angle, 645
Cartilage, articular, 28
hyaline, 28
changes in, in joint tuberculosis, 39
epiphyseal, 28
of joints, 28, 38
hyaline, 38
semilunar, of knee, 230
Cartilaginous ankylosis, 960
lining of acetabulum, 190
Cautery, actual, in tuberculosis of knee, 239
Cerebral diplegia, 790
paralysis of childhood, 790
Cerebrospinal fluid in diagnosis of infantile paralysis, 685
in infantile paralysis, 671
Cervical coxa valga, *x*-ray examination in, 175
vara, 466. See also *Coxa vara, cervical.*
lymphadenitis as focal infection, 286
ribs, 385
arterial effects, 386
clinical features, 385
diagnosis, 386
injuries to brachial plexus from, 801
nervous effects, 386
operation for excision, 386
prognosis, 386
symptoms, 386
treatment, 386
x-ray examination in, 171
Cervicodorsal scoliosis, 405
Chair deformity in rickets, 651
Charcot-Marie-Tooth type of pseudohypertrophic muscular paralysis, 809
deformities in, 809
Charcot's arthropathy, 331, 803, 807
treatment, 804
Chest, rachitic, 644
Chilblains, 846
Children, hip-joint lesions in, *x*-ray examination in, 175
kyphosis of, 427
spastic paralysis of, 790. See also *Spastic paralysis.*
syphilis of hip in, *x*-ray examination in, 176
tuberculous osteitis of knee in, treatment, 240
Chisels, types of, 562
Cholecystitis as focal infection, 287
Chondro-arthritis, gummatous, 307
Chondrodystrophia fetalis, 658
x-ray examination in, 173
Chondroma of bones, 938
Chorea, congenital, 791
Choreic diplegia, 791
Cicatricial contraction, scoliosis from, 411
Cinematic amputation through lower third of forearm, 1031
apparatus for stump, 1031
Circumflex nerve, operative exposure, 1079
wounds of, symptoms, 1072
treatment, 1074
Clavicle, abnormalities of, 385
cysts of, 941
defects of, 385
Claw-foot, 830
of first degree, treatment, 840
of fourth degree, treatment, 842
of second degree, treatment, 840
of third degree, treatment, 841
tendon transplantation in, 744
Claw-hand, 906
Cleft-hand, 906
Club-foot, 821. See also *Talipes.*
Club-hand, 905
Clubbed nails in hypertrophic pulmonary osteo-arthropathy, 659
Coccydynia, 348
Coccygodynia, 348
operation for, 349
treatment, 348
Codivilla's method in internal rotation in congenital dislocation of hip, 890
Coffee-ground vomitus in infantile paralysis, 675
Cold abscess. See also *Ichor pockets.*
Collodion, salicylic, for corns, 844
Colon, transverse, changes in, in scoliosis, 400
Command depots for wounded soldiers, 998
Condyloid joints, 30
Congenital dislocation of hip, 873. See also *Dislocation of hip, congenital.*
Constitutional affections producing general and localized distortions, 640
Contracted foot, 839. See also *Claw-foot.*
toes, 843
Contraction, congenital, of fingers, 905
Dupuytren's contracture and, differentiation, 910
of tendo Achillis, right-angled, 925
Contracture of palmar fascia, Dupuytren's, 909. See also *Dupuytren's contracture.*
of stumps, 1009
of tendons, hemiplegic, Dupuytren's contracture and, differentiation, 910
Contusions of spine, 347
Cook's operation for relapsed congenital talipes, 828
Corns, papilloma from, treatment, 844
treatment, 844
Coronal ligament of knee, 231
Corset, improper, sacro-iliac joint affections from, 430
plaster-of-Paris, in scoliosis, 426
Van Winkle, in sacro-iliac joint sprain, 437
Corset-brace, Van Winkle's, in scoliosis, 427
Costotransversectomy for ichor pockets in tuberculosis of spine, 130
for paralysis in tuberculosis of spine, 137
Cottrell and Gibney's treatment for flat-foot, 854
Cotyloid ligament of hip, 190
notch, 190

Counterextension in tuberculosis of joints, 64
Counterirritation in tuberculosis of joints, 64
Coxa valga, 484
acquired, 484
cervical, *x*-ray examination in, 175
congenital, 484
associated with dislocation of hip, 484
diagnosis, 485
etiology, 484
from amputation through thigh, 484
from infantile paralysis, 484
in rickets, 645
signs, 484
symptoms, 484
treatment, 485
vara, 465
adolescent, 470
treatment, 476
anatomical types, 466
bilateral, symptoms and signs, 469
cervical, 466
forcible abduction with plaster-of-Paris fixation in, 471
mechanical deformity in, 469
osteotomy in, 471–476
symptoms and signs, 469
x-ray examination in, 175
classification, 468
clinical features, 469
congenital, 470
clinical features, 470
congenital dislocation of hip and, differentiation, 471
diagnosis, 471
etiology, 470
x-ray examination in, 470
epiphyseal, 466, 470
treatment, 476
etiology, 467
false, 467
from rickets, 467
in rickets, 645
infantile, Perthés' disease and, differentiation, 462
traumatic, treatment, 476
treatment, 471
trochanteric, 466
forcible abduction with plaster-of-Paris fixation in, 471
mechanical deformity in, 469
osteotomy in, 471–476
symptoms and signs, 469
varieties, 467
tuberculous, Perthés' disease and, differentiation, 462
unilateral, symptoms and signs, 469
varieties, 470
Coxitis, tuberculous, congenital dislocation of hip and, differentiation, 471
Craniotabes, 643
Cranium. See *Skull*.
Crinolin for plaster-of-Paris bandage, 986
Crucial ligaments of knee, 230
rupture of, 495
Cubitus valgus in rickets, 644
varus in rickets, 644
Cuboid, fracture of, 637
osteotomy in congenital talipes, 829
Cuneiform, fracture of, 637
osteotomy, curved, of neck and head of astragalus, in congenital talipes, 830
in hallux valgus, 863
internal, in congenital talipes, 829
of os calcis, in congenital talipes, 831
with inlay bone-graft in tuberculosis of knee, 253
Cureting in tuberculosis of joints, 64
Curvature of leg, congenital, 914
of spine, anterior, 428. See also *Lordosis*.
lateral, 396. See also *Scoliosis*.
posterior, 427. See also *Kyphosis*.
of tibia, syphilitic, 308
Cutaneous nerve, internal, operative exposure, 1079
Cystitis as focal infection, 287
Cysts, dentigerous, tuberculosis of lower jaw and, differentiation, 279
of bones, benign, 938
hydatid, 317
of hands, 947
of feet, 947
x-ray examination in, 170
of clavicle, 941
of femur, 941
at lower end, 946
differential diagnosis, 942
echinococcus, 464
pathology, 946
treatment, 949
x-ray examination in, 942
of humerus, 939
bone-graft inlay in, 948
clinical history, 939
deformity in, 940
diagnosis, 940
etiology, 941
fracture in, 939
pain in, 940
pathology, 940
treatment, 948
x-ray examination in, 940
of knee, 505
of patella, 947
of pelvic bones, 947
of radius, 941
of skull, 947
of tibia, 946
of ulna, 941
of upper end of femur, 463
clinical history, 463
etiology, 463
excision, inlay bone-graft after, 464
mass of new growth in, 464
pathology, 464
sarcoma and, differentiation, 464
traumatic fracture of femur and, differentiation, 464
treatment, 464
x-ray examination in, 463

Dactylitis, syphilitic, 308
spina ventosa and, differentiation, 269
Dakin-Carrel method in infectious osteomyelitis, 542
in war wounds, 995
Dane hip-splint in tuberculosis of hip, 212
Dawbarn's sign in subacromial bursitis, 509
Deformities from degeneration of spinal cord, 803
from facial nerve paralysis, 707
from injuries to brachial plexus, 707
to spinal accessory nerve, 707
from multiple neuritis, 805
from muscular dystrophies, 808
from myopathies, 808
in congenital dislocation of hip, 877
in cysts of humerus, 940
in flatfoot, 850
in infantile paralysis, 678, 721. See also *Infantile paralysis, deformities in.*
in locomotor ataxia, 803
in peroneal type of muscular atrophy, 809
in proliferative arthritis, 326
in pseudohypertrophic muscular paralysis, 808
in rickets, 643
in scleroderma morphea, 661
in tabes dorsalis, 803
in tuberculosis of ankle, corrective treatment, 265
of elbow, 274
of hip, gradual correction, 214
treatment, 214
of joints, correction, 64
of knee, 233
correction, 251
forcible, by reverse leverage, 251
mechanical, 251
operative, 252
following treatment, 235
of spine, gradual correction, 133
operative correction, 132
pelvic, 79
recording, 88
thoracic, 79
of wrist, 276
Madelung's, 908
mechanical, in coxa vara, 469
of ankle, 821
of arms, acquired, 908
congenital, 903
of fingers, acquired, 909
of foot, 821
acquired, 921
congenital, 912
in infantile paralysis, 698
treatment, 722
non-congenital, 839
static, 847
of hands, acquired, 908
congenital, 903
of hip, 464
of legs, acquired, 921
congenital, 912
of lower extremity in spastic paraplegia, treatment, 794
of neuropathic origin, 803
Deformities of pelvis in tuberculosis of spine, 79
of spine, congenital, 381
static, 396
with malformation of other parts, 385
without malformation of other parts, 381
of thorax, in tuberculosis of spine, 79
of toes, congenital, 921
static, 860
of upper extremity in spastic paraplegia, treatment, 793
paralytic, following nerve injuries, 705
Sprengel's, 512. See also *Sprengel's deformity.*
Degenerative arthritis, 330. See also *Arthritis, degenerative.*
Deltoid ligament of ankle, 258
paralysis, transplantation of pectoralis major in, 755
Dentigerous cyst, tuberculosis of lower jaw and, differentiation, 279
Diaphyseal osteotomy in tuberculosis of knee, 254
Diaphysis, 29
Diarrhea in infantile paralysis, 676
Diarthrosis, 38
rotatoria, 39
Dichloramin-T in war wounds, 996
Didot's operation for webbed fingers, 907, 908
Diet in bone tuberculosis, 52
Digestive system in infantile paralysis, 675
Diplegia, cerebral, 790
choreic, 791
Dislocation in degenerative arthritis, 335
of ankle, congenital, 524
of forefoot, traumatic, 525
of hip, 447
congenital, 873
acetabulum in, 873
arthrotomy in, 894
at five to six years, bilateral, 893
reduction, 892
unilateral, 891
at two to three years, bilateral, 889
unilateral, 880–888
retention of reduction, 885
bilateral, 876
bone-graft wedge remodeling operation in, 895–900
capsule in, 874
clinical features, 876
complete, 876
diagnosis, 877
congenital coxa vara and, differentiation, 471
coxa valga associated with, 484
deformities in, 877
developmental theory, 876
diagnosis, 877
differential, 879
etiology, 876
frequency, 873
gluteus maximus in, 875
head of femur in, 873
history, 873

Dislocation of hip, congenital, incomplete, 876
diagnosis, 877
ligamentum teres in, 875
lordosis in, 876
manipulative treatment, 879
results, 894
mechanical theory, 876
muscles in, 875
neck of femur in, 874
occurrence, 873
pathological anatomy, 873
pelvicrural group of muscles in, 875
pelvifemoral group of muscles in, 875
pelvis in, 874
pelvitrochanteric group of muscles in, 875
position of head of femur in, 879
prognosis, 879
psoas tendon in, 875
reduction, abduction after, treatment, 889
accidents and complications, 894
flexion after, treatment, 889
internal rotation after, treatment, 889
reluxations after, treatment, 890, 893
rupture of nerve trunks with paralysis in, 894
tearing capsule in, 894
soft parts in, 874
spondylolisthesis and, differentiation, 350
treatment, 879
Trendelenburg's sign in, 875
tuberculous coxitis and, differentiation, 471
unilateral, 874, 876
varieties, 875
x-ray examination in, 175
in infantile paralysis, 699
operative, for tuberculosis, 225
paralytic, 448
treatment, 448
posttyphoidal, 314
spontaneous, 449
of knee, congenital, 503
symptoms, 503
treatment, 503
of patella, acquired, 921
treatment, 923
habitual, 624
bone-graft wedge in, 627–630
Dumferline's operation in, 625
Goldthwait's operation for, 626
Graser's operation for, 626
knock-knee with, 625
Krogius' operation for, 625
Murphy's operation for, 626
Whitlock's operation for, 625
of shoulder, congenital, 512
habitual, 513
treatment, 513
operative, 514
tuberculosis and, differentiation, 272
of spine, 352
Dislocation of spine, symptoms, 352
treatment, 353
Walton's method of reduction, 353
of tibia in knee tuberculosis, 232
x-ray examination in, 166
Disuse atrophy of muscles, 21, 819
Dorsal scoliosis, primary, 404
Dorsolumbar scoliosis, 404
Dowel instrument of motor outfit, 182
Drainage of ankle for suppuration, 527
of elbow, 519
of hand for suppuration, 523
of hip for suppuration, 487
of shoulder for suppuration, 517
of wrist for suppuration, 523
Drekmann's operation in ischemic myositis, 814
Drill, notched, for motor outfit, 183
twist, for motor outfit, 183
Drop-foot. See *Talipes equinus*.
Drop-wrist, paralytic, Albee's technic in, 770
Duchenne type of pseudohypertrophic muscular paralysis, 808
deformities in, 808
Dumb-bell abscess, 315
Dumferline's operation for habitual dislocation of patella, 625
Dupuytren's contracture, 909
causation, 909
congenital contraction of fingers and, differentiation, 910
etiology, 909
fingers affected in, 909
open operation in, 911
osteo-arthritis with contraction of hand and, differentiation, 910
pathology, 909
prognosis, 910
symptoms, 910
tendon adhesions and, differentiation, 910
treatment, 910
Dura in infantile paralysis, 671
Dysbasia angiosclerotica, 847
Dystrophies, muscular, deformities from, 808

Echinococcus cysts of femur, 464
Elbow, amputation at, artificial limb for, 1021
ankylosis of, position of election, 1088
arthrectomy of, extracapsular, 520
arthrodesis of, 768
arthroplasty of, for ankylosis, 966
MacAusland's technic, 968
aspiration of, 517, 520
drainage of, 519
exercises in infantile paralysis, 715
flail-, 517. See also *Flail-elbow*.
flexion deformity at, with excessive pronation, in spastic paraplegia, treatment, 793
injection of, 520
in chronic synovitis, 517
normal anatomy, 273
operations on, 519

Elbow, synovitis of, chronic, 517
tennis, 517
traumatic affections of, 517
tuberculosis of, 273. See also *Tuberculosis of elbow.*
x-ray examination, 160
Electric motor operating outfit, 177. See also *Albee's electric motor operating outfit.*
reaction of degeneration in infantile paralysis, 677
Electricity in infantile paralysis, 700
introduction into orthopedic surgery, 18
Elevation of scapula, congenital, 387, 512. See also *Sprengel's deformity.*
Embryonic bone-marrow, 29
Emetin in pyorrhea dentalis, 294
Empyema articuli in gonorrheal arthritis, 304
as focal infection, 286
scoliosis from, 411
Enarthrosis, 30
Enchondroma of bone, *x*-ray examination in, 169
of hand or foot, spina ventosa and, differentiation, 269
of spine, 375
Endameba buccalis in focal infection of teeth, 286
Endarteritis obliterans in bone tuberculosis, 32
End-bearing stumps, 1002, 1008
Endometritis as focal infection, 287
Endothelioma of bones, 955
Epidemic poliomyelitis, 665
Epiphyseal cartilage, 28
coxa vara, 466. See also *Coxa vara, epiphyseal.*
Epiphysis, 28
separation of, *x*-ray examination in, 174
Epiphysitis of hip, acute, 450
syphilitic, 308
rickets and, differentiation, 642
Epistaxis in infantile paralysis, 674
Erasion, bone-graft with, in tuberculosis of knee, 245. See also *Albee's tibial bone-graft.*
Erb type of pseudohypertrophic muscular paralysis, 808
Erb-Duchenne type of obstetrical paralysis, 798
operation for, 800
Erythromelalgia, 846
Esmarch's tourniquet in tendon transplantation, 731
Esophagus, changes in, in scoliosis, 400
Excision in tuberculosis of joints, 64
of ankle for tuberculosis, 264
Kocher's method, 264
Ochsner's method, 265
of cervical rib, operation for, 386
of elbow for tuberculosis, 275
of hip-joint for tuberculosis, 223
of knee for tuberculosis, 249
of war wounds, 995
of wrist, 521
for tuberculosis, 277
Exercises in chronic infectious arthritis, 298
in flatfoot, 853
in infantile paralysis, 703–721
in scoliosis, 414
Exostoses, cancellous, 938
injuries to brachial plexus from, 801
ivory, 937
of foot, 845
of spine, 375
x-ray examination in, 169
Extension in tuberculosis of ankle, 261
Extensor carpi radialis brevis, transplantation of, in paralysis of flexors of hand and fingers, 757
longus, transplantation of, in paralysis of flexors of hand and fingers, 757
communis digitorum, transplantation of, for paralysis of extensor pollicis longus, 758
proprius hallucis, transplantation of, in talipes equinovarus, 744

Face bones, syphilis of, hereditary, 308
rachitic deformity of, 643
Facial nerve paralysis, deformities from, 797
Faradic reaction in infantile paralysis, 677
Fascia of spine, 75
Fascial transplantation in flail-elbow, 518
Faucial tonsils as foci of infection, 285
Feet. See *Foot.*
Femur and patella, ankylosis of, arthroplasty for, 981
ankylosis of patella to, in tuberculosis of knee, 251
cysts of, 941. See also *Cysts of femur.*
fracture of neck, 595. See also *Fractures.*
of upper end, juxta epiphyseal, 476. See also *Fractures.*
head of, in congenital dislocation of hip, 873
neck of, angles of inclination, 465
in congenital dislocation of hip, 874
osteitis fibrosa cystica of, autogenous bone-graft in, 949
sarcoma of, cysts and, differentiation, 464
upper end, cyst of, 463
Fibrocartilage of joints, connecting, 38
interarticular, 38
marginal, 38
white, 38
Fibrocystic disease of bones, 938
clinical types, 947
distribution of, 939
multiple, 947
Fibroma of bone, 938
Fibrous ankylosis, 960
treatment, 962
Fibula, congenital absence, 914
bone-graft restoration in, 915–919
osteotomy of, in congenital talipes, 830
Fillet jacket in tuberculosis of spine, 127
Finger, baseball players', 912
construction of, by synthetic graft, Albee's method, 1015–1019
exercises in infantile paralysis, 714
mallet-, 912

Finger, trigger-, 911
treatment, 912
Finger-drop, transplantation of flexor carpi radialis in, 755
Fingers, contraction of, congenital, 905
Dupuytren's contracture and, differentiation, 910
deformities of, acquired, 909
hypertrophy of, 908
supernumerary, 906
suppression of, 906
web, 906
Didot's operation for, 907, 908
Fixation by plating in tuberculous osteitis of knee in adult, 241
end results, 242
in tuberculosis of ankle, 260
of joints, 64
of knee, 236
of wrist, by bone-graft, 277
plaster-of-Paris, 277
of tendons, 1083
Flail-elbow, 517
arthrodesis in, 768
fascial transplantation in, 518
operative treatment, 518
silk ligaments in, 518
Flail-joints, ankylosis of, 1091
Flail-shoulder, arthrodesis in, 766
Flat back, 428
Flatfoot, 849
abduction and eversion in, 852
adduction or inversion in, 851
adhesive plaster straps in, 854
Albee's cast for brace in, 855
arch supports in, 855
associated pathologic changes, 849
attitudes in, 851, 853
bearing surface in, 851
brace for, adjustment, 858
modification, 858
building up shoes in, 853
Cottrell and Gibney's treatment, 854
deformity in, 850
diagnosis, 851
disability in, 850
distribution of weight and strength in, 851
etiology, 850
exercises in, 853
flexion and extension in, 851
in rickets, 651
in soldiers, 1084
intrinsic causes, 850
irregular types, 851
mechanism of pronation in, 849
metal brace for, 857
operative treatment, 860
pain in, 850
paralytic, astragaloscaphoid arthrodesis in, 761
passive motion in, 852
predisposing causes, 850
prognosis, 852
pronated, bone-graft wedge in, 860
range of motion in, 851
rigid, brace in, 859
Flatfoot, rigid, forcible overcorrection, 859
tenotomy of tendo Achillis in, 859
treatment, 858
shape, 851
shoes in, 853
swelling in, 850
symptoms, 850
tabetic, 803
Thomas wrench in, 859
treatment, 852
types, 850
in childhood, 851
Whitman's cast for brace in, 856
with weak ankle, 851
Flexion deformity at elbow with excessive pronation in spastic paraplegia, treatment, 793
at wrist in spastic paraplegia, treatment, 793
Flexor carpi radialis, transplantation of, in paralysis of extensors of digits and hand, 755
longus hallucis, transplantation of, in talipes valgus, 751
Focal infection, 285
acute articular infection from, 290
osteomyelitis from, 291
affections of bones from, treatment, 295
of joints from, treatment, 295
bone infections related to, 290
channels of dissemination in, 289
chronic infectious arthritis from, treatment, 296
diagnosis of focus in, 288
etiology, 285
gonococcal arthritis from, 291
treatment, 296
hematogenous dissemination, 289
immunity in, acquired, 288
natural, 288
joint infections related to, 290, 292
lymphogenous dissemination, 289
osteomyelitis from, treatment, 296
personal cleanliness in prevention, 294
prevention, 294
primary, location of, 285
systemic intoxication from, 289
transmutability of bacteria in, 289
treatment, 294
reaction in bone tuberculosis, 45
Foot, amputation of, 1004
anterior metatarsal arch, 847
arches of, 847
arthrodesis of, 760
as lever in walking, 848
astragalonavicular joint, 858
bones, cysts of, 947
bony outgrowths, 845
bromidrosis of, treatment, 844
bursæ, affections of, 867
calcaneocuboid joint, 858
circulatory disturbances of, 846
contracted, 839. See also *Claw-foot.*
deformities of, 821. See also *Deformities of foot.*
exercises in infantile paralysis, 703
exostoses of, 846

Foot, functions of, 848
hollow, 830. See also *Claw-foot*.
hooking up extensors, in infantile paralysis, 780
in standing, 848
internal arch of, 848
longitudinal arch, 847
Madura, 318
mechanical center, after tendon transplantation, 750
movements, 848
pain in soles, 844
pronated, 840
Raynaud's disease of, 846
splay, 840
sprain of, 523
chronic, 524
treatment, 523, 524
structure of, 847
tendons, affections of, 867
tenodesis of, 771
transplantation of tendons of, 742
transverse section of, for paralytic talipes calcaneocavus, 781
traumatic affections of, 523
weak, 840
Forbes' apparatus in scoliosis, 421
operation for anterior metatarsalgia, 866
Forced manual correction in tuberculosis of hip, 220
Forceps, stirrup, for nerve operations, 1071
Forearm, amputation of, 1004
artificial limbs for, 1016
ankylosis of, position of election, 1088
lower third, cinematic amputation through, 1031
Forefoot, dislocation of, traumatic, 525
Fork and knife combined, for one-armed, 1028
Formalin-glycerin injection for infectious synovitis of hip, 486
Fracture-dislocation of spine, 355
bed-sores in, treatment, 359
diagnosis in transverse lesions of cord following, 358
indications for operation, 357
location, 356
prognosis, 358
Fractures, armamentarium for treatment, 552
Balkan bed-frame for, 1045
frame for, 562, 563
indications for operative treatment, 565
juxta-epiphyseal, *x*-ray examination in, 174
kangaroo tendon in, 555
metal fixation in, dangers of, 570
of astragalus, 632
treatment, 633
of carpal scaphoid, 637
of clavicle, bone-graft inlay in, 592
of cuboid, 637
of cuneiform, 637
of external tubercle of tibial spine, 496
of femur, traumatic, cysts and, differentiation, 464
ununited, 566
Fractures of fibula, ununited, 565
of forearm, ununited, 568
of frontal bone, tibial bone-graft in, 1064–1069
of hip, 447
of humerus, ununited, 564, 584
with bone loss, tibial bone-graft in, 1050–1053
of ilium, operative exposure for, 485
of joints, treatment, 1043
of long bones, malunited, 549
ununited, 549
of lower jaw with bone loss, inlay bone-graft in 1054, 1059
of neck of femur, 595
bone-graft in 602. See also *Albee's technic*.
deficiency of periosteum in, 602
deficient osteogenesis in, non-union from, 601, 602
in adults, 483
in children, 481
diagnosis, 482
treatment, 482
interposition of capsule, non-union from, 601
intracapsular location, non-union from, 601
mechanics, 601
non-operative treatment, 600
obstacles to union in, 601
poor blood-supply in, 602
small diameter of neck, non-union from, 601
Stimson's classification, 599
treatment, 599
ununited, Brackett's operation in, 611
Whitman's abduction treatment, 600
of olecranon, 622
treatment, 624
of os calcis, 630
bone-graft peg in, 630
reducing posterior fragment, 635
treatment, 634
of patella, 614
comminuted, 620
irregular, 620
quadriceps rupture in, 614
rupture of ligamentum patellæ in, 614
transverse, 614
bone-graft inlay in, 615
kangaroo tendon suture in, 615
treatment, 615
vertical, 620
of shaft of femur, ununited, 573
of spine, 353
of tibia, 495
treatment, 499
treatment, 353
of tarsal bones, 630
diagnosis, 638
scaphoid, 636
of tibia, compound, sliding graft in, 590
displacement from faulty alignment in, 583
non-union in, 558, 565

Fractures of tuberosities of tibia, with injury to spine, 497
of upper end of femur, causes, 477
juxta-epiphyseal, 476
diagnosis, 478
history of case, 478
physical signs, 477, 478
treatment, 478, 480
osteoblasts in repair, 151
osteotomes in, 558
screws for, 553
silver wire in, 553
treatment, British Medical Association report on, 567
ununited, bone-graft inlay in, 572. See also *Albee's technic*.
inlay bone-graft in, 569
intramedullary bone-graft in, 582
Lane plate as cause, 559, 564, 569, 570
of lower jaw, with or without bone loss, 1047
x-ray examination in, 165
Fragilitas ossium, 653
Frame, Abbott's, in scoliosis, 417, 419
Albee's modification of Bradford's, for scoliosis, 417
Balkan, adjustable, 562, 563, 1045
Goldthwait, in sacro-iliac joint affections, 436
Frictional irritation law of Roux, 21, 150, 157
Friedreich's ataxia, 804
scoliosis with, 411
Frontal bone, fracture of, tibial bone-graft in, 1064–1069
Functional irritation, Roux's law of, 21, 150, 157
Furuncle as focal infection, 287
treatment, 295
Furunculosis, bone, 530

Gait in congenital dislocation of hip, 876
in infantile paralysis, 700–702
in spastic paralysis of infancy and childhood, 792
in tuberculosis of spine, 84
Gallie's tenodesis of foot, 772, 773, 774
advantages of, 776
Galvanic reaction in infantile paralysis, 678
Gant's transverse linear subtrochanteric osteotomy in tuberculosis of hip, 219
Gastrocnemius, contraction of, in spastic paraplegia, treatment, 795
involvement in infantile paralysis, 695
Gastro-intestinal tract as focus of infection, 285, 286
preventing foci of infection in, 295
Gauvain's fillet jacket in tuberculosis of spine, 127
Minerva jacket in tuberculosis of spine, 127
Genito-urinary tract as focus of infection, 287
female, treatment, 295
male, treatment, 295
in infantile paralysis, 676
Genu recurvatum, acquired, 504
congenital, 912
in infantile paralysis, 697
treatment, 724
valgum in habitual dislocation of patella, 625
in rickets, 645
braces in, 646
operation in, 646
in tuberculosis of knee, 233
varum in rickets, 648
anterior, 651
braces in, 648
osteoclasis in, 650
osteotomy in, 650
in tuberculosis of knee, 233
Genuclast in tuberculosis of knee, 252
Gibney's method of strapping ankle, 523
Ginglymus, 39
lateral, 39
Gluteal bursa, operative exposure, 486
bursitis, 485
Goldthwait's back brace in sacro-iliac joint sprain, 437
frame in sacro-iliac joint affections, 436
method of transplanting sartorius in paralysis of quadriceps extensor cruris, 754
operation for habitual dislocation of patella, 626
portable frame for applying plaster jacket, 129
symptom in sacro-iliac joint affections, 435
Gonorrhea, sacro-iliac joint affections from, 430
Gonorrheal arthritis, 304. See also *Arthritis, gonorrheal*.
osteitis, 304. See also *Arthritis, gonorrheal*.
spine, 374
prognosis, 375
treatment, 374
vaginitis as focal infection, 287
Gouging and curetting in tuberculosis of bones, 62
Graser's operation for habitual dislocation of patella, 626
Grattan osteoclast, 650
Guard with spray for motor outfit, 183
Gummatous chondro-arthritis, 301
osteitis, 307
osteomyelitis, 307
synovitis, 307
Gunshot wounds of bones and joints, 1034
angle of impact, 1038
character of bone in, 1038
distance or range in, 1037
of lower extremity, 1082
of spine, 365
treatment, 368

Hadra's treatment in tuberculosis of spine, 133
Hallux extensus, 864
flexus, 863
rigidus, 863

Hallux rigidus, etiology, 863
pathology, 864
symptoms, 863
treatment, 864
valgus, 860
cuneiform osteotomy in, 863
etiology, 860
manual correction, 862
Mayo's operation in, 862
operative treatment, 862
pathology, 860
Sampson's toe posts in, 862
signs, 861
symptoms, 861
treatment, 861
varus, 864
Halter sling in tuberculosis of elbow, 274
Hammer-toe, 842
congenital, 921
Hammock frame method in tuberculosis of spine, 127
Hamstrings, contraction of, in spastic paraplegia, treatment, 705
transplantation of, in paralysis of quadriceps extensor cruris, 752
Hand, amputation of, 1004
artificial, Keller's, 1016
bones of, cysts of, 947
club-, 905
deformities of, acquired, 908
congenital, 903
drainage of, for suppuration, 523
exercises in infantile paralysis, 714
extreme hyperextension of, in infantile paralysis, treatment, 725
osteo-arthritis with contraction of Dupuytren's contracture and differentiation, 910
transplantation of tendons of, 755
x-ray examination, 166
Harrison's groove in rickets, 644
Hartley-Kenyon method of sterilizing motor outfit, 184
Haversian canals, 28
Hawley fracture table, 554
Head supports in tuberculosis of spine, 130
Heart, changes in, in scoliosis, 400
disease, congenital, scoliosis with, 411
involvement of, in tuberculosis of spine, 79
Heat, local, in tuberculosis of knee, 232
Heberden's nodes in degenerative arthritis, 332
Heel, painful, 846
in soldiers, 1084
policeman's, 846
Heine-Medin's disease, 665
Heliotherapy in bone tuberculosis, 51
Hemilaminectomy, 360
technic, 362
Hemiplegia, infantile, 790
Hemophiliac joints, 660
Hemorrhagic osteomyelitis, chronic, 950. See also *Osteomyelitis, chronic hemorrhagic.*
Hereditary ataxia, 804
syphilis of bones and joints, 308
Heredity in bone tuberculosis, 27
Hernia of muscle, 819
Heteroplastic bone-graft, 144
Hexamethylenamine in prophylaxis of infantile paralysis, 687
Hibbs' method of osteotomy in anteversion of femoral neck in congenital hip dislocation, 889
operation in tuberculosis of spine, 120
patellar bone-graft in tuberculosis of knee, 248
Hinge joints, 39
Hip, accessory bands, 191
affections of, 447
anatomy of, 190
ankylosis of, 464. See also *Ankylosis.*
arthroplasty for, 973. See also *Arthroplasty.*
arthritis of, 450. See also *Arthritis of hip.*
deformans of, 453. See also *Arthritis deformans of hip.*
arthrotomy of, 486. See also *Arthrotomy of hip.*
aspiration of, 486
cancer of, 463
capsular ligament of, 190
congenital dislocation of, *x*-ray examination in, 175
cotyloid ligament of, 190
deformities of, 464
in infantile paralysis, treatment, 724
disease, 190
quiet, 460
dislocations of, 447. See also *Dislocation of hip.*
congenital, 873. See also *Dislocation of hip, congenital.*
epiphysitis of, acute, 450
exercises in infantile paralysis, 708–712
extra-articular affections, 485
fracture of, 447. See also *Fracture of hip.*
hysterical, 462
iliofemoral band, 191
infectious processes of, 449
inflammatory processes of, 449
injection of, 486
ischiofemoral band of, 191
lesions in children, *x*-ray examination in, 175
ligamentum teres of, 191
neuropathies of, 462
operations on, 485
osteo-arthritis of, degenerative, 453
osteomyelitis of, acute, 450
operation for drainage, 487
Perthés' disease and, differentiation, 462
pseudo-arthrose flottante of, 451
pubofemoral band, 191
sarcoma of, 463
snapping, 449
extra-articular, 449
intra-articular, 449
subluxation of, congenital, 449
synovial membrane, 191
synovitis of, chronic, 459
treatment, 460

Hip, syphilis of, in children, *x*-ray examination in, 176
transplantation of tendons in, 754
transverse ligament, 190
traumatisms of, 447
tuberculous disease of, 190. See also *Tuberculosis of hip.*
x-ray examination, 166
Hip-rest, adjustable, 989
Schultze's, 990
Hip-shapers, 186
Hip-splint, Bradford, in tuberculosis of hip, 211
Dane, in tuberculosis of hip, 212
Phelps' traction, in tuberculosis of hip, 210
Plimpton's convalescent, in tuberculosis of hip, 213
Taylor traction, in tuberculosis of hip, 214
Thomas, combined with traction splint, in tuberculosis of hip, 211
double, in tuberculosis of hip, 214
in tuberculosis of hip, 209
with high boot and crutches in tuberculosis of hip, 211
traction, in tuberculosis of hip, 209, 211
Hoffa's operation in congenital dislocation of hip, 895, 900
Hoke's operations for congenital talipes equinovarus, 829
Hollow back, 428
foot, 839. See also *Claw-foot.*
Homoplastic bone-graft, 144
fibrous encapsulation in, 144
Hook for ingrown toe-nail, 843
Horsley spine forceps, 366
Housemaid's knee, 504
Hübscher's operation in congenital dislocation of knee, 503
Humerus, cysts of, 939. See also *Cysts of humerus.*
fracture of, with bone loss, tibial bone-graft in, 1050–1053
osteotomy of, for inward rotation, 515
to restore external rotation, 803
rachitic deformities, 644
subluxation of, in infantile paralysis, 698
Huntington's fibula transplantation in infectious osteomyelitis, 543
Hyaline cartilage, articular, 28
of joints, 38
Hydatid cysts of bones, 317
Hydrops articuli in gonorrheal arthritis, 304
in knee tuberculosis, 232
Hydrotherapy in chronic infectious arthritis, 298
Hyperemia, Bier's. See also *Bier's hyperemia.*
sacro-iliac joint affections from, 430
Hyperextension in sacro-iliac joint affections, 436
Hypertrophic arthritis of Goldthwaite, 330
osteo-arthritis of sacro-iliac joint, 432
Hypertrophy of bone, 154
of fingers, 908

Hysterical affections of bones and joints, 809
hip, 462
spine, 348, 387

Ichor pockets in tuberculosis of bones, 35, 36
treatment, 55, 134
of hip, 199, 221
of knee, 233, 255
of lower jaw, 279
of shoulder, 271
of spine, 80, 90, 133
aspiration, 134
costotransversectomy for, 136
iliac, 136
in Petit's triangle, 136
incision, 134
lumbar, 136
operative treatment, 134
prevertebral cervical, 135
thoracic, 135
retropharyngeal, 135
rib resection in, 135
special spinal, 134
subcostal, 136
supraclavicular, 135
symptoms due to, 84
of wrist, 276
Ichthyol ointment in tuberculosis of knee, 239
Iliac dislocation of hip, 448
Iliofemoral band of hip, 191
Iliopsoas bursitis, 485
Ilium, exposure of, for fracture or disease, 485
Immobilization in tuberculosis of ankle, 260
Immovable joints, 38
Immunity in focal infection, acquired, 288
natural, 288
Immunization in infantile paralysis, 688
Industrial reconstruction surgery, 994
Infancy, arthritis of, acute, 313
kyphosis of, 427
spastic paralysis of, 790. See also *Spastic paralysis.*
Infantile hemiplegia, 790
paralysis, 665
abdominal paralysis in, treatment, 693
abortive, 679
acquired immunity in, 668
ambulatory treatment, 692
arthrodesis in, 760
of ankle and mediotarsal joints, 781
with bone-peg, 780
astragalectomy in, 776
blood findings in diagnosis, 685
bone-peg arthrodesis in, 780
braces in, 693
for walking, 694
brain in, 672
bulbospinal, 679
calcaneocavus in, treatment, 723
carriers of, 687
cerebral, 679
prognosis, 686

Infantile paralysis, cerebro-spinal fluid in, 671
in diagnosis, 685
chronic stage, treatment, 721
circulatory symptoms, 674
clinical course, acute stage, 673
contracture in, 678
convalescent stage, treatment, 692
coxa valga from, 484
deformities in, 678, 721
from sustained malposition, 697
of ankle and foot, treatment, 722
of foot, 698
of hip, treatment, 724
of knee, 724
of scapula, 698
of upper extremities, 725
prevention, 697
varieties, 697
diagnosis, 684
diarrhea in, 676
digestive system in, 675
dislocation of hip in, 699
distribution of paralysis in, 681
domestic animals in transmission, 667
fly in transmission, 667
dura in, 671
electric reaction of degeneration in, 677
electricity in, 700
epistaxis in, 674
etiology, 665
exercises in, 703
for muscle training, 702
of ankle, 704
of elbows, 715
of fingers, 714
of foot, 703
of hand, 714
of knee, 706
of lower extremity, 703
of neck, 720
of shoulder, 716
of spine, 712
of thumb, 714
of toes, 703
of upper extremity, 714
of wrist, 714
extent of paralysis, 683
extreme hyperextension of hand, treatment, 725
faradic reaction in, 677
fatal cases, 686
gait in, 700–702
galvanic reaction in, 678
gastrocnemius involvement in, 695
genito-urinary system in, 676
genu recurvatum in, 697
treatment, 724
valgum in, treatment, 724
globoid bodies in, 670
heart symptoms, 674
hexamethylenamine in prevention, 687
hip exercises in, 708–712
hooking up extensors of foot in, 780
immunization in, 688
immunology, 668
improvement of function in, 726
Infantile paralysis, incubation period, 673
individual susceptibility to, 668
infectious agent in, 665
isolation in, 687
joints in, 673
kidneys in, 672
learning to walk after, 697
liver in, 672
lumbar puncture in prognosis, 686
lungs in, 672
lymphatics in, 672
manual examination of muscles in, 702
massage in, 699
medulla and pons in, 672
meninges of brain and cord in, 671
meningism in, 676
meningitis in, 677
muscle training in, 700
exercises for, 702
muscles in, 673
muscular distribution of paralysis, 684
neurotization of muscle in, 759
neutralization test in diagnosis, 685
neutralizing substances in, 688
onset, 674
operations for improving muscle balance in, 726
pain in, 676
paralytic scoliosis in, treatment, 725
stage, 677
pathology, 670
of acute stage, 671
of chronic stage, 672
period of regeneration in, 677
periosteal flap over joint surface in, 780
pia-arachnoid in, 671
plastic tenotomy in, 723
prodromal symptoms, 673
prognosis, 686
prophylaxis, 686
psychoses in, 676
pulse symptoms, 674
quadriceps extensor femoris involvement in, 695
reflexes in, 676
regional distribution of paralysis, 683
relation of meninges and choroid plexus to infection by, 669
respiratory symptoms, 675
restoration of balance in, 696
of nerve and muscle power in, 699
routes of travel, 667
scoliosis in, 410, 698
serum treatment, 688. See also *Serum treatment of infantile paralysis.*
silk ligaments in, 781
sitting position for treatment, 692
skeleton in, 673
skin disorders in, 676
special types, 678
spinal, 665
cord in, 671, 672
spleen in, 672
spring-balance muscle test in, 721
stabilizing procedures in, 759
stage of degeneration, 677
of recovery, 677

Infantile paralysis, streptococci in, 670
subluxation of humerus in, 698
susceptibility in, 687
sustained malposition in, deformity from, 697
symptomatology, acute stage, 673
talipes calcaneus in, treatment, 723
equinus in, 697
treatment, 722
valgus, in 697
treatment, 723
varus in, treatment, 723
temperature in, 675
tendon fixation in, 770. See also *Tenodesis.*
shortening in, 782
transplantation in, 726. See also *Tendon transplantation.*
tendons in, 673
transmission by parasites, 667
transplantation of nerves in, 759
of tendons in, 726. See also *Transplantation of tendons.*
treatment, 688
ulnar deviation in treatment, 725
variability of epidemics, 667
vasomotor disturbances in, 675
vibration in, 699
virus of, 665
avenues of discharge, 666
fate in body, 667
location, 666
method of infection by, 666
neutralization by nasal washings, 668
relation to types of disease, 666
resistance, 666
survival in glycerol, 670
vomiting in, 675
walking frame in, 696
without braces in, 694
rickets, 640
scurvy, rickets and, differentiation, 642
Infection, focal, 285. See also *Focal infection.*
Infectious arthritis, chronic, 320
treatment, 296
diseases of bones, 303
of joints, 303
osteomyelitis, 530. See also *Osteomyelitis, infectious.*
Inflammation of muscle, 811
Infraclavicular lesions of brachial plexus, 797, 802
Ingrown toe-nail, hook for, 843
Injuries. See *Wounds.*
Inlay bone-graft. See *Bone-graft, inlay.*
Intestinal stasis as focal infection, 286
prevention, 295
Intramedullary bone-graft, 146
in ununited fractures, 582
Intra-uterine amputation of toes, 926
Iodoform gauze in tuberculosis of bones, 62
starch in tuberculosis of bones, 62
Irritable spine, 387
Ischemia theory of congenital torticollis, 929
Ischemic myositis, 811. See also *Myositis, ischemic.*
Ischias scoliotica, 411
Ischiofemoral band of hip, 191
Ivory bone-graft, 146
exostoses of bones, 937

Jaw as foci of infection, 285
lower, fractures of, with bone loss, inlay bone-graft in, 1054, 1059
restoration of, by ilium bone-graft, 1059–1063
sarcoma of, inlay bone-graft after partial removal, 1056
tuberculosis of, 279. See also *Tuberculosis of lower jaw.*
ununited fractures of, with or without bone loss, 1047
periostitis of, tuberculosis and, differentiation, 279
upper, tuberculosis of, 280
Jerk-finger, 911
treatment, 912
Joints, acute infections of, related to focal infection, 290
affections of, from focal infection, treatment, 295
articular surfaces, 38
ball-and-socket, 39
capsule, 38
cartilages of, 28, 38
Charcot's, 331, 803, 807
treatment, 804
condyloid, 39
connective tissue, 38
diseases of, related to focal infection, 290, 292
x-ray examination, 167
fibrocartilage, 38
fractures of, treatment, 1043
gunshot wounds of, 1034. See also *Gunshot wounds.*
hemophiliac, 660
hinge-, 39
hyaline cartilage, 38
hysterical affections of, 809
immovable, 38
in infantile paralysis, 673
infectious diseases of, 303
injuries to, *x*-ray examination in, 164
ligaments of, 38
loose bodies in, *x*-ray examination, 171
mice, 324
in knee, 490
neuromimetic affections of, 809
neuropathic conditions of, 806
normal anatomy, 38
pivot, 39
sacro-iliac. See also *Sacro-iliac joint.*
saddle, 39
snap, 493
synovial membrane, 38
syphilis of, 306
acquired, 306
hereditary, 308
treatment, 309
temporary, 38

Joints, transplantation of, 983
traumatic lesions, *x*-ray examination in, 174
tuberculosis of, 26. See also *Tuberculosis of joints.*
typhoid affections of, 314
varieties, 38
of movement, 39
with slight movement, 38
wounds of, treatment, 1043
x-ray examination, in children, 171
Jones and Ridlon halter sling in tuberculosis of elbow, 274
crab splint in tuberculosis of ankle, 261
method of exposure of knee, by bisection of patella, 497, 498
of tendon shortening in paralytic talipes calcaneus, 782
of transplanting extensor proprius hallucis, 744
operation for displaced semilunar cartilage, 494
Albee's modification, 494
for paralytic calcaneocavus, 777
talipes equinovalgus, 770
routine in spastic paraplegia, 793
skin fixation of elbow, 709
splints in talipes, 825
tenotome, 724
Jury-mast in tuberculosis of spine, 130
with plaster-of-Paris bandage, 992

Kanavel's fat transplants in infectious osteomyelitis, 545
Kangaroo tendon, Albee's knot for, 560, 561
in fractures, 555
of olecranon, 624
in tendon transplantation, 731
in transverse fractures of patella, 615
tensile strength, 555
Kausch's boiled bone-graft, 145
Keller's artificial hand, 1016
Kennedy's operation in obstetric paralysis, 709
Kidneys, changes in, in scoliosis, 400
in infantile paralysis, 672
Kinetic stumps, 1012
Sauerbruch's method of producing, 1029–1031
Kingsley's table for computing degrees of flexion of hip, 198
Kleinberg's spinal brace for rotation in scoliosis, 420
Klumpfuss, 821
Knee, anatomy, normal, 230
pathological, 231
surgical, 231
ankylosis of, position of election, 1089
arthroplasty of, for ankylosis, 979
Murphy's technic, 980
Putti's technic, 976
aspiration of, 507
cysts of, 505
deformities in infantile paralysis, 724
treatment, 724
dislocation of, congenital, 503. See also *Dislocation of knee, congenital.*
Knee exercises in infantile paralysis, 706
housemaid's, 504
hypertrophied synovial fringes in, displaced semilunar cartilage and, differentiation, 492
internal derangements, 490
joint mouse in, 490
lateral incisions at, 507
ligaments of, 230
loose bodies in, 495
displaced semilunar cartilage and, differentiation, 492
manipulation under anesthesia, 505
operations on, 505
operative exposure, by bisection of patella, 497, 498
osteitis of, tuberculous, 231
plaster-of-Paris bandage of, 991
posterior incision of, 507
quadriceps extensor of, rupture of, repair, 505
transplantation of sartorius for, 506
weak, transplantation of hamstrings to replace, 506
ruptured crucial ligament, displaced semilunar cartilage and, differentiation, 492
repair of, 499
treatment, 497
internal lateral ligament, displaced semilunar cartilage and, differentiation, 492
snapping, 500
sprain of, 501
of internal lateral ligament, 1085
treatment, 502
synovitis of, acute, 501
chronic, 502
from hypertrophic synovial villi, 502
from lipoma arborescens, 503
tuberculous, 231
traumatic affections, 490
tuberculosis of, 230. See also *Tuberculosis of knee.*
tuberculous osteitis of, in adult, fixation with inlay bone-graft in, 242
with plating in, 241
treatment, 241
war wounds of, 1085
x-ray examination, 167
Knee-brace, Thomas, in tuberculosis of knee, 236, 239, 252
with plastic bandage, 287
Knife and fork combined for one-armed, 1028
Knight brace in genu varum, 648
Knock-knee. See *Genu valgum.*
Kocher's excision of ankle for tuberculosis, 264
incision for arthrotomy of shoulder, 516, 517
lateral excision for tuberculosis of elbow, 275
posterior excision in tuberculosis of hip, 223
König's treatment of displacement of peroneal tendons, 868

Krogius' operation for habitual dislocation of patella, 625
Kümmel's disease, 348
Kyllopodic, 821
Kyllose, 821
Kyphosis, 427
hereditary, 428
in rickets, 643
treatment, 644
in tuberculosis of spine, 77
neuropathic, 428
of adolescents, 428
treatment, 428
of adults, 428
of childhood, 427
of infancy, 427
rachitic, 427
senile, 428
with chest deformities, 428

Lamellæ, changes in, in tuberculosis, 31
of bone, 28
Lameness in Perthés' disease, 461
in tuberculosis of hip, 193, 194, 232
of knee, 232
Laminatome, Albee's, 183
Laminectomy, 360
bilateral, 360, 363
for paralysis in tuberculosis of spine, 137
indications for, 360
unilateral, 360
Landouzy-Déjerin type of pseudohypertrophic muscular paralysis, 809
Lane plates as cause of non-union in fractures, 559, 564, 569, 570
faulty technic in, 571
infection from, 570
Langenbeck's external incision for excision of hip in tuberculosis, 223
posterior excision for tuberculosis, 275
Lange's internal steel splints in tuberculosis of spine, 133
method of tendon transplantation, 735
of transplanting vastus externus for paralyzed glutei, 754
position after reduction of congenital dislocation of hip, 885
Lannelongue's sclerogenic injections in tuberculosis of knee, 239
treatment of displacement of peroneal tendons, 868
Lateral curvature of spine, 396. See also *Scoliosis*.
ligament of knee, external, 230
internal, 230
Lathe of motor outfit, 182
Law, Roux's, of functional irritation, 21, 150, 157
Wolff's, 150
Leg, amputation of, artificial limb for, 1014
artificial, 1033. See also *Artificial legs*.
curvature of, congenital, 914
deformities of, acquired, 921
congenital, 912
exercises in infantile paralysis, 703
lower, amputation of, 1005
right, congenital absence, 917
Leg, transplantation of tendons in, 752
Leontiasis ossea, 658
Ligaments, 38
changes in, in joint tuberculosis, 40
of ankle, 258
of knee, 230
of spine, 74
rupture of, 347
strain of, 347
Ligamentum mucosum of knee, 230
patellæ, 230
teres, 191
of hip, 191
Limp, intermittent, 847
Linear osteotomy in tuberculosis of knee, 253
Lingual tonsils as foci of infection, 285
Lipoma arborescens, 41
chronic synovitis of knee from, 503
displaced semilunar cartilage and, differentiation, 492
in degenerative arthritis, 334
Little's disease, 790
Liver, changes in, in scoliosis, 400
in infantile paralysis, 672
Lobster-claw hand, 906
Locomotor ataxia, deformities in, 803
scoliosis with, 411
Longitudinal arch of foot, 847
Lordosis, 428
in congenital dislocation of hip, 876
in tuberculosis of spine, 87
non-compensating, 429
partial, 429
total, 429
treatment, 429
Lorenz's operation in congenital dislocation of hip, 880, 895, 900
short plaster spica in tuberculosis of hip, 210
splint with stilt in tuberculosis of hip, 211
treatment in tuberculosis of hip, 207
Lovett's method in scoliosis, 416
of estimating abduction and adduction in tuberculosis of hip, 198
table for computing distortion in tuberculosis of hip, 199
Lower extremity, amputation of, 1004
artificial limb for, 1013
deformities of, in spastic paraplegia, treatment, 794
gunshot wounds of, 1082
Lumbago, chronic, 388
Lumbar puncture in prognosis of infantile paralysis, 686
scoliosis, 404
Lungs, changes in, in scoliosis, 399
in infantile paralysis, 672
Luxations in proliferative arthritis, 324
Lymphadenitis as focal infection, prevention, 294
cervical, as focal infection, 286
Lymphatics as focus of infection, 285
in infantile paralysis, 672

MacAusland's technic for arthroplasty of elbow, 968

MacCormac's supracondylar osteotomy for genu valgum, 647
Madelung's deformity, 908
Madura foot, 318
Malar bone, tuberculosis of, 280
Malleolus, external, bone-graft improvisation of, 920
Mallet-finger, 912
Malum coxæ senilis, 453
Malunited fractures, 540
Marmorek's serum in tuberculosis of bones, 61
Marrow, bone-, 20. See also *Bone-marrow*.
Martin's spring balance muscle test in infantile paralysis, 721
Massage for war wounds, 999
in infantile paralysis, 699
of stump, 1008
Mastoiditis suppurativa, as focal infection, 286
Maxillary sinus as focus of infection, 285, 286
Mayer's method of re-amputation of leg, 1011
of suturing nerves, 1077
perineural stitch, 1077
rules for treatment of nerve wounds, 1075
Mayo's operation in hallux valgus, 862
Mechanical fixation in tuberculosis of joints, 63
Median nerve, operative exposure, 1078
paralysis of, treatment, 1074
wounds of, symptoms, 1072
tendon transplantation in, 1082
Mediotarsal joints, ankle and, arthrodesis of, in infantile paralysis, 481
Medulla and pons in infantile paralysis, 672
Mehnarto's serum in tuberculosis of bones, 61
Meninges of brain and cord in infantile paralysis, 671
Meningism in infantile paralysis, 676
Meningitis in infantile paralysis, 677
Meningocele, 381
Meningomyelocele, 381
Menstrual relaxation of sacro-iliac joint, 429
treatment, 438
Metacarpal bones and joints, disease of, operation for, 522
tuberculosis of, 268. See also *Tuberculosis of metacarpal bones*.
Metal, dangers of, in fixation of fractures, 570
Metaphysis, 28
Metatarsal arch of foot, anterior, 847
bones and joints, suppuration of, drainage, 527
fifth, pain at base, 846
tuberculosis of, 268. See also *Tuberculosis of metatarsal bones*.
osteotomy in congenital talipes, 829
Metatarsalgia, anterior, 864
brace in, 866
etiology, 865
Forbes' operation for, 866
Metatarsalgia, anterior, forcible manipulation in, 866
mechanism, 865
symptoms, 865
treatment, 865
Metatarsus, ankylosis of, position of election, 1091
Metzger-Goldthwait apparatus for applying plaster jacket, 129
Mice, joint, 324
in knee, 490
Mikulicz's theory of congenital torticollis, 929
Military reconstruction surgery, 994
surgery, *x*-ray examination in, 164
Milk history in bone tuberculosis, 45
Minerva jacket in tuberculosis of spine, 127
Mobility, abnormal, in sacro-iliac joint affections, 433
limited, in sacro-iliac joint affections, 432, 434
Mollities ossium, 939
Mommsen's provisional artificial limb, 1012
Monoplegia, 791
Morbus coxæ, 190
Morison's incision for resection of elbow, 519
Moro's reaction in bone tuberculosis, 45
Morton's disease, 864. See also *Metatarsalgia, anterior*.
Mosetig-Moorhof's plug in tuberculosis of bones, 62
Motion, limitation, in tuberculosis of knee, 232
Motor-driven instruments, advantages, 19
introduction into orthopedic surgery, 18
Mouth, tapir, 809
Mucous membranes, infected wounds of, as infections foci, treatment, 295
Murphy's fat and fascia flap method in infectious osteomyelitis, 545
formalin-glycerin injection for infectious synovitis of hip, 486
glycero-gelatin plug in tuberculosis of bones, 62
incision for arthrotomy of hip, 486
method in acute infectious osteomyelitis, 539
of arthroplasty of hip, 978
of knee, 980
of transplanting extensor carpi radialis longus and brevis in paralysis, 757
flexor carpi radialis in paralysis, 755
operation for habitual dislocation of patella, 626
Muscle balance, operations for improving, in infantile paralysis, 726
Muscles, changes in, in ischemic myositis, 812
hernia of, 819
in congenital hip dislocation, 875
in infantile paralysis, 673
inflammation of, 811
injuries and diseases, 810
manual examination, in infantile paralysis, 702
neurotization of, in infantile paralysis, 759

Muscles, neutral pull, position of, 22
rupture of, spontaneous, 810
traumatic, 810
syphilis of, 811
training of, in infantile paralysis, 700
exercises for, 702
tuberculosis of, 815
Muscular atrophy of, disuse, 819
in arthritis deformans of hip, 455
in tuberculosis of elbow, 274
of knee, 233
of wrist, 276
dystrophies, deformities from, 808
paralysis, pseudohypertrophic, Charcot-Marie-Tooth type, 809
deformities in, 809
Duchenne type, 808
deformities in, 808
Erb type, 809
Landouzy-Déjerin type, 809
peroneal type, 809
deformities in, 809
rigidity in scoliosis, 403
in tuberculosis of spine, 89
spasm in tuberculosis of knee, 232
Musculocutaneous nerve, operative exposure, 1079, 1080
wounds of, symptoms, 1072
treatment, 1074, 1075
Musculospiral nerve, operative exposure, 1078
wounds of, symptoms, 1070
treatment, 1074
Mycetoma, 318
Myelocele, 381
Myeloid sarcoma of bone, *x*-ray examination in, 170
Myeloma of bone, 955
of spine, 375
Myopathic deformities, 803
Myopathies, 790
deformities from, 808
Myositis, 811
ischemic, 811, 812
Albee's splint in, 813
clinical features, 812
curative treatment, 813
diagnosis, 812
Drehmann's operation in, 814
etiology, 811
muscular changes in, 812
nerve changes in, 812
operative treatment, 814
preventive treatment, 813
prognosis, 812
skin changes in, 812
ossificans circumscripta, 817
progressiva, 816
traumatic, 817
x-ray examination, 167
toxic, 811
Myxomatous bone-marrow, 29

Nasal obstruction, scoliosis from, 411
Nasopharyngeal tonsils as foci of infection, 285
Neck exercises in infantile paralysis, 720
Neck, wry-, 929. See also *Torticollis*.
Nélaton's method of arthroplasty of hip, 978
Nerve-ends, treatment, in amputation, 1003
Nerves, changes in, in ischemic myositis, 812
injuries of, paralytic deformities following, 795
operative exposure, 1078
peripheral, wounds of, frequency, 1060
symptoms, 1070
suture of, 1060
Mayer's method, 1077
perineural, 1077
transneural, 1077
transplantation of, in infantile paralysis, 759
wounds of, 1048
of upper extremity, tendon transplantation in, 1081
postoperative treatment, 1080
prognosis, 1080
symptoms, 1064
treatment, 1073
Neuber's iodoform starch in tuberculosis of bones, 62
Neugebauer's classification of spondylolisthesis, 350
Neuker's method of invagination in sequestrotomy, 542
Neuralgia, plantar, 844
Neurasthenic spine, 387
Neuritis, multiple, deformities from, 805
Neuromimetic affections of bones and joints, 809
Neuropathic conditions of bones and joints, 806
deformities, 803
kyphosis, 428
Neuropathies, 790
of hip, 462
Neurotic spine, 348
Neurotization of muscle in infantile paralysis, 759
Neurotrophic diseases, *x*-ray examination in, 171
Neutralization test in diagnosis of infantile paralysis, 685
New growths of bones, malignant, secondary, 956
primary malignant, 952
Night cries in joint tuberculosis, 43
in tuberculosis of hip, 194
of spine, 84
Nose, bones of, syphilis of, hereditary, 308
Notch, cotyloid, 190
Notched drill for operating outfit, 183

Ober's operation for congenital talipes equinovarus, 827
Obesity, sacro-iliac joint affections from, 430
Obstetric paralysis, 797
Erb-Duchenne type, 798, 799
operation for, 800
etiology, 798
operative treatment, 799

Obstetric paralysis, palliative treatment, 709
pathology, 708
prognosis, 709
specific lesions, 708
symptoms, 708
treatment, 709
relaxation of sacro-iliac joint, 429
treatment, 438
Ochsner's excision of ankle for tuberculosis, 265
Olecranon, fracture of, 622
treatment, 624
Ollier's excision of wrist for tuberculosis, 277
incisions for arthrotomy of wrist, 521
for resection of elbow, 519
One-armed, combined knife and fork for, 1028
typewriter for, 1033
Opsonic index in bone tuberculosis, 45
Orr's spinal brace for rotation in scoliosis, 419
Orthopedic surgery, scope of, 17
Os calcis, cuneiform osteotomy of, in congenital talipes, 831
fracture of, 630. See also *Fracture of os calcis.*
osteotomy of, in congenital talipes, 829
resection of, in tuberculosis of tarsus, 267
suppuration of, drainage, 527
Osgood and Bucholz's method of recording curvature in scoliosis, 402
Osgood's brace in sacro-iliac joint sprain, 437
osteotomy for flexion deformity with motion in tuberculosis of knee, 254
Osteitis deformans, 655
clinical features, 657
etiology, 655
pathology, 657
prognosis, 657
treatment, 657
x-ray examination in, 168
fibrosa, 938
cystica, of femur, autogenous bone-graft in, 949
x-ray examination in, 169
gonorrheal, 304. See also *Arthritis, gonorrheal.*
gummatous, 307
of ankle, tuberculous, bone-graft fixation in, 261
of knee in adult, fixation with inlay bone-graft in, 242
with plating in, 241
tuberculous, 231
in children, treatment, 240
syphilitic, of elbow, tuberculosis and, differentiation, 274
tuberculous, of knee in adult, treatment, 241
Osteo-arthritis, 330
hypertrophic, of sacro-iliac joint, 432
of hip, degenerative, 453
with contraction of hand, Dupuytren's contracture and, differentiation, 910
Osteo-arthritis, *x*-ray examination in, 170
Osteo-arthropathies, 807
Osteo-arthropathy, hypertrophic pulmonary, 658
clinical features, 659
clubbed nails in, 659
diagnosis, 660
etiology, 659
pathology, 659
prognosis, 660
treatment, 660
x-ray examination in, 171
Osteoblasts in repair of fractures, 151
Osteochondritis deformans juvenilis, 460. See also *Perthes' disease.*
Osteoclasis in genu varum, 650
Osteoclast, Grattan, 650
Osteoconductive theory of bone-graft, 144
Osteodystrophia cystica, 941
Osteogenesis imperfecta, 653
of femoral neck, 602
x-ray examination in, 173, 174
Osteogenetic power of bone, 22
of periosteum, 155
theory of bone-graft, 144
Osteoma, 937
of spine, 375
Osteomalacia, 653
in *x*-ray examination, 173
of spine, 377
x-ray examination in, 169
Osteomyelitis, acute, from focal infection, 291
bone marrow in, 536
chronic hemorrhagic, 950
classification, 950
clinical diagnosis, 950
features, 950
pathology, 952
treatment, 952
fat transplants in, 545
from focal infection, treatment, 296
gummatous, 307
infectious, 530
abscess in, 537
acute, drainage in, 539
bone cortex in, 536
marrow in, 536
bone-graft inlay, for restoration of bone shaft in, 544
Carrel-Dakin method, 542
chronic, removal of sequestra in, 540
cortical changes in, 535
diagnosis, differential, 537, 538
direct causes, 530
etiology, 530
fat and fascia flap in, 545
fever in, 537
fibula transplantation in, 543
hyperleukocytosis, 537
joint tenderness, 537
location, 531
marrow changes in, 534
method of infection, 531
pain in, 537
pathology, 533
periosteal changes in, 535

Osteomyelitis, infectious, periosteum in, 536
physical signs, 537
predisposing causes, 530
prognosis, 538
pulse in, 537
repair in, 534
histologic changes in, 534
sequestrotomy in, 542
sinuses in, 537
soft tissues in, 537
subacute, removal of sequestra in, 540
swelling in, 537
symptoms, 537
toxemia in, 537
treatment, 538
abortive, 539
curative, 539
reparative, 543
of hip, acute, 450
astragalus graft for loss of head and neck of femur in, 451
remodeling joint in, 451
treatment, 450
operation for drainage, 487
Perthés' disease and, differentiation, 462
of sacro-iliac joint, prognosis, 443
of spine, acute, 371
causes, 372
operation in, 373
symptoms, 372
sacro-iliac joint affections from, 430
x-ray examination in, 167, 175
Osteopathies, 806
Osteoplasty, autogenous, in tuberculosis of spine, 97
Osteoporosis in tuberculosis of bones, 31
Osteosclerosis in tuberculosis of bones, 31
Osteotome, Albee's, 101
in fractures, 558
types of, 562
Osteotomy, cuneiform in hallux valgus, 863
for coxa vara, 471
circular method, 472
advantages, 473
cuneiform method, 475
linear method, 475
in congenital talipes, 829
cuboid, 829
cuneiform, of os calcis, 831
curved cuneiform, of neck and head of astragalus, 830
fibula, for backward dislocation of external malleolus, 830
internal cuneiform, 829
metatarsal, 829
os calcis, 829
in genu varum, 650
in tuberculosis of knee, cuneiform, with inlay bone-graft, 253
diaphyseal, 254
linear, 253
Osgood's, for flexion deformity with motion, 254
supracondylar, 253
of acromion for depression, 516
of femur, for anteversion in congenital hip dislocation, 889
Osteotomy of humerus, for inward rotation, 515
to restore external rotation, 803
Overlapping toes, 843

Paget's disease, 381, 655. See also *Osteitis deformans.*
Pain at base of fifth metatarsal, 846
in cysts of humerus, 940
in flatfoot, 850
in infantile paralysis, 676
in infectious osteomyelitis, 537
in sacro-iliac joint affections, 432
in scoliosis, 403
in soles of feet, 844
in stump, 1010
in tuberculosis of bones, 42
of elbow, 273
of hip, 194
of joints, 43
of knee, 232
of lower jaw, 279
of shoulder, 271
of skull bones, 278
of spine, 84
of wrist, 276
referred, 22
Painful great toe, 863
heel, 846
in soldiers, 1084
toe, Morton's, 864. See also *Metatarsalgia, anterior.*
Palmar fascia, dissection of, for Dupuytren's contracture, 911
Dupuytren's contracture of, 909. See also *Dupuytren's contracture.*
Papilloma from corns, treatment, 844
Paralysis, abdominal, in infantile paralysis, treatment, 693
deltoid, transplantation of pectoralis major in, 755
in tuberculosis of spine, 90, 136
bone-graft fixation for, 137
costotransversectomy for, 137
laminectomy for, 137
prognosis, 95
infantile, 665. See also *Infantile paralysis.*
muscular, pseudohypertrophic, Charcot-Marie-Tooth type, 809
deformities in, 809
Duchenne type, 808
deformities in, 808
Erb type, 809
Landouzy-Déjerin type, 809
peroneal type, 809
deformities in, 809
obstetric, 797. See also *Obstetric paralysis.*
of facial nerve, deformities from, 797
of infancy and childhood, spastic, 790. See also *Spastic paralysis.*
of median nerve, treatment, 1074
of ulnar nerve, complete, tendon transplantation in, 1082
spastic, of infancy and childhood, 790. See also *Spastic paralysis.*

Paralysis, Volkmann's, 811. See also *Myositis, ischemic.*
Paralytic calcaneocavus, Jones' operation for, 777
deformities following nerve injuries, 795
causes, 795
prognosis, 797
symptoms, 796
treatment, 796
dislocation of hip, 448
treatment, 448
drop-wrist, Albee's technic in, 770
equinovarus, bone-graft mortise in, 762
flat-foot, astragaloscaphoid arthrodesis in, 761
scoliosis in infantile paralysis, treatment, 725
talipes calcaneocavus transverse section of foot in, 781
calcaneovalgus, astragalectomy in, 776
calcaneus, Jones' method of tendon shortening in, 782
tenodesis in, 772
equinovalgus, Jones' operation for, 779
tenodesis in, 773
equinovarus, congenital and, differentiation, 837
tenodesis in, 773
treatment, 837
equinus, tenodesis in, 773
valgus, tenodesis in, 773
varus, tenodesis in, 771
tibialis posticus, tenodesis of, 773
triceps suræ, tenodesis of, 773
Paraplegia, compression, in tuberculosis of spine, 70
Pott's, in tuberculosis of spine, 90
spastic, adductor contraction in, treatment, 794
contraction of gastrocnemius in, treatment, 795
of hamstrings in, treatment, 795
flexion deformity at elbow with excessive pronation in, treatment, 793
at wrist in, treatment, 793
Jones' routine in, 793
Parker's anterior excision for tuberculosis of hip, 223
Paronychia, suppurative, as focal infection, 287
treatment, 295
Patella, absent, 912
and femur, ankylosis of, arthroplasty for, 981
ankylosis of, to femur, in tuberculosis of knee, 251
cysts of, 947
dislocation of, acquired, 921
treatment, 923
habitual, 624. See also *Dislocation of patella, habitual.*
displacement of, acquired, 921
treatment, 923
fracture of, 614. See also *Fracture of patella.*
Patella, ligament of, 230
median bisection, for exposure of knee, 498
rudimentary, 912
Pelvis, bones of, cysts of, 947
changes in, in scoliosis, 399
deformities of, in tuberculosis of spine, 79
in congenital dislocation of hip, 874
rachitic, 645
static obliquity of, scoliosis from, 410
x-ray examination, 166
Peri-articular suppuration in gonorrheal arthritis, 304
Perineural stitch for nerve suture, 1077
Periosteal sarcoma of bones, 953
Periosteum, 28
cambium layer of, 155
changes in, in tuberculosis, 31
in infectious osteomyelitis, 535, 537
osteogenetic power of, 155
rôle of, 155
viability of, 142
Periostitis, localized, syphilitic, 306
of jaw, tuberculosis and, differentiation, 279
simple inflammatory, *x*-ray examination in, 167
Peripheral nerves, wounds of, frequency, 1060
symptoms, 1070
Peroneal tendons, displacement of, 868
Peroneus longus or brevis, transplantation of, in talipes valgus, 747, 751
Perthés' disease, 460
articular rheumatism and, differentiation, 462
clinical features, 461
diagnosis, differential, 461
etiology, 460
infantile coxa vara and, differentiation 462
juvenile arthritis deformans and, differentiation, 462
lameness in, 461
osteomyelitis of hip and, differentiation, 462
pathology, 460
treatment, 462
tuberculous coxa vara and, differentiation, 462
x-ray examination in, 460
Pes cavus, 839. See also *Claw-foot.*
planus, 849. See also *Flatfoot.*
Petit's triangle, ichor pocket in, in spinal tuberculosis, 136
Phalangeal bones and joints, diseases of, operation for, 522
suppuration of, drainage, 527
Phalanges, tuberculosis of, 268. See also *Tuberculosis of phalanges.*
Phelps' operation in congenital talipes equinovarus, 828
traction hip-splint in tuberculosis of hip, 210
Phlegmonous inflammation in gonorrheal arthritis, 304

Physics of bone, 24
Pia-arachnoid in infantile paralysis, 671
Pied bot, 821
Pigeon-breast in rickets, 644
Pigeon-toe, 822, 851, 864
Pique's exposure of sacro-iliac joint, 442
Pituitary extract in proliferative arthritis, 328
Pivot joint, 39
Plantalgia, 844
Plantar neuralgia, 844
Plaster-of-Paris, 985
bandage, 985
accessories to, 992
and Thomas knee-brace in tuberculosis of knee, 237
application, 988
crinolin for, 986
impregnation of crinolin in, 986
in congenital talipes, 826
in tuberculosis of ankle, 260
of elbow, 274
of hip, 214
of knee, 238, 251
of shoulder, 272
of wrist, 277
jury-mast with, 992
metal bridges in, 992
method of preparing crinolin for, 986
of storing, 986
of knee, 991
padding of, 987
removal, 992
requirements, 987
saturation of, 988
spreader for, 992
technic, 987
bed in sacro-iliac joint sprain, 437
circular splint in tuberculosis of shoulder, 272
corset in scoliosis, 426
dehydration by baking, 987
jacket in congenital torticollis, 932
in sacro-iliac joint affections, 436
sprain, 437
in scoliosis, 422
in tuberculosis of spine, 96, 123, 124
modifications, 125
spica, double, in sacro-iliac joint sprain, 438
in tuberculosis of knee, 237
long, in tuberculosis of hip, 208
with forcible abduction in coxa vara, 471
Stillé's cutter for, 990
strengtheners, 987
technic, 985
Pleurisy, scoliosis from, 411
Plexus brachial. See *Brachial plexus*.
Plimpton hip-splint, in tuberculosis of hip, 213
Pneumococcal arthritis, 313
Pneumococcus in infectious osteomyelitis, 530
Pockets, ichor. See *Ichor pockets*.
Poker-back, 380
Poliomyelitis, acute, anterior, 665. See also *Infantile paralysis*.
Poliomyelo-encephalitis, anterior, 665
Polydactylism, 906
Popliteal nerve, external, destruction of, treatment, 1083
with drop-foot, 1083
operative exposure, 1080
wounds of, symptoms, 1072
treatment, 1074
internal, operative exposure, 1080
wounds of, symptoms, 1073
treatment, 1075
Posterior curvature of spine, 427. See also *Kyphosis*.
ligament of knee, 230
Postoperative relaxation of sacro-iliac joint, 429
Post-typhoid dislocation of hip, 314
lesions of bones, *x*-ray examination in, 168
Postural relaxation of sacro-iliac joint, 429
treatment in scoliosis, 414
Postures assumed in sacro-iliac joint affections, 433
Pott's disease, 72. See also *Tuberculosis of spine*.
paraplegia in tuberculosis of spine, 90
Preiser's theory of origin of arthritis deformans, 331
Prepatellar bursitis, 504
Pressure exercise for stump, 1008
Pretibial bursitis, 505
Proliferative arthritis, 321. See also *Arthritis, proliferative*.
Pronated foot, 849
Pronator teres, and radial and ulnar flexors, transplantation of, into extensors of finger and thumb, 1081
Prostate as focus of infection, 287
Protein antigens, non-specific, in chronic infectious arthritis, 299
Pseudarthrosis, bone-graft inlay in, after-treatment, 592
in ununited fracture, 578
Pseudo-arthrose flottante of hip, 451
Pseudohypertrophic muscular paralysis, Charcot-Marie-Tooth type, 809
deformities in, 809
Duchenne type, 808
deformities in, 808
Erb type, 809
Landouzy-Déjerin type, 809
peroneal type, 809
deformities in, 809
Psychoses in infantile paralysis, 676
Pubic dislocation of hip, 448
Pubofemoral band of hip, 191
Pulmonary osteo-arthropathy, hypertrophic, 658
x-ray examination in, 171
Putti's technic for arthroplasty of knee, 976
Pyarthrosis, 41
Pyogenic arthritis of sacro-iliac joint, 432
Pyorrhea dentalis as focal infection, 285
prevention, 294

Quadriceps extensor femoris involvement in infantile paralysis, 695
of knee, rupture of, repair, 505
transplantation of sartorius for, 506
weak, transplantation of hamstrings to replace, 506

Rachitic kyphosis, 427
rosary, 644
Rachitis, 640. See also *Rickets.*
Radial nerve, operative exposure, 1070
Radius, congenital absence, 903
cysts of, 941
rachitic deformities, 644
Railroad spine, 347, 388
Raynaud's disease of feet, 846
Reamers, 186
Re-amputations, 1010
femoral, 1011
indications for, 1010
of leg, Bier's osteoplastic method, 1011
Mayer's method, 1011
Reconstruction hospitals, equipment for, 997
workshops for, 997
surgery, 994
industrial, 994
military, 994
scope of, 17
stabilizing procedures in, 1081
Recrudescent rickets, 640
Rectum, diseases of, as focal infections, 287
prevention, 296
Recumbency in scoliosis, 414
in tuberculosis of spine, 96
Re-educational schools, 997
administration and control, 997
for wounded soldiers, 997
Referred pain, 22
Relaxation of sacro-iliac joint, 429, 431
Reluxations after reduction of congenital hip dislocations, treatment, 890, 893
Resection of astragalus for tuberculosis of tarsus, 267
of lower jaw, subperiosteal, with inlay bone-graft restoration, in tuberculosis, 280
of os calcis in tuberculosis of tarsus, 267
Respiratory system as focus of infection, 285
Retractor for osteotomy, 473
Retrocalcaneobursitis, 867
Rheumatic affections of sacro-iliac joint, prognosis, 443
typhoid arthritis, 314
Rheumatism, articular, Perthés' disease and, differentiation, 462
of spine, 388
Rheumatoid arthritis, 321
Rhinoplasty by bone-graft, 309
Ribs, abnormalities of, 385
beaded, in rickets, 644
cervical, 385. See also *Cervical ribs.*
fusion of, 385
tuberculosis of, 281
Rice bodies, 41
Rickets, 640
Rickets, anterior curvature of tibia in, 651
attitude in, 644
beaded ribs in, 644
chair deformity in, 651
chest in, 644
coxa valga in, 645
vara in, 467, 645
cubitus valgus in, 644
varus in, 644
deformities of, 640, 643
etiology, 640
flatfoot in, 651
genu valgum in, 645
braces in, 646
operation in, 646
varum in, 648. See also *Genu varum.*
Harrison's groove in, 644
infantile, 640
scurvy and, differentiation, 642
kyphosis in, 643
treatment, 644
late, 640
of spine, 376
pathology, 640
pelvis in, 645
pigeon-breast in, 644
predisposing factors, 640
prominent abdomen in, 644
recrudescent, 640
saber-shins in, 651
scoliosis in, 409, 644
treatment, 644
scurvy, 652
treatment, 653
spine in, 643
spondylolisthesis and, differentiation, 350
symptoms, 641
syphilitic epiphysitis and, differentiation, 642
thorax in, 644
torticollis in, 643
varieties, 640
x-ray examination in, 173, 174
Riedinger's artificial arm, 1022, 1026
Riggs' disease as focal infection, 285
Roberts' technic for astragalus graft in loss of femoral head and neck in septic arthritis, Albee's modification, 451
Roentgen-ray. See *X-ray.*
Rollier's treatment of bone tuberculosis, 51
Rongeur forceps, 364, 365
Rosary, rachitic, 644
Rotary cutter for motor outfit, 182
Round and hollow back, 428
back, 428
shoulders, 427. See also *Kyphosis.*
Roux's functional irritation law, 21, 150, 157
Rudimentary patella, 912
Rupture of muscles, spontaneous, 810
traumatic, 810
of quadriceps extensor, 505

Saber-shins, 308, 309
in rickets, 651
Sacro-iliac joint affections, 429
abnormal mobility in, 433

Sacro-iliac joint affections, attitudes on standing or walking in, 433
bone-graft, bridge, from sacrum to wing of ilium in, 438
complications, treatment, 443
degenerative, 430
developmental peculiarities, 430
diagnosis, 435
differential, 435
displacement of sacrum in, treatment, 436
etiology, 429
from gonorrhea, 430
from hyperemia, 430
from improper attitudes and postures, 430
corsets, 430
from muscular atony, 430
from obesity, 430
from osteomyelitis, 430
from traumatism, 430
from tuberculosis, 430
Goldthwait's frame in, 436
symptom in, 435
hyperextension in, 436
in female, 430
in male, 430
infectious proliferative, 430
intrapelvic abscess in, treatment, 443
limited mobility in, 432, 434
local abscess in, treatment, 443
luxation of sacrum in, treatment, 436
plaster-of-Paris jacket in, 436
subluxation of sacrum in, treatment, 436
suspension in, 436
swelling in, 433
symptoms and signs, 432
treatment, 436
operative, 438
anatomy, 430
congenital anomalies of, 432
constitutional anomalies, 429
degenerative arthritis of, 432
developmental anomalies, 429
gonorrheal arthritis of, 432
prognosis, 443
hypertrophic osteo-arthritis of, 432
infections, 431
infectious arthritis of, 429
malignant disease of, 432
mechanics of, 431
menstrual relaxation, 429
treatment, 438
obstetrical relaxation, 429
treatment, 438
operative exposure of, 486
osteomyelitis of, prognosis, 443
pathology, 431
Pique's exposure of, 442
postoperative relaxation, 429
postural relaxation, 429
pyemic disease, prognosis, 443
pyogenic arthritis of, 432
relaxation of, 388, 429, 431
bone-graft inlay into joint in, 440
rheumatic affections, prognosis, 443
Sacro-iliac sprain, 436
double plaster-of-Paris spica in, 438
extreme, treatment, 438
Goldthwait back brace in, 437
hard pillow in, 437
moderate, treatment, 437
night supports in, 437
Osgood's brace in, 437
plaster-of-Paris bed in, 437
jacket in, 437
recumbency in, 438
stiff leather jacket in, 437
strapping in, 437
Van Winkle corset in, 437
weight and pulley in, 438
wide-webbing belt in, 437
woven elastic trunks in, 437
traumatic relaxation, 429
prognosis, 443
tuberculosis of, 431
prognosis, 443
strain, 388
Sacrum, displacement of, treatment, 436
Saddle joints, 30
Saddle-back, 350
Salicylic collodion for corns, 844
Salpingitis as focal infection, 287
Sampson's toe-posts in hallux valgus, 862
Sand, bone, 32, 35
Saphenous nerve, external, operative exposure, 1080
Sarcoma of bones, 952
cellular, 952
connective-tissue, 952
diagnosis, 954
egg-shell crackling in, 953
periosteal, 953
prognosis, 954
pulsating, 956
treatment, 954
x-ray examination in, 169
of femur, cysts and, differentiation, 464
of hip, 463
of lower jaw, bone-graft inlay after operation for, 1056
of spine, 375
Sartorius tendon, transplantation of, for quadriceps extensor, 506
Sauerbruch method of producing kinetic stump, 1012, 1029–1031
Saw, single, for motor outfit, 181
small, for motor outfit, 183
twin, for motor outfit, 181
Sayre's apparatus in congenital torticollis, 931
halter and sling in tuberculosis of spine, 122
Scapula, congenital elevation of, 387, 512. See also *Sprengel's deformity*.
deformities of, in infantile paralysis, 698
Schede's method in internal rotation in congenital dislocation of hip, 890
Schlatter's disease, 499
diagnosis, 499
symptoms, 499
treatment, 500
x-ray examination in, 174

Schulthess' level indicator in scoliosis, 402
Schultze's hip-rest, 990
Sciatic nerve, destruction of, treatment, 1084
great, wounds of, symptoms, 1072
operative exposure, 486, 1079
wounds of, treatment, 1074
Scissors deformity in spastic paralysis of infancy and childhood, 702
Scleroderma morphea, deformity in, 661
Scoliosis, 396
Abbott's frame in, 417, 419
after anterior poliomyelitis, 410
age in, 396
of onset in relation to prognosis, 412
Albee's modification of Bradford frame in, 415
American Orthopedic Association report on treatment, 420
amount of curve in relation to prognosis, 413
articular processes, changes in, 399
associated anatomical changes, 399
bodies of vertebræ, changes in, 398
cause, in relation to prognosis, 412
cervicodorsal, 405
clinical course, 403
features, 397
types, 404
colon, transverse, changes in, 400
congenital, 407, 408
constitutional, 408
costovertebral articulations, changes in, 399
curves in, 397
developmental stage, 403
diagnosis, 412
disequilibration in, 412
dorsal, primary, 404
dorsolumbar, 404
early stage, 403
etiologic classification, 407
etiology, 406
exercises in, 414
fixation in, 415
flexibility in, 401
Forbes' method in, 422
frequency, 396
from cicatricial contraction, 411
from empyema, 411
from excessive malleability of bones, 408
from fatigue, 409
from loss of arm, 410
from nasal obstruction, 411
from pleurisy, 411
from static obliquity of pelvis, 410
from unequal hearing, 410
vision, 410
from untreated torticollis, 410
heart changes in, 400
heredity in, 396
history taking in, 400
in hod-carriers, 409
in infantile paralysis, 698
in joiners, 409
in nurse-maids, 409
Scoliosis in rickets, 644
treatment, 644
in school children, 409
in tuberculosis of spine, 80
Kleinberg's spinal brace for rotation in, 420
ligaments, changes in, 399
liver changes in, 400
location of curvature in, 397
of curve in relation to prognosis, 413
Lovett's method in, 416
lozenge-shaped vertebræ in, 399
lumbar, 404
lung changes in, 399
manipulation in, 415
mentality in relation to prognosis, 412
muscles, changes in, 399
rigidity in, 403
nature of curve in relation to prognosis, 413
occupation in relation to prognosis, 412
occupational, 409
Orr's spinal brace for rotation in, 419
pain in, 403
paralytic, in infantile paralysis, treatment, 725
manipulation and fixation with inlay bone-graft and spinal brace in, 422
pathology, 398
pedicles, changes in, 399
physical condition in relation to prognosis, 412
examination in, 400
plaster-of-Paris corset in, 426
jacket in, 422
postural methods in, 414
prognosis, 412
rapid connection, 415
rate of growth in relation to prognosis, 412
recording curvature in, 402
recumbency in, 414
rotation in, 401
Schulthess' level indicator in, 402
sex in, 396
in relation to prognosis, 412
spinal insufficiency in, 400
spinous processes, changes in, 399
splenic changes in, 400
stage of arrest in, 403
of improvement in, 403
state of curve in relation to prognosis, 413
symptoms, 403
Taylor suspension apparatus in, 414
thoracic changes in, 399
total, 404
tracheal changes in, 400
transverse processes, changes in, 399
treatment, 413
corrective, 414
in relation to prognosis, 413
preventive, 413
Van Winkle's corset-brace in, 427
varieties, 397
vertebral foramen, changes in, 399
visceral changes in, 399
wedge vertebræ in, 398

Scoliosis with arthritis deformans, 409
with compensated dorsal curves, 405
with congenital heart disease, 411
with Friedreich's ataxia, 411
with pulmonary tuberculosis, 411
with rickets, 409
with spastic paralysis, 411
with syringomyelia, 411
Scorbutic spondylitis, 377
Scorbutus, infantile, 652
treatment, 653
Screws for fracture work, 553
Scurvy, infantile, 652
rickets and, differentiation, 642
treatment, 653
rickets, 652
treatment, 653
x-ray examination in, 173, 174
Semilunar cartilage, anatomical data, 490
clinical anatomy, 491
displacement, 490, 491
ambulatory treatment, 493
diagnosis, 492
etiology, 491
hypertrophied synovial fringes and, differentiation, 492
lipoma arborescens and, differentiation, 492
loose bodies and, differentiation, 492
operative treatment, 493
ruptured crucial ligaments and, differentiation, 492
internal lateral ligament and, differentiation, 492
Senile kyphosis, 428
Sequestra in bone tuberculosis, 35
Séquestre dur, 35
Sequestrotomy in infectious osteomyelitis, 542
Serofibrinous synovitis in gonorrheal arthritis, 304
Serum treatment of chronic infectious arthritis, 298
of infantile paralysis, 689
dosage, 689
mode of administration, 689
New York City Health Department method, 689
of proliferative arthritis, 330
Shin, saber-, 308
Shirt-stud abscess, 315
Shoes in flatfoot, 863
Shoulder, ankylosis of, position of election, 1086
arthrodesis of, for flail-shoulder, 767
arthroplasty of, for ankylosis, 982
arthrotomy of, 516, 519. See also *Arthrotomy of shoulder.*
caries carnosa of, 270
sicca of, 270
contractures, manipulations to relieve, 514
dislocation of, congenital, 512
habitual, 513
treatment, 513
operative, 514
tuberculosis and, differentiation, 272
Shoulder exercises in infantile paralysis, 716
normal anatomy, 270
operations on, 514
round, 427. See also *Kyphosis.*
suppuration of, drainage for, 517
stiff and painful, 507
transplantation of tendons in, 755
traumatic affections of, 507
tuberculosis of, 270. See also *Tuberculosis of shoulder.*
x-ray examination, 166
Shoulder-rest, adjustable, 989
Sign, Trendelenburg's, in congenital dislocation of hip, 875
Silk ligaments in flail-elbow, 518
in infantile paralysis, 781
in paralytic conditions of knee, 506
Silver wire, in fracture work, 553
Sinuses, cranial, as foci of infection, 285, 286
in tuberculosis of bones, treatment, 59
of hip, 22
of joints, 41
of knee, 233, 255
of spine, 90
of stump, 1010
Skeleton in infantile paralysis, 673
Skin, changes in, in ischemic myositis, 812
disorders in infantile paralysis, 676
infected wounds of, as infectious foci, treatment, 295
Skull bones, tuberculosis of, 278. See also *Tuberculosis of skull bones.*
cysts of, 947
rachitic deformity of, 643
syphilis of, hereditary, 308
Sling in tuberculosis of shoulder, 272
Smith-Peterson approach in arthrodesis of hip, 216
in congenital dislocation of hip, 896, 897
Snap-finger, 911
treatment, 912
Snap-joint, 493
Snapping hip, 449
extra-articular, 449
intra-articular, 449
knee, 500
Soft tissues, tonicity of, as factor in treatment, 21
Soldiers, flatfoot in, 1084
painful heels in, 1084
wounded. See also *Wounded soldiers.*
Soule's modification of Albee's technic in paralytic talipes equinovarus, 765, 839
Soutter's operation for Sprengel's deformity, 513
silk ligaments in flail-elbow, 518
Spastic paralysis of infancy and childhood, 790
acquired after birth, 791
cardinal signs, 791
clinical features, 791
types, 791
etiology, 791
from traumatism in labor, 791
gait in, 792
mental condition in, 792

Spastic paralysis of intra-uterine origin, 791
operative treatment, 793
contra-indications to, 793
indications for, 792
pre-operative treatment, 793
prognosis, 792
rigidity in, 791
scoliosis with, 411
varieties, 790
paraplegia, 790, 791. See also *Paraplegia, spastic.*
Spengler's I. K. serum in tuberculosis of bones, 61
Spica, long plaster in tuberculosis of hip, 208
with high boot and crutches, in tuberculosis of hip, 210
Lorenz short plaster, in tuberculosis of hip, 210
double, in sacro-iliac joint sprain, 438
in tuberculosis of knee, 237
short with traction splint in tuberculosis of hip, 211
Spina bifida, 381
inlay bone-graft for, 383
occulta, 384
treatment, 384
prognosis, 382
radical operation for, 383
treatment, 382
palliative, 382
ventosa, 33, 268
enchondroma of hand or foot and, differentiation, 269
syphilitic dactylitis and, differentiation, 269
Spinal accessory nerve injuries, deformities from, 797
brace in tuberculosis of spine, 128
cord, deformities from degeneration of, 803
in infantile paralysis, 671, 672
infantile paralysis, 665
Spine, actinomycosis of, 375
anterior curvature of, 428. See also *Lordosis.*
arthritis deformans of, 379. See also *Arthritis deformans of spine.*
articular processes, 74
articulations of, 74
blood supply, 75
carcinoma of, 375
contusions of, 347
deformities of, 381. See also *Deformities of spine.*
dislocation of, 352. See also *Dislocation of spine.*
enchondroma of, 375
exercises for, in infantile paralysis, 712
exostoses of, 375
fascia of, 75
fracture of, 353
fracture-dislocation of, 354
forceps, Horsley's, 366
gonorrheal, 374
prognosis, 375
treatment, 374
Spine, gunshot wounds of, 365
treatment, 368
hysterical, 348, 387
insufficiency of, in scoliosis, 406
intervertebral disks, 74
irregularities of, in spinal tuberculosis, 86
lateral curvature of, 396. See also *Scoliosis.*
ligaments, 74
rupture, 347
strain, 347
myeloma of, 375
neural arch, 73
neurasthenic, 387
neurotic, 348
normal anatomy, 73
movements, 397
osteoma of, 375
osteomalacia of, 377
osteomyelitis of, acute, 371. See also *Osteomyelitis of spine.*
pathological curves, 397
physiological curves, 396
physiology, 396
posterior curvature, 427. See also *Kyphosis.*
rachitic, 643
railway, 347, 387
rheumatism of, 388
rickets of, 376
sarcoma of, 375
stab wounds of, 369
surgery of, history, 359
traumatic affections of, 347
neurosis of, 347
tuberculosis of, 72. See also *Tuberculosis of spine.*
tumors of, 375
typhoid, 374
x-ray examination, 166
Splay foot, 849
Spleen, changes in, in scoliosis, 400
in infantile paralysis, 672
Splint, Albee's, in ischemic myositis, 813
Billroth, in tuberculosis of knee, 252
Butler, 1034, 1035
hip-. See *Hip-splint.*
Jones' crab, in tuberculosis of ankle, 261
in talipes, 825
Lorenz, with stilt, in tuberculosis of hip, 211
plaster-of-Paris circular, in tuberculosis of shoulder, 272
Taylor's convalescent, in tuberculosis of hip, 213
traction, in tuberculosis of hip, 214
Thomas caliper convalescent, in tuberculosis of knee, 239
Spondylarthritis, 83
Spondylitis deformans, *x*-ray examination in, 171
scorbutic, 377
syphilitic, 307, 369
treatment, 371
traumatic, 348
tuberculous, 72. See also *Tuberculosis of spine.*

Spondylolisthesis, 349
bone-graft fixation in, 350
causes, 350
congenital dislocation of hip and, differentiation, 350
diagnosis, 350
lumbar lordosis in, 350
mechanics of production, 349
Neugebauer's classification, 350
rickets and, differentiation, 350
treatment, 350
tuberculosis of spine and, differentiation, 350
tuberculous, 86
Spondylose rhizomelique, 330
Spontaneous dislocation of hip, 449
rupture of muscles, 810
Sprain of foot and ankle, 523
chronic, 524
treatment, 523, 524
of internal lateral ligament of knee, 1085
of knee, 501
treatment, 502
sacro-iliac joint, 436. See also *Sacro-iliac joint sprain.*
Sprengel's approach in congenital dislocation of hip, 896, 897
deformity, 512
etiology, 512
of scapula, 387
pathology, 513
symptoms, 512
treatment, operative, 513
Spring-balance muscle test in infantile paralysis, 721
Spring-finger, 911
treatment, 912
Stab wounds of spine, 369
Staphylococcal arthritis, 310
treatment, 312
Staphylococcus pyogenes aureus in infectious osteomyelitis, 530
Stasis, intestinal, as focal infection, 286
prevention, 295
Static backache, 388
treatment, 389
deformities of foot, 847
of spine, 396
of toes, 860
Steel splints, internal, in tuberculosis of spine, 133
Steindler's operation for fourth-degree claw-foot, 842
Steinmann's instruments for direct application of extension, 582, 583
Sterilization of electric motor outfit, Hartley-Kenyon method, 184
Sternomastoid muscle, open division, in congenital torticollis, 931
Stiffness in tuberculosis of joint, 193
traumatic, tuberculosis of elbow and differentiation, 274
Still's disease, 340
Stillé's plaster cutter, 990
Stimson's classification of fractures of neck of femur, 599
Stirrup forceps for nerve operations, 1071
Stomach, changes in, in scoliosis, 400
Stone's transplantation of fibula in infectious osteomyelitis, 543
Strain, back, chronic, 388
sacro-iliac, 388
Strephodie, 821
Streptococcal arthritis, 310
treatment, 311
Streptococcus in infectious osteomyelitis, 530
viridans in focal infection of teeth, 286
Stromeyer's theory of congenital torticollis, 929
Stump, affections of, 1010
as prosthesis, 1025
bandaging of, 1008
baths for, 1008
care of, 1006
cinematic apparatus for, 1031
contractures, 1009
education of, 1012
end-bearing, 1002, 1008
kinetic, 1012
Sauerbruch's method of producing, 1029–1031
limitation of motion in, 1006
massage of, 1008
movements for, 1008
muscular weakness in, 1006
painful, 1010
preliminary treatment, 1005
pressure exercise for, 1008
re-amputations of, 1010
indications for, 1010
routine for proper treatment, 1007
sinuses in, 1010
specialized training of, 1024
ulceration of, 1010
Subacromial bursæ, anatomy, 507
pathogenesis, 507
bursitis, 507. See also *Bursitis, subacromial.*
Subcutaneous abscesses as foci of infection, 285, 287
Subdeltoid bursa, 508
bursitis, tuberculosis of shoulder and, differentiation, 271
Subluxation of ankle, congenital, 524
of hip, congenital, 449
of humerus in infantile paralysis, 698
Submucous abscesses as foci of infection, 285
Subtrochanteric osteotomy in tuberculosis of hip, 219
circular, 219
cuneiform, 219
transverse linear, 219
Supernumerary fingers, 906
Suppression of fingers, 906
Suppurative paronychia as focal infection, 287
treatment, 295
Supraclavicular lesions of brachial plexus, 797
Supracondylar osteotomy in tuberculosis of knee, 253
Suspension in sacro-iliac joint affections, 436

Suture of nerves, 1060
Mayer's method, 1077
perineural, 1077
transneural, 1077
Swelling in sacro-iliac joint affections, 433
white, 40, 230
Symphysis, 38
Synarthrosis, 38
Synchondrosis, 38
Syndactylism, 906
Didot's operation for, 907, 908
Syndesmosis, 38
Synostosis of vertebræ, 385
Synovectomy in tuberculosis of joints, 64
Synovia, 38
Synovial gland, 190
of hip, 190
ligaments of knee, 230
membrane, 38
changes in, in joint tuberculosis, 39
of ankle, 259
of hip, 191
of knee, 231
sacs of wrist, 276
villi, hypertrophic, chronic synovitis of knee from, 502
Synovitis, chronic, of elbow, 517
gummatous, 307
of hip, chronic, 459
treatment, 460
of knee, acute, 501
chronic, 502
from lipoma arborescens, 503
tuberculous, 231
of wrist, chronic, 520
serofibrinous, in gonorrheal arthritis, 304
serous, syphilitic, 307
tuberculous, acute miliary, 40
arborescent, 41
chronic, 40
fibrous, 41
fungating, 41
granulating, 41
with effusion, 41
Syphilis of bones, 306
acquired, 306
hereditary, 308
of nose, hereditary, 308
treatment, 309
of cranium, hereditary, 308
of face bones, hereditary, 308
of hip in children, *x*-ray examination in, 176
of joints, 306
acquired, 306
hereditary, 308
treatment, 309
of muscles, 811
of tibia, hereditary, 308
theory of congenital torticollis, 929
Syphilitic curvature of tibia, 308
dactylitis, 308
spina ventosa and, differentiation, 269
disease of bones and joints, 306
epiphysitis, 308
rickets and, differentiation, 642
Syphilitic osteitis of elbow, tuberculosis and, differentiation, 274
periostitis, localized, 306
spondylitis, 307, 369
treatment, 371
synovitis, serous, 307
Syringomyelia, 804
scoliosis with, 411
Syringomyelocele, 382

Tabes dorsalis, deformities in, 803
Tabetic flat-foot, 803
Table, Albee's traction, 552–557
Hawley fracture, 554
Talipes, 821
arcuatus, 839. See also *Claw-foot.*
calcaneocavus, paralytic, transverse section of foot in, 781
calcaneovalgus, paralytic, astragalectomy in, 776
calcaneus from paralysis of triceps suræ, tendon transplantation in, 751
in infantile paralysis, treatment, 723
paralytic, Jones' method of tendon shortening in, 782
tenodesis in, 772
cavus, 839. See also *Claw-foot.*
congenital, 821
equinovalgus, Jones' operation for, 779
paralytic, tenodesis in, 773
equinovarus, acquired, 837
treatment, 837
congenital, 821
adhesive plaster straps in, 825
anatomy, 822
bone-graft wedge between split halves of scaphoid in, 833, 835
etiology, 823
Hoke's operations for, 829
Jones' splints in, 825
long slender, operative treatment, 831
nature of deformity in, 821
Ober's operation for, 827
operations for, 827
osteotomy in, 829. See also *Osteotomy in congenital talipes.*
paralytic and, differentiation, 837
Phelps' operation in, 828
plaster-of-Paris dressing in, 826
plastic operation on body of astragalus in, 830
prognosis, 824
relapsed, Cook's operation for, 828
short, chunky, operative treatment, 835
Thomas wrench in, 826
treatment, 824
in adults, 824
in infants, 824
of mild cases over two and a half years, 826
of severe cases over two and a half years, 826
paralytic, bone-graft mortise in, 762
congenital and, differentiation, 837
tenodesis in, 773

Talipes equinovarus, paralytic, treatment, 837
with moderate cavus and dropping of head of first metatarsal, tendon transplantation in, 744
equinus, destruction of external popliteal nerve with, 1083
in infantile paralysis, 697
treatment, 722
paralytic, tenodesis in, 773
tendon transplantation in, 742
plantaris, 839. See also *Claw-foot.*
valgus from paralysis of anterior tibial, transplantation of tendons in, 747
of tibialis posticus, tendon transplantation in, 751
in infantile paralysis, 697
tenodesis in, 773
treatment, 723
varieties, 821
varus and equinovarus from paralysis of peroneals, tendon transplantation from, 745
in infantile paralysis, treatment, 723
paralytic, tenodesis in, 771
Tapir mouth, 809
Tarsal bones, fracture of, 630
diagnosis, 638
scaphoid, fracture of, 636
Tarsectomy in tuberculosis of tarsus, anterior, 267
posterior, 267
Tarsus, ankylosis of, position of election, 1091
normal anatomy, 266
suppuration of, drainage, 527
tuberculosis of, 265. See also *Tuberculosis of tarsus.*
Taylor's brace in tuberculosis of spine, 128, 129
hemilaminectomy, 362
ring in tuberculosis of spine, 132
suspension apparatus in scoliosis, 414
traction splint in tuberculosis of hip, 214
Teeth as foci of infection, 285
Temporomaxillary joint, arthroplasty of, for ankylosis, 966
Tender toes, 845
Tendo Achillis, right-angled contraction of, 925
tendonitis of, 869
tenocellulitis of, 868
tenotomy of, in rigid flatfoot, 859
Tendonitis of tendo Achillis, 869
Tendons, fixation of, 1083
foot, affections of, 867
in infantile paralysis, 673
operations on, 1084
shortening, in infantile paralysis, 782
transplantation of, in infantile paralysis, 726. See also *Transplantation of tendons.*
wounds of, 1084
Tennis elbow, 517
Tenocellulitis of tendo Achillis, 868
Tenodesis, 770
combination of other stabilizing procedures with, 775
in infantile paralysis, 770
in paralytic talipes calcaneus, 772
equinovalgus, 773
equinovarus, 773
equinus, 773
valgus, 773
varus, 771
modifications of technic, 773
of foot, 771
of paralytic tibialis posticus, 773
triceps suræ, 773
Tenosynovitis of ankle, 524
of wrist, chronic, 521
Tenotome, Jones's, 724
Tenotomy of tendo Achillis in rigid flatfoot, 859
plastic in infantile paralysis, 723
Thigh, amputation at, 1005
artificial limb for, 1013
Thomas brace in genu valgum, 646
collar in tuberculosis of spine, 131
combined with traction splint in tuberculosis of hip, 211
double, in tuberculosis of hip, 214
in tuberculosis of hip, 208
with high boot and crutches in tuberculosis of hip, 211
knee-brace in knee tuberculosis, 236, 239, 252
with plaster bandage, 237
wrench in congenital talipes, 826
in flatfoot, 859
Thomsen's disease, 819
Thorax, changes in, in scoliosis, 399
deformities of, in tuberculosis of spine, 79
Thrombo-angiitis obliterans, 847
Thumb exercises in infantile paralysis, 714
Thymus extract in proliferative arthritis, 329
Tibia, anterior curvature, in rickets, 651
backward displacement, in tuberculosis of knee, 233
congenital absence of, 914
curvature of, syphilitic, 308
cysts of, 946
dislocation of, in knee tuberculosis, 232
outward rotation, in tuberculosis of knee, 233
saber-shaped, 309
spine of, avulsion, 496
external tubercle of, fracture, 496
fracture of, 495
treatment, 499
internal tubercle of, avulsion, 496
syphilis of, hereditary, 308
tuberosities of, fracture, with injury to spine, 497
Tibial nerve, anterior, operative exposure, 1080
wounds of, symptoms, 1073
posterior, operative exposure, 1080
wounds of, symptoms, 1073
treatment, 1075

Tibialis anticus, transplantation of, for paralysis of pronators of foot, 745
posticus, paralytic, tenodesis of, 773
Toe-nail, ingrown, hook for, 843
Toe-posts, Sampson's, in hallux valgus, 862
Toes, amputation of, intra-uterine, 926
contracted, 843
deformities of, congenital, 921
static, 860
exercises for in infantile paralysis, 703
great, painful, 863
hammer-, congenital, 921
overlapping, 843
pigeon-, 822
tender, 845
in typhoid fever, 845
Tonsillitis as focal infection, 280
Tonsils as foci of infection, 285
prevention, 294
Torticollis, 929
acquired, 933
acute, 934
spastic types, 934
chronic, 934
spasmodic, 935
varieties, 933
congenital, 929
Bratz apparatus for, 930
clinical features, 930
etiology, 929
ischemia, theory of, 929
manipulative treatment, 930
open division of sternomastoid muscle in, 931
operative treatment, 930
overcorrection in, 931
pathology, 929
plaster-of-Paris jacket in, 932
posterior, 933
Stromeyer's theory, 929
theory of nervous origin, 929
of syphilitic origin, 929
rachitic, 643
untreated, scoliosis from, 410
varieties, 929
Toxemia in bone and joint tuberculosis, 42
Toxic myositis, 811
Trachea, changes in, in scoliosis, 400
Transmutability of bacteria in focal infection, 289
Transneural stitch, for nerve suture, 1077
Transplantation in nerve injuries of upper extremity, 1081
of brachioradialis in paralysis of flexors of hand and fingers, 757
of extensor carpi radialis brevis in paralysis of flexors of hand and fingers, 757
longus in paralysis of flexors of hand and fingers, 757
communis digitorum for paralysis of extensor pollicis longus, 758
of flexor carpi radialis in paralysis of extensors of digits and hand, 755
Transplantation of hamstrings forward to replace weakened quadriceps extensor, 506
in paralysis of quadriceps extensor cruris, 752
of head of femur to trochanter for ununited fracture of neck, 611
of joints, 983
of nerves in infantile paralysis, 759
of pectoralis major in deltoid paralysis, 755
of pronator teres and radial and ulnar flexors into extensors of fingers and thumb, 1081
of sartorius for quadriceps extensor, 506
in paralysis of quadriceps extensor cruris, 754
of tendons, 726
Biesalski's method, 735
causes of failure in, 730
Esmarch's tourniquet in, 731
in complete paralysis of ulnar nerve, 1082
in infantile paralysis, 726
causes of failure, 734
general considerations, 733
time for, 733
in nerve injuries of upper extremity, 1081
in talipes calcaneus from paralysis of triceps surae, 751
equinovarus with moderate cavus and dropping of head of first metatarsal, 744
equinus, 742
valgus from paralysis of anterior tibial, 747
of tibialis posticus, 751
varus and equinovarus from paralysis of peroneals, 745
in wounds of median nerve, 1082
of ulnar nerve, 1082
kangaroo tendon for, 731
Lange's method, 735
mechanical center of foot after, 750
methods, 726, 727
of foot, 742
of hand, 755
of hip, 754
of leg, 752
of shoulder, 755
rules in technic, 727
selection of method, 735
technic, 737
Vulpius' method, 735
with arthrodesis, 741
of vastus externus in paralysis of gluteus minimus and medius, 754
Transverse ligament of hip, 190
of knee, 231
Traumatic affections of spine, 347
myositis ossificans, 817
neuroses of spine, 347
relaxation of sacro-iliac joint, 429
prognosis, 443
treatment, 443
rupture of muscles, 810
spondylitis, 348

Traumatism of hip, 447
sacro-iliac affections from, 430
Trendelenburg's sign in congenital dislocation of hip, 875
Triceps suræ, paralytic, tenodesis of, 773
Trigger-finger, 911
treatment, 912
Trochanteric coxa vara, 466. See also *Coxa vara, trochanteric.*
Trochoides, 39
Trypsin in tuberculosis of bones, 59
Tubby's operation for flexion deformity at elbow with excessive pronation in spastic paraplegia, 793
Tuberculin tests in tuberculosis of bones, 44
treatment of tuberculosis of bones, 59
Tuberculins, autogenous, in tuberculosis of bones, 60
Tuberculosis of ankle, 258
amputation in, 265
bone-graft fixation in, 261
deformities in, treatment, corrective, 265
diagnosis, 259
. differential, 260
etiology, 258
excision for, 264
Kocher's method, 264
Ochsner's method, 265
extension in, 261
fixation in, 260
frequency, 258
immobilization in, 260
Jones' crab splint in, 261
normal anatomy, 258
pathology, 259
prognosis, 260
signs, 259
symptoms, 259
treatment, 260
of bones, 26
abscess formation in, 42
allyl sulphide in, 59
antituberculous serums in, 61
associated changes, 30
atrophic lesion in, 33
autogenous tuberculins in, 60
Beck's bismuth paste in, 62
Bier's hyperemia in, 53
blood-vessel changes in, 32
Calmette's reaction in, 44
climatic conditions for, 51
clinical features, 41
counterirritation in, 54
diagnosis, 44
differential, 45
diet in, 52
dissemination, 42
drugs in, 52
encysted lesions in, 32
endarteritis obliterans in, 32
etiology, 26
family history in, 44
fate of lesions, 35
fixation of part in, 53
focal reaction in, 45
frequency of affection, 27
Tuberculosis of bones from injury, 27
gouging and curetting in, 62
heated serum test in, 45
heliotherapy in, 51
heredity in, 27
histology and histogenesis of original tubercle, 29
hygienic home conditions in, 50
hospital conditions for, 51
hypertrophic lesion in, 34
ichor pocket in, 36
treatment, 55
infiltrating lesion in, 32
intravascular tubercle in, 29
lamellar changes in, 31
localization of lesion in, 37
Marmorek's serum in, 61
marrow changes in, 31
Mehnarto's serum in, 61
milk history in, 45
Mosetig-Moorhof's plug in, 62
Murphy's glycero-gelatin plug in, 62
muscular wasting in, 42
Neuber's iodoform starch in, 62
opsonic index in, 45
osteoporosis in, 31
osteosclerosis in, 31
pain in, 42
pathology, 29
periosteal changes in, 31
perivascular tubercle in, 30
portals of entry for bacilli, 26
predisposition to, 27
preliminaries to operation in, 62
process of repair in, 37
prognosis, 49
retrogressive changes in original follicle, 30
Rollier treatment, 51
secondary infection in, 42
sequestra in, 35
sinuses in, treatment, 57
source of infection, 26
Spengler's I. K. serum in, 61
symptoms and signs, 42
thickening in, 42
toxemia in, 42
treatment, 50
general, 50
local conservative, 53
operative, 61
preventive, 50
trypsin in, 59
tubercular sensitiveness in, 60
tuberculin tests in, 44
treatment, 59
von Pirquet's reaction in, 45
x-ray examination in, 48, 168, 174
treatment in, 54
of elbow, 273
Bier's hyperemia in, 274
deformity in, 274
excision for, 275
halter sling in, 274
muscular atrophy in, 274
pain in, 273
pathology, 273

Tuberculosis of elbow, physical signs, 273
plaster-of-Paris bandage in, 274
prognosis, 274
stiffness in, 273
swelling in, 273
symptoms, 273
syphilitic osteitis and, differentiation, 274
tenderness in, 273
traumatic stiffness and, differentiation, 274
treatment, 274
conservative, 274
operative, 275
of hip, 190
abduction in, estimation of, 198
adduction in, estimation of, 198
age in, 190
Albee's arthrodesis in, 215–219. See also *Albee's arthrodesis*.
bone-graft fixation in, 222
alterations of contour in, 193
altered contour of head and neck in, 192
amputation for, 225
arthroplasty for, 224
Bradford hip-splint in, 211
circumference in, 199
constitutional disturbances in, 194
convalescent lateral brace in, 214
Dane hip-splint in, 212
deformities in, gradual correction, 214
operative treatment, 215
degree of flexion in, 197
diagnosis, 203
differential, 203
distortions of limb in, 194
etiology, 190
excision in, 223
after-results, 224
after-treatment, 224
forced manual correction in, 220
functional cure in, 205
general inspection in, 194
ichor pockets in, 199, 221
joint movements in, 196
lameness in, 193, 194
lengthening in, 197
long plaster-of-Paris spica in, 208
with high boot and crutches in, 210
Lorenz short plaster spica in, 210
splint with stilt in, 211
treatment, 207
measurements in, 197
morbid anatomy, 191
mortality in, 206
muscular spasm in, 196
night cries in, 194
operations for removal of foci in, 224
operative dislocation in, 225
pain in, 194
palpation of joint and neighboring structures in, 195
pathology, 191
Phelps' traction hip-splint in, 210
physical signs, 194
Tuberculosis of hip, plaster-of-Paris bandage in, 214
Plimpton's convalescent hip-splint in, 213
prognosis, 205
protective attitudes in, 194
relative frequency, 190
repair by natural process in, 192
sex in, 190
short spica with traction splint in, 211
shortening in, 197
side most affected, 190
sinus formation in, 221
stiffness in, 193
subtrochanteric osteotomy in, 219
symptoms, 193
Taylor's convalescent splint in, 213
traction splint in, 214
Thomas hip-splint in, 208
combined with traction splint in, 211
double, 214
traction hip-splint in, 209, 211
treatment, 206
ambulatory, 209
convalescent, 212
general, 209
in acute stage, 207
local, 206
of deformities in, 214
operative, 215
operative, 221
recumbent, 207
weight and pulley in, 214
x-ray examination in, 175, 200
of joints, 26
abscess formation in, 41, 44
altered position in, 43
alteration in bony outlines in, 44
amputation in, 64
arthrectomy in, 64
arthrotomy in, 64
Bier's hyperemia in, 63
blood-vessel changes in, 40
bone changes in, 40
cartilage changes in, 39
changes in soft parts in, 40
clinical features, 41, 42
varieties, 41
counterextension in, 64
counterirritation in, 64
cureting in, 64
deformity in, correction, 64
diagnosis, 46
differential, 47
disorganized joint in, 41
elevation of surface temperature in, 43
etiology, 26
excision in, 64
fixation in, 64
fluid in joint in, 192
frequency of affection, 27
from injury, 27
gross varieties, 40
heredity in, 27
ligament changes in, 40
limitation of movement in, 43

Tuberculosis of joints, mechanical fixation in, 63
muscle rigidity in, 43
spasm in, 43
wasting in, 44
night cries in, 43
pain in, 43
pathology, 39
physical signs, 46, 193
portals of entry for bacilli, 26
predisposition to, 27
process of healing in, 41
prognosis, 49
secondary infection in, 42
sinus formation in, 41
source of infection, 26
stiffness in, 43
swelling in, 43
symptomatology, 46
symptoms and signs, 42
synovectomy in, 64
synovial membrane changes in, 39
tenderness in, 43
toxemia in, 42
traction in, 63
treatment, 63
conservative, 63
radical, 64
x-ray examination in, 46, 48
of knee, 230
absolute rest in, 236
actual cautery in, 239
adhesions in, 232
alterations in length of limb in, 233
amputation in, 249
ankylosis of patella to femur in, 251
arthroplasty in, 255
backward displacement of tibia in, 233
Bier's hyperemia in, 239
Billroth splint in, 252
Calot's injection treatment, 239
changes in appearance of joint in, 233
deformities in, 233. See also *Deformities*.
diagnosis 234
differential, 234
dislocation of tibia in, 232
erasion with bone-graft in, 245. See also *Albee's technic*.
etiology, 230
excision in, 249
fixation in, 236
fluid in, 231
functional prognosis, 235
genu valgum in, 233
genu varum in, 233
genuclast in, 252
gradual reduction of traction in, 236
hydrops articuli in, 232
ichor pockets in, 233, 255
ichthyol ointment in, 239
inspection in, 233
lameness in, 232
Lannelongue's sclerogenic injections in, 239
limitation of motion in, 232
local heat in, 232
Tuberculosis of knee, maceration of cartilage in, 232
measurements in, 233
method of examination in, 233
mortality, 235
muscular atrophy in, 233
spasm in, 232
osteotomy in, cuneiform, with inlay bone-graft, 253
diaphyseal, 254
linear, 253
Osgood's, for flexion deformity with motion, 254
supracondylar, 253
outward rotation of tibia in, 233
pain in, 232
palpation in, 233
patellar bone-graft in, 248
physical signs, 232
plaster-of-Paris bandage in, 238, 251
spica in, 237
prognosis, 235
reactive inflammation in, 232
recumbency with traction in, 236
removal of para-articular bone focus in, 249
results of examination in, 233
sensitiveness in, 232
sinuses in, 233, 255
swelling in, 232
symptoms, 232
synovial membrane in, 231
Thomas caliper convalescent splint in, 239
knee-brace in, 236, 239, 252
with plaster bandage, 237
treatment, 235
conservative, 235, 236
general, 235
local, 235
operative, 240
weight and pulley in, 236, 251
of lower jaw, 279
adenitis in, 279
bone-graft inlay restoration after subperiosteal resection in, 280
dentigerous cyst and, differentiation, 279
diagnosis, 279
ichor pockets in, 279
loose teeth in, 279
pain in, 279
pathology, 279
physical signs, 279
prognosis, 280
swelling in, 279
symptoms, 279
treatment, 280
tuberculosis and, differentiation, 279
of malar bone, 280
of metacarpal bones, 268
diagnosis, 269
etiology, 268
pathology, 268
prognosis, 269
resection with restoration by bone-graft in, 269

Tuberculosis of metacarpal bones, symptoms and signs, 269
treatment, 269
conservative, 269
operative, 269
of metatarsal bones, 268
diagnosis, 269
etiology, 268
pathology, 268
prognosis, 269
resection with restoration by bone-graft in, 269
symptoms and signs, 269
treatment, 269
conservative, 269
operative, 269
of muscles, 815
of phalanges, 268
amputation for, 270
diagnosis, 269
etiology, 268
pathology, 268
prognosis, 269
resection with restoration by bone-graft in, 269
symptoms and signs, 269
treatment, 269
conservative, 269
operative, 269
of ribs, 281
of sacro-iliac joint, 431
and lumbar vertebræ, bone-graft inlay from wing of ilium to spine in, 441
prognosis, 443
of shoulder, 270
abnormal positions in, 271
after-treatment, 275
arthrodesis with bone-graft peg in, 272
diagnosis, 271
dislocation and, differentiation, 272
ichor pockets in, 271
insidiousness of onset, 271
pain in, 271
pathology, 270
physical signs, 271
plaster-of-Paris bandage in, 272
prognosis, 272
rigidity in, 271
sling in, 272
subdeltoid bursitis and, differentiation, 271
symptoms, 271
tenderness in, 271
treatment, 272
conservative, 272
operative, 272
wasting in, 271
x-ray examination in, 274
of skull bones, 278
bone-graft in, 278
pain in, 278
pathology, 278
physical signs, 278
prognosis, 278
swelling in, 278
symptoms, 278
Tuberculosis of skull bones, treatment, 278
of spine, 72
age in, 72
ambulatory treatment, 96
anterior, 75
appendiceal, 75
appliances in, 121
associated changes in, 77
attitude in, 84
autogenous osteoplasty in, 97
back brace in, 123
blood-vessel involvement in, 79
boarding in, 87
bone-graft in, 99
fixation in, 132
Bradford-Whitman frame in, 122, 123
Calot's correction of deformity under anesthesia, 132
grand jacket in, 126
military jacket in, 126
plaster jacket in, 133
causes of death in, 95
central, 75
cervical compensatory curve in, 78
kyphosis in, 78
signs and symptoms, 92
spinal ichor pocket in, 80
cervicodorsal, signs and symptoms, 92
circulatory symptoms, 92
compensatory curves in, 78
complications in, treatment, 133
compression paraplegia in, 79
cord changes in, 79
involvement in, 79
cranial symptoms, 92
deformities in. See also *Deformities.*
diagnosis, 93
dorsal compensatory curve in, 79
kyphosis in, 78
spinal ichor pocket in, 80
symptoms, 92
dorsolumbar, attitude, 85
symptoms, 92
epiphyseal, 75
essentials of spinal supports in, 124
etiology, 72
expectation of life in, 95
extent of permanent deformity in, 95
fibrosis in, 82
fillet jacket in, 127
from injury, 73
gait in, 84
Gauvain's fillet jacket in, 127
general appearance in, 86
grand jacket in, 126
Hadra's method of wiring spinous processes in, 133
hammock frame method in, 128
head supports in, 130
heart involvement in, 79
symptoms, 92
heredity in, 73
Hibbs' operation in, 120
ichor pockets in, 80, 90, 133. See also *Ichor pockets.*
internal steel splints in, 133
irregularities of spine in, 86

Tuberculosis of spine, jury-mast in, 130
kyphosis in, 77
latent period, 83
lateral curvature, 79
localization, 75
lordosis in, 87
lower cervical, attitude in, 85
lumbar compensatory curve in, 79
lumbar, and sacro-iliac joint, bone-graft inlay from wing of ilium to spine in, 441
kyphosis in, 78
spinal ichor pocket in, 81
lumbosacral, symptoms, 93
mid-dorsal, attitude in, 85
military jacket in, 126
Minerva jacket in, 127
muscular rigidity in, 89
natural method of cure, 82
night cries in, 84
of last lumbar vertebræ, attitude in, 86
pain in, 84
paralysis in, 90, 137. See also *Paralysis*.
paralytic symptoms, 84
pathology, 75
pelvic symptoms, 92
peripheral, 75
perivertebral thickening in, 87
physical condition, 86
signs, 84
plaster-of-Paris jacket in, 96, 123, 124
modifications, 125
prognosis, 95
rare forms, 82
recumbency in, 96
relative frequency, 72
Sayre halter and sling in, 122
scoliosis in, 87
sex in, 72
sinuses in, 90
spinal brace in, 128
changes in, 77
spondylolisthesis and, differentiation, 350
structural changes in, 75
symptoms, 83
Taylor brace in, 128, 129
ring in, 132
Thomas collar in, 131
thoracic symptoms, 92
traction in, 123
treatment, 95
ambulatory, 124
conservative, 120
duration of, 95
general, 95
local, 95
mechanical, 120
operative, 100
recumbent, 121, 123
upper cervical, attitude in, 85
signs and symptoms, 92
upper dorsal, attitude in, 85
lumbar, attitude in, 85
varieties, 75
x-ray examination in, 92, 174
Tuberculosis of spine, yielding on pressure in, 87
of tarsus, 265
diagnosis, 267
etiology, 265
pathology, 266
resection of astragalus for, 267
of os calcis in, 267
signs, 266
symptoms, 266
tarsectomy in, anterior, 267
posterior, 267
treatment, 267
of upper jaw, 280
of wrist, 275
after-treatment, 278
deformities in, 276
diagnosis, 276
excision for, 277
fixation in, by bone-graft, 277
by plaster-of-Paris bandage, 277
ichor pockets in, 276
limitation of motion in, 276
muscular atrophy in, 276
pain in, 276
pathology, 276
physical signs, 276
prognosis, 277
swelling in, 276
symptoms, 276
treatment, 277
conservative, 277
operative, 277
pulmonary, scoliosis with, 411
sacro-iliac joint affections from, 430
Tuberculous coxitis, congenital dislocation of hip and, differentiation, 471
disease of hip, 190. See also *Tuberculosis of hip*.
osteitis of ankle, bone-graft fixation in, 261
of knee, 231
in adult, fixation with inlay bone-graft, 242
with plating in, 241
treatment, 241
in children, treatment, 240
sinuses, *x*-ray examination in, 168
spondylitis, *x*-ray examination in, 174
spondylolisthesis, 86
synovitis, 40. See *Synovitis, tuberculous*.
of knee, chronic, 231
Tumor albus, 41, 230
Tumors of bones, 937
benign, 937
malignant, 952
of spine, 375
Twist drills for motor outfit, 183
Typewriter for one-armed, 1003
Typhoid affections of joints, 314
arthritis, 314
rheumatic, 314
septic, 314
bone affections, 315
age in, 316
etiology, 315
localization of lesions, 316

Typhoid bone affections, pathology, 315
prognosis, 317
sex in, 316
symptoms, 317
time of onset, 316
treatment, 317
varieties of lesion in, 315
fever, tender toes in, 845
spine, 374

Ulceration of stump, 1010
Ulna, congenital absence, 904
cysts of, 941
deviation of, in infantile paralysis, treatment, 725
rachitic deformities, 644
Ulnar nerve, operative exposure, 1070
paralysis of, tendon transplantation in, 1082
wounds of, symptoms, 1070
tendon transplantation in, 1082
treatment, 1074
United States Government's classification of orthopedic surgical conditions, 17
Ununited fractures, 549
Upper extremity, amputation of, 1004
artificial limbs for, 1016
deformities of, in spastic paraplegia, treatment, 703
nerve injuries of, tendon transplantation in, 1081
Uterine backache, 388

Vaccines, autogenous, in tuberculosis of bones, 58
in chronic infectious arthritis, 298
in proliferative arthritis, 330
Vaginitis, gonorrheal, as focal infection, 287
Van Winkle corset in sacro-iliac joint sprain, 437
corset-brace in scoliosis, 427
Vastus externus, transplantation of, in paralysis of glutei, 754
Vertebræ, bone-graft fixation of, in tuberculosis of spine, 100. See also *Albee's technique*.
changes in, in scoliosis, 398
increase in number, 381
individual, 73
synostosis of, 385
Vertebral column. See *Spine*.
Vesiculitis seminalis as focal infection, 287
Vibration in infantile paralysis, 699
Vocational re-education of wounded soldiers, 1000
Volkmann's canals, 28
paralysis, 811. See also *Myositis, ischemic*.
Vomiting in infantile paralysis, 675
von Pirquet's reaction in bone tuberculosis, 45
von Recklinghausen's disease, 939
Vulpius' method of tendon transplantation, 735

Walking frame in infantile paralysis, 696
Walton's method of reduction in dislocation of spine, 353
Wandering acetabulum, 192
War wounds, Dakin-Carrel method in, 995
developments in treatment, 996
dichloramin-T in, 996
excision of, 995
massage for, 999
methods of treatment at front, 995
of knee, 1085
Wright's treatment, 995
Warts from corns, treatment, 844
Waxy degeneration in tuberculosis of spine, 82
Web fingers, 906
Didot's operation for, 907, 908
Wedge cross-section in inlay bone-graft in ununited fractures, 581
Weight and pulley in tuberculosis of hip, 214
of knee, 236, 251
in sacro-iliac joint sprain, 438
White swelling, 40, 230
Whitlock's operation for habitual dislocation of patella, 625
Whitman's abduction treatment of fractures of neck of femur, 600
cast for brace in flatfoot, 855
cuneiform osteotomy of femur, 475
method of correcting deformities in tuberculosis of knee, 251
valgus plates in flatfoot, 855
Wiring spinous processes in tuberculosis of spine, 133
Wolff's law, 150
Wounded soldiers, certificates for, after re-education, 999
command depots for, 998
massage for wounds, 999
physical rehabilitation, 999
processes of treatment, 998
re-educational school for, 997
return of, to homes, 999
vocational re-education of, 1000
Wounds, gunshot. See also *Gunshot wounds*.
of anterior tibial nerve, symptoms, 1073
of brachial plexus, symptoms, 1072
treatment, 1074
of circumflex nerve, symptoms, 1072
treatment, 1074
of external popliteal nerve, symptoms, 1072
treatment, 1074
of great sciatic nerve, symptoms, 1072
of internal popliteal nerve, symptoms, 1073
treatment, 1075
of joints, treatment, 1043
of knee in military service, 1085
of median nerve, symptoms, 1072
tendon transplantation in, 1082
of musculocutaneous nerve, 1072
symptoms, 1072
treatment, 1074, 1075

Wounds of musculospiral nerve, symptoms, 1070
treatment, 1074
of nerves, 1048
of upper extremity, tendon transplantation in, 1081
postoperative treatment, 1080
prognosis, 1080
symptoms, 1064
treatment, 1073
of peripheral nerves, frequency, 1060
symptoms, 1070
of posterior tibial nerve, symptoms, 1073
treatment, 1075
of sciatic nerve, treatment, 1074
of tendons, 1084
of ulnar nerve, symptoms, 1070
tendon transplantation in, 1082
war, 904. See also *War wounds*.
Wrede's arthrodesis of ankle, 765
Wrench, Thomas, in congenital talipes, 826
in flatfoot, 859
Wright's treatment of sinuses in bone tuberculosis, 59
of war wounds, 996
Wrist, amputation at, 1004
anatomy, 276
ankylosis of, position of election, 1088
arthrodesis of, 770
arthrotomy of, 521. See also *Arthrotomy of wrist*.
aspiration of, 523
carpal bones of, 276
drainage of, for suppuration, 523
excision of, 521
exercises in infantile paralysis, 714
flexion deformity at, in spastic paraplegia, treatment, 793
injection of, 523
operations on, 521
synovial sacs of, 276
synovitis of, chronic, 520
tenosynovitis of, chronic, 521
traumatic affections of, 520
tuberculosis of, 275. See also *Tuberculosis of wrist*.
x-ray examination, 166
Wrist-drop, transplantation of flexor carpi radialis in, 755
Wry-neck, 929. See also *Torticollis*.

X-RAY apparatus, portable, 22
diagnosis, differential, of cystic appearances in bones, 170
examination, dangers of misinterpretation, 163
in abscess of bones, 168
in achondroplasia, 174
in acromegaly, 171
in arthritis deformans of hip, 456
in benign bone cysts, 170
in carcinoma of bone, 169
in cervical coxa valga, 175
coxa vara, 175
X-ray examination in chondrodystrophia fetalis, 173
in chronic arthritis, 170
in congenital coxa vara, 470
dislocation of hip, 175
in cysts of femur, 942
of humerus, 940
of upper end of femur, 463
in diseases of bones, 167
of joints, 167
in dislocations, 166
in enchondroma, 169
in fractures, 165
in hip-joint lesions in children, 175
in injuries to bones, 164
to joints, 164
in joint tuberculosis, 46
in juxta-epiphyseal fracture, 174
in military surgery, 164
in myeloid sarcoma of bone, 170
in myositis ossificans, 167
in neurotrophic diseases, 171
in osteitis deformans, 168
fibrosa, 169
in osteogenesis imperfecta, 173, 174
in osteomalacia, 169, 175
in osteomyelitis, 167, 175
in Paget's disease, 168
in Perthés' disease, 460
in posttyphoid bone lesions, 168
in pulmonary osteo-arthropathy, 171
in rickets, 173, 174
in sarcoma of bone, 169
in Schlatter's disease, 174
in scurvy, 173, 174
in separation of epiphysis, 174
in simple inflammatory periostitis, 167
in spondylitis deformans, 171
in subacromial bursitis, 509
in syphilis of bones, 168, 174
of hip in children, 176
in traumatic bone lesions, 174
joint lesions, 174
in tuberculosis of bones, 48, 168, 174
of hip, 200
of joints, 48
of shoulder, 274
of spine, 92
in tuberculous spondylitis, 174
methods, 165
of ankle, 167
of bones in children, 171
of cervical ribs, 171
of elbow, 166
of hip, 166
of joints, in children, 171
of knee, 167
of loose bodies in joints, 171
of pelvis, 166
of shoulder, 166
of spine, 166
of tuberculous sinuses, 168
treatment of bone tuberculosis, 54

WELLCOME LIBRARY