32.

INJURIES AND DISEASES OF THE HIP

FRED H. ALBEE

INJURIES AND DISEASES
OF THE HIP

IN PREPARATION

By the Same Author

UNUNITED FRACTURES

PAUL B. HOEBER, INC., PUBLISHERS

MEDICAL BOOK DEPARTMENT OF HARPER & BROTHERS

Frontispiece

Composite drawings. A. Outlines and dimensions of tibial grafts to bring about extra-articular arthrodesis of hip. Illustration at left indicates influence of Wolff's law upon any stress-bearing graft. Trochanter ends of grafts become much larger in diameter and stronger because more stress comes upon that portion of them. As stress increases from iliac ends toward trochanter, grafts coincidentally gradually increase their diameter, thus becoming cone shaped. Drawing from x-ray taken twenty-two years after implantation of grafts.

INJURIES AND DISEASES OF THE HIP

SURGERY & CONSERVATIVE TREATMENT

by

FRED H. ALBEE

M.D., LL.D., F.A.C.S.

Past President, American Orthopaedic Association;
Chairman, Rehabilitation Commission of the State
of New Jersey

Assisted by

ROBERT L. PRESTON, M.D.

Associate in Orthopedic Surgery, Columbia University
(New York Post-Graduate Medical School)

WITH 100 ILLUSTRATIONS,
INCLUDING 3 IN COLOR

PAUL B. HOEBER, INC.

MEDICAL BOOK DEPARTMENT OF HARPER & BROTHERS

NEW YORK MCMXXXVII

INJURIES AND DISEASES OF THE HIP

 PUBLISHED JUNE, 1937. PRINTED IN THE UNITED STATES OF AMERICA.

To My Wife

PREFACE

A METAMORPHOSIS in the treatment of conditions of the hip has been wrought by the ever-increasing application of surgical procedures to the numerous diseases and distortions of this joint. Many of the conditions heretofore regarded as hopeless can now be overcome by means of surgery. The rapid and extensive evolution of this operative work plus the epoch-making influence of the World War has justified the publication of this work.

Although I have by no means minimized the importance of conservative methods, it has been my chief aim to bring to the attention of the medical profession those surgical procedures which have stood the test of time, and which have contributed so largely to the reclamation of cripples suffering from hip conditions. The selection of material for inclusion within the covers of this book has been based upon the following two criteria:

1. All the procedures, conservative or operative, which I use, have been included.
2. I have also included those procedures which I do not use but which are commonly employed by surgeons of experience and mature judgment.

The inspiration for the assembling of this material has been largely derived from the appeals of my graduate and undergraduate students of the past thirty years for a book dealing with the treatment of hip conditions, no book having ever been written in any language on this subject. These students asked for a book which covered not only those conservative methods of treatment which time and experience have demonstrated to be sound, but also the technique of operative methods. A detailed description of operative technique is especially important since orthopedic textbooks have never thoroughly covered this phase of the treatment of hip conditions. In answer to these appeals, therefore, I have tried in this book to present a complete survey of the problem of hip disease.

An effort has been made to provide a bibliography which is selective and usable rather than complete, and credit has been given, according to the knowledge of the author, to the ideas and methods of others. If any omissions or errors have occurred, they will be gladly corrected.

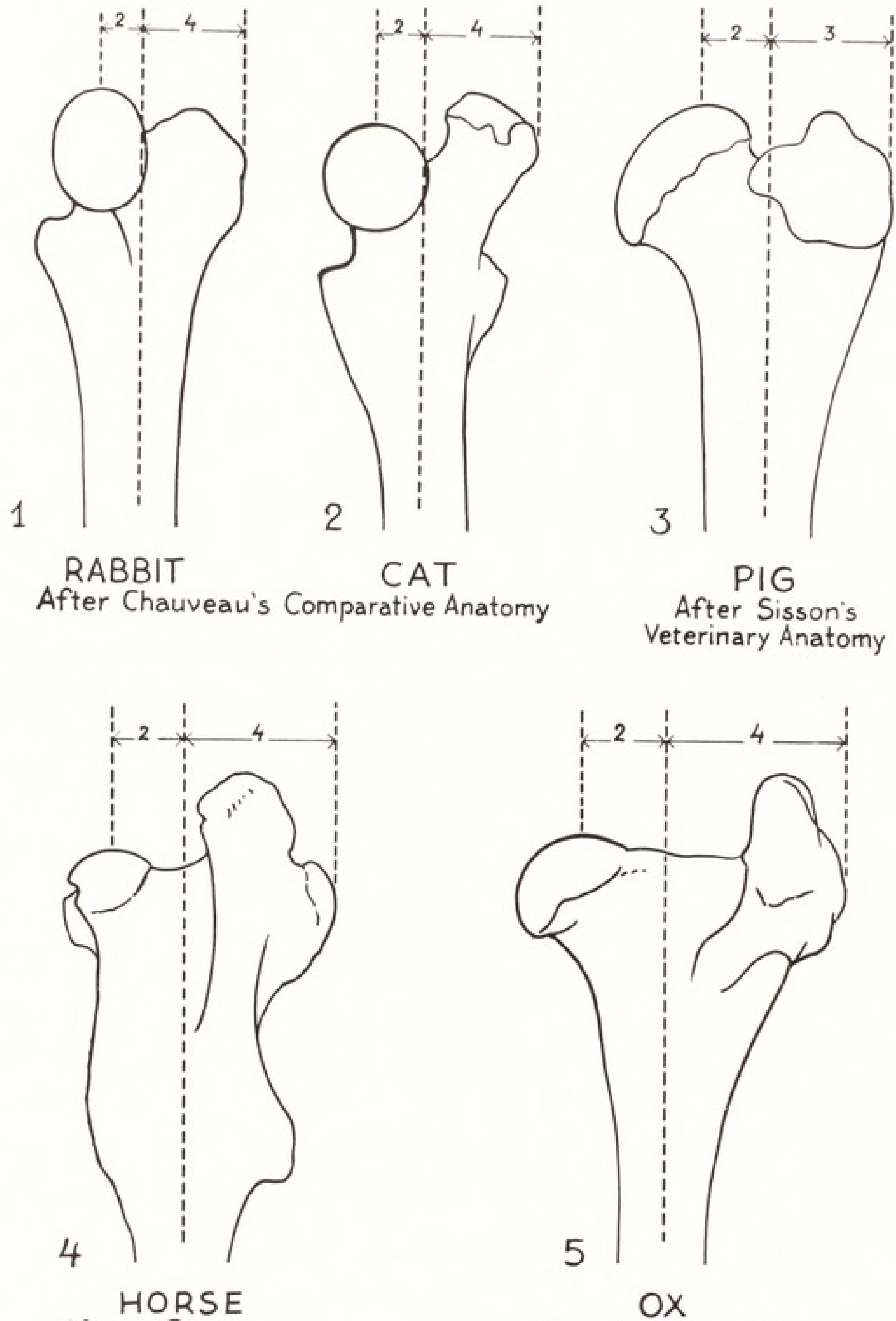
Acknowledgment must be made of my obligation and indebtedness to the members of the American Orthopaedic Association and to the profession in general, especially to the late Sir Robert Jones, to Royal Whitman, and to my many foreign colleagues. Sincere gratitude should be expressed to all those who have so ably assisted in this work, especially Mr. Paul B. Hoeber of Harper and Brothers, and Miss Florence Fuller of the publishers' staff. Appreciation is also due Mr. Ernst Weigman for his cooperation in the preparation of the original illustrations.

FRED H. ALBEE

New York, N. Y.,
May, 1937

CONTENTS

LIST OF ILLUSTRATIONS



Upper end of femur of various animals discloses relationship of lever at top of femur with axis of shaft approximating very closely conditions brought about by my reconstruction operation. This is in contrast to condition brought about by Whitman and Colonna operations, in which outer end of lever arm is greatly depressed, thus shortening it and diminishing its mechanical effectiveness. Also in both these operations the great trochanter, which makes up a part of this lever arm, is removed.

DISEASES OF THE HIP

CHAPTER I

INTRODUCTION

THE hip joint above all others offers to the bone surgeon the greatest opportunity to apply his ingenuity and skill. Yet there is probably no large joint upon which less surgery had been attempted up to the past thirty years. In fact, although arthrodesis of the knee joint for tuberculosis and other conditions had been frequently undertaken by a large number of surgeons in the course of many years, no one had even attempted to devise an operation for arthrodesis of the hip joint until the author offered such an operation * in 1908.

It may be that the peculiar character of this joint has been the main obstacle to the development of surgical procedures for its diseases and disabilities. Not only is it a ball and socket joint, which increases the difficulties of adequate treatment, but it is also a weight-bearing joint and subject to the stresses and strains of active function for that purpose. This joint is unique among the larger joints in that active weight-bearing is dependent upon the coordinated pull of the most powerful muscles of the body upon physiological bone levers, the most important of which is the neck of the femur. In the absence of these bony levers, their restoration further tests the versatility of the surgeon.

A further problem presented is the deep situation of the joint, making access and diagnosis difficult. For a long time, successful surgical reconstruction was deemed impracticable, if not impossible. For instance, a congenital dislocation of the hip in which the acetabulum was so shallow that the hip, even though reduced, would not stay in place, was regarded

* Albee, F. H. Arthritis deformans of the hip. *J. A. M. A.*, 50: 1977, 1908.

as a hopeless problem, and no operation was proposed until 1914.* No suggestion to this end was made even in the final report of the Commission for the Study of Congenital Dislocated Hip of the American Orthopaedic Association (1922). Thirty years ago, there were no motor-driven tools or fracture orthopedic tables and roentgenographic diagnosis was in its infancy. These have been no small factors in changing the aspect of the problem, contributing to the most far-reaching advances in treatment of lesions of the hip within the relatively short space of three decades. In addition to advances in technique, a better understanding of the biophysiological conditions within the joint has developed and has had the effect of opening up avenues of attack which have led to far better results than had hitherto been obtained.

It is vitally necessary, therefore, that any one undertaking treatment of pathological conditions of the hip-joint be fully cognizant of the new light that has been thrown upon the whole subject within a very short space of time.

It is of importance to understand the interrelationship between the biophysiological requirements of the joint and its treatment. Among the various problems of equal importance, might be cited fracture of the neck of the femur—one of the most widely discussed problems in surgery today. The multiplicity of methods which have been proposed for its treatment is evidence of the interest it arouses and also of the lack of understanding of its underlying biophysiology. This was emphasized by the fact that for the annual fracture oration before the Clinical Congress of the American College of Surgeons in 1934, Dr. Kellogg Speed † chose as his subject fracture of the neck of the femur and justified his choice with the remark that the problem of subcapital fracture of the neck of the femur is, as yet, unsolved. In fact, he chose "The Unsolved Fracture" as the title of his oration.

In congenital dislocation of the hip, if it is possible to re-

* Albee, F. H. The bone graft wedge. *New York M. J.* (Aug.), 1915.

† Speed, K. The unsolved fracture. *Surg., Gynec. Obst.*, 60: 341, 1935.

duce the hip, the rim of the acetabulum can be augmented sufficiently to hold the head of the femur firmly in place. If it is impossible to reduce the head of the femur into the socket, a so-called shelf technique has made it possible to build by bone graft a new socket higher up on the ilium. This technique has been made available for the case of recurrent or permanent dislocation, whether of congenital, traumatic, paralytic or pathologic origin.

Both intra-articular and extra-articular arthrodeses for treatment of chronic joint lesions have resulted in rapid healing of these conditions, not only saving many months and years of disability but also preventing the complication of marked underdevelopment of the whole extremity and distortions such as marked joint laxity (knock-knee and genu recurvatum) which resulted from long-continued splintage.

Furthermore, hips long ankylosed from any cause whatever may be restored not only to motion but also to stabilized weight-bearing strength and active joint function. This follows because the contour of the upper end of the femur is changed by massive bone grafts, thus affording the proper leverage to the musculature.

These techniques so briefly touched upon were previously considered impossible, or at least impracticable. They have been made available because of concurrent developments in diagnostic measures, preoperative and postoperative control of the extremity by means of the fracture orthopedic table, and operative versatility made possible by motor-driven precision tools, permitting accurate cutting and molding of bone. By such means, operating time and the hazards of shock have been markedly diminished, and in innumerable ways the execution of complicated and otherwise prolonged technical operations has been made feasible.

Treatment of subcapital fracture of the neck of the femur is not a matter of mechanics alone, as it has been almost universally considered. In fact, an entirely new conception is necessary to take this difficult problem out of the category of mere mechanics and place it where it belongs, in conjunction with therapeutics based on physiology and biology.

It is a peculiarity of the human mind in the mass that it is more inclined to accept than to question. This habit of thinking underlies the unquestioning acceptance of two erroneous beliefs concerning subcapital fracture of the neck of the femur, the first being that treatment of this fracture is solely a mechanical problem, requiring only reduction and immobilization; and the second that the head and neck of the femur isolated by fracture, because of their intra-articular situation, are adequately supplied with blood by way of the ligamentum teres and are capable of forming callus.

By attempts to inject the blood vessels of the ligamentum teres in the cadaver with metallic mercury, Wolcott * recently showed that in 15 per cent not a vestige of blood supply was anatomically demonstrable from this source. I can safely say that during the course of twenty years of observation at the operating table in 412 cases of removal of the head of the femur following non-union, non-existence of circulation was evidenced by absence of complicating bleeding from the ligamentum teres in all but one case. My experience tends to show that in the cases of non-union, the blood vessels of the ligamentum teres supplying the proximal fracture fragment were destroyed with rupture of the ligament at the time of the initial trauma.

As a result of these observations, the proper treatment of this fracture is, in many cases, based upon a tripod, of which one element represents reduction and mechanical mobilization, another the physiological or vascular requirements and the third the biological or osteogenetic needs.

Reduction and mechanical immobilization have been made possible by the development of new apparatus—motor-driven tools, fracture orthopedic table and the double plaster spica. Once one realizes that there is no blood supply to an isolated femoral head, it becomes evident that this must be furnished,

* Personal communication to the author with permission to quote.

if possible, by other means. Such a femoral head isolated by subcapital fracture constitutes in fact a joint mouse. A lack of osteogenesis or callus-forming capability is a direct result of the dearth of blood-supply. Johnson * showed that the osteogenetic capability of a cross-section of bone is in direct relation to its blood-supply. The bone graft, because it is capable of conducting blood-vessels when placed across the fracture line, not only brings the necessary supply of blood to the capital fragment from the vascular cancellous tissue of the trochanter, but also furnishes bone cells locally to the inactive fracture junction.

Open surgery of the hip is principally a development of the past three decades. Thirty years ago entering the hip-joint surgically was thought to be fraught with great hazards. Methods of procedure were relatively primitive, and there was by no means the understanding of the underlying principles governing the successful treatment of lesions of the hip that we have today.

The bone graft alone has played a major part toward this end.

* Johnson, R. W. A physiological study of the blood supply of the diaphysis. *J. Bone & Joint Surg.*, 9: 153, 1927.

Chapter II

ARMAMENTARIUM OF THE SURGEON FOR HIP WORK

HOSPITALS are, as a rule, poorly equipped for fracture work, and in many instances surgeons of the general staff, overstimulated by their zeal for 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 their favorite departments, and have sadly neglected to provide an adequate armamentarium for fracture and other bone work. A strong impetus to rectify this discrepancy was afforded by the large number of fractures and other bone injuries accruing from the World War.

A complete armamentarium for the bone surgeon should contain the following:

1. Traction operating table;
2. Electro-operative bone outfit;
3. Suitable retractors, sharp-pointed and rake, and of varying sizes and depth of tooth;
4. Bone clamps;
5. Bone elevators (*e.g.*, Lane's);
6. Double tenaculum for aiding in extracting and holding head of the femur (author's);
7. Hip shapers (convex and concave) for arthroplasty;
8. Materials for external and internal fixation of fragments, including kangaroo tendon of various sizes;
9. Various metal nails, fracture plates, screws and tools for their application:
    (a) Smith-Petersen nail;
    (b) Vall's nail;

(c) Telson-Ransohoff-Mayer threaded nail;
(d) Moore adjustable nail with nut;
(e) Bunnell guide which is attached to the Albee motor and aids in the accurate placement of the bone peg through the neck and head of the femur.

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 with a mechanical tap, should be used.

Furthermore, the author is convinced from a very careful laboratory investigation, that silver wire should be entirely omitted from the surgeon's armamentarium; 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 a large strand of silver wire will withstand at the twist junction when placed in an accurate machine for testing tensile strength. In many instances, the wire will begin to yield at the twist or knot before the dial of the testing machine has begun to register.

10. Osteotomes of various widths. The author never under any circumstances uses a blunt-edged chisel. There is so little flexibility in bone that it brushes or breaks very readily under the chisel, and for that reason, a thin-edged osteotome is preferable.
11. Rongeurs of various types;
12. Lion-jaw forceps;
13. Gouges with long handles and of various widths;
14. Heavy mallet; should be large and of solid metal, although one of lignum vitae is very good;
15. 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 technique. 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;

16. The Balkan bed-frame;
17. Thomas brace and other necessary apparatus.

The Electro-operative Bone Mill and Technique of Its Usage

In modeling the graft into dowels, wedges and inlays, and in making use of the different well-known mechanical devices, such as tongue-and-groove joints, dovetail joints, mortises, etc., the motor outfit is indispensable. An accurate cabinetmaker's fit may mean success in many instances where an ordinary crude coaptation would mean failure. Especially is this true at the hip.

It is only when the most precise cabinetmaker's fit has been secured, that the full influence of Roux's law of frictional stimulation to osteogenesis is obtained. This is a most potent influence in stimulating callus formation or securing union.

The ideal electromotor 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. The flexible shaft formerly used in dental outfits but given up some years ago, is not suitable for transmitting the power to the cutting tool, because, for the

same reason given by the dentist, it causes the cutting tool to vibrate or "chatter" and does not allow the tool to be directed in every conceivable direction.

Electrically Driven Circular Saws and Drills

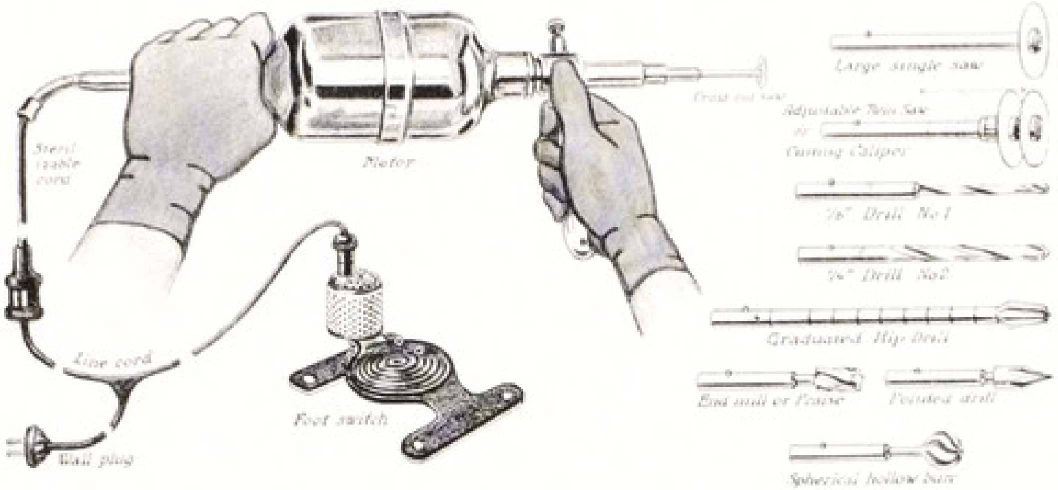


FIG. 1.

4. It should permit easy and convenient control of the electric current and speed of the cutting tool.
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 electric 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—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 (Fig. 1) 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. Various motor driven dies should

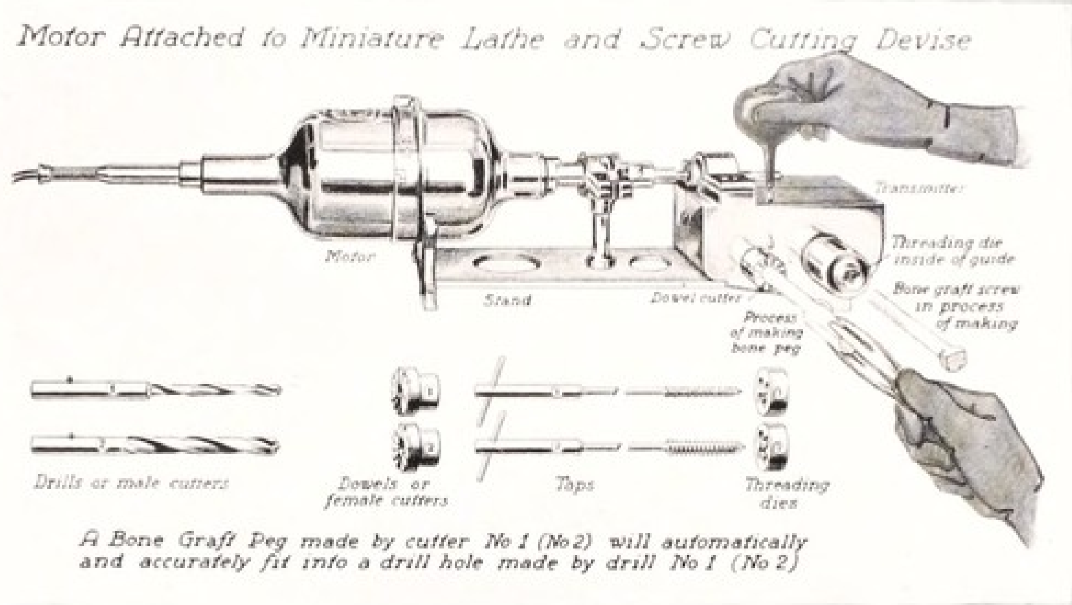


Fig. 2.

allow threads to be put on pegs of any size, thus transposing them to screws (Fig. 2). Corresponding size drills and taps make the threaded holes for the reception of the bone-graft screws.

9. The motor should furnish enough power to drive rapidly a twin saw or large drill through the thickest cortex of human bone without tendency to stall. The motor tool is best attached directly to the motor shaft; the motor 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 (4 pounds) has been found to be an advantage rather than a drawback in its application.

The Fracture Orthopedic Operating Table

In recent years, several excellent fracture orthopedic tables have been developed. The author, however, has had no experience with these new tables, as he has used exclusively the one which he designed over twenty years ago.* Some of the important features of this table are detailed.

The table is comparatively light in weight. Its top is constructed of Monell metal, which is non-corrosive and non-oxidizable. The frame is made of brazed tubular material, to afford the lightest and strongest structure possible. All four wheels are swiveled, the two at the foot end being furnished with foot-locks to fix the table and prevent it from rolling. When folded up, this table is as short as the usual general operating table, and because of this and the fact that there are no parts projecting when it is not being used for traction, it is of use for general surgery.

DETAILS

The *trucks* of the table rest on swivel rollers, permitting it to be moved about easily, while a locking apparatus (Fig. 3) over the two at the lower end, operated by the foot, permits it to be easily fixed in the desired place. The ability to move the table about easily is of the greatest convenience, in that at any time during the operation, the table can be so moved that better light is secured in the depth of the wound, or the clinical observers can be afforded a better view of the operative procedure.

A sliding leaf at the foot and a hinged leaf at the head allow the table to be lengthened as much as necessary, while a *removable shelf* steadied by a rest can be used for instruments or to support the arm or leg of the patient.

The long traction arms are telescoped and therefore allow sufficient shortening so that they can be swung under and out of the way when the table is being used for general purposes and traction is not required (Fig. 4).

Hip rests are of two sizes. The head of the table is movable up and down from the hip rest, so as to allow the application of various widths of spicas.

* Albee, F. H. A new fracture-orthopedic operating table. *Surg. Gynec. Obst.*, June, 683, 1918.

The foot end of the table can be elevated to any desired height, by means of a wheel with handle (Fig. 5, B). This *ability to raise or lower the foot end* of the table by

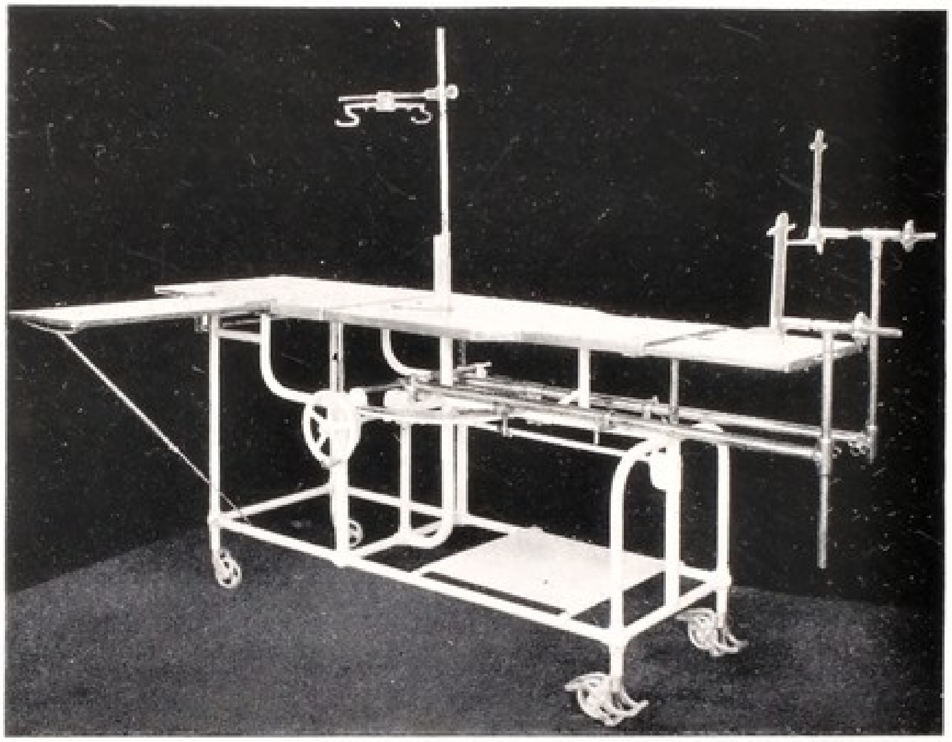


FIG. 3. Author's fracture orthopedic operating table. Table opened to its full extent, showing sliding leaf at foot, hinged leaf at head, removable arm-shelf with rest, long traction rods with foot bars, arm suspension apparatus, perineal post, swiveled rollers with locking apparatus, etc. (From Albee's "Orthopedic and Reconstruction Surgery," Saunders.)

graduated adjustment is an important innovation, in that it allows sand-bags or pillows to be placed beneath the sagging ends of fracture fragments, to elevate these fragments in the proper alignment. This is readily accomplished by a few turns of the wheel, the handle of which is accessible to the surgeon, by whom it may be grasped under a sterile towel, so that at any time during the operation the surgeon has the mechanism of the table under his complete control. The surgeon is enabled by depressing this portion of the table and inserting a sand-bag under one buttock, to have complete control of the upward rotation of the patient's hip or pelvis in any degree desired, both before and during the operation. Also a double-ended rake retractor may be hooked beneath the movable leaf of the table and any desired traction down and outward or retraction may be exerted by a few turns of the wheel (B).

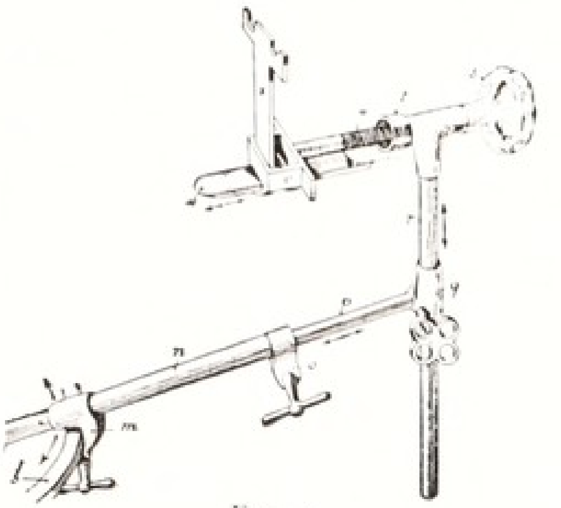


FIG. 4.

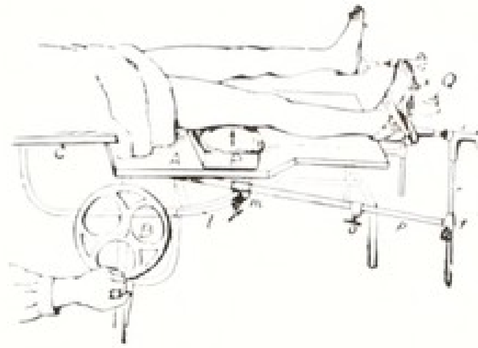


FIG. 5.

FIG. 4. Author's fracture orthopedic operating table. Details of distal portion of traction arm and foot hold. *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. (From Albee's "Orthopedic and Reconstruction Surgery," Saunders.)

FIG. 5. Practical application of traction. Foot bandaged by Q to foot bar, bandage passing over projection X of foot bar. Leg is swung into 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 sand-bag P may be placed under offending fragment and table again elevated, levering fragment into place, while internal fixation agent (inlay bone graft, kangaroo suture, wire or Lane plate) is applied. In a similar way rotation of patient's trunk may be controlled by placing a sand-bag between hip and movable portion of table. A few turns of wheel up or down controls situation very satisfactorily. (From Albee's "Orthopedic and Reconstruction Surgery," Saunders.)

Lengthening of the traction arm is accomplished by two adjustments. Coarse adjustment is attained by graduated telescoping of the arm; and a more powerful, fine adjustment, accomplished by means of a screw. This screw feeds as well distally as proximally when the wheel is turned. Failure of this back-feed has proved a great annoyance in other traction tables. The screw threads are covered by a metal cuff which prevents jamming of sheets or towels into the threads while traction is being made.

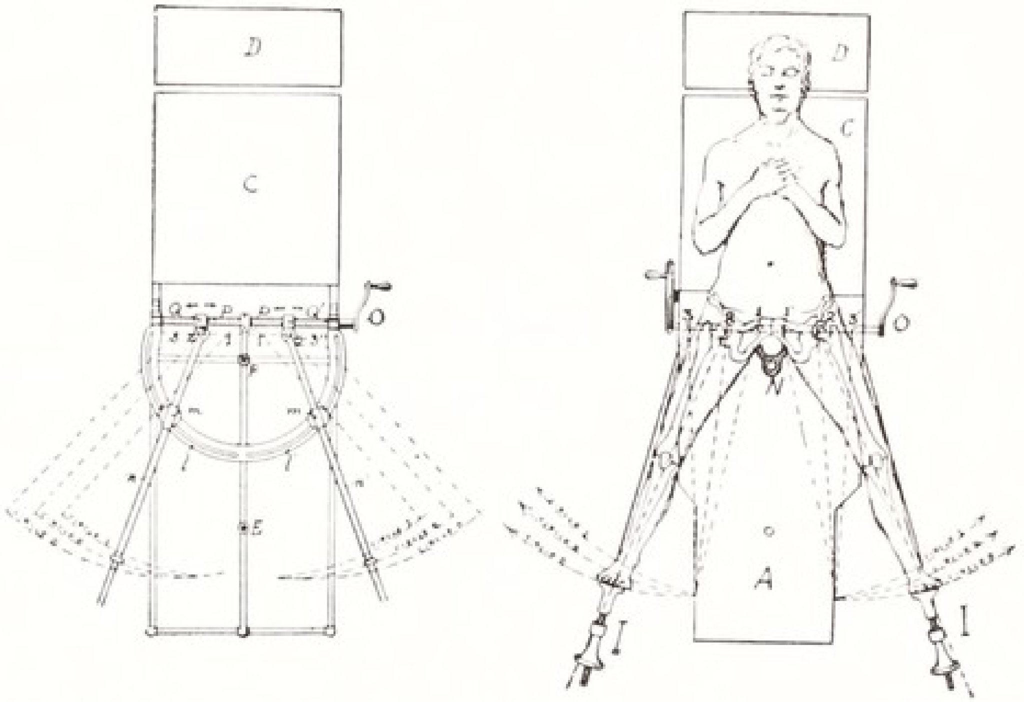


FIG. 6. Screw adjustment of proximal ends of traction arms, a mechanical device for shifting centers of rotation of traction arms to points corresponding with, or greater or less than, interval between hip joints of individual. Crank O turns bar P, halves of which have worm threads cut in opposite directions. Turning crank moves riders Q and Q′ simultaneously, keeping them always equidistant from center of table. Pivots of arms *n* and *n′* are thus made to travel along lines from 1 to 3 and 1′ to 3′ respectively, enabling abduction or adduction of these arms to describe arc of a new circle with each new position. Traction arms can be fixed upon quadrant *l*, *l′*, in any given position, by set screws *m*, *m′*. (From Albee's "Orthopedic and Reconstruction Surgery," Saunders.)

The foot is held in position by a muslin bandage placed over it and including in its folds the movable *flat bar*, placed against the plantar surface of the foot and the curved plate beneath the heel. These flat bars (foot-plates) are very strong, being made of steel. These plates fit into the distal extremities of the traction rods, at which point *the small sliding curved plate* prevents compression of the heel and obviates dropping down of the foot due to the obliquity of its dorsal aspect where the bandages encircle it during the application of a large amount of traction. This sliding plate prevents the foot from skidding downward away from the foot piece. After plaster-of-Paris dressings have been applied, and the restraining muslin bandages cut, both of these sliding plates are removed, thus freeing the patient's limb from the traction arm without disturbing the plaster.

Screw-adjustment of pelvic ends of traction arms (Fig. 6). The proximal ends of the traction arms are universally adjustable by means of a heavy screw placed crosswise to the table. This screw bar is placed (to correspond with the horizontal plane of the hip joint) slightly above the perineal post.

The direction of the threads of this screw are reversed on the opposite sides of the center, so that when the attached crank is turned, the ends of the traction bar uniformly converge upon or diverge from the center of the table. This enables the surgeon to make his adjustments in accordance with the distance between the hip joints of each individual case, so that traction remains constant throughout abduction or adduction, which is usually desired. However, by placing the axes of the traction arms farther apart, the amount of traction may be increased as abduction is increased. In the management of dislocations and fractures near the hip joint, this may be an important and valuable adjustment, particularly in fracture dislocations of the femoral head through the floor of the acetabulum.

The Plaster-of-Paris Bandage and Technique of Its Use

Plaster-of-Paris. The plaster-of-Paris should be that used by dentists, of very superior quality and rapidly setting. 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.

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 x 32 threads to the square inch. 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, 5 and 8 inches wide, respectively. In his own practice the author has found these to be the only three sizes required.

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 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.

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 newspapers or wrapping paper, and packed in tin pails with accurately fitting covers. (The tin 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.

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, and 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.

REQUIREMENTS OF A PLASTER-OF-PARIS BANDAGE

The crinolin should be of such quality that in applying the bandage it can be made to conform smoothly 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 technique, 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, if flat, awkward of application, and does not take the form of a roller bandage. 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 molding and stay "put."

PLASTER-OF-PARIS TECHNIQUE

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 in place the wound dressing (postoperatively or otherwise) by means of the sheet wadding bandage, rather than by applying a gauze bandage directly over the dressing, 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.

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.

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 application.

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 mold the plaster about the bony prominences, and be on the alert to increase this coaptation effect at the proper time, before the plaster becomes too hard. 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 excellent practice.

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 formation of such 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.

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 a point two or three inches above the malleoli, a spreader being applied below the foot and weights attached in the usual manner, or the traction straps may be incorporated in the plaster at their exit, and the plaster may be extended over the other leg, including the foot, while the patient is still held on the fracture table. By molding the plaster snugly to the plantar surface of the foot of the involved side, counter pressure may be exerted to the traction on the normal limb. Thus the equivalent or better of Anderson's * counter-traction is secured.

Plaster dressings well applied and of good material will last many weeks or months.

REMOVAL OF A PLASTER-OF-PARIS SPICA

In the author's experience, this is best done by a Stillé cutter. If this is not accessible, a saw or a heavy jack-knife serves the purpose. To soften the plaster along the line of

* Anderson, R. New method for treating fractures. *Surg. Gynec. Obst.*, 54: 207, 1932.

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. Having cut the gutter, the dressing is spread with a special clamp.

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 should be carefully avoided.

Chapter III

SURGICAL LANDMARKS, PREOPERATIVE PREPARATION AND INCISIONS

THE hip joint is deeply placed and surrounded by numerous powerful muscles. The psoas and iliacus muscles are in front of the articulation. Behind it are the quadratus femoris, the obturator internus, the two gemelli, and the pyriformis. To the outer side lie the gluteus medius and minimus and rectus femoris, and to the inner side are the pectineus and obturator externus.

The upper border of the greater trochanter is on a level with the center of the hip joint. Nélaton's line extends from the anterior superior spine of the ilium to the most prominent part of the tuberosity of the ischium, running across the center of the acetabulum and passing over the top of the greater trochanter.

The head of the femur lies just below and to the outer side of the central point of Poupart's ligament.

The hip joint is a typical enarthrodial *(ball-and-socket) diarthrosis.* The rounded femoral head is received into the acetabulum of the pelvis.

The *cartilaginous lining* of the acetabulum is horseshoe-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 greater 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, which are differentiated portions of the capsule, 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.

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.

Preoperative Preparation

On the day before operation, the operative site and a generous area of the surrounding skin is shaved and scrubbed vigorously with green soap. All traces of the soap are removed with water, and the part is washed with benzene to remove as much surface oil or grease as possible. A 50 per cent solution of alcohol is then applied. After this dries, the region is painted with a half-strength solution of tincture of iodine and covered with sterile towels. In the operating room, these towels are removed and the part is again painted with a half-strength solution of tincture of iodine.

One hour before operation, an adult patient is given $\frac{1}{6}$ gr. of morphine sulphate, and $\frac{1}{150}$ gr. of atropine sulphate.

In the selection of an approach, careful consideration should always be given to the placement of the incision in such a way as to avoid damage to important anatomical structures. An equally important consideration is to have the incision generous enough to permit the operation to be done. An adequate incision necessitates less retraction. Undue pulling of the soft parts leads to devitalization of tissue and possibility of infection.

The author does not favor the no-hand contact technique of Lane, or the clamping of towels or other materials to the wound edges as he believes that as much or more is lost than gained, particularly in bone work where an excess of instrumentation is necessary. The edge of the skin wound is likely to be devitalized by crushing of clamps and the drying effect of the fabric.

The chief concern is the hair follicles, sebaceous and sweat glands and the organisms which they may contain. It is believed that operative hazard as to infection is minimized when the following points are observed:

1. Thorough preoperative preparation;
2. Adequate approach with minimum retraction;
3. Reasonable speed with minimum of traumatization;

4. The use of as little absorbable suture material as will answer both for the closure of the soft parts and the fixation of the bony elements;
5. Every provision to avoid hematoma, and it is believed that a continuous link suture of No. 1 chromic catgut accomplishes this better than any other method;
6. Closure of the skin with No. 0 plain catgut;
7. Thorough puddling of the suture holes as well as the line of incision by smashing 3½ per cent tincture of iodine into them by repeated sharp blows with the gauze of a sponge;
8. Rigid immobilization of the parts, usually by well-molded plaster-of-Paris cast.

There is no more trustworthy means of avoiding infection than good immobilization and when dealing with infection the Orr concept should be the guide. This method consists of dressing the wound with either vaseline gauze or paraffin-vaseline compound, without windows in the cast and avoiding too frequent changes of the cast. Instillation of specific autogenous bacteriophage should be used, through catheters or rubber tubes into the depths of the wound.

Surgical Approaches

The relatively small size of the hip joint, no less than its position of great depth from the surface, and its relation to very important structures, all conspire to render surgical approach difficult. This difficulty is well illustrated by the great number of routes which have, from time to time, been described by different operators. Moreover, it is evident that no one approach will satisfy all conditions; a route which is ideal for drainage of the joint may prove quite unsuitable for plastic work or arthrodesis.

The names of such surgeons as Lisfranc, Sedillot, Percy, Roux, Langenbeck, Lucke, Barber, Kocher and many others are associated with methods of opening the hip joint. In times past, arthrotomy of the hip was done in desperate haste for desperate conditions. Present-day surgical methods have made the operation less lethal in character, and have vouchsafed to the surgeon a greater sense of security. Nevertheless, the operation remains a major surgical procedure, one not to be undertaken lightly, and requiring surgical experience and judgment as well as skill and deftness in the handling of tissues.

Among the lesions which may require arthrotomy are acute infections of the hip joint; tuberculosis; fracture of the femoral neck; traumatic or paralytic dislocations; arthritis with painful motion or loose bodies; ankylosis; unreduced displacement of the upper femoral epiphysis; obscure arthritis demanding tissue examination; congenital dislocation at all ages; and paralysis, notably that due to poliomyelitis. It is of great importance to select the method of approach best suited to the condition and case in question.

The dangers which may be encountered in arthrotomy of the hip are those common to any serious surgical procedure performed upon patients who, as a rule, are not in good physical condition. Consequently the operation must be done with reasonable speed and with due regard for the tissues. The automatic machine tools have done much to reduce the surgical shock from trauma. Nowhere in surgery are careful technique and rigid asepsis more necessary.

The three principal methods of approach to the hip are the anterior, the anterolateral, and the posterior. A fourth, the lateral approach, is not to be recommended. For all intra-articular work I use the Smith-Petersen-Sprengel approach (anterolateral), the degree of lateral exposure depending on how far back the incision is carried along the crest of the ilium. In fractures of the neck of the femur the vertical incision of Smith-Petersen with a very short posterior arm is preferred, the length of this varying with the obesity of the patient and the necessities of exposure in the particular case.

Acute infections demanding drainage are the only condition for which I use the posterior approach.

ANTEROLATERAL APPROACH

*Smith-Petersen-Sprengel Approach.** From a point three to four inches below the anterosuperior spine, a vertical incision following the external border of the sartorius 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 can compare with this in the extent of exposure and the facility it offers for all plastic procedures.

POSTERIOR APPROACH

Kocher Approach. Kocher makes an incision from the posterior margin of the base of the trochanter major upward to the posterosuperior angle of the trochanter, and thence to the posterosuperior iliac spine. The gluteus maximus is then divided in the line of its fibers and the edges are retracted. The gluteus medius is separated at its insertion into the trochanter major and turned upward. The pyriformis, obturator internus and gemelli are divided at their insertion into the trochanter and turned inward. The capsule is incised, and then the superior half of the trochanter major divided from the main bone with a saw and turned upward with its attached muscles. By adducting the diseased limb across the sound one and rotating it outward, the head of the femur is dislocated posteriorly.

Langenbeck Approach. In Langenbeck's approach an incision is made from the posterosuperior iliac spine to the

* Smith-Petersen, M. N. A new supra-articular subperiosteal approach to the hip joint. *Am. J. Orthop. Surg.*, 15: 592, 1917. A similar approach was used by Sprengel about one hundred years ago in Germany, and later by Anderson in England.

posterosuperior angle of the greater trochanter. The gluteus maximus is divided in the line of its fibers and the edges are retracted. This exposes the posterior margin of the gluteus medius and the superior margin of the pyriformis. These are retracted and, if necessary, the pyriformis is divided or loosened at its insertion. This is a rapid and easy approach with little disturbance to the tissues. The joint exposure is, however, limited as the superior margin of the tendon of the pyriformis is at least 1/8 inch above the posterosuperior margin of the neck of the femur. This factor also makes drainage difficult.

Dixon Approach. For further exposure, Dixon recommends loosening the gluteus medius and minimus at their insertions, and then retracting them backward. The division of all these muscles may, however, weaken the stability of the joint.

Osborne Approach. As the outcome of many experimental operations on the cadaver, Osborne * of the University of Manchester, suggests a combined Langenbeck-Kocher approach. Finding Langenbeck's method less mutilating than Kocher's, but the exposure somewhat limited, he has combined the best points of both. His method depends on the observation that the tendon of the pyriformis runs along the posterosuperior margin of the neck of the femur, and that the gemellic mass runs obliquely across the neck.

With the diseased limb adducted across the sound limb, an incision is made from a point 1 3/4 inches below the posterosuperior iliac spine to the posterosuperior angle of the greater trochanter and then down the posterior edge of the trochanter for 2 inches.

The gluteus maximus is divided in the line of its fibers and the edges retracted. The first part of the incision corresponds to a line just above the lower edge of the pyriformis. The limb is rotated internally and the tendons of the pyri-

* Osborne, R. P. Approaches to the hip: a critical review and a suggested new route. *Brit. J. Surg.*, 18: 49, 1930.

formis and the gemellic mass divided close to their insertions, the two turned inward to be held by the assistant. The capsule of the joint is next exposed and incised. Further exposure can be gained, if required, by retracting the quadratus femoris downward and the gluteus medius upward.

There is no difficulty from hemorrhage, but the following vessels will be encountered: A branch from the sciatic artery which runs between the tendon of the pyriformis and the superior gemellus; the ascending branch of the internal circumflex artery; a branch of the gluteal artery running along the upper border of the pyriformis, and this should be retracted upward. It will be noted that the reflection of the gemellic mass protects the sciatic nerve from injury.

The advantages of this route would appear to be: Exposure of practically the whole of the posterior surface of the joint and the neck of the femur; no interference with the greater trochanter (*cf.* Kocher); slight and easily reparable displacement of the tissues; adequate provision for drainage.

As the result of his investigation Osborne concludes that, for all "quiet" work, the Smith-Petersen approach is the one of election, but for "infected" cases of any type requiring a direct attack on the joint or head and neck of the femur, with subsequent drainage, he recommends the combined posterior route just described.

Ober Approach. The patient lies face down on the table. Incision is made in a straight line running from the posterolateral aspect of the femur obliquely upward and backward toward the sacrococcygeal articulation, directly over the neck of the femur and in the line of the fibers of the gluteus maximus. The fibers of the gluteus maximus are separated. The underlying fat is pushed aside by blunt dissection, care being used to avoid the sciatic nerve which is in the region of the medial extremity of the incision. The tendon of the obturator internus, the quadratus femoris, and the gemelli and pyriformis are now exposed and separated by blunt dissection, and retracted to expose the posterior surface of the joint capsule. The joint capsule is divided the whole length of the incision, and drainage or removal of tissue accomplished. In order to maintain drainage the capsule may be sutured to the gluteal fascia, or cigarette drains may be stitched to the capsular margins. Closure is simple, the edges of the wound being approximated with catgut sutures and the skin sutured with silk.

LATERAL APPROACH

Murphy and Lexer advocate the lateral approach for arthroplasty, but I consider the anterolateral superior. In fact, I do not use the lateral approach for any operation on the hip.

Ollier Lateral Approach. The patient lies on his side with the thigh flexed to forty-five degrees. A curved incision through skin and subcutaneous fat is made, starting at the anterosuperior spine and running to the posterosuperior spine. The curve is flat, U-shaped, with its lowest point about 1 inch below the tip of the greater trochanter. The aponeurosis of the gluteus maximus is divided vertically and retracted backward. The trochanter major is now cut through about 1 inch below its tip. The direction of this osteotomy is oblique, so that the upper end of the cut is at the upper surface of the femoral neck. This detached fragment is pulled upward, and carries with it the muscles which have insertion at the greater trochanter, that is, the gluteus medius, gluteus minimus, pyriformis, and gemelli. The anterior margin of the gluteus medius is dissected from the posterior margin of the tensor fasciae femoris. This exposes the upper surface of the joint capsule and the acetabular margin. The capsule is divided vertically, and the head of the femur dislocated by adduction and internal rotation of the thigh. The fragment of the trochanter is sutured in place either by catgut stitches or a bone pin.

Chapter IV

FRACTURES

1. Fracture of the Neck of the Femur

ALTHOUGH operative intervention and the implantation of metal nails or other foreign agents have been practiced in the treatment of fractures of the neck of the femur for over thirty-five years, yet there is no other fracture in which union fails so frequently. The surgeon who is consulted regarding the insertion of a bone-graft peg months after the fracture has occurred and when conservative measures have failed and much absorption of the femoral neck has taken place, is impressed by his success at this late stage even though appreciating that an earlier operation would have saved months or years of convalescence or invalidism and would have contributed to a much better functional result.

Statistics have shown that there is a mortality of approximately 20 per cent in aged patients with fractures of the hip joint, and that of those remaining only about 50 per cent secure good bony union. This appalling situation constitutes a real challenge to try to improve the treatment that has been used in the past. The old dictum—"Treat the patient and disregard the fracture"—is not good advice. The best way to treat the patient is to treat the fracture. Pain is relieved as soon as the fracture is accurately immobilized, and the patient has a much better chance to recover.

Realizing that the end results of both conservative and operative fixation by metal nails or other means of this most troublesome fracture were extremely poor, the American Orthopaedic Association in 1928 appointed a committee to make a comparative study in this country and abroad of the end results following every accepted method of treatment.

Two reports were made by this committee, one in 1929, and another in 1930. The first presented the end results of unimpacted fractures of the neck of the femur within the capsule in persons over sixty years of age. The second was a comparative study of true end results of the same type of fracture in persons under sixty years, treated by various methods, and in persons of any age treated by open operation.

No case was considered a true end result unless at least one year had elapsed between the beginning of treatment and the date on which the end result was recorded.

The first report (1929) was based on a review of 331 fractures, the results in 201 cases being suitable for study. The second report (1930) was based on a review of 419 fractures of which 365 were suitable for study. Of the 365 cases, 262 had been treated by closed methods and 103 by open surgical attack.

The mortality rate for all ages treated by open surgical methods was only 2.7 per cent as compared with 9.2 per cent in cases under sixty years treated by closed reduction.

In these serious fractures the question of prime importance is proved bony union one year or more after the beginning of treatment, and in this respect open methods again show up in strikingly favorable contrast to results by closed methods.

	Proved Bony Union
Closed Reduction	*Per cent*
Series 1. (Patients over sixty treated by closed methods)	30.4
Series 2. (Patients under sixty treated by closed methods)	51.9
Average percentage of firm bony union ff. closed reduction	41.1
British Fracture Committee	22
Open Operation	
Patients of all ages, Smith-Petersen method	64.8

The statement that fracture of the neck of the femur shows a much more marked tendency to heal in children and young persons than in adults is erroneous. With lateral fractures of the neck of the femur there is great danger of pseudarthroses, and in isolated fractures of the head of the femur there is great danger of aseptic necrosis. From serial roentgenograms made in typical cases, it appears that after lateral fractures of the neck of the femur in young persons between eleven and seventeen years of age aseptic necrosis of the upper end of the femur may develop very gradually after roentgenologic and clinical healing of the fracture has taken place. The disease pictures show a resemblance to Perthes' disease, which, according to these observations, occurs as a sequel to a traumatic vascular injury causing a metabolic disturbance of the head.

Isolated fracture of the head of the femur usually remains undiagnosed for a long time. The early symptoms subside, but after three to six months the condition becomes worse again because of local necrosis in the capital epiphysis. Later, the head appears flattened and shows a trough-shaped depression. Because of the danger of secondary necrosis of the head, apparatus to relieve weight-bearing must be used for at least six months in cases of fracture of the neck of the femur, even in young persons.

In 1913 the author described * the use of a bone-graft peg for non-union taken from the crest of the tibia of the same patient and in 1929 reported 91.7 per cent of proved bony union with this method. Campbell † at about the same time reported close to the same percentage of results, and in 1932, in a series of 10 cases, reported bony union in 100 per cent. Most of these cases had been previously treated unsuccessfully by various mechanical methods (including metal nails. A comparison of the foregoing results is

* In: Murphy, J. B. Clinics at Mercy Hospital, Phila., 1913.

† Campbell, W. C. Central or intracapsular fractures of the neck of the femur. *Proc. California Acad. Med.*, 1931-32, p. 53.

most instructive when one considers that in the case of fresh fractures with the original urge to repair still present, the percentage of non-union varied from 22 to 64.8 when mechanical methods alone were used, whereas in the case of non-union with conditions much more unfavorable to union, the autogenous bone graft resulted in a much higher percentage of good results, namely, 91.7 per cent.

Analysis of these statistics drives one to the premise that the requirements of this particular fracture are such that mechanical immobilization alone will not suffice unless supplemented by biophysiologic influences, from which the conclusion may be drawn that fracture of the central portion of the neck of the femur presents obstacles to union not present in other fractures, even in those situated less than 1½ inches away. I refer to fractures at the base or transtrochanteric region where union almost always occurs. Of these obstacles to union, the following seem to be the most important:

(a) Its location within a joint, so situated that a solution of continuity through it cuts off the proximal fragment from its principal source of blood supply, namely, that from the trochanteric region;

(b) The rotation of the fragment, avulsion or tear at the time of fracture of the ligamentum teres resulting in complete or partial obliteration of the blood-supply even from this source, if one exists;

(c) It can be further claimed that from a mechanical standpoint this fracture is unfavorable because of the fact that the proximal fragment is practically a sphere in a slippery joint cavity and very likely to move at the slightest body movement or muscle spasm. Further, the fracture being in a joint, the fracture space is immediately filled by synovial fluid which is inhibitory to callus formation. By the same token, there is no periosteum with its osteogenetic influences, nor is there blood-supply coming to the point of fracture from the periphery.

It is impossible to speak in definite terms as to the relative amount of blood-supply to the head and proximal portion of the neck of the femur, coming from these two sources, but it is certainly safe to say that considerably more than 70 per cent comes from the trochanteric region of the femur, and that in some instances, it all comes from this source.

These statements have been confirmed by Wolcott * who, in some very interesting work, has injected both the nutrient vessels of the upper end of the femur and those of the ligamentum teres with mercury and found that in a considerable portion of cases the small and unimportant blood vessels of the ligamentum teres did not extend into the head at all, and that the age of the patient had very little, if any, influence upon these findings.

Since callus potentiality has been proved repeatedly by my own animal experimental work and by that of others to be in direct relationship with the amount of blood brought to the part, the importance of this consideration is evident.

It is principally in this respect that this fracture differs radically from others. In other skeletal fractures blood comes from every direction—from both fragments, and particularly from the blood-supply of a collateral nature which is conducted to the point of fracture by the overlying adherent soft parts. It is believed that in fractures of the central portion of the neck of the femur that result in non-union, practically all blood-supply is cut off, except that which is available from the broken end of the distal fragment. If the overlying capsule should be torn, there is little likelihood of the torn edges becoming sufficiently adherent to aid in the establishment of a blood-supply of any consequence, especially since dense capsular tissue is unsatisfactory for this purpose. An important consideration bearing upon this is the relative prognosis of an intracapsular fracture and one only 3/4 inch farther out in the neck at the base of the transtrochanteric region, in which instance cap-

* Personal communication.

sular and extracapsular tissue is attached to the distal end of the proximal fragment, thus serving to bring to it a sufficient blood-supply. Non-union practically never occurs in such fractures.

It is difficult to explain careful roentgenographic studies of non-union of subcapital fractures on any assumption other than that of faulty blood-supply. The suggestion of erosion from the rubbing of one fragment end on another will not suffice, since in many instances of extensive disappearance of bone, no motion of one fragment on the other had ever been allowed to occur.

It is my conviction that the blood-supply of the ligamentum teres, if one exists, is almost universally destroyed at the time of the fracture in those cases coming later to non-union. This statement is based upon the experience of myself and associates at the operating table during the past ten years, during which time in 412 cases the femoral head has been removed while doing the author's arthroplastic reconstruction. In only one instance has there been any bleeding of consequence from the stump of the ligamentum teres. When one realizes that any extreme traumatic rotation of the head, which should be expected, at the time of fracture must tear this ligament, such findings should not cause surprise.

In view of these biophysiologic conditions, it is apparent that the treatment should be largely directed in accordance with these requirements. As the problem of non-union is so much more difficult of solution than that of fresh fractures, it is consistent to maintain that the unusually successful results and experience in the former (in author's series 91.7 per cent proved bony union) are eminently applicable to the problem of the latter. These results, coupled with a percentage of results both in fresh and ununited fractures far above those universally reported with purely mechanical methods when applied to fresh fractures, leads me to recommend for operative cases the employment of the autogenous tibial bone-graft peg in all cases of fracture of the central portion of the neck of the femur, reserving the manipulative methods, Smith-Petersen nail and Kirschner and other wires for those cases where open reduction is not considered wise.

The urgent indication is to bring blood not only to the point of fracture, but to the anemic capital fragment. This objective can be accomplished in only one satisfactory way, and that is by an autogenous bone graft so put in that it not only mechanically reduces and immobilizes the fragments, but also furnishes an osteogenetic callus-forming influence, serving at the same time as a vascular conducting scaffold. I have been employing the graft in this way and studying its results for twenty-four years, having first reported it in 1913.

This function of the early and profuse vascularization by the bone graft cannot be too much emphasized. Sir Arthur Keith in his work at the Museum of the Royal College of Surgeons has demonstrated this extremely well. It is well known that the Haversian canals of a graft composed solely of cortical bone will canalize and enlarge in a few months to such proportions that a narrow canal may develop with its incidental vascularity. This is particularly striking when the urge to the passage of blood through the graft is present, as when it replaces loss of bone across a hiatus; and the author has accumulated over the past twenty years a mass of evidence to prove this assertion. With the ligamentum teres torn, or its blood vessels absent or destroyed, this reparative urge is certainly present under favorable conditions to influence the conduction of blood from the vascular spongiosa of the trochanter to the anemic head and area of the fracture.

It is apparent that in this fracture, it is not enough to achieve exact reduction of the fracture fragments and their mechanical maintenance in position. Something more is necessary to secure a better percentage of results.

The bone-graft peg is the treatment of choice for selected cases of fresh fractures and for all cases of ununited fracture of the neck of the femur at any portion of the neck, where the capital fragment is of sufficient length to receive it favorably, and, if a manipulative method or without metallic internal fixing agent has been employed, the first evidences of absorption of bone or non-appearance of callus should be immediately followed by this treatment.

TREATMENT OF FRESH FRACTURES OF THE NECK OF THE FEMUR

Because the whole question of treating fresh fractures by open or closed methods is still in a state of flux, and depends so much upon the findings in the individual case, I shall discuss methods of treatment in the order of my personal preference, rather than classify them as open and closed.

1. Bone-graft peg operation, in selected cases;
2. Whitman abduction method of closed reduction;
3. Leadbetter method of closed reduction;
4. Smith-Petersen operative technique;
5. Kirschner or other wires and nails, including Gaenslen, Moore and Vall's nail.

Bone-graft Peg Operation (Albee). I first described this operation in 1913 in Murphy's Clinics. The joint may or may not be exposed in fresh fracture, but always in non-union, by an anterior incision straight downward from the antero-superior spine; a second incision is made over the great trochanter for the purpose of inserting the bone-graft peg. The neck of the femur is inspected through the anterior incision. Eversion of the foot and limb causes the femoral fragments to separate anteriorly, and the ends of both are then thoroughly freshened with osteotome and mallet. The foot is then restored to the anteroposterior axis and sufficient abduction (about 30 degrees) and traction applied by means of the fracture table, to bring the freshened fragment ends into close apposition.

Attention is next turned to the short incision over the trochanter which has been carried down to the fascia covering the vastus externus. These structures are now both split longitudinally so as to expose the lateral surface of the great trochanter. The point of application of the drill lies ½ inch below the bony ridge to which the fascia overlying the vastus

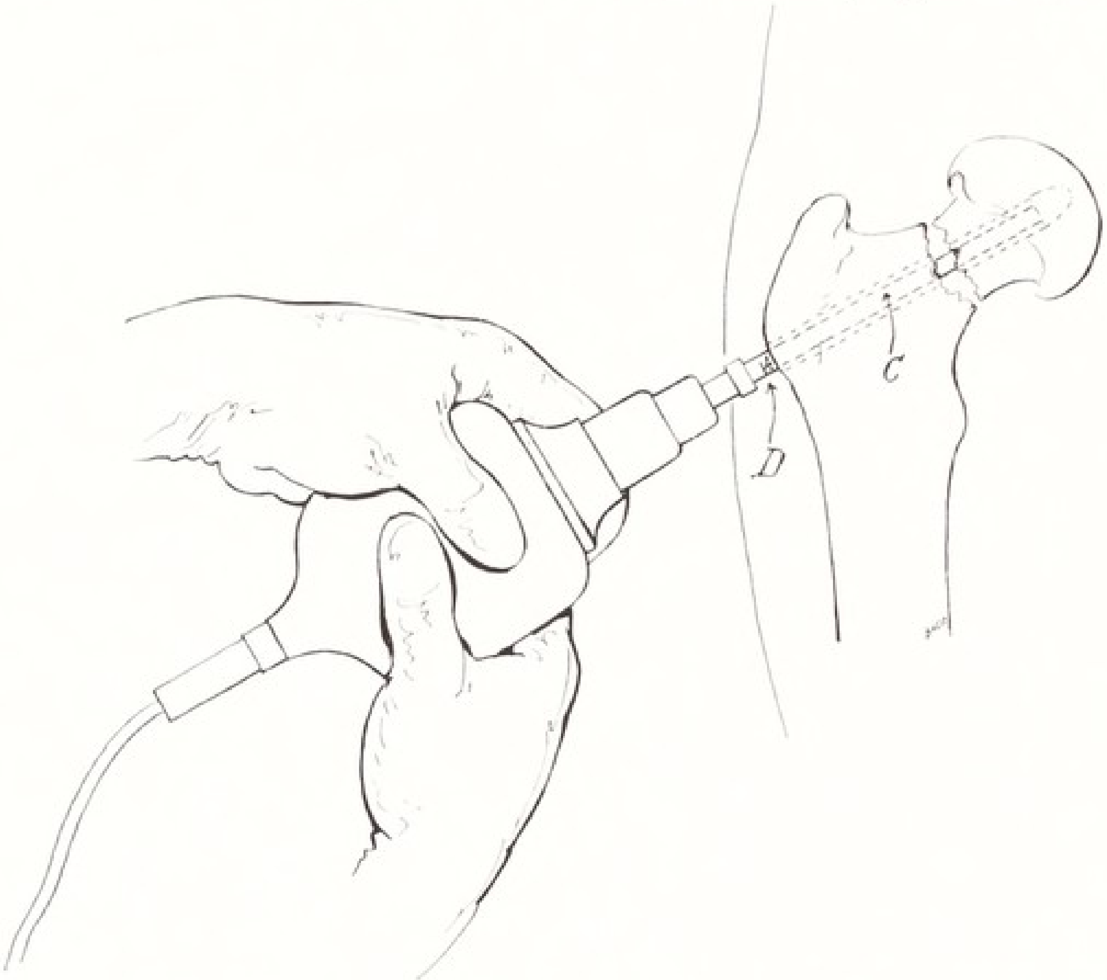


Fig. 7. Motor drill.

externus is attached. Since the direction of the drill must follow the central line of the neck, due consideration must be given to the angulation of the neck with both the axis of the femur and the vertical intertrochanteric plane. In the average adult, the neck makes an angle of 130 degrees with the femur, and 12 degrees with the vertical intertrochanteric plane, when the foot is in the anteroposterior plane.

With the motor drill held in the direction thus indicated, a hole ½ inch in diameter is drilled through from the lateral aspect of the great trochanter to the broken end of the distal fragment. This point is determined by instrumental palpation of the head of the drill between the opposed fragments.

The reading on the drill (at D. Fig. 7) indicates the length of penetration through the distal fragment. With the drill head against the freshened end of the capital fragment, it

FIG. 8.

is now carried into this fragment until the reading shows sufficient penetration. The degree of penetration through both fragments usually required is 7 or 8 cm. (2½ inches) and is determined by a study of the roentgenogram. The drill is left *in situ* while a graft is taken from the crest of the tibia of the same side.

The tibia is exposed by a generous incision over its lower third. This lower portion is preferred on account of the greater thickness and strength of the cortex. A portion is chosen where the crest is straight and regular, and the muscle and soft tissues dissected away. With the motor saw, longitudinal cuts are made on each side of the crest at a suitable angle with each other and at an interval sufficient to provide a peg ½ inch in diameter after shaping. Two transverse saw cuts are now made at an interval equal to the reading on the drill, and the segment loosened by means of an osteo-

FIG. 9. Ununited fracture of neck of femur. Preoperative x-ray.

tome and gentle blows of a mallet. The selected end of this segment is seized by two Ochsner clamps. The other end is inserted in the pencil sharpener cutter attached to the dowel-shaper, by means of which the end is shaped to a blunt conical point favorable not only for subsequent engagement in the dowel tool, but also for reception in the drill hole already prepared in the femoral fragments. The pencil sharpener attachment is now replaced by the dowel tool and the peg run through it. During both these shaping processes, a drip of normal saline is arranged to fall constantly on the tool, not only to hasten its cutting but also to prevent any possibility of undue heating. The saline solution also pre-

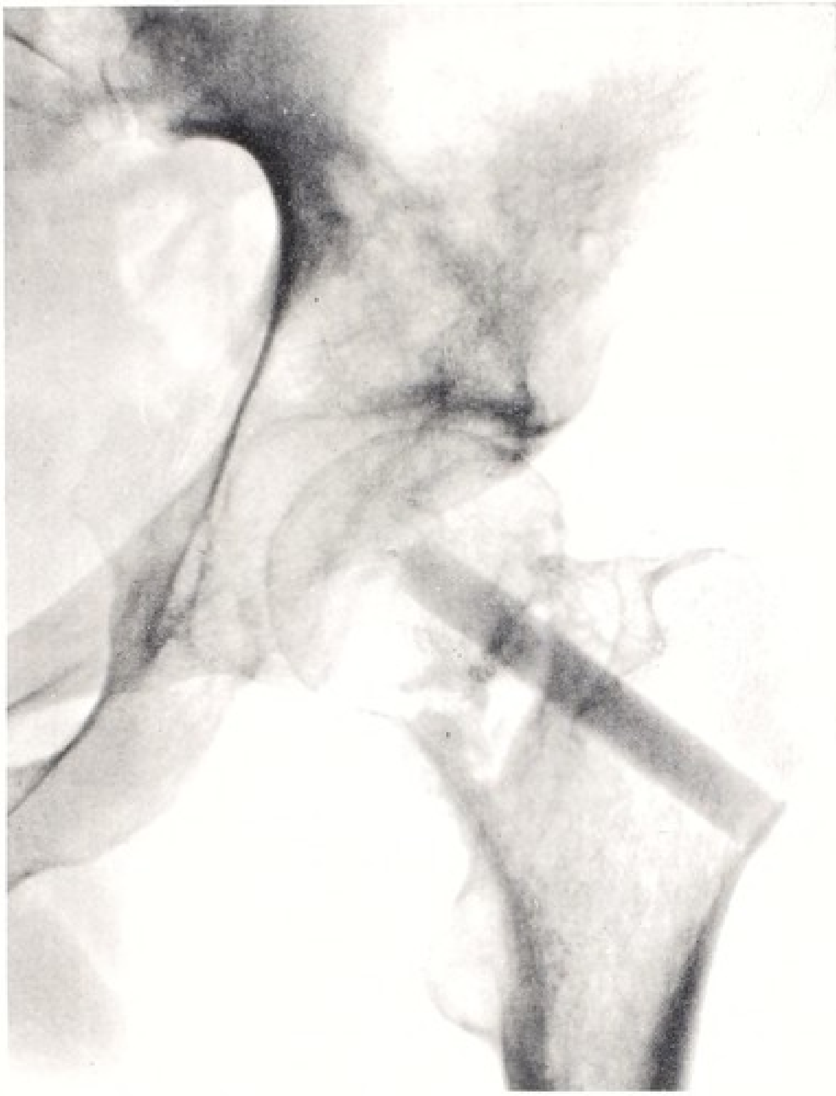


FIG. 10. Same case as Figure 9. Postoperative x-ray, nine months after operation.

vents dehydration of the graft by exposure to the air. Moreover, in the industries, either oil or saline solutions are used in the cutting of hard substances, for the purpose of clearing debris from the path of the cutting instrument, as well as for increasing the speed of cutting and for diminishing friction. The Bunnell's or Vall's guide may be used to aid in the proper direction of the drill.

The drill is now removed from the trochanter, and the peg inserted in its place and driven home with the bone drift and mallet. With the end of the handle of a wooden mallet against the great trochanter (Fig. 8, B) close to the peg

FIG. 11. Same case as Figures 9 and 10. X-ray taken six years after operation.

graft, I insure close approximation of the fragments by striking the palm of the hand or a sand-bag against the head of the mallet.

The deep fascia is closed by interrupted sutures of No. 1 chromic catgut and the skin with a continuous suture of No. 0 plain catgut. The limb is put up in a position of slight abduction, in a double plaster-of-Paris spica extending to the base of the toes on the affected side and to the knee on the sound side for a period of eight to ten weeks. Preoperative and postoperative roentgenograms are shown in Figures 9, 10, and 11.

Let us examine in detail some of the points in this tech-

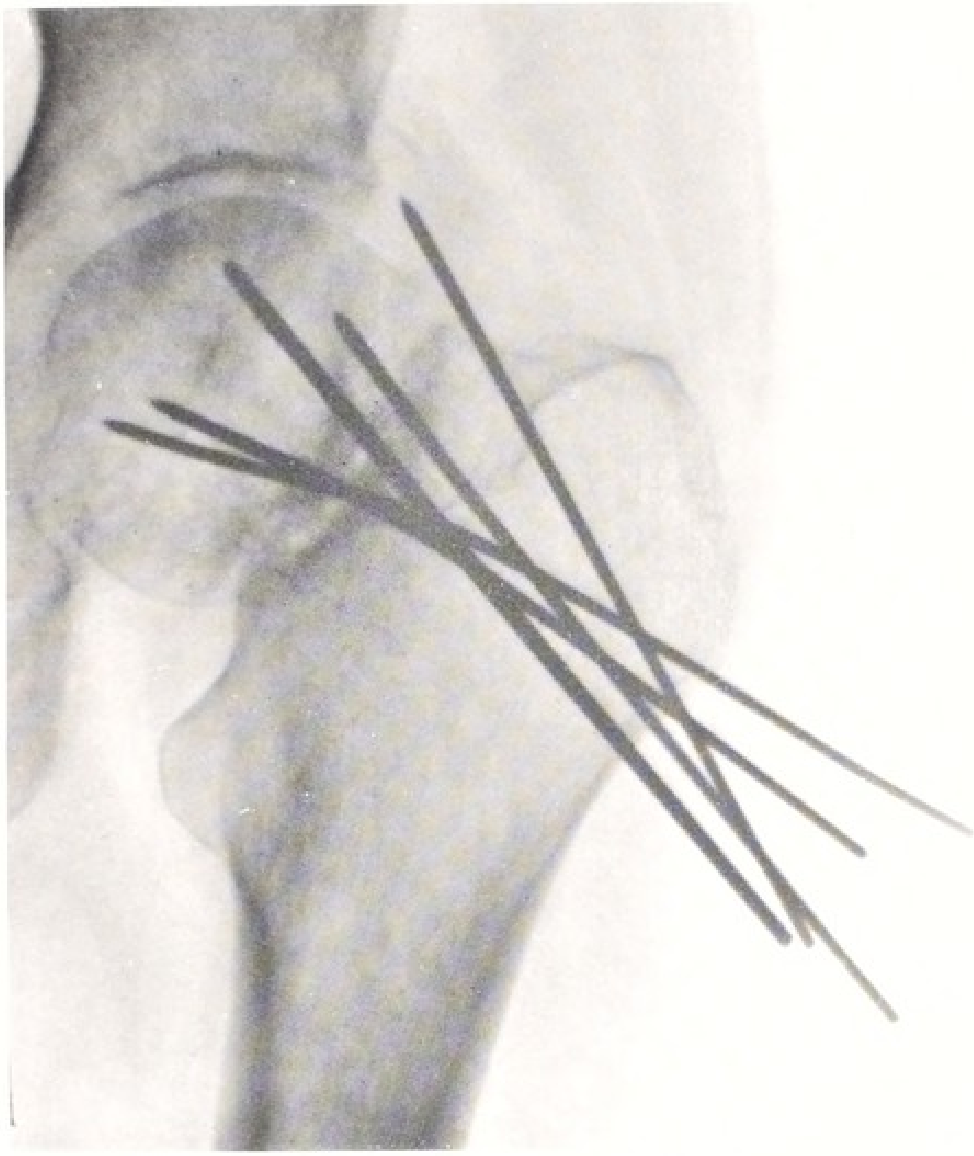


FIG. 12. X-rays (anteroposterior and lateral) taken immediately after insertion of nails showed apposition of fragments to be very satisfactory. This x-ray, taken five months after operation, shows non-union and marked absorption of neck of femur, and extrusion of nails.

nique. By means of the graduated drill and palpation between the fragments, one can determine the point to which the drill hole ought to be carried.

I wish to emphasize that the introduction of a nail or screw, or any material other than an autogenous bone graft, does not meet the requirements or overcome the physiologic and biologic barriers to union (Fig. 12). Nails are foreign bodies and have no biologic or physiologic properties, except destruction, as those of us who have been removing nails

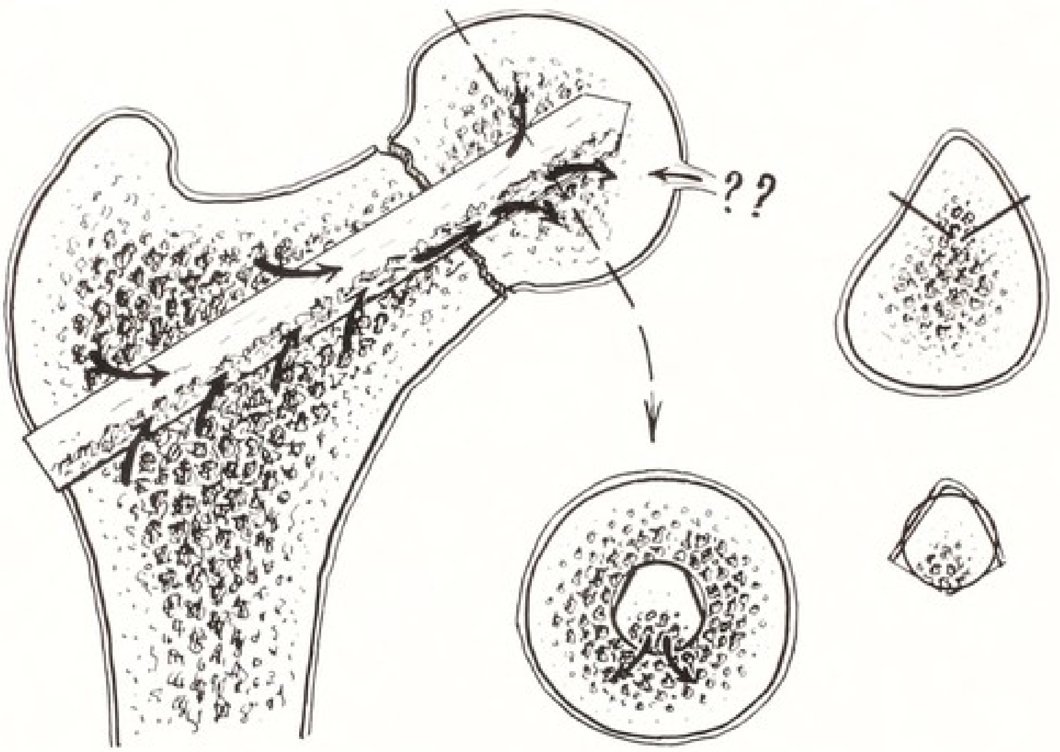


FIG. 13. Diagram showing vascularization of anemic head of femur through blood-vessels of autogenous bone-graft peg.

for years and observing their destructive influence can emphatically attest.

Accuracy of fit of the autogenous bone-graft peg is another essential (Figs. 13 and 14). This can be accomplished only by the use of electrically driven automatic machinery which brings about a fit commensurate with that of a glass stopper in a bottle. The insertion of the graft should not produce compression by too tight or inaccurate a fit, nor should there be a dead space, filled with air, blood clot, or tissue débris, between the surface of the graft and the host bone tissues. In other words, there should be the closest coaptation of the Haversian canals of the host and graft tissues so that early and complete vascular canalization of the graft will take place. Obviously a graft of irregular cross-section is not desirable. The square peg in a round hole is a misfit here as in every other human endeavor. The early and complete vascularization which will occur best in an accurately fitted autogenous peg graft is not only essential to survival of the

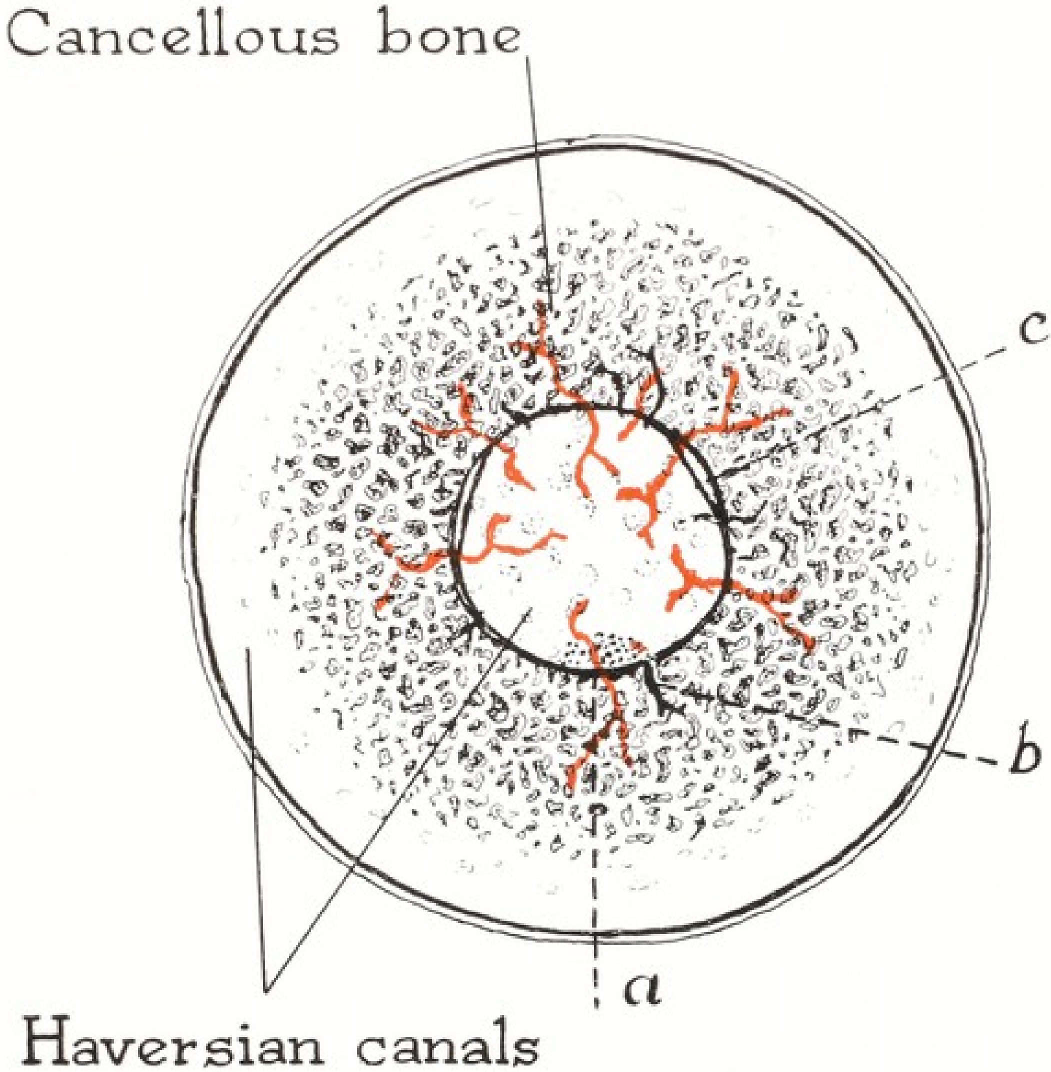


Fig. 14.

graft, but serves to carry blood and callus-forming material to the anemic capital fragment and to the point of fracture. Boiled bone is undesirable and in no sense a substitute. Boiled bone, cow horn or ivory, because of their relative inherent weakness, must be larger in diameter than a metal nail or screw and are, therefore, more undesirable because they displace more cancellous bone at the fracture junction. They do not serve as an osteogenetic scaffold or vascular stimulant to osteogenesis (Fig. 15).

*Whitman Abduction Method of Closed Reduction.** "The limb having been powdered, a fitted covering of stockinet, extending from the neck to the toes, is applied to protect

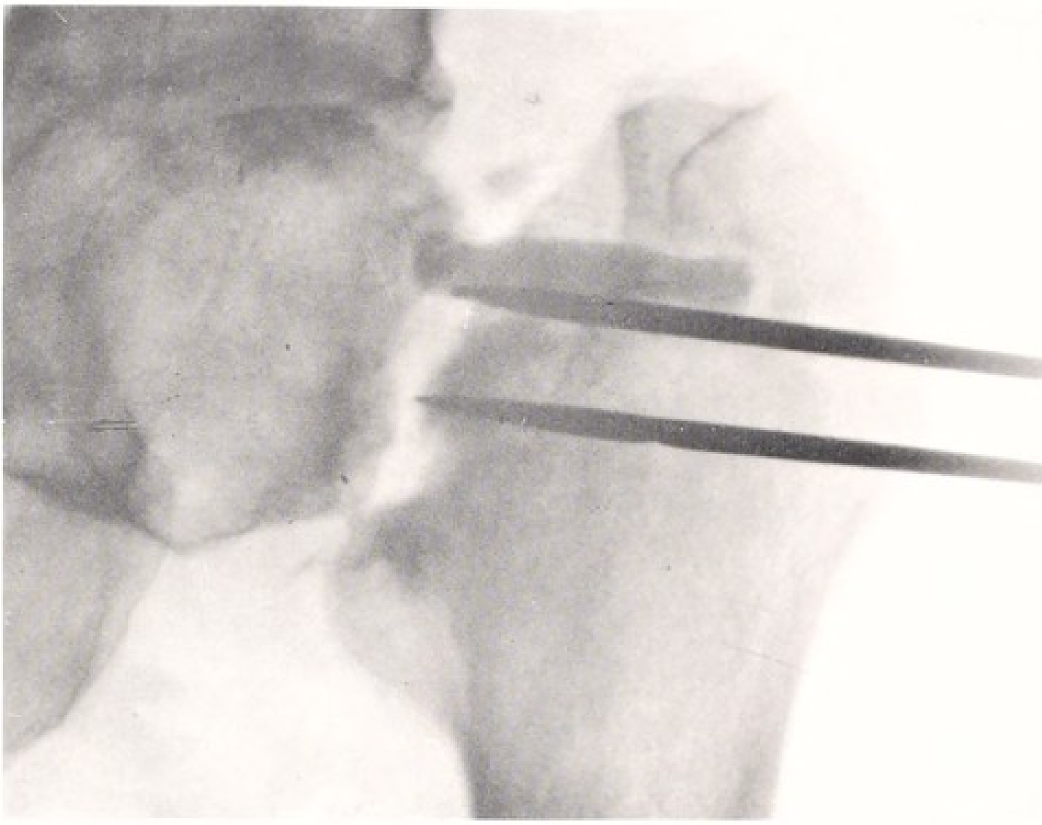


Fig. 15. Boiled ox-bone was first inserted. It broke and absorbed, leaving fragment shown just above nails which were inserted two months later in an added effort to secure union. A loose non-union is disclosed by x-ray.

the skin from wrinkles. The patient is then placed in a fracture-table and anesthetised, since complete muscular relaxation is essential to ligamentous tension. The two apposed and extended limbs are supported by assistants, and the shortening is reduced by direct manual traction aided by pressure on the trochanter, the limb meanwhile being rotated slightly, as indicated by the position of the patella. The two limbs, under manual traction, are then abducted by the assistants, the sound side indicating the normal range to which the other must correspond. At this stage the operator must assure himself that the two limbs are equally ab-

* Whitman, R. The abduction treatment. *Lancet*, 2: 726, 1931.

ducted on a level pelvis, and that the anatomical landmarks on the two sides correspond absolutely.

"The trunk and limb are bound with sheet wadding, many layers being applied about the chest and pelvis, and the bony prominences of the limb being carefully protected. A final covering of Canton flannel bandage assures an even elastic surface for the plaster splint. A long spica, extending from the axillary line to the extremities of the toes, is then constructed. This is strengthened by reverses at the points of strain and, for greater security, a steel bar bent to the proper angle is inserted in the trochanteric region. The long spica when properly applied supports the limb in full abduction, to assure adjustment by ligamentous tension; in full extension, to maintain the normal lumbar lordosis; in slight rotation, to turn the fractured margin away from the capsule; in flexion at the knee, to lessen the strain, the foot being held in the neutral attitude. The patient usually remains for a time on the table, the drying-out of the plaster being hastened by electric heaters. Meanwhile, the support is carefully trimmed about the margins and cut away sufficiently to permit full flexion of the thigh on the uninjured side.

"The patient is then placed on the bed, the head of which has been raised for a foot or more, with cross-boards beneath the mattress to prevent sagging. The inclination is very important. It enables the patient to look about the room and to dispense with pillows. It increases the blood-supply of the injured part, and as compared with the reverse position, usually employed with traction, it should lessen the tendency to congestion of the thoracic organs and aid the digestive processes."

Anderson, utilizing the well leg for countertraction and abduction,* pulls the legs down in a nearly parallel position. It may seem paradoxical to expect abduction with the legs

* Anderson, R. New method for treating fractures. *Surg. Gynec. Obst.*, 54: 207, 1932.

so close together, but radiographic evidence proves that abduction does occur. During the movement of reduction, the traction force pulls the acetabulum down on the injured side, while countertraction forces the well acetabulum up, thereby changing the angle of the transpelvic line with the axis of the injured leg from an acute to an obtuse angle. This in turn forces the angle of the neck with the shaft of the injured femur into the normal position of 135 degrees. Skeletal traction transmits tension to the hip joint capsule, its ligaments and adjacent muscles, thereby accomplishing apposition and immobilization. Thus the fragments are held in fixed position between a taut, muscular and ligamentous envelope—an internal splint, as it were.

Technique of Applying the Apparatus. First, a well-padded plaster-of-Paris cast is applied to the well leg extending from the toes to the mid-thigh. The countertraction stirrup is applied to this cast after the plaster hardens. The fracture ends are anesthetized with 2 per cent novocaine, a local anesthetic. A Steinman pin is driven through the tibia on the side of the fracture at a point two fingers' breadth above the tip of the internal malleolus. This pin is incorporated in a padded plaster-of-Paris cast extending from the toes to about four inches below the knee-joint. The traction stirrup is applied over the pin after this cast hardens. The fracture is then reduced, using the Whitman maneuver.

Author's Comment. The Whitman method of closed reduction is mechanically sound and usually brings about a reduction and fixation of the fracture. Every effort should be made to check the position of the fragments postoperatively, with x-rays of the neck of the femur taken in two planes at right angles to each other. Often a fracture which seems to be in good position in the anteroposterior films is shown to be in bad alignment in the other plane. I do not recommend this method of treatment of fracture of the neck of the femur in operable cases, because, although it furnishes a means of bringing the fractured fragments into proper position, it does not furnish the biophysiological aid which makes it possible for these fragments to unite. The mechanical equivalent of the Anderson method has been accomplished for many years by the author through the use of the long double plaster spica applied on the fracture orthopedic table while traction is exerted on the fractured leg and countertraction on the well leg.

*Leadbetter Method of Closed Reduction.** The patient is anesthetized on the fracture table. The uninjured leg is harnessed to the foot-stirrup. The injured leg is then flexed at the hip at 90 degrees, with the lower leg at 90 degrees to the thigh. Direct manual traction in the axis of the flexed thigh is made, together with slight adduction of the femoral shaft. In this position the thigh is internally rotated approximately 45 degrees. The leg is slowly circumducted into abduction, the internally rotated position being maintained. The amount of abduction varies with the individual and can be measured accurately, representing the difference in degrees of the angle made by the fractured neck with the shaft and the angle between the neck and the shaft on the normal side, as evidenced by the roentgenogram.

After the leg has been brought down in the measured degree of abduction and internal rotation, the heel of the injured leg is allowed to rest on the outstretched palm. If the reduction is complete the leg will not evert itself. Should there be no interlocking of the fragments, however, the leg will slowly rotate externally. The observation is made that as the leg is circumducted into a position of abduction and internal rotation without tension, the position of the leg tends to assume the proper degree of abduction and internal rotation. If abducted too far, one will feel the definite tension of the adductors which can be neutralized by allowing the leg to assume a smaller angle of abduction. If internal rotation is too great, the leg, under the heel-palm test, will rotate

* Leadbetter, G. W. A treatment for fracture of the neck of the femur, *J. Bone & Joint Surg.*, 15: 931, 1933.

outward until the proper degree of internal rotation is reached. One can approximate the desired degree of such abduction and internal rotation by a study of premanipulative roentgenograms, for, at the time of the actual manipulation, the finer degrees will be adjusted automatically by muscle tension of the hip.

With the hip reduced a one-layer thickness of glazed cotton is placed about the torso from the nipple line over the affected hip to a point about halfway between the hip and the knee. Then a long strip of felt, ½ inch thick, is placed about the pelvis, extending from just above the iliac crests to the trochanters, and completely encircling the pelvis. This is all the padding necessary and allows very tight application of plaster. The body portion is first applied as tightly as possible, snug coaptation being the aim. Firm pressure over the injured hip is necessary. Below the hip no padding is applied. Two plaster slabs molded carefully to the contour of the leg, one posteriorly and one anteriorly, are bandaged closely to the skin. No padding is placed beneath the heel as this is molded well and the plaster coapted tightly. This cast remains on for a period of eight to ten weeks.

Author's Comment. It has been the author's practice to apply over several layers of sheet wadding, a double spica cast extending to the toes on the injured side, and to the tubercle of the tibia on the uninjured side. This type of cast holds the fracture securely but permits the thorax and most of the abdomen to be exposed. On the day after reduction and on subsequent days, the patient is turned on his face night and morning. These measures have practically eliminated pulmonary and abdominal complications. If it seems necessary to apply traction it can be secured as easily as with the Anderson * well leg turn-buckle method by applying moleskin traction straps to the leg. The lower ends of these

* Anderson, R. New method for treating fractures. *Surg. Gynec. Obst.*, 54: 207, 1932.

straps are incorporated into the plaster, the double spica is then applied and the plaster molded firmly against the plantar surface of the opposite foot.

The Leadbetter method is sound mechanically and brings about a reduction of the fracture but does not furnish the other, biophysiological requirement of an ideal treatment of fracture of the neck of the femur—the reestablishment of blood-supply to the anemic capital fragment. Cases should be followed carefully by x-rays and at the first evidence of bone absorption at the fracture junction a bone graft should be inserted.

Smith-Petersen Operative Technique. The Smith-Petersen approach is made as described in Chapter III, p. 28. The fracture is reduced, and in this manipulation it should be kept in mind that adduction, accompanied by lateral pressure applied to the inner aspect of the thigh, is helpful in unlocking the fragments. When the fracture is in alignment, the position is most easily retained by internal rotation, extension and abduction of the hip. The nail is now driven in through the lateral surface of the trochanter, at a point between the insertion of the gluteus medius and minimus and the origin of the vastus lateralis, these muscle attachments having previously been reflected subperiosteally.

As the nail enters the proximal fragment there is a tendency to separation of the fragments. This tendency is overcome by the use of a most valuable tool, "the impactor," which fits over the head of the nail so that the force of the blows is transmitted *directly to the cortex* of the femur in the subtrochanteric region, thus approximating the fragments. By alternately striking the nail and using the impactor, the nail is driven home. Impaction of the fragments is extremely important, and the nail should not be struck after impaction has been brought about, since by so doing we tend immediately to distract the fragments.

Before closing the capsule the success of the procedure should be put to the test by moving the hip through a wide range in flexion, abduction, adduction and rotation. There is no change in the fracture line as these manipulations are carried out, and it gives the surgeon confidence in the absolute fixation, so that he will start function early.

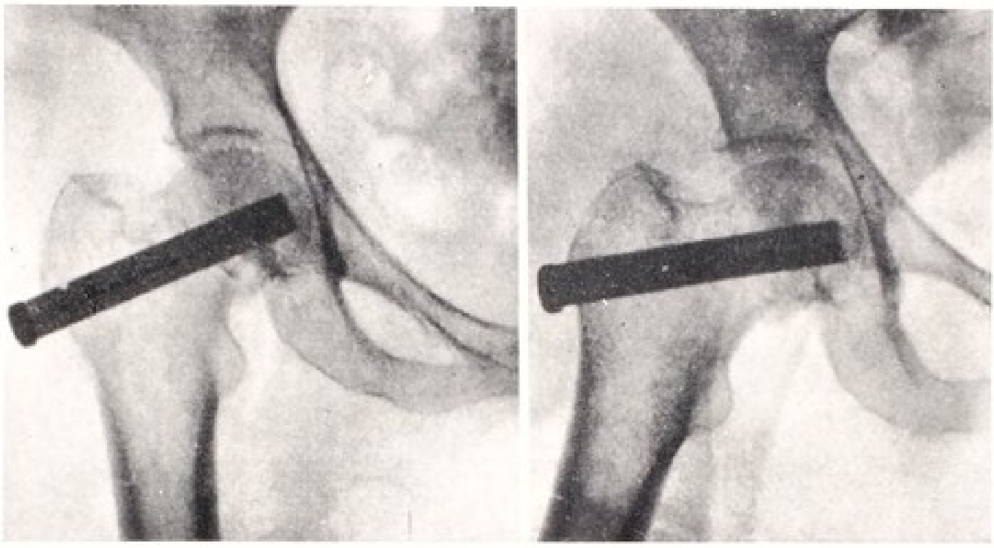


Fig. 16. Fig. 17.

Figs. 16 and 17. X-rays of Smith-Petersen nails in place.

"The capsular flap is now sutured back in position. Since it carries with it a portion of the reflected head of the rectus, it is a strong structure and repair is satisfactory indeed. The muscular flap from the lateral aspect of the ilium is best sutured back into position with the hip in abduction, thereby relaxing the muscles contained in the flap. The same is true of the repair of the insertion of the tensor fascia femoris muscle. The remaining closure of the wound needs no detailed description."

Because of the difficulty in placing the Smith-Petersen nail accurately, Henderson has offered the following very ingenious remedy, which he states was formerly advocated by Johansson of Gothenburg and King of Australia. The modification mentioned is briefly as follows: The hip should be reduced in the ordinary manner, and anteroposterior and lateral roentgenograms taken to be certain that the position is correct. A Kirschner wire is then introduced through the trochanter, neck and head, and a slight distance into the acetabular wall. Anteroposterior and lateral roentgenograms are taken to determine that the position of the wire is correct; if the position is not correct, the wire can easily be withdrawn and reinserted. When satisfied that the line of the wire is correct, a special cannulated Smith-Petersen nail is threaded over the wire and driven in. Another anteroposterior film is taken (or the fluoroscope may be used) and discloses whether the nail is safely embedded, although it should not be so far in as to engage the acetabulum. This is the only untoward thing that may happen, because the nail must follow the wire. When it is determined that the nail does not engage the acetabulum, the wire is withdrawn, the wound closed and a plaster-of-Paris cast applied. The cast is split at the end of a week and movement of the hip begun. At the end of three weeks, the cast can be removed and the patient allowed to be up on crutches. When roentgenological examination discloses bony union, the nail may be withdrawn, usually about five months after the operation.

No external fixation is used by Smith-Petersen and the patient is allowed out of bed as soon as the wound permits.

Author's Comment. The flange nail destroys and compresses the cancellous bone within the neck of the femur. Although this method meets the mechanical requirement of a successful treatment of fracture of the neck of the femur, it not only fails to fulfill the physiological requirements, but it is actually antagonistic to them.

At best the conditions for callus to span the fracture junction and unite the fragments is poor, therefore, postoperative splint immobilization of the limb is considered by the author as advisable. In any event, at the first appearance of bone absorption at the fracture junction or the non-appearance of callus when it should conservatively be expected, the nail should be withdrawn and a bone-graft peg inserted.

*Fixation of Fractured Neck of Femur with Kirschner Wires (Telson and Ransohoff).** The site of fracture is anesthetized by the introduction of 10 to 15 c.c. of 2 per cent

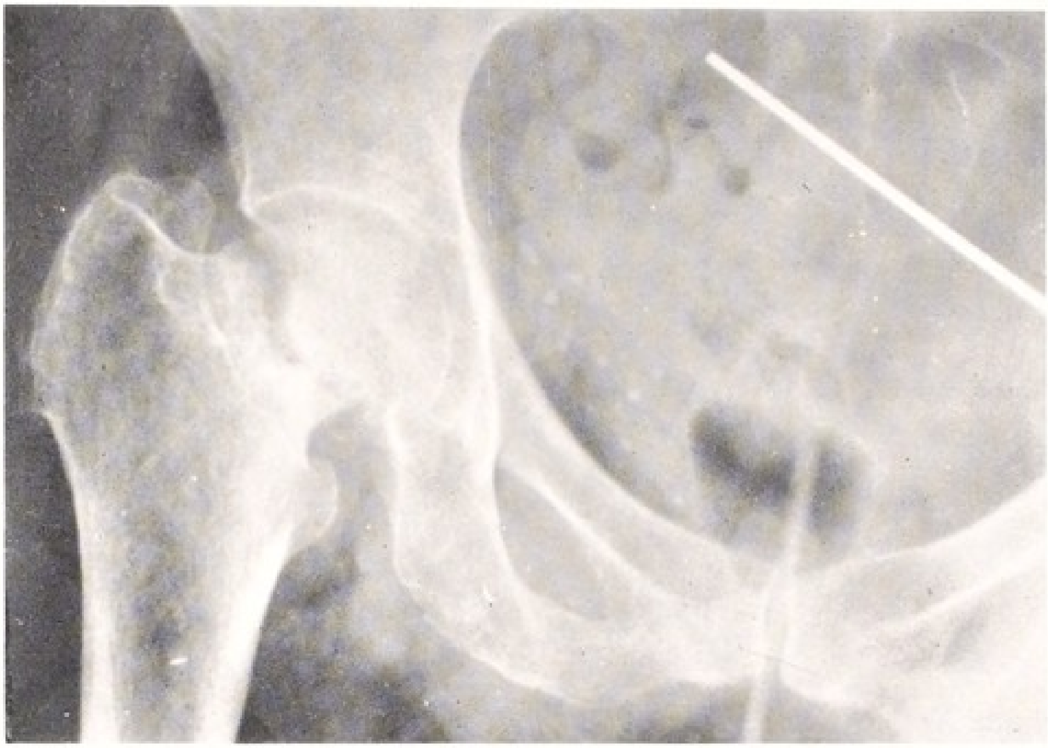


FIG. 18. Wisdom of either threading nails or placing nuts upon them is shown by this x-ray which shows a Kirschner wire which has wandered into pelvis. (Courtesy of Dr. Austin Moore.)

novocaine solution into the hematoma at the site of fracture. The fracture is then reduced. The procedure is carried out on the x-ray table and a film is then taken to determine the accuracy of the reposition of the fragments. Measurements are made on this film which enable the surgeon to ascertain the points of entrance, direction and depth to which the wires are to be inserted. The point of entry is determined by drawing a line through the longitudinal axis of the neck and measuring the distance between the tip of the greater trochanter and the point where this line meets the lateral contour of the femur. The direction of the wire is determined by measuring the angle made by this line with the lateral outline of the thigh. The depth to which it is necessary to

* Telson, D. R., and Ransohoff, N. S. Treatment of fractured neck of the femur by axal fixation with steel wires. *J. Bone & Joint Surg.*, 17: 727, 1935.

bury the wire is determined by measuring the distance from the center of the head of the femur to the periphery of the shaft. These measurements must be corrected to allow for the distortion of the x-ray shadows.

No skin anesthesia is used. The wire is introduced with a motor-driven drill. A movable collar stabilizing prong is first applied to the apparatus. This prong is pushed through the skin until it strikes bone, and the movable collar is locked at the predetermined distance on the scale. After the first wire is introduced, its position is checked with a roentgenogram. If the position is satisfactory, two other wires are introduced from different angles, an attempt being made to cross them in the capital fragment. Any changes necessary are made following x-ray checkup. The skin is then depressed as far as possible and the wires are cut. No dressing is applied.

No external immobilization is used. In some cases, a short posterior splint with an 8-inch cross-rod is applied to the ankle to prevent external rotation.

After fixation, the patient is allowed to sit up in bed immediately, and may be placed in a wheel-chair, within a day or so. At the end of ten weeks, if the x-ray shadow shows sufficient union has taken place, the wires are removed under local anesthesia through a 2 inch lateral incision.

Mayer has modified the Telson-Ransohoff nail by threading it to prevent creeping. Moore has gone still further by devising an adjustable nail with a nut threaded on it at the trochanter end around which he lashes a fine soft stainless wire (.014 inches orthodontic) connecting all of the nails over which he draws the soft parts.

Author's Comment. Largely to avoid the destruction and compression caused by a nail of as large cross-section as the Murphy, Smith-Petersen or Vall nails, Telson and Ransohoff in 1931 suggested the use of multiple Kirschner wires. This treatment does not furnish any of the biophysiological influences necessary to prevent absorption of the neck. It seems to offer no advantages over the other purely mechanical methods.

I have frequently seen these wires gradually work out through the skin, an evidence of the lack of complete immobilization of the fracture. Moore by inserting 3 to 5 nails in different planes and lashing their distal ends firmly together with wire, secures complete immobilization but does not furnish the biophysiological influences required by the fracture.

TREATMENT OF UNUNITED FRACTURES OF THE NECK OF THE FEMUR

Methods of treatment in order of preference:

1. Bone-graft operation (Albee);
2. Reconstruction operation (Albee);
3. Whitman reconstruction operation;
4. Ellis Jones operation;
5. Artificial impaction.

Pathology. Anatomical dissection of the ununited fracture shows many interesting details. The cancellous structure, the cortex and the cartilage of the capital fragment are markedly atrophied; the end of the fragment is covered with a pannus, on the outer rim of which is attached the new fibrous formation. Over the end of the base of the neck is a fibrous covering, which is usually somewhat heavier than the covering of the head. When this covering is removed, the bone is found to be in good condition, the atrophy is only moderate, and usually the remains of the old strengthening bands in the anterior portion of the cortex are found. Between the fragments can be demonstrated new joint formation, that is, one or more cavities lined with epithelium and containing viscous joint fluid. A true pseudarthrosis is almost always present and fibrous union of fragments is practically never seen. Under pressure, sliding of the opposed joint surfaces upward can be demonstrated, the amount varying from 1/4 inch to a full inch. When the sliding is minimum in degree, the hip is fairly stable, while the reverse is true of a hip that allows motion of an inch. The weight-bearing strain is borne entirely by the heavy fibrous ligaments and scar tissue attached to the base of the neck.

I want to emphasize that it is absolutely essential to enter between the fractured fragments of ununited fractures of the neck of the femur and remove the synovial membrane that is almost always found on the ends of these fragments, and freshen them up in such a way that they will come in as perfect apposition as possible after application of the bone-graft peg and artificial impaction.

This is necessary for the following reasons:

1. It is important that the closest apposition without interposing synovial membrane or connective tissue be brought about between the two femoral fragments with favorable conditions for union and establishment of blood-supply.
2. As the ends of the bone are often irregular in shape and do not fit into each other, the surfaces should be transformed into perfectly plane surfaces so that they will fit with the greatest accuracy.
3. As it is believed that the synovial fluid is an inhibitor of bone growth, it is desirable also to furnish conditions which will permit the encroachment of callus between the femoral fragments to push out the synovial fluid, or better, to coapt the bone fragments so accurately that the synovial fluid is completely kept out. If the synovial fluid does not of itself have a particular inhibiting influence, it must be granted that the presence of any fluid inhibits and delays union.

Sir Arthur Keith, the British pathologist, makes a very strong point of early and profuse vascularization of massive bone grafts. The autogenous bone-graft tissues act in an unusual way as a vascular conducting scaffold.

Bone-graft Peg Operation. In every case of ununited fracture of the neck of the femur in which the capital fragment has sufficient length to receive favorably a bone-peg and of sufficient length to furnish a lever to permit the abductor muscles to carry out their function, the bone-graft peg is the preferable treatment. If this leverage is too short, the Albee reconstruction operation, which restores its length, must be used.

Reconstruction Operation (Albee). In spite of the wide applicability of the bone-graft peg operation, there will always be a certain number of cases of long standing non-union in which there has been much erosion because of lack of blood-supply, ill-nourishment of the capital fragment and the eroding effect of ill-advised locomotion, in which one must employ a different type of procedure. For this type of case, I use a partial arthroplastic or reconstruction operation.*

The approach is that devised by Smith-Petersen and is very similar to the Sprengel approach, with modifications to meet the requirements of this operation.

With the wide osteotome used for splitting the spinous processes in operation for Pott's disease, the muscles are stripped down from the side of the ilium by subperiosteal separation, and are separated from one another directly downward from the anterior superior spine. The capsule of the hip joint is completely exposed. The joint is entered by a T-incision with the stem running directly downward along the neck of the femur. The head of the T is made about ¾ inch from the rim of the acetabulum, for the purpose of protecting this rim both mechanically and as to blood-supply, and of furnishing a cuff of capsule to act as a lining of the outer portion of the joint and for the neck to rest against when the joint has been reconstructed.

Care should be taken to make the incision into the capsule sufficiently spacious so that the difficulty of getting the head out of the acetabulum will be minimized. The liga-

* Albee, F. Orthopedic and reconstruction surgery. Phila., Saunders, 1919.

mentum teres is then severed by means of a ½ inch osteotome thrust deep into the joint, and any adhesions of the capsule to the periphery of the head are carefully separated with a scalpel.

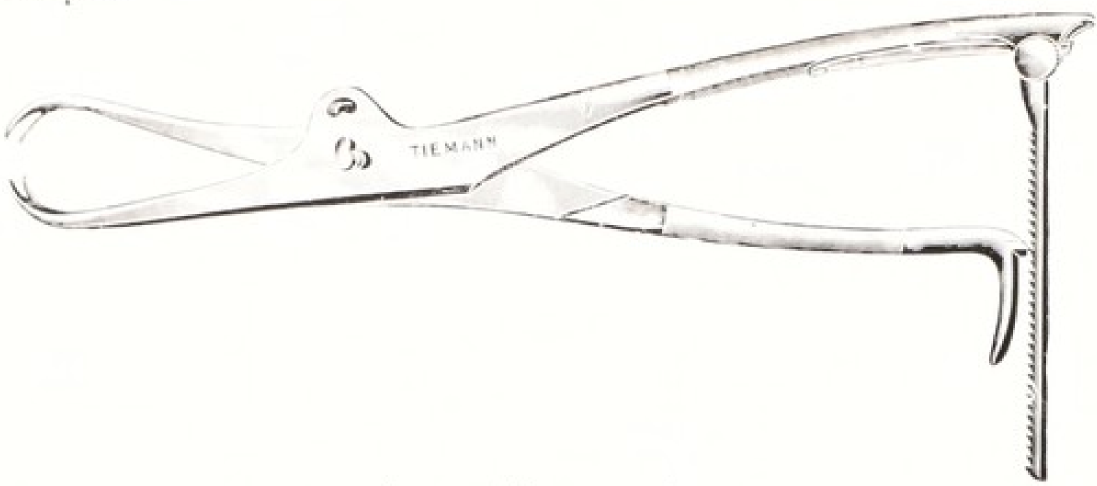


FIG. 19. Hip tenaculum.

The limb is then strongly everted by adjusting the fracture table, so as to make room for the delivery of the head. With two long ½ inch chisels or osteotomes, the head is pried out of the acetabulum, with a motion much like that used in eating with chopsticks; one osteotome is thrust into the inner and one into the outer substance of the head, and the two are used as levers against the soft parts to pry the head out of place. A better technique is to use the forceps-tongs, or a double cervical tenaculum to seize the femoral head and extract it. The instrument shown in Figure 19 was recently designed for this purpose.

As soon as the head is delivered, the patient's limb and foot should be inverted by the adjustment of the table, so that the foot points directly upward. Then, with the scalpel, the soft parts are severed straight down on to the anterior surface of the trochanter (care being taken not to separate them from the bone) in the form of an inverted "L." In the clefts thus made in the soft parts with the scalpel two osteotomes are placed, a 1½ inch one to make the bone incision of the long arm of the "L" and a ½ inch one for the short arm. These osteotomes then are driven in through the trochanter synchronously, so as to separate the bony lever intact and unbroken. The broad osteotome is driven from above downward beneath the circumflex artery so as not to

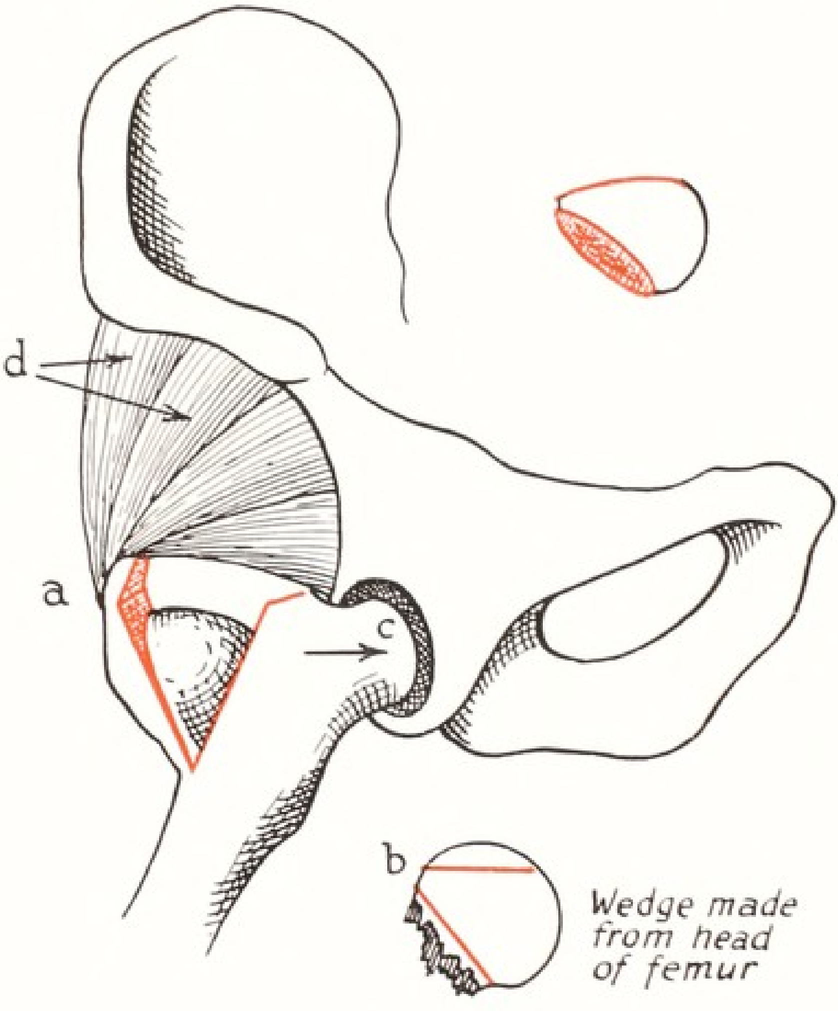


Fig. 20.

sever it, or the periosseous soft parts. The bone-muscle lever (a), which should be about 4 inches long, is then pried outward by the osteotomes still in place and a greenstick fracture is produced at the lower end, thus separating the lever from the main portion of the trochanter. Care should be taken not to separate the muscles and soft parts from the bony lever. The cut made in and at right angles to the trochanter determines the amount of shortening of the limb and should not be made until the limb has been pulled down to the maximum by the fracture table; it is then made as high up in the trochanter as possible, in fact, just level with the rim of the acetabulum. In this way the minimum amount of shortening is produced and this is less than by any other operation yet devised.

FIG. 21. X-ray showing result of technique shown in Figure 20.

The last step is to fracture the bone-muscle lever outward at its extreme lower end by using the wide osteotome (driven from above downward without separation of soft parts). Formerly fragments of cancellous bone were removed from the cut surface of the trochanter and shaft by means of a curette, and placed in the angle of the gap thus formed. The stump of the neck is then rounded so as to cause minimal irritation of the acetabulum.

The assistant is directed to adjust the table so that the limb is brought to the limit of physiologic abduction at the hip, and at the same time the upper end of the femur is lifted forward and guided into the acetabulum. The bone lever is thus automatically held by the limb posture in the oblique relation to the shaft of the femur with its upper

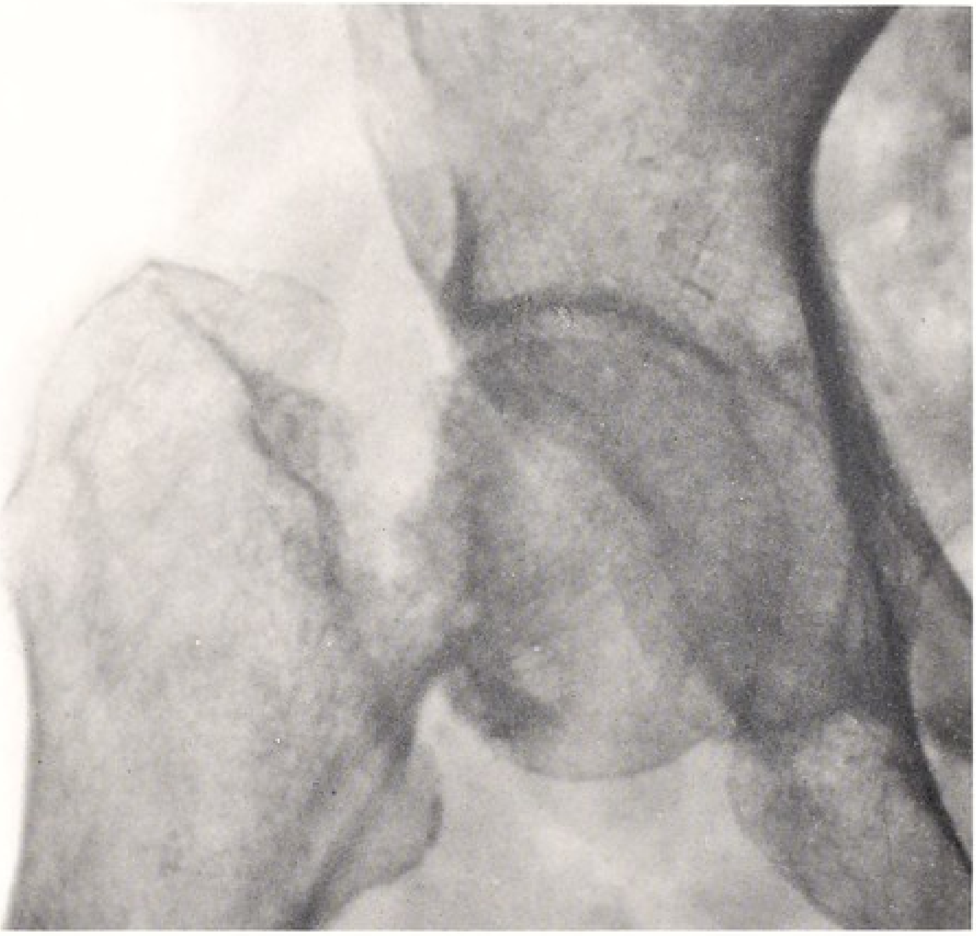


FIG. 22. X-ray of non-union of neck of femur, six months after fracture.

end above and lateral to the rim of the acetabulum.

My recent innovation is to shape the excised femoral head into a wedge (Fig. 20, b) by means of motor saw, osteotome, etc., care being taken to remove all of the articular cartilage, and to place this wedge in the angle between the shaft and the trochanteric lever. This has been found to be far superior to bone fragments for this purpose. It produces a firm fit and immediately holds the bone-muscle lever in its proper relation without waiting for callus formation and reduces the time of plaster immobilization to three weeks (Figs. 20, 21).

The upper end of the bone-muscle lever is pulled forward and held with medium kangaroo tendon sutures placed in the surrounding attached soft tissues. The wound is now ready for closure. All dead spaces are overcome by means of continuous suture of No. 1 chromic catgut.

FIG. 23. Postoperative result in same case as Figure 22, after leverage at top of femur was elongated by wedged femoral head.

Mechanical Action of Bone-muscle Lever. The mechanics of this operation may be further elucidated by a description of the mechanical action of the bone-muscle lever. The insertions of the short trochanteric or abductor muscles are carefully left intact on the trochanter or proximal end of the lever (Fig. 20, d). As the approach to the hip does not interfere with the innervation of these muscles, the ability to abduct, lost with the leverage action of the neck of the femur, is restored (Fig. 24). However, the lever substitution for the femoral neck is outside of the long axis of the femoral shaft, precisely as in the ox and many other animals (see figure facing page 1). At the same time, when the leg comes to the midline or beyond, dislocation is prevented by the outward excursion of the proximal end of the lever and the resultant

FIG. 24. Photograph in case of ununited fracture of neck of left femur of ten years' duration. This patient had been compelled to use crutches for whole period of ten years. Neck of femur had entirely disappeared and there was a marked laxity of head at point of non-union. This photograph, taken eighteen months after operation, shows splendid abducting and weight-bearing function, following reconstruction operation with bone-muscle lever. Patient was walking without crutch or cane, with painless, free motion.

tension not only on the trochanteric muscles, but also on the soft parts surrounding them. This action holds the newly formed femoral head firmly in the acetabulum and prevents it riding on the rim of the acetabulum, leading to bone absorption of the rim and possible remote dislocation and pain.

In the cases of arthroplasties of the hip in which the patient has weak abductor power following operation, I erect the same type of bone-muscle lever. In this type of case, a wedge graft taken from the side of the ilium is used to hold the bone-muscle lever in its new position (see p. 218). The increase of efficiency of the abductors following this lengthening of the lever they act upon results in a much better gait, usually eliminating the positive Trendelenburg sign which so many of these patients have. This same principle is also used to elongate this lever at the top of the femur beyond its anatomical length in cases where the musculature has been weakened, as in infantile paralysis involving the gluteus medius, etc., muscles.

At the conclusion of the operation, the leg is put up in a double spica, extending from the tips of the toes on the operated side, and to the tubercle of the tibia on the other side. The plaster is so molded as to hold the upper end of the femur anteriorly and is kept on for a period of three and one-half to four weeks. The leg is then allowed gradually to resume the normal position. The patient is persuaded to begin walking with crutches immediately after the removal of the cast, and daily massage and manipulation at hip and knee are at once instituted.

The choice of operation is determined by the condition of the fragments, and in some borderline cases the selection of operation cannot be determined until the head and neck of the femur have been exposed.

*Whitman Reconstruction Operation.** "An incision is made in the shape of a half U, beginning about 1 inch behind the anterior superior spine and extending downward and backward, crossing the femur at a point 3 inches below the apex of the trochanter. The interval between the tensor

* Whitman, R. The reconstruction operation for ununited fracture of the neck of the femur, *Surg. Gynec. Obst.*, 32: 479, 1921.

vaginae femoris and gluteus medius muscles is exposed; the capsule is opened and the head of the femur is removed (Figs. 25 and 26).

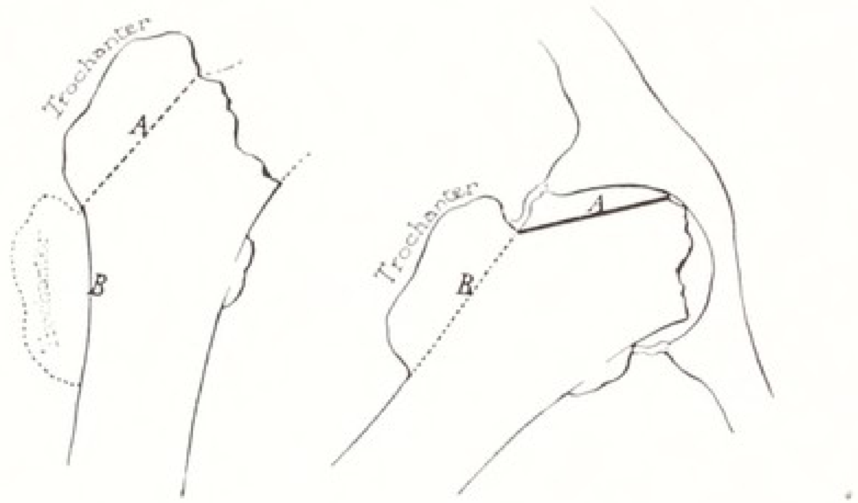


FIG. 25. FIG. 26.

FIGS. 25 and 26. Whitman reconstruction operation, showing line of section of trochanter and point on shaft to which it is to be transferred.

"The anterior margin of the gluteus minimus is followed to its insertion, and at this point with a wide, thin chisel, the base of the trochanter is cut through in an oblique direction corresponding to the angle of the neck (Fig. 25, A), including all its muscular attachments and often a part of the capsule. This flap of bone and muscle is turned upward and the upper extremity of the femur, having been somewhat remodeled by cutting away the projections of the posterior intertrochanteric line, is freed from any restraining tissues and is thrust completely within the acetabulum at an angle of about 25 degrees of abduction.

"The trochanter is then drawn downward, as far as its attachments will permit, and sufficient cortex having been removed from the lateral aspect of the femur, the two bare surfaces are apposed, the axis of the trochanter being thereby changed from a direction upward and inward, to outward and upward. In this position (Fig. 26, B) it is secured either by a drill or a peg, but usually by suture passed through the bones. The wound is closed in layers and a long plaster spica is applied fixing the limb in extension and abduction. When repair has sufficiently advanced, or in about four weeks, this may be replaced by a short spica and the patient is encouraged to bear weight in order to hasten the reconstruction of the articulation by a functional adaptation of the limb to the new conditions. When weight may be borne without discomfort, the support is removed and muscular control is re-established by systematic exercises."

FIG. 27. Relationship of reconstructed neck to weight-bearing. Note inadequate leverage afforded abductor muscles.

Author's Comment. The transplantation of the attachment of the trochanteric muscles downward on the femoral shaft does not restore the physiological function of these muscles. Normally, they act upon a lever composed of the head and neck of the femur. If this lever is shortened by the loss of the head and neck the efficiency of these muscles is very much diminished, resulting in a loss of abduction power and an unstable waddling gait. The Albee reconstruction operation restores the physiological length of the neck and makes it possible for the abductor muscles to function normally.

*Ellis Jones' Technique.** "With the patient lying on the sound side on a fracture table and with the injured leg under the control of an assistant, a 6 inch, straight, external Langenbeck incision is made, extending from the iliac crest downward over the trochanter laterally along the shaft of the

* Jones, E. Trochanteric transplantation in the treatment of fractures of the neck of the femur. *J. Bone & Joint Surg.*, 14: 259, 1932.

femur to a point 3 inches below the trochanter. With a motor saw or osteotome a bone graft, 3 inches in length, 1/2 inch in width, and 3/4 inch in thickness, and including the longitudinal mid-third of the trochanter, is removed from the external lateral surface of the femur. The removal of the graft affords an excellent view of the femoral neck and full exposure of the fracture. The fracture is reduced by leverage and manipulation. A drill hole is passed, as in the Albee method, through the trochanter and neck into the head of the femur, the length of the drill hole having been previously estimated from a roentgenogram of the opposite normal hip joint. The bone graft is shaped, the periosteum removed, and the graft is driven with its trochanteric end outward into the bed prepared. The wound is closed in the usual manner. The patient is turned on his back recumbent on a sacral rest and a double plaster spica is applied in the required amount of abduction and internal rotation.

"The advantage of this method is that through a single incision the bone graft is obtained as part of the operative approach to the hip joint. Also, the removal of the mid-third of the trochanter as part of the bone graft fully exposes the entire neck and avoids 'blind pegging,' since with full exposure of the entire length of the fragments, the angle and length of the drill hole is very easily determined.

"The trochanteric bone graft is mainly composed of spongy bone, the lacunae of which are filled with hematopoietic tissue, extremely favorable to early vascularization. The graft consists of barely sufficient cortical bone to maintain firm internal fixation of the fracture. The environment of the bone graft is little changed by transplantation, since the operation consists of transposing the trochanteric graft into a recipient bed of cancellous bone of which the graft itself is mainly composed. This is in distinct contrast to the dense cortical structure of a tibial bone graft, composed almost entirely of compact bone, made up of a strong thick framework with small connective tissue spaces which do not contain hematopoietic tissue, and is not so readily vascularized. Also, in the use of a tibial graft implanted into the femoral neck, we have noted in a study of roentgenograms a much slower adaptation of the dense cortical bone to the spongy bed, as indicated by tardy trabeculization.

"We have not found it necessary to dowel the graft. The use of this rather oblong graft in a round hole insures a snug fit, further contributing to firm fixation. We employ a 5/8 inch drill hole to receive a graft approximately 1/2 inch in width and 3/4 inch in thickness, the graft being composed of cortical bone, approximately 1/4 inch to 3/8 inch in thickness, and 1/2 inch of cancellous bone. The cancellous bone is sufficiently yielding to permit firm impaction into the bed. The average length of the bone graft employed is 2 1/2 inches.

"The trochanteric defect made by removing the graft from the external aspect of the femur is firmly repaired at the end of eight weeks as in the healing of a peritrochanteric fracture. No muscle attachments are disturbed and the lateral contours of the trochanter are not altered."

Author's Comment. It is too early to determine the true value of this method. My reaction, based upon an inadequate experience with the operation, however, is that the approach in thin subjects is undoubtedly a favorable one. In stout subjects I have found in one instance that it produced a very deep wound, and in that case I would have far preferred the anterior Smith-Petersen approach. To be sure the graft contains a large amount of cancellous bone; but by the same token, however, its strength is proportionately fatally diminished. From a very extensive experience in the use of the peg in both fresh and ununited fractures, I have been impressed with the value of the strength of the graft. The readiness of the vascularization of the compact bone content of a graft when accurately implanted by automatic shaping electrical tools, however, has been underestimated, and thus from this standpoint, the cancellous nature of Jones' graft loses its significance.

Artificial Impaction. If there is any virtue in artificial impaction it is undoubtedly along the same lines as that of the autogenous bone-graft peg, but to an infinitely lesser degree, namely, it so enmeshes the cancellous bone of one fragment into the other that if this enmeshment is not disturbed, blood vessels will spring across from one fragment to the other. This is the first essential step toward union. Unfortunately, this enmeshing contact is most difficult to attain, and there is great danger of the very flimsy enmeshment giving way. This has been impressed upon me by the accumulation of experience. Artificial impaction should always follow the insertion of the bone-graft peg. The immobilization of the peg thus insures the permanency of the cancellous bone contact.

My method of accomplishing impaction is somewhat different from that of Cotton.* I use a large wooden mallet with the tip end of the handle sawed off at right angles to its shaft, leaving a plane surface of considerable size. This end of the handle is placed against the outer surface of the trochanter just below the peg while the head end of the mallet is struck with something heavy, preferably a sandbag (Fig. 8, B). Such a dead massive blow sets the upper end of the lower fragment of the femur in motion and thus accentuates the impact of one fractured surface against the other.

DISCUSSION

Santos † builds up a very strong argument for the use of the autogenous bone-graft peg. He made a careful study of the changes in the femoral heads in 15 cases after complete intracapsular fracture of the neck of the femur. He found that the life of the proximal fragment depended on the circulation through the ligamentum teres. The vessels in the ligamentum teres were more abundant in young persons,

* Cotton, F. J. Artificial impaction in hip fractures. *Surg. Gynec. Obst.*, 45: 307, 1927.

† Santos, J. V. Changes in the head of the femur after complete intracapsular fracture of the neck. *Arch. Surg.*, 21: 470, 1930.

but were inadequate in many elderly persons. Bony union occurred in most cases in which the head remained alive, and there was adequate reduction and fixation. Even in the presence of necrosis of the proximal fragment, union might take place with efficient reduction or impaction followed by immobilization. Weight-bearing should be avoided until repair of the fracture is completed. The replacement of the dead bone took place by invasion of newly formed tissue from the round ligament and by vascularization through adhesions formed between the capsule and the eroded surface of the fracture.

The head of the femur may undergo necrosis after complete intracapsular fracture of the neck of the femur in spite of the presence of the ligamentum teres. Secondary vascularization may or may not occur. In some cases the blood-supply may penetrate the spongiosa through the fovea by way of the round ligament or through adhesions along the surface of the eroded neck or articular cartilage. When this occurs, considerable parts of the femoral head may be preserved and active bone regeneration may follow. If the necrotic head fails to obtain a secondary blood-supply from the ligamentum teres, simple destruction and fragmentation of the articular cartilage and bone result. If connective tissue extends from the ligamentum teres into the eroded head, there is replacement of cartilage and bone about the fovea with absorption of the deep layer of articular cartilage, the process continuing to regeneration.

When bony union occurs in spite of necrosis of the head, it is brought about by new bone coming from the distal fragment. When the head of the femur remains alive after the fracture and the fragments are in good position, bony union of the fracture will occur in the majority of cases. It has been observed that in unions secured by the use of the bone graft, there is much less tendency to flattening and mushrooming of the head which is undoubtedly due to the more complete vascularization of the part.

There are four main causes of non-union:

1. Displacement of fragments;
2. Excessive mobility of fragments;
3. Necrosis of the head of the femur; and
4. Necrosis and erosion of the neck fragments.

The most important factors in obtaining bony union are exact reduction and fixation of fragments. Necrosis of the head is an important cause of non-union. When the circulation of the head is completely interrupted and the entire structure dies, any callus that is formed for the repair of the fracture must come from the distal fragment. Union between a completely necrotic head and a living distal fragment is more difficult to obtain than union between two living fragments.

Still further reasons for using an autogenous peg are pointed out by Freund,* who examined nine fractures of the neck of the femur in old persons which had occurred from three to nine years previously. From a careful study of 203 sections he came to the following conclusions:

Preservation of the vascular connections (round ligament, cervical periosteum, newly formed strands) is of great importance in the life of the head of the femur. If these connections are entirely interrupted, the marrow and spongiosa become necrotic after phagocytes from the reticulum of the marrow have initiated decomposition of the dead fatty tissues and have themselves died off. The importance of the round ligament is still very much underestimated. While it is true that the marrow tissues and spongiosa may sometimes become necrotic when this ligament alone is preserved, in other instances its preservation may entirely prevent necrosis. Later, by way of this ligament, necrotic tissues are removed and gradually replaced by newly formed marrow and spongiosa to the fracture surfaces with the formation of a nearthrosis.

* Freund, E. Ueber die mikroskopischen Vorgaenge im Hueftkopf nach Schenkelhalsbruechen. *Virchow's Arch. f. path. Anat.*, 277: 325, 1930.

Also when remnants of the periosteum of the femoral neck are preserved and when connecting strands between fractured fragments are formed, regeneration proceeds from the surfaces of the nearthrosis.

2. Transtrochanteric Fractures of the Femur

One of the most interesting contrasts in the field of bone and joint surgery is the marked difference in the healing of transcervical fractures of the neck of the femur and transtrochanteric fractures. Although these transtrochanteric fractures occur only an inch lateral to the neck, solid bony union following closed reduction occurs in about 90 per cent. The reason for this apparent inconsistency is evident when it is remembered that bone repair is in direct relationship to the blood-supply of the fragments. The trochanteric region of the femur receives an unusually profuse blood-supply from the muscles which surround it and for this reason, if reduction is accurately done and a good position of the fragments maintained, union practically always occurs. The Whitman reduction and a double plaster-of-Paris spica are used. At the end of eight weeks the cast is removed and if roentgenograms show an adequate amount of callus, the patient is allowed to get out of bed and begin cautious weight-bearing.

3. Fractures of the Acetabulum

These fractures are usually the result of force applied directly to the greater trochanter acting in the direction of the neck of the femur. The diagnosis, differentiating this condition from fracture of the neck of the femur and dislocation of the hip, is made by means of the roentgenogram. The lines of fracture may be confined entirely to the acetabulum, or may extend into the acetabulum from the surrounding pelvic bones. The treatment of this type of injury, without displacement of the femoral head, consists of immobilization of the hip in the Whitman position for a period of six weeks after which unrestricted weight-bearing is permitted.

Fractures of the acetabulum with penetration of the head of the femur through it into the pelvic cavity present a more difficult problem. The head of the femur locks behind the acetabular rim in such a way as to make reduction by direct traction impossible. In order to pull the head of the femur out of the pelvic cavity, it is necessary to exert traction in the direction of the plane of the neck of the femur. Under general anesthesia with the patient on the Albee fracture table, moderate traction is made on both feet to pull the head of the femur down to the center of the perforation through the floor of the acetabulum. The pelvic ends of the traction arms to which the feet are attached are displaced laterally as far as possible. Both legs are then abducted to their physiological limits. By this maneuver, traction is exerted along the plane of the neck and the head of the femur is withdrawn from its intrapelvic position.

A double plaster-of-Paris spica cast is applied which remains on for eight weeks. Cautious weight-bearing is then started.

The end results in fractures of the acetabulum vary with the severity of the injury. Most of the cases of simple fissure fracture have practically no residual disability. Osteoarthritic changes frequently develop following the more severe crushing fractures of the acetabulum. Occasionally, these changes become so marked that an arthrodesis of the hip is necessary for the relief of pain.

Chapter V

DISLOCATIONS

Congenital Dislocation

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 on the maternal side) and of hereditary syphilis.

Scaglietti * states that congenital dislocation of the hip is more frequent in Europe than in America and in the lowlands than in mountainous regions. In the province of Bologna, Italy, there is an average of 2 such dislocations to every 1,000 inhabitants, but in some districts there are more than 3 and in one community the average is 4.33. *Congenital dislocation of the hip constitutes 73.5 per cent of all congenital deformities.* It is 4 times as frequent as club-foot, the incidence of which is 18 per cent, and 28 times as frequent as torticollis, the incidence of which is 2.65 per cent.

* Scaglietti, O. A clinicostastical study of cases of congenital dislocation of the hip. *Internat. Abst. Surg.*, 56: 137, 1933.

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 the roentgenogram 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 roentgenography 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

Fig. 28. Double congenital dislocation of hips. (From Albee's "Orthopedic and Reconstruction Surgery," Saunders.)

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 (Figs. 28, 29). 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

Fig. 29. Unilateral congenital dislocation of hip. (From Albee's "Orthopedic and Reconstruction Surgery," Saunders.)

may be increased to 90 degrees, although usually only to about 45 degrees (Fig. 30) and is due to anteversion of the neck, which seems to come off directly in front of the shaft. 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.

4. *Pelvis.* Abnormalities of the pelvis depend upon

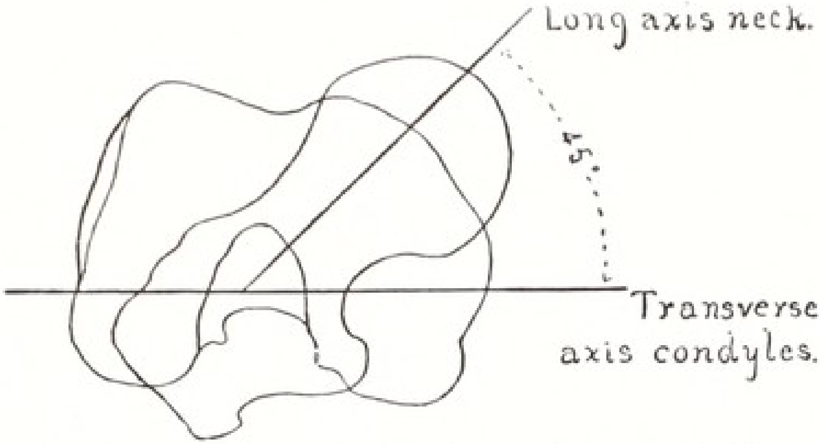


FIG. 30. Twist of neck in congenitally dislocated femur, looking from above downward. (From Bradford and Lovett's "Treatise on Orthopedic Surgery," Wood.)

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 (Figs. 31, 32). 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 hourglass 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

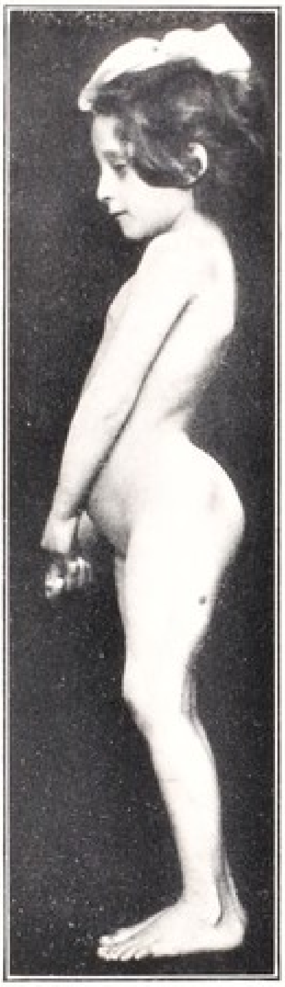


FIG. 31.

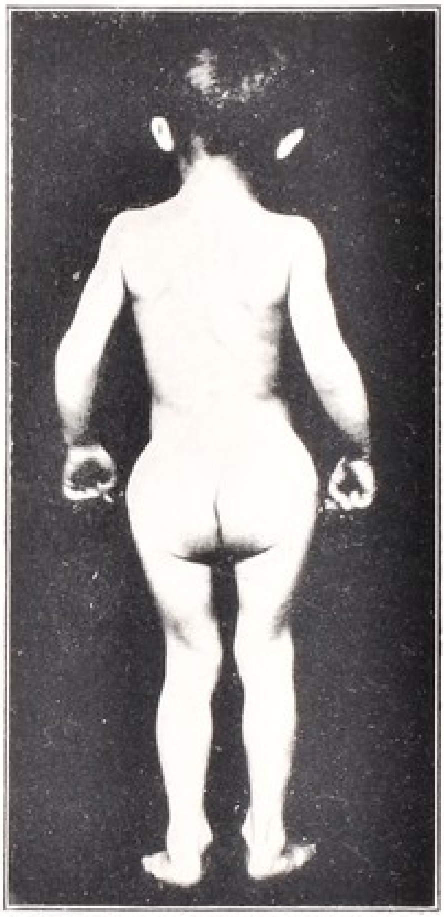


FIG. 32.

FIG. 31. Lordosis in double congenital dislocation of hip. (From Jones and Lovett's "Orthopedic Surgery," Wood.)

FIG. 32. Broadening of perineum with prominence of trochanters in double congenital dislocation. (From Jones and Lovett's "Orthopedic Surgery," Wood.)

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 pelvicrural groups, pelvitrochanteric, and pelvifemoral.

(*a*) *Pelvicrural Group.* This comprises the hamstrings, gracilis, pelvic portion of the rectus femoris, sartorius, tensor vaginae 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 preoperative 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 incompetency of these muscles 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 obstacles against reduction are the muscles arising from the pelvis and inserted below the middle of the femur, *viz.*, the hamstrings, rectus, tensor vaginae 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 the 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 39 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 occurrence 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 the same family.

2. *Mechanical Theory.* It is argued by some that prolonged intrauterine 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 intrauterine flexion of the fetal ovoid is produced by oligohydramnios, multiple pregnancy, hydrocephalus, etc.

Other evidences of abnormal intrauterine forces are congenital genu recurvatum, congenital club-foot, etc.

Additional theories, less plausible and hence less generally accepted, are:

3. *Intrauterine 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 a corresponding protrusion of the abdomen.

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.

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.

Putti * stresses the importance of early roentgen-ray signs in the diagnosis of congenital dislocations and reports the re-

* Putti, V. Analyses of the roentgen symptom triad of predislocation states. *Internat. Abst. Surg.*, 57: 252, 1933.

sults of studies which he made of roentgenograms of normal infants and infants developing dislocations in an attempt to discover signs of predislocation states. He states that a predislocation is a potential complete dislocation and must be treated as such. The following diagnostic signs were noted:

1. Abnormal obliquity of the roof of the acetabulum in roentgenograms of infants from twelve hours to eight days of age. While the importance of the degree of obliquity is relative, it seems that the more oblique the line of the roof, the greater the likelihood of dislocation. The greater frequency of the more oblique roof in the female is in accord with the greater incidence of congenital dislocation in the female. The changes described may be noted at birth.

2. Retardation of the appearance and hypoplasia of the femoral epiphysis. These signs may be detected only after from three to four months of life.

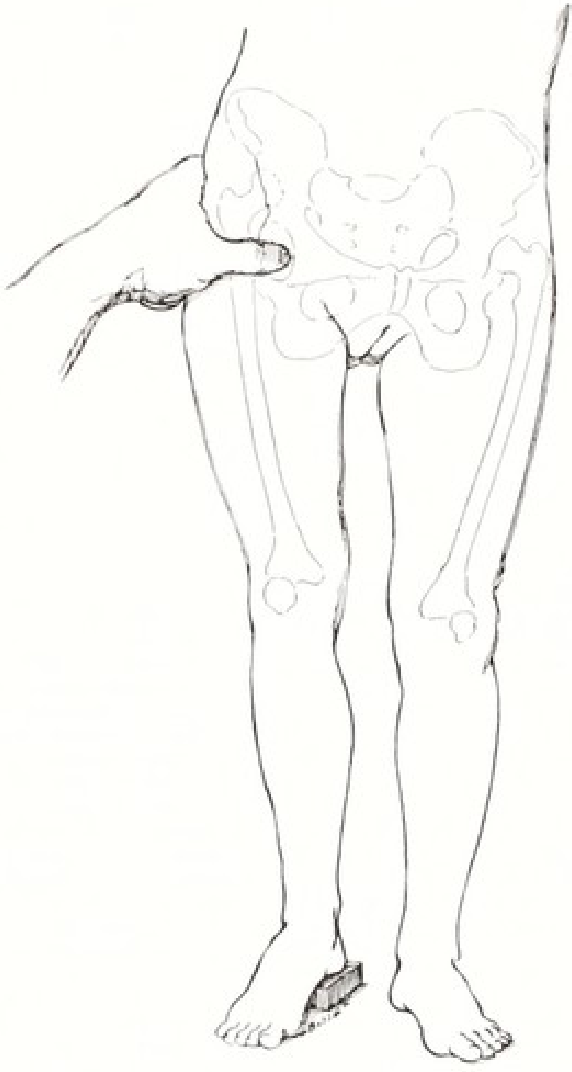


FIG. 33. Congenital dislocation of hip, showing palpability of acetabulum in absence of head, as diagnostic feature of considerable importance. (From Albee's "Orthopedic and Reconstruction Surgery," Saunders.)

Complete or Partial Dislocation. This point can be effectually determined by roentgenography. 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 (Fig. 33), the axis of rotation of the femur comes halfway between these two points in congenital dislocation; if coxa vara or an 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 congenital 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.

Freiberg * states that in the early diagnosis of congenital dislocation of the hip, the obvious, visible abnormalities play the most important roles. Asymmetrical skin folds in the thigh are most frequently overlooked. If the creases on the mesial aspect of the thigh are deeper on one side than on the other, some explanation must be sought. Realizing that at birth and during early infancy there has been no compensation for the shortening of the distance from the pelvis to the knee, which exists if the hip is dislocated, the soft tissues, skin and muscles, must fold or crease. After the child is two years of age, these soft tissue folds are less prominent because the skin and muscles compensate by shortening. In bilateral dislocations of the hip, no asymmetry of skin folds is seen but abnormally deep folds on both sides may be noted.

Second in importance in the early diagnostic signs is eversion or external rotation of the affected leg. If this external rotation of the leg is noted, and abduction is attempted passively, it will be found that this motion is markedly limited. A normal child's leg will abduct passively from 70 to 80 degrees. If abduction is limited to 40 or 50 degrees, some explanation should be sought.

Most deceptive of the early signs of dislocation is shortening of the affected leg. The actual shortening may be so slight that measurement with a tape line is inconclusive. If, on the other hand, the knees are flexed, and the hips are

* Freiberg, J. A. Early diagnosis and treatment of congenital dislocation of the hip. *J. A. M. A.*, 102: 89, 1934.

flexed so that the feet rest evenly on a firm examining table an inequality in length of the legs becomes apparent. In this position, if one leg is shorter than the other, there will be a definite variation in the level of the knees.

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. In young subjects, "telescoping" (free vertical mobility) of the head can be accomplished by fixing the pelvis.

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 bowlegs.	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.

Differential Diagnosis. The most confusing condition is coxa vara. The table on page 89 indicates the most important features in the differential diagnosis between congenital dislocation of the hip and other conditions.

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.

Julius Wolff propounded the theory, accepted almost universally, that the bone develops depending on the functional stresses placed on it. In a congenital dislocation of the hip there is an absence of the normal functional stimulation of the acetabulum and the femoral head, and a delayed or pathologic development ensues. On this basis, the earlier the dislocation is reduced, the less severe will the secondary bony abnormalities have become, and the more perfect will be the end-results.

With treatment, the results vary with the method used. Manipulative, bloodless reduction gives 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.

If the results of treatment of congenital dislocation are to be improved treatment should be begun at a much earlier age than that in which it is customarily undertaken. In fact, treatment should be begun as soon as the diagnosis is made. In Italy * educational propaganda among general practitioners and parents is leading to a marked increase in the

* Putti, V. Early treatment of congenital dislocation of the hip. *J. Bone & Joint Surg.*, 11: 798, 1929.

number of very young children brought for examination. In the United States the deformity is not usually detected until after a child begins to walk. I rarely have patients of this type referred to me earlier than two years of age, although I would treat them earlier if they were brought to me. I do not agree with Fairbank * that reduction should not be attempted before eighteen months of age. In dealing with very young children one should remember that structures are very delicate, and breaking the bone or stretching the artery or nerve unduly should be avoided. Also, immobilization has to be maintained for a longer period.

The normal relationship of the head and shaft of the femur to the vertical and horizontal planes of the pelvis are of importance when considering the methods of treatment for congenital dislocation of the hip. The ideal is reposition at the level of the original acetabulum with stability and mobility assured, but it is physically impossible to accomplish this reposition in certain resistant young patients and in most older subjects.†

Obstacles to a satisfactory reduction are maldevelopment of the acetabulum, hour-glass contraction of the capsule, and the shortened pelvitrochanteric muscles. Fairbank * has discussed the anatomy of congenital dislocation of the hip based on a study of 35 museum specimens of 46 dislocated hips, as well as upon a large number of cases operated upon personally. His conclusions are most interesting and valuable. He believes that the underlying fault in the development of the dislocation is primarily a poorly developed acetabulum.

CLASSIFICATION OF CASES

For purposes of treatment, cases of congenital dislocation may be divided into the following groups:

* Fairbank, Congenital dislocation of the hip. *Brit. J. Surg.*, 17: 380, 1930.

† Colonna, P. Congenital dislocation of the hip in older subjects. *J. Bone & Joint Surg.*, 14: 277, 1932.

1. Those in which it is possible either by bloodless or open operation to secure reduction with a stable hip.

2. Those in which it is possible by closed or open methods to reduce the hip, but which, because of shallowness of the acetabulum or torsion of the neck of the femur, will not remain reduced.

3. Those in which it is impossible to pull the head down sufficiently to reduce the hip. In such cases a shelf must be erected on the acetabulum or, rarely, one may resort to bifurcation. In late years I have included in this group cases that formerly I attempted to reduce at the cost of considerable trauma. The unfavorable results in the way of ankylosis or limitation of motion at the hip have led me to believe that it is better to erect an acetabulum high on the ilium rather than to use so much force in reduction that one runs the risk of subsequent ankylosis.

Infants up to two years of age. Predislocation is becoming more frequently recognized in these young children. The simple abduction treatment of Putti prevents dislocation in these cases. Putti * states that the early recognition and treatment of the condition is of importance not only for the prevention of dislocations but also because, according to the experience of the Rizzoli Institute, congenital preluxation is the causative factor in 40 per cent of cases of arthritis deformans of this joint.

Children from two to four years of age. Those children of about two to four years in whom manipulation easily reduces the dislocation, present such a perfect functional recovery that it is difficult to see how anything better could be desired. The important point is that the reduction must be simple and easy of performance. By this I mean that, under an anesthetic, traction followed by flexion, abduction, and rotation should be able to put the head of the femur back into its socket and that it goes back with a click which

* Putti, V. Statistics regarding the results of the treatment of congenital preluxation of the hip. *Internat. Abst. Surg.*, 56: 138, 1933.

can be felt or actually heard. In these early cases there is one and only one serious obstacle to reduction, and that is the constriction of the capsule.

In children, congenital dislocation of the hip should always be treated in the first place by manipulation under the guidance of roentgenograms, so that the head of the bone can be followed as it approaches and enters the acetabulum. As a general rule up to the age of three to four years manipulation under roentgenographic guidance will effect this reduction, and then, if the limb is kept in an abduction plaster for about six to nine months, permanent recovery takes place, so that after a few years no abnormality can be detected in walking, and the roentgenograms show a normal joint, or one with a shallow socket.*

Children from four to fourteen years of age. In those children in whom manipulation, aided by an anesthetic and the x-ray screen, fails to reduce the dislocation, open operation is necessary. These children are generally aged from four to fourteen years. The hip is exposed by the anterior incision. The capsule is cut open by a longitudinal incision over the femoral head, and it is found that a narrow constriction leads into the acetabulum. The incision in the capsule is prolonged through this constriction, so that the socket is fully exposed. It is now quite easy, by means of manipulation aided by Murphy's shoehorn retractor, to place the head into the socket, but it generally becomes evident that it is not likely to stay in this position because of the shallow character of the acetabulum. At this juncture three courses may be followed:

1. The head may simply be kept in its socket by abduction of the limb fixed in plaster-of-Paris, trusting to the pressure of the head to deepen the cavity in which it lies. This plan should be used only in those cases where the socket is reasonably well formed, as tested by its ability to hold the head when the limb is allowed to lie in the same line as the trunk.

* Hey Groves. Congenital dislocation of the hip. *Brit. J. Surg.*, 14: 486, 1927.

2. The next and most obvious plan consists in deepening the acetabulum by means of a gouge or burr so as to accommodate the whole head, which is then pushed into the new socket and the capsule closed over it. This closure of the capsule will have to be in a transverse direction after the manner of a pyloroplasty, so as to overcome the constriction and at the same time shorten the capsule, tying the femur close to the pelvis. This method of operation has the great merit of gaining good security for the joint, and from this point of view it is the best treatment which is available. But, unfortunately, the price paid for this security is the danger that the joint will become ankylosed. This is accounted for by the fact that the acetabulum is robbed of its cartilage by the act of scooping out a new socket, while the head of the bone, which has been dislocated for a long time, has a very poor cartilaginous covering. This leads to a close fibrous union occurring between the bones. In the case of a unilateral dislocation, a firm but more or less fixed hip will give a good functional result, but if the deformity is bilateral then the double stiff hip will give a sadly crippled condition.

3. The third available method is to leave the natural cartilaginous floor of the acetabulum and to try to hold the femoral head in place by constructing a bone-graft shelf to the upper edge of the socket.

There is a growing tendency in the United States and Great Britain to favor open reduction not only when manipulative reduction has failed, but almost as a routine, even in the youngest children. The decision for or against open operation depends very largely on the view held by the individual surgeon as to the degree of development of the capsular isthmus in young children, and the obstruction this offers to reduction. The results of manipulative reduction prove conclusively that in the youngest children, at any rate, the reduction is complete in the vast majority. Is it right to inflict the extra risk of open operation on all because very occasionally capsular constriction, an abnormal ligamentum teres, or some less obvious factor prevents a stable reduction being obtained by manipulation? Simple open reduction which comprises the important details of dividing the psoas and enlarging the isthmus, is unquestionably a useful procedure in favorable cases, which are rarely met with before the age of four, though more commonly afterwards.

In recent years Galloway * has been the strongest advocate of a more extended use of open reduction in all children of two and a half years of age. Open reduction *per se* has no advantage whatsoever over the closed method, providing reduction is complete and permanent.

The next question involves the importance of antetorsion, the influence of this on the results, and the advisability of correcting this deformity by osteotomy. Opinions differ widely. Lorenz, Bradford, and Gill regard it as unimportant, the first going so far as to say that its correction may lead to posterior subluxation. On the other hand, most writers are not prepared to disregard it, though they differ as to how, when, and where it should be corrected. Osteotomy is the usual method. Soutter and Lovett say antetorsion improves with weight-bearing, especially after two or three years. Hibbs, Calot, and others do osteotomy in the lower third of the bone, while Froelich snaps the atrophied femur over the edge of the plaster some months after reduction. Krida also does a manual osteoclasis. Schede and Codivilla use a nail driven into the trochanteric region to control the upper fragment. As to the degree of antetorsion demanding correction, Bradford and Lovett say 90 degrees antetorsion is incompatible with normal gait and must be corrected. Our experience is that if hips are reduced early, say before the fourth year, it is rare to meet with a case which demands osteotomy. In the older cases, which should become less and less numerous, a degree of antetorsion of real importance, *i.e.*, over 90 degrees, is more common, but still rare. Failure

* Galloway, H. P. H. The open operation for congenital dislocation of the hip. *Surg. Gynec. Obst.*, 37: 674, 1923.

of the upper lip of the acetabulum to grow out seems a far more potent factor leading to re-dislocation than any deformity in the femur.

The next problem is: Should anything be done, and if so, what, to the adolescent with this deformity who suffers little or no discomfort, and never complains of real pain? Fairbank has shown how far from perfect were the anatomical results after reduction in the older cases, even though the head of the femur, or what was left of it, remained in the acetabulum. Gross erosion from absorptive arthritis was present in most instances.

A bone-grafting operation to make an upper lip for the acetabulum when the femur can be brought down to the requisite level, is the procedure of choice for cases beyond nine years of age. Unless this can be achieved with reasonable ease it is better to leave the head of the femur where it is, after constructing a bone-graft shelf over it on the ilium (see p. 120).

CLOSED REDUCTION

Technique of Closed Reduction. Too much emphasis is placed on different stereotyped methods in "bloodless" reduction of congenitally dislocated hips. In the treatment of predislocation and subluxation in very young infants, up to two years of age, the abduction method described by Putti * in 1929 is the most satisfactory. No anesthesia is used. The legs are fixed to a triangular pillow or brace in such a way as to hold them in extreme abduction (Fig. 34). This position is maintained until roentgenograms show sufficient deepening of the acetabulum to maintain reduction. The period of treatment is usually seven to nine months. In one case one type of manipulation will be most successful; in another case a quite different type. The important thing is that throughout the manipulation the surgeon should always follow the

* Putti, V. Early treatment of congenital dislocation of the hip. *J. Bone & Joint Surg.*, 15: 16, 1933.

trochanter and head of the femur and do the necessary amount of adductor muscle stretching. Gentleness and accuracy should be observed throughout the procedure. I have

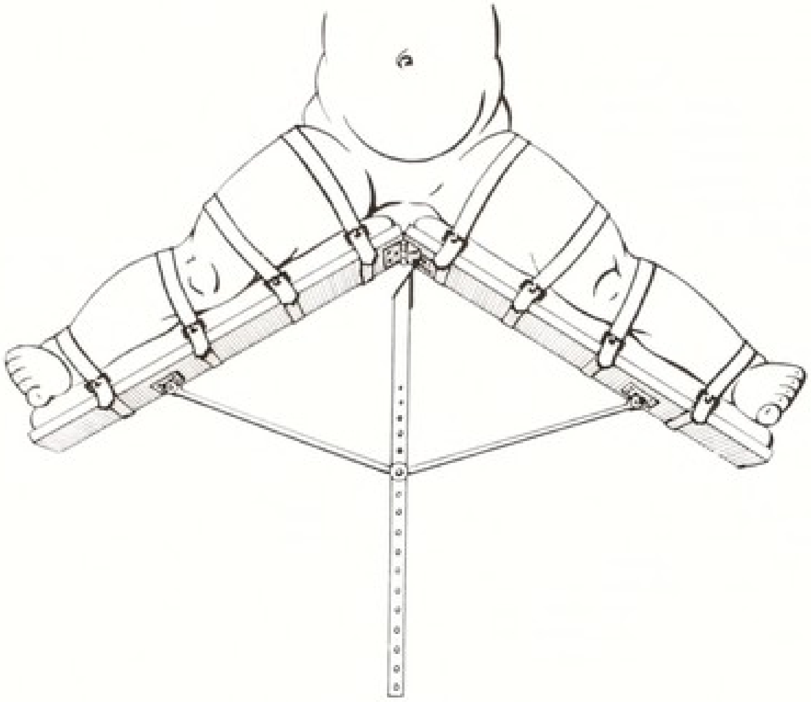


FIG. 34. (After Putti.)

found the principles of manipulation laid down by Lorenz and Calot to be the most satisfactory. On general principles the method of Calot is preferable to that of Lorenz. I do not advocate the old method of overstretching and laceration of the muscles about the hip or its capsule, as these structures, if they are in tone, aid in retaining the head in position after reduction. Each case should be judged on its own merits and studied as to the postoperative position which gives most stability to the head in the acetabulum.

1. 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 periarticular structures by circumduction of the hip in all directions, and by kneading and massage.

FIG. 35. Kneading of adductors (on right side), affected thigh being in *flexion.* Thigh is carried into abduction after having previously been placed in flexion at an angle of 90 degrees. (After Calot.)

FIG. 36. First maneuver made by two persons: an assistant makes traction on affected thigh, grasping it with his two hands a little above knee. Surgeon applies his two thumbs directly over head of femur in order to push it into acetabulum. (From Albee's "Orthopedic and Reconstruction Surgery," Saunders.)

Massage of the Adductors: The pelvis is immobilized by an assistant who flexes the sound thigh upon the abdomen. A second assistant makes traction on the extended affected

FIG. 37. Second maneuver. Surgeon flexes thigh to an angle of 90 degrees, and then carries it into forced abduction. In this movement femur seesaws under thumbs of surgeon who presses head from below upward, reduction being effected in a variable degree of abduction, according to character of individual case. (From Albee's "Orthopedic and Reconstruction Surgery," Saunders.)

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 (Fig. 35).

Maneuvers of Reduction: The femoral head is made to follow the anatomical movements executed in the reduction of traumatic dislocations.

First Maneuvers: Flex the knee to 90 degrees and exert direct traction on the flexed knee without abduction, adduction, or rotation (Fig. 36).

(*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

Fig. 38. Third maneuver, characterized by adduction and internal rotation added to flexion. Child is laid on its sound side; assistant grasps thigh at its lower third, carries it in flexion to 90 degrees, then in forced adduction and internal rotation of 90 degrees. Surgeon presses with his thumbs upon head of 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 head of femur and two for traction on knee. (After Calot.)

the knee, the other making direct pressure on the head of the femur.

Second Maneuver: Abduction of the *thigh* to 90 degrees (no rotation) (Fig. 37).

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. The child lies upon the sound side. An assistant flexes the thigh to a right angle, adducts and internally rotates to 90 degrees while 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

FIG. 39. Third maneuver (continued). Assistant at knee, making continuous and strong traction toward him, raises himself gradually in order to reach position of abduction. Surgeon continues to press upon head of femur. Second assistant shown here immobilizes pelvis. (After Calot.)

FIG. 40. Third maneuver (concluded). Thigh brought gradually to an abduction of 90 degrees. (After Calot.)

in place, an assistant makes traction and gradually brings about an abduction of 90 degrees (Figs. 38-40).

Retention of the Reduction. To insure the head's remain-

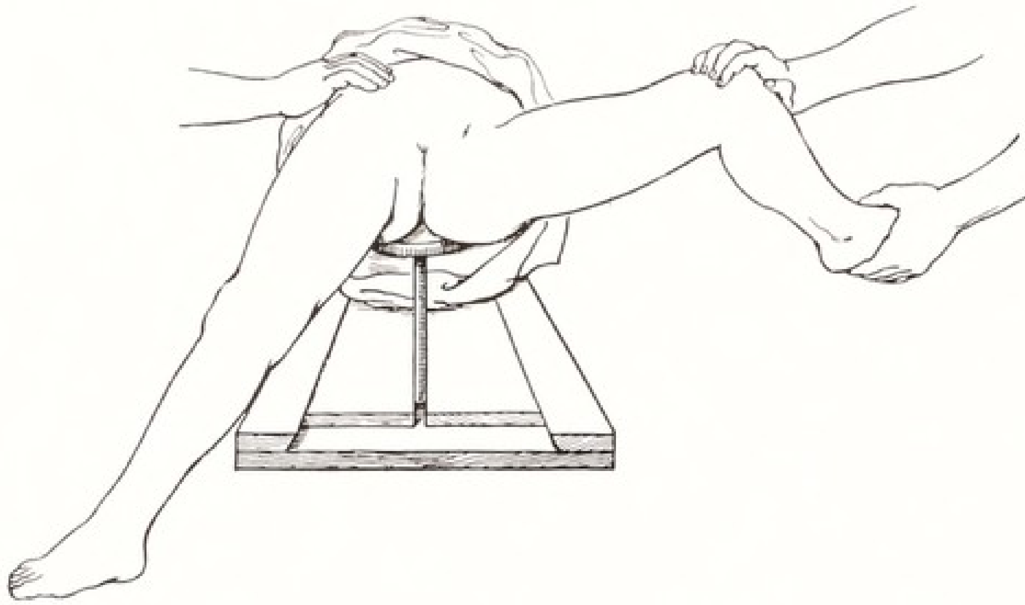


FIG. 41. Chosen position. Flexion 70 degrees; abduction 70 degrees; rotation 0 degrees. (After Calot.)

ing 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 (Fig. 41).

(*a*) *First Position, First Plaster:* 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. 42). The child is kept recumbent for two and a half months (Figs. 43 and 44).

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 molding the plaster inward in this region. (Fig. 45.)

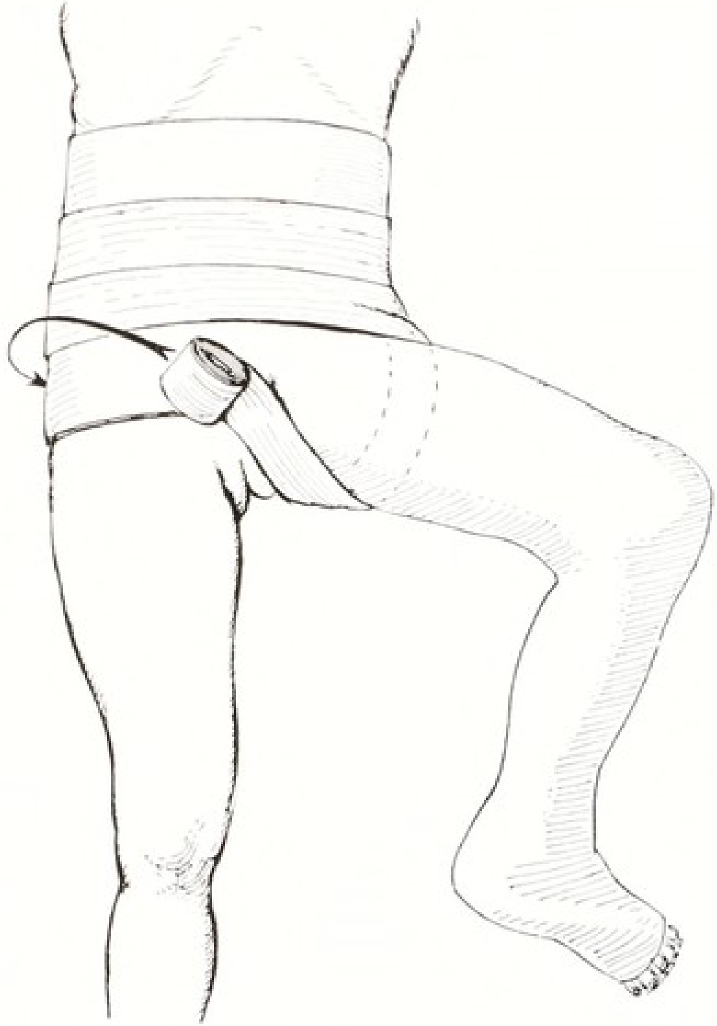


FIG. 42. Application of plaster-of-Paris rolls over the stockinet and cotton wadding.

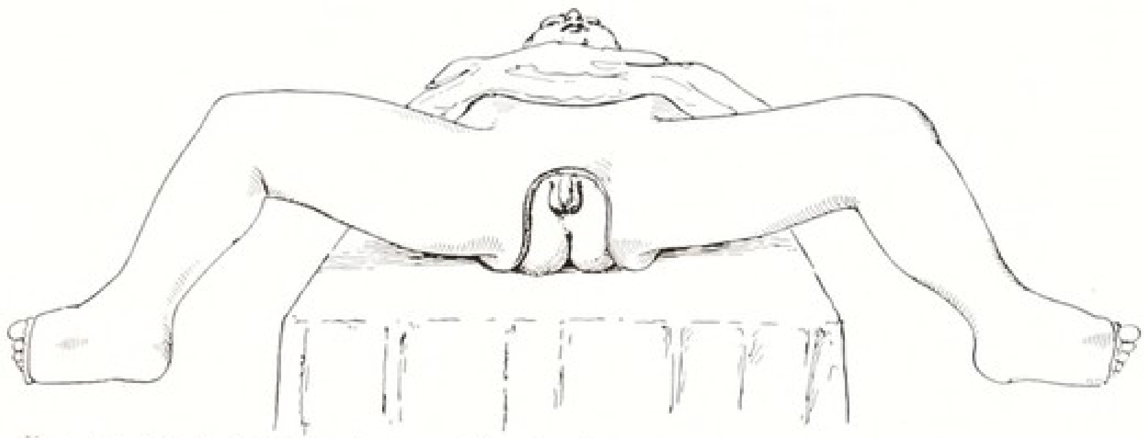


FIG. 43. Long double plaster-of-Paris spica following reduction of congenital dislocation of hip.

(*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 de-

FIG. 44. X-rays taken through plaster a few days after reduction of a double congenital dislocation of hips. Wisdom of always doing this is demonstrated in this case by fact that both hips are shown to have slipped. One femoral head is above 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. (From Albee's "Orthopedic and Reconstruction Surgery," Saunders.)

grees 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.

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 up on his feet, walking at first by holding onto a chair or table. At the end of seven to ten days, in this manner, he is allowed to walk with the

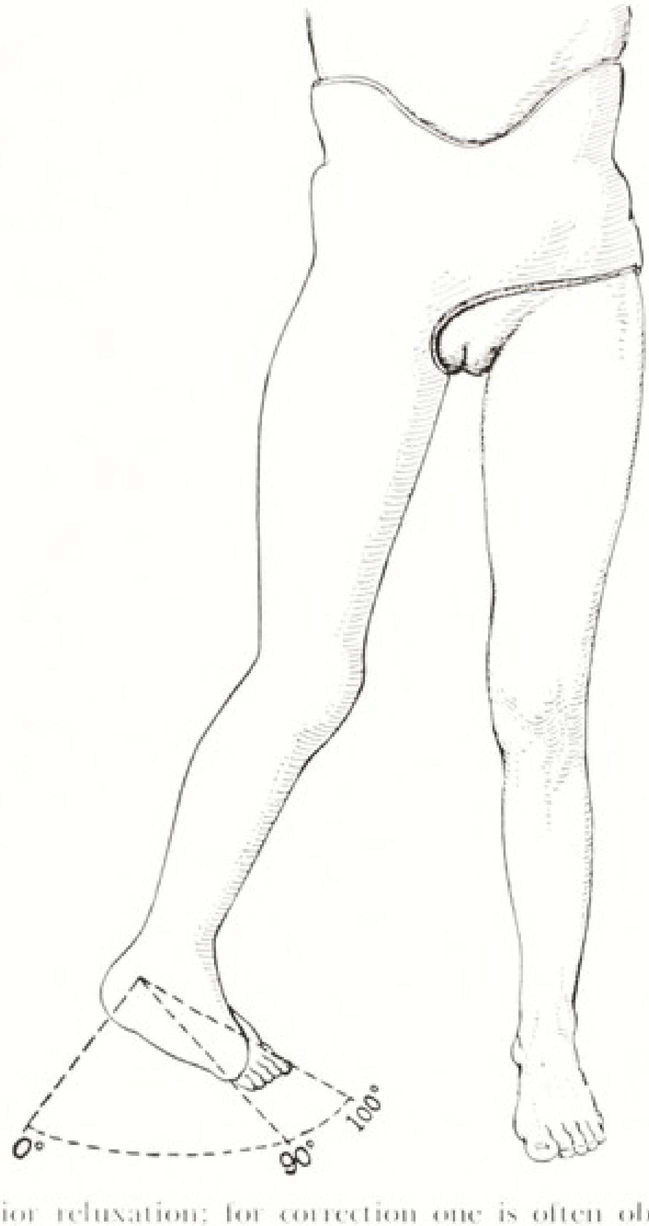


FIG. 45. Anterior reluxation; for correction one is often obliged to make internal rotation of the knee of more than 90 degrees. (After Calot.)

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.

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.

2. *Dislocations in Children Five to Six Years of Age and More*

Unilateral Dislocation. Preoperative 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.

(*b*) and (*c*) may be overcome by the maneuvers described under the treatment of cases two to three years old.

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.

*Davis Method.** The method described by G. G. Davis may be divided into the following steps:

* Dickson, F. D. The Davis method for closed reduction of congenital dislocation of the hip. *J. Bone & Joint Surg.*, 7: 873, 1925.

1. The child, under anesthesia, is placed in a prone position on a well-padded table.

2. The hip on the affected side is acutely flexed with the knee bent until the knee lies against the side of the chest in a position of acute axillary flexion. This brings the head from a high position on the dorsum of the ilium to a low position.

3. With the knee held firmly against the side of the chest, downward thrusts are made on the trochanter with the heel of the hand. This stretches the adductors. As the adductors stretch, the perineum, which is elevated when the thigh is flexed, approaches the table and when all possible has been gained in this way the doubled-up fist of an assistant is placed under the knee, thus raising the perineum sufficiently to permit further stretching. As this stretching proceeds, the head slips from the posterior plane of the pelvis onto the anterior plane. The indications that this has occurred are the following: (a) Feeling the head slip forward; (b) noting when the knee lies definitely dorsal to the plane of the hip joint; and (c) feeling the forward movement of the head with the fingers of the unengaged hand placed in the groin.

4. With the head on the anterior plane, the hip is gradually brought from the position of acute axillary flexion to a position of right angle flexion by a "pump handle" movement, firm pressure being maintained on the trochanter with the heel of the hand while this maneuver is carried out. As the thigh approaches a right-angled position, the head slips upward into the acetabulum through the cotyloid notch.

The hip or hips are then placed in plaster in a right-angled position or as near this position as the stability of the reduction will permit.

Throughout the procedure little force and no violence is used. No leverage action is necessary, the force being applied directly to the upper end of the femur. If the thigh is held closely to the chest wall until the head slips forward, there is no possibility of causing a fracture or epiphyseal separation.

The stretching of the adductors is accomplished gradually and with little trauma, so that there is never a reaction of any consequence. In fact, the child suffers so little from the procedure, that it is the practice to let it be taken home the day after the reduction.

*Krida's Method.** "At the first sitting the dislocation is reduced and fixed in a plaster-of-Paris spica in the original 90-90 degrees attitude of Lorenz, except that the dressing is carried below the knee. This attitude is maintained for two weeks.

"At the second sitting, two weeks later, the anterior distortion is evaluated by a study of the roentgenograms made before reduction, but particularly by the evaluation of what may be gained by palpation of the hip joint structures. The abduction is carefully reduced to about 25 or 30 degrees and the patella is brought into the sagittal plane. If the head remains deeply placed in the tissues of the groin, and in its proper relation beneath the femoral artery, it may be assumed that no abnormal anterior distortion is present. The limb is then fixed in this attitude, which is maintained until the end of the period of fixation treatment and no third sitting is required. If, on the contrary, it be found that in this attitude the head of the femur becomes prominent in the groin, and if upon even slight outward rotation of the extremity it becomes displaced slightly laterally to the line of the femoral artery, it may be assumed that a degree of anterior distortion exists which is inimical to the ultimate security of the joint. In those cases in which such a state of affairs is found to be present, the extremity is rotated inwardly to a degree sufficient to place the head deeply into the groin and in its proper relation to the line of the femoral artery. The amount of energy expended in this manipulation need not be small, since there is at this time no danger of dislocation over the posterior rim of the acetabulum. A plaster-of-Paris spica is

* Krida, A. Congenital dislocation of the hip joint. *Am. J. Surg.*, 6: 185, 1929.

applied in the corrected attitude, an attitude in which the hip joint elements are in approximately physiological relations, or at least one from which such relations may be attained without further basic alteration. This fixation dressing is designed to remain in place for three months.

"Third sitting. This is required only in those cases in which, as above outlined, it has been found necessary to impose inward rotation upon the extremity. The imposition of the necessary degree of inward rotation demands that a correction of this secondary distortion be made, since upon release from fixation dressings the head of the femur would be levered forward as soon as an attitude consistent with progression was assumed.

"At this sitting, upon removal of the plaster, the extremity lies, as it were, upon its inner side, with the knee flexed. The knee is grasped with one hand and the shaft of the femur adjacent to it with the other, and a fracture is produced in the supracondylar region by manual force. This fracture invariably occurs in the segment above the epiphyseal line, a fact originally pointed out by Brandes. The fracture is completed and then one hand grasps the head and neck of the femur, the other the flexed knee joint. Outward rotation of the lower fragment is made, the upper hand maintaining the original relation of the head and neck at the hip joint. The lower fragment is rotated outwardly until the patella lies outside the sagittal plane. A plaster-of-Paris spica is applied in the corrected attitude, in about 20 degrees of abduction and slight flexion at the hip and knee joints.

"This plaster is designed to remain on for two months, thus giving, in the ideal case, a period of fixation of somewhat less than six months. During the last month of fixation treatment, the patient is to stand and make attempts at ambulation in so far as that may be possible."

Although Krida's results seem to be very good, many, including myself, do not feel that the fracturing of the femur is necessary except in a small minority of cases.

RESULTS OF MANIPULATIVE METHOD

In his review of 1842 cases, Maffei * attributes failures in reduction to ineffective application of traction preliminary to manipulation, and insists upon application of a carefully molded cast following reduction. In old cases he recommends open reduction without an attempt at closed manipulation, as the latter procedure is uniformly unsuccessful.

Putti † states that it is a complete delusion that one can have a result permanently satisfactory in function in a hip incompletely reduced. This delusion has led to a too optimistic view of the results. Clinical and roentgenological observations of cases examined from five to thirty years after the end of treatment demonstrate irrefutably that every subluxated, or transposed hip, every hip in which one has not obtained from the first, or not preserved, normal anatomical relationship between the femoral epiphysis and the acetabulum, every such hip is inevitably destined to become the subject of that precocious articular senility, which is usually diagnosed as osteoarthritis. In other words, no complete and permanent restoration of function occurs apart from perfect anatomical reduction.

Putti ‡ brought out that the greater part of the complications arising in the treatment of the luxation must be attributed to the traumatic factor, and that in order to reduce the trauma to a minimum it is necessary to intervene early, after a diagnosis made a few days after the birth of the child.

Lagomarsino § states that the changes in the congenitally dislocated hip following its reduction depend upon: (1) the time at which the reduction is done, (2) correct centering of

* Maffei, F. Traumatic dislocation of the hip (1842 cases). *Internat. Abst. Surg.*, 36: 28, 1923.

† Putti, V. Early treatment of congenital dislocation of the hip. *J. Bone & Joint Surg.*, 15: 16, 1933.

‡ Putti, V. Report at the Congress of Orthopedics. *J. A. M. A.*, 100: 1355, 1933.

§ Lagomarsino, E. H. Subsequent changes in the congenitally dislocated hip reduced by the Paci Lorenz method. *Internat. Abst. Surg.*, 60: 53, 1935.

the cephalic ossifying nucleus until there is perfect retention by reconstruction of the acetabular roof, (3) the gentleness and smoothness of manipulation during reduction and subsequent handling, (4) the reconstructive power of the reduced hip, and (5) the extent of osteochondral changes instituted by the reduction. To a certain extent the last two factors are governed by the first three. There are no infallible signs upon which an accurate prognosis can be based.

Professor Annovazzi of Milan, who based his conclusions on 1,610 cases, stated that in children treated under two years of age, the percentage of good results was 82 per cent; in children under five and more than two years of age, 66 per cent, while in children more than five years old the percentage of favorable results diminished gradually. These statistics show the need of resorting to the manipulative method as early as possible.

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 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.

Sciatic paralysis * was found by Lorenz in 23 of 755 cases, and crural paralysis was found by Taylor in 9 of 50 cases in which a congenital dislocation of the hip has been reduced. Froelich states that the nerve involvement nearly always occurs in children between the ages of five and nine years and in cases in which the original shortening was over 5 cm.

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.

OPEN REDUCTION

The open operation, which affords the opportunity to study the pathology and which involves much less danger than forcible manipulative and mechanical procedures, *may be used to advantage more often than it is customarily employed.* Examination of the pathological changes often reveal

* Corret, P. Les accidents nerveux de la réduction de la luxation congenital de la hanche. *Rev. d'orthop*, 19: 5, 1932.

an hour-glass constriction of the capsule, or marked anteversion of the femoral neck, or an acetabulum filled with adherent tissue covered over with the inferior capsule. In the presence of such alterations it is futile to use the closed method.

Many different methods of open reduction have been devised. Igianni, Richard, Corner, Frisch, Lambotte, Lexer, Tubby, LeDamany, Thomas, Patschke, Ludloff, Fairbank, Davis, Dixon, Willis, Berstein, Clarke, Sherman, Bradford, Galloway, and Burghard have reported cases treated by open operation.

The first surgeon on this continent who strongly opposed the manipulative method and advocated open reduction was the late Harry M. Sherman of San Francisco.* Discouraged with the generally unsatisfactory results of the manipulative method, he had abandoned it in 1919, and employed the cutting operation in all of his subsequent cases.

In June, 1920, Galloway, who had been using the open method ever since hearing Sherman's paper, strongly advocated this procedure and presented an impartial view of his results. The technique of choice which he now uses follows:

Galloway Technique.† "The patient is placed on the table with a sand-bag under the trunk, so arranged as to raise the pelvis on the side to be operated on. Beginning at a point just below the crest of the ilium and from 2 to 3 inches behind the anterior superior spinous process, an incision is carried forward just below the crest to a point immediately below the tip of the anterior superior spinous process. The incision is then carried down about 3 inches in the long axis of the thigh. The first incision should include merely the skin and superficial fascia. Skin towels, backed with waterproof material, are then clamped on the edges of the wound. With a fresh knife the interval between the rectus and tensor

* Before the American Orthopaedic Association.

† Galloway, H. P. H. *Loc. cit.*, p. 95.

fasciae femoris is now located and opened up; then the incision along the crest of the ilium is deepened to the bone. In young children it is necessary to do this with some care because the bone is so thin and soft that it can easily be cut through. With a periosteal elevator the muscles are easily stripped from the ilium and the capsule of the hip joint fully exposed. By rotating the limb inward and outward the head is now readily felt, usually a little below the level of the anterior superior spinous process.

"While the limb is held fully rotated inward a longitudinal incision is made through the capsule, this incision being an inch, or slightly more, in length. The capsule is always surprisingly thick, and this incision should be carried down through it with great care so as not to wound the cartilage of the head. The object of rotating the limb inward, before commencing the incision into the capsule, is that this effectually guards against any possible wounding of the ligamentum teres. The moment the joint has been opened, some synovial fluid escapes and the glistening head can be seen.

"The longitudinal incision through the capsule is now converted into a crucial incision by incising the anterior and posterior margins of the longitudinal cut to the extent of from $\frac{1}{4}$ to $\frac{3}{4}$ of an inch.

"If the limb be now rotated outward the ligamentum teres, which is nearly always surprisingly large, comes into view, and, by following it in toward the pelvis with the finger, the acetabulum is located.

"In practically every instance, deep in toward the joint, a constriction is felt in the capsule; to the finger it gives the sensation of a sharp crescentric fold, the free concave margin of which looks upward toward the roof of the acetabulum. This is divided freely in a downward direction, using for this purpose a hernia knife which is introduced flat-wise along the left index finger, cutting edge turned toward the constriction after it has been introduced to sufficient depth.

"In some instances the head may, without any difficulty, be maneuvered into place by abducting the limb and rotating it inward, but usually it will be found of advantage to use a hip skid. The instrument I use is one which has been slightly modified from a model kindly furnished me by Dr. W. R. MacAusland. This instrument is introduced into the acetabulum and holds the soft tissues out of the way while acting as a kind of 'shoehorn' along which the head is slid deeply into the acetabulum.

"Always redislocate the head once or twice so as to test the position of greatest stability. It will usually be found that abduction of from 45 to 60 degrees and pronounced inward rotation will maintain a perfectly stable reduction.

"With a continuous suture of plain catgut, the deep tissues are quickly brought together, particular care being used to bring the muscles which were divided along the crest of the ilium into place again. Usually no attempt is made to close the opening in the capsule; in fact, the moment the head is reduced the incision in the capsule falls together so perfectly that often it cannot be seen.

"A plaster-of-Paris spica is applied from the nipples to just above the ankle, the knee being slightly bent so as to maintain the position of internal rotation.

"An x-ray picture is taken through the plaster two or three days later. About three weeks after the operation, the plaster is removed and the stitches taken out. The plaster is then reapplied without changing the position of the limb, except that the knee is bent to a less degree. From that time on the child is encouraged to bear weight on the limb. In from six to eight weeks the plaster is again removed and reapplied, this time the degree of abduction and inward rotation being slightly lessened.

"One or two other changes of the plaster are made, at intervals of about six weeks, and each time the limb is brought nearer to the normal position. Within five or six months all dressings are discarded and the child allowed to go about freely."

Howorth and Smith * state that open reduction is almost always successful primarily. When redislocation occurs it usually takes place shortly after the removal of the plaster. Therefore the hip should be carefully watched at this time, particular attention being paid to roentgenograms made with the patient standing. Secondary manipulations to improve the reduction have been of little value.

Galloway states that he was "driven to the open method by the distracting uncertainty and frequent failure which attended my former efforts at manipulative cure."

He considers "the ideal time for operating is between two and three years. In a general way the operation becomes more difficult and uncertain as the age advances, although exceptionally, in children from five to twelve years of age, or younger, who have not been subjected to manipulative or other treatment, the ligamentum teres is usually intact and is an important guide in locating the acetabulum. In older children, and in those who have had a previous unsuccessful manipulative reduction, the ligamentum teres is usually absent, or is found detached from the head and curled up in the acetabulum." † "In children past three, and occasionally even in younger patients, after opening the capsule freely and dividing the constricted part, the finger in the acetabulum detects this cavity more or less occupied by a kind of fibrous mass, part of which represents the remains of the ligamentum teres." When this condition is encountered, Galloway introduces his left index finger and passes the convex side of a shallow gouge along its palmar surface into the acetabulum, and with a kind of combined pushing and leverage motion strips this mass from the roof and walls, and pushes it towards the floor of the socket.

* Howorth, M. B. and Smith, H. W. Congenital dislocation of the hip treated by open operation. *J. Bone & Joint Surg.*, 14: 299, 1932.

† Galloway, H. P. H. *Loc. cit.*, p. 95.

taking the greatest care not to wound the cartilaginous lining; the left index finger all the time guiding and controlling the edge of the instrument.

While age is not always a fair criterion, and each case must be individually judged, it is felt that as a rule cases over five years of age will not lend themselves to a satisfactory reduction by this method.

In old cases, Allison suggests sectioning the lesser trochanter, thus doing away with the resistance of the psoas muscle. In addition the head is brought forward as much as possible. Three weeks later, during which time heavy skeletal traction has gradually brought the head down to the upper level of the acetabulum, a second operation is done. The acetabulum is cleared of dense, fibrous tissue and the head replaced without difficulty. In one case he did an osteotomy three months later to correct internal rotation of 90 degrees.

Patients over nine years of age. Open or closed reduction? Closed reduction after the age of sixteen is possible rarely and justified even more rarely, because of the undue violence necessary. Successfully reduced cases after this age have, however, been reported. Skeletal traction by the Kirschner method was used.*

No method of closed reduction yet presented may be regarded as generally feasible in the age group under consideration. What is the utility of putting the head into the acetabulum if the result is a stiff hip, because of the extensive trauma in getting it into place? Far better to have an inch of shortening and have the head of the femur upon the side of the pelvis under a bone-graft shelf and with a mobile hip.

Shelf Operations. The "shelf operation" or formation of an artificial lip to the acetabulum is a most useful one for older cases and is being performed with increasing frequency

* See Gaenslen, F. J. Rapport au 1er Congress International d'Orthopedie, Paris, 1930.

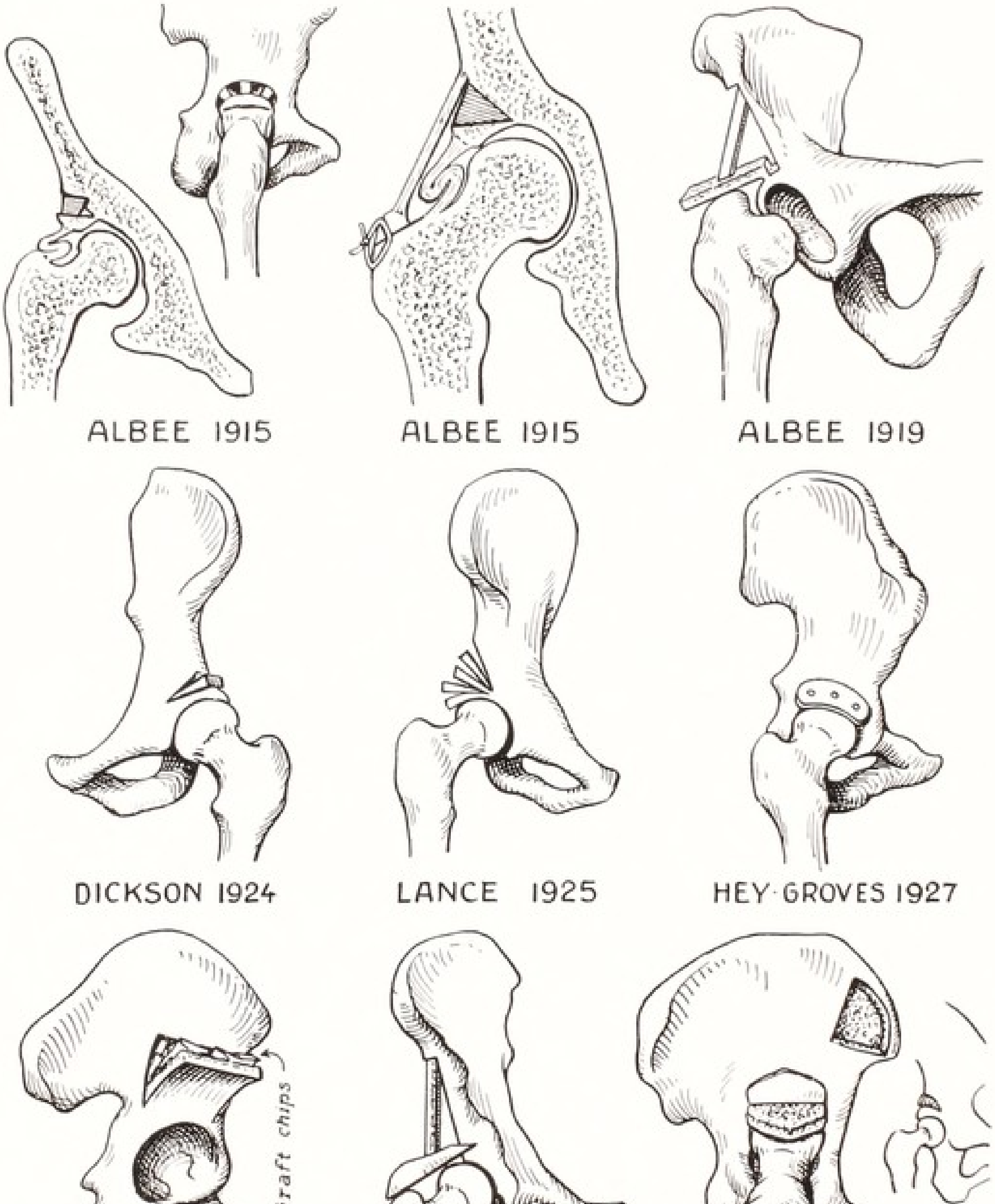


FIG. 46. Various shelf operations for stabilization of hip in congenital dislocation.

by surgeons throughout the world, which is evidence of appreciation of its value.

Many variations have been reported * (Fig. 46) to meet the exigencies of varying anatomical and mechanical conditions, depending on whether or not the hip can be reduced, or how high up on the ilium it must be stabilized.

The operation is sound from the anatomical point of view. The making of an efficient shelf is comparatively easy; the difficulty lies in making the shelf at precisely the right level. When relapse is seen to be occurring after manipulative reduction followed by prolonged fixation, or when simple reduction offers but little hope of a cure—for example, in a subluxated hip at four years of age upward, this operation is invaluable. Fairbank believes the procedure should always be added to open reduction when the condition of the patient permits.

In most cases of old unreduced congenital dislocation, or in cases in which reduction can be accomplished but cannot be held, some type of shelving operation offers the best means of stabilization. The procedure also offers the best chance for functional improvement. The operation is indicated for old congenital dislocations in which the head is riding well up behind or anteriorly to the acetabulum on the posterior portion of the ilium, as well as for cases of subluxation from infantile paralysis.

The similarity of the various shelf operations is obvious; the principle involved is the same in all. There are two points in regard to the application of this type of operation which might be emphasized: (1) The hip should be reduced or at least brought as far down as possible by heavy traction applied either before operation or at the time of operation, and (2) the shelf should cover as much as possible of the entire

* Fairbank, Lambeau, Vance, Delagenière, Mauclaire, Dujarier, Hallopeau, Spitzy, Dickson, Allison, Swett, Wallace, Ober, Bruce Gill, Frisch, Lambotte, Lexer, Tubby, LeDamany, Thomas, Patschke, Ludloff, Davis, Dixon, Willis, Berstein, Clarke, Bradford, Sherman, Galloway, and Deutschlaender.

upper surface of the femoral head, but should not extend far enough laterally to interfere with abduction. It is not necessary to have the shelf jut out over the trochanter if the head is present.

Fig. 47.

The bony shelf relieves pain and fatigue in both young and old, helps to improve locomotion, and maintains the length of the leg.

*Shelf Operation of Choice.** The joint is approached by the Smith-Petersen (or Sprengel) incision. Adequate traction is applied to the limb in order to lengthen it as much as possible. With the single small motor saw parallel cuts are made, about 1.5 inches apart in adults and less in children, through the outer table of the ilium in a position immediately above the acetabulum (Fig. 47). The upper ends of these saw cuts are connected by a horizontal cut made with the single saw. With an osteotome, this flap of bone is turned down so that it comes to lie snugly upon the capsule of the hip joint (see A_1, Fig. 48). The bone shelf still remains attached to the ilium in a hinge-like manner at its lower portion. With the small single saw or the twin saw blades, a rectangular block of bone of the same width is removed from the outer table of the ilium a short distance above the flap of bone already mentioned. This block of bone is completely detached, is placed as a strut or brace,

* Albee, F. H. Bone-graft Surgery. Phila., Saunders, 1915.

and fastened by one or two kangaroo tendon sutures placed in drill holes (see B_1, Fig. 48). A double plaster-of-Paris spica is applied extending from the waist line to the toes

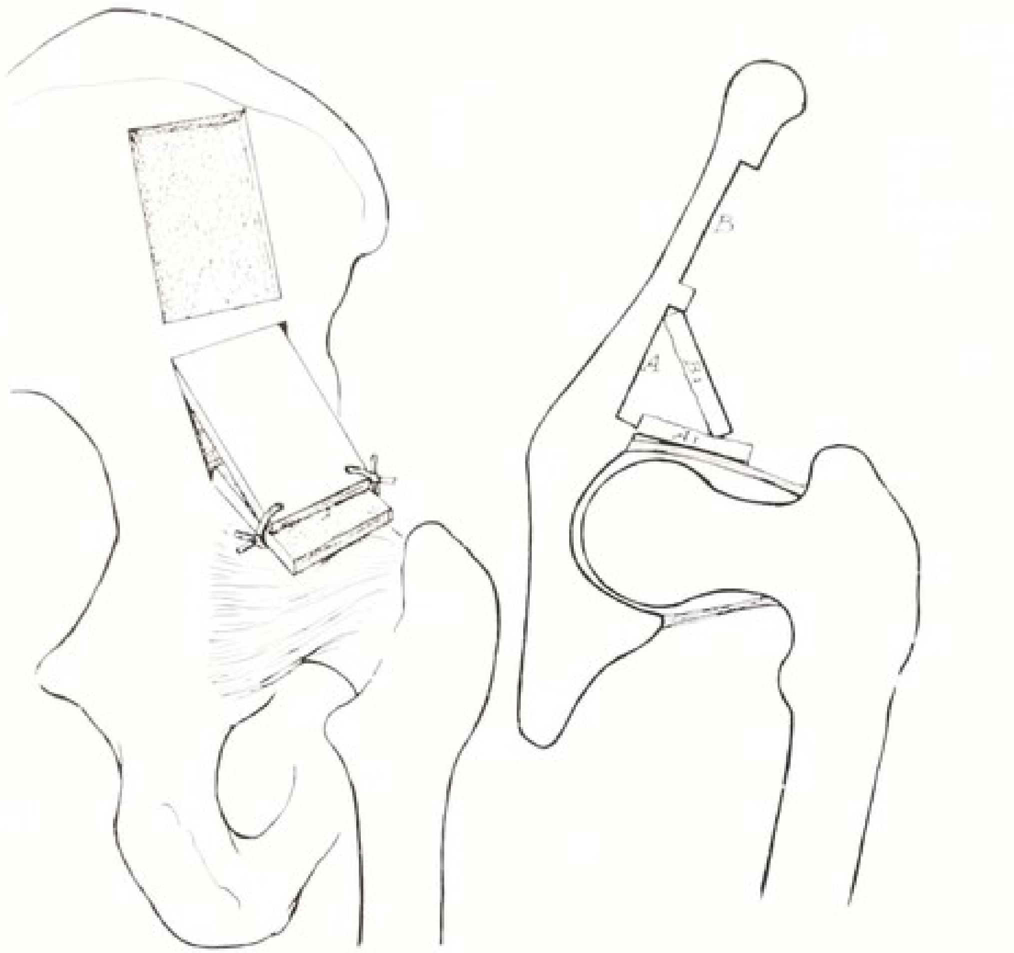


FIG. 48.

on both sides. It is usually necessary to apply traction to the limb postoperatively beneath the cast. This is accomplished by placing moleskin adhesive upon the inner and outer side of the thigh as well as on the upper half of the lower leg. As the plaster is applied, the lower ends of the moleskin straps are incorporated in it at a point about three to four inches above the ankle joint. Following this the countertraction is secured by molding the plaster firmly against the plantar surface of the foot on the unoperated side. This traction is continued until the cast is removed at the end of seven or eight weeks, after which massage and passive and active motion are carried out to restore motion to the hip and function to the limb (Fig. 49).

Dickson * states that the chief cause of trouble following

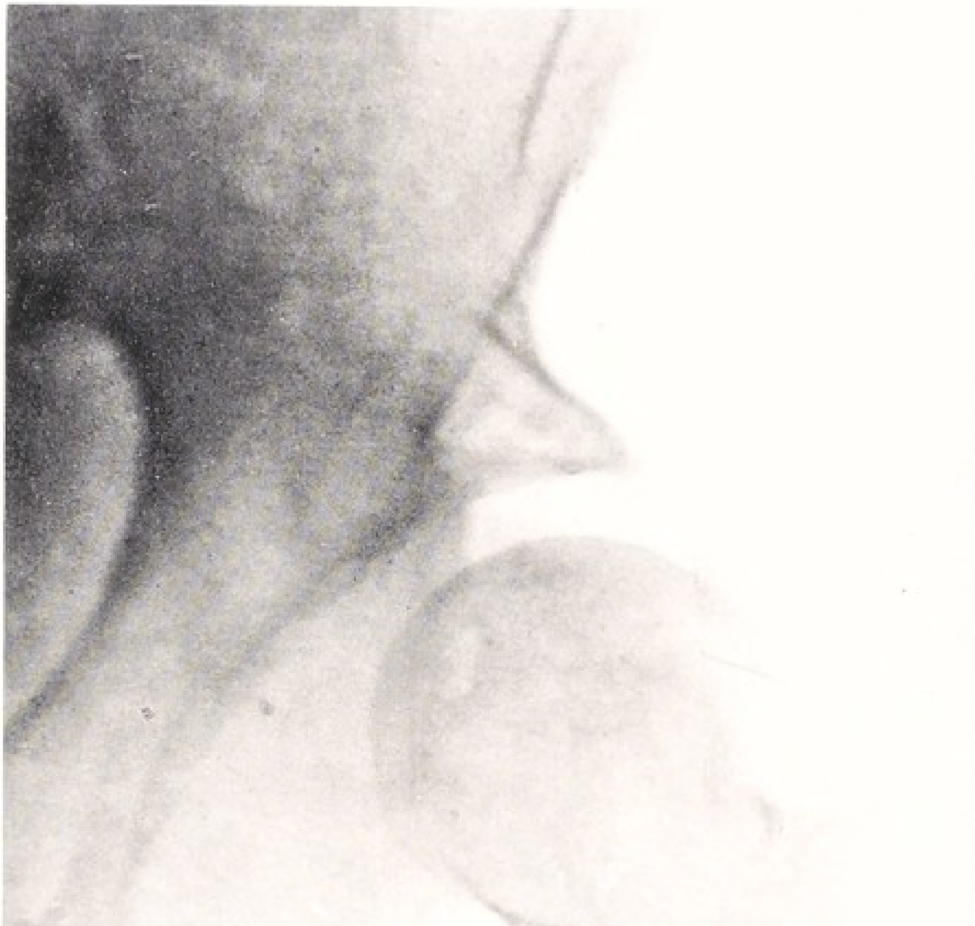


FIG. 49. Congenital dislocation of hip. X-ray taken five years after operation.

shelf operations has been the failure to improve the weight-bearing position of the head by restoring it to approximately its normal position above the true acetabulum. This pre-

* Dickson, F. D. Shelf operation in treatment of congenital dislocation. *J. Bone & Joint Surg.*, 17: 43, 1935.

vents any improvement in tilting of the pelvis and correction of lordosis, an important advantage secured by a shelf operation properly done. Attempts to secure too much length will result in the same excessive pressure against the head which occurs in these older cases if the head is restored to the acetabulum with absorption of articular cartilage and rigidity or ankylosis of the joint.

Gill's Shelf Operation. "An incision is made along the anterior third of the crest of the ilium to the anterosuperior spine and continued in a curve downward and backward, after the method of Smith-Petersen. The tensor fasciae femoris and a portion of the gluteus medius are freed subperiosteally from the ilium. The anterior portion of the incision is carried by sharp dissection downward between the tensor fasciae femoris and the sartorius muscles, following the anterior border of the pelvis until the anterior inferior spine of the ilium is reached. Below and posterior to this point it is found that the periosteum is closely attached to the ilium where the capsule of the hip joint blends with it." The further procedures necessary from this point depend on the type of dislocation. Three types of operation are described by Gill. Type No. 1 is not described because of its similarity to my own technique.

Gill's Operation, Type No. 2. "The capsule of the hip joint is opened by cutting it with a knife or pair of scissors close to its attachment to the ilium, beginning at the inferior spine of the ilium and extending backward 1.5 to 2 inches. Through this incision the finger can be inserted into the acetabular cavity.

"The head lies in the capsular pocket, above and posterior to the acetabulum. It is usually impossible to pass the finger into this pocket, owing to the constriction of the capsule, and it is usually impossible to reduce the head through this hour-glass constriction. Another incision is therefore made in the capsule, beginning about midway in the incision already made and extending at a right angle to it up to the head of the femur. Through this second incision the head can be delivered into the wound.

"With scissors or knife or curved gouge the acetabular cavity is enlarged by removing from it the fibrous tissue which is found to fill it. In no instance in this series of cases, in this type of dislocation, has the acetabular cavity been found sufficiently large to hold the head of the femur. After removing the fibrous tissue and sometimes even some of the cartilage lining of the acetabulum, the head of the femur can be placed in it. But even then the acetabulum is not large enough to give stability to the femur in this position. It is therefore enlarged and reinforced by turning down a bone flap from the side of the ilium and by turning down the roof of the acetabulum as described in Type 1. The head remains securely in the acetabulum if the femur is maintained in slight abduction. The capsule is brought up over the bone flap which has been turned down, but it cannot be sutured in any fashion. The wound is closed as described in Type 1, and the after-treatment is similar."

Gill's Operation, Type No. 3. "The capsule is opened and the head exposed in the manner already described in Type 2. In order to allow the head to go forward, it is necessary that the capsule be cut through entirely in the perpendicular incision which begins at the middle of the horizontal incision and extends upward and backward to the head of the femur. If any portion is allowed to remain encircling the neck of the femur, it is impossible to bring the head of the femur forward well into the wound.

"Moderate traction is now made on the extremity to see how far down the head of the femur can be brought. This will largely depend, of course, on the age of the patient and the amount of the upward dislocation. It is frequently found that the head can be brought to a position just below the anterior inferior spine of the ilium.

"The original acetabulum is identified. It is usually found to be very small and frequently it is entirely obliterated.

especially in the older cases. With a curved gouge the acetabulum is enlarged upward and backward until the head of the femur can be placed in it with moderate traction. It will remain there if the femur is slightly abducted, but the cavity cannot be made large enough to hold the head of the femur unless abduction is maintained. A bone flap, oftentimes one inch or more in width, is then turned down above and behind the head as it lies in the depression made above the original acetabulum. It is necessary to maintain the femur in abduction constantly until plaster-of-Paris is applied, lest on adduction the head should slip out and break down the bone flap. This accident has never happened in our experience.

"Where the thickness of the pelvis above the newly constructed acetabulum permits, the osteotome is driven in deeply above the head of the femur, after the flap has been detached from the side of the pelvis, so that the entire newly constructed roof of the acetabulum is reflected downward and the wedge pieces of bone are driven in deeply above the roof. This makes the reconstructed acetabular roof very solid and secure, and brings it into close apposition with the entire head of the femur. The wound is closed in the usual manner. The plaster cast is applied with the extremity in 20 to 30 degrees of abduction and in internal rotation.

"The after-care is the same as in the preceding types. The purpose of this treatment is to secure as much mobility of the hip as possible. Six weeks in plaster cast is ample time to secure stability of the reconstructed acetabular roof. In later cases where larger pieces of bone have been taken from the crest of the ilium and driven in deeply above the reflected roof of the acetabulum, the cast has been removed at the end of four weeks. At the end of twelve weeks, the patient is allowed out of bed with crutches and begins to bear weight on the operated hip." *

* Gill, B. Congenital dislocation of the hip. *J. Bone & Joint Surg.*, 10: 696, 1928.

*Dickson Technique** 1. The Smith-Petersen incision, which runs from well back on the iliac crest down onto the thigh, is used. This incision is the only one which gives sufficient exposure to allow the subsequent steps of the operation to be carried out efficiently. The skin edges are protected by towels fastened with tetra clamps. The incision is deepened in the usual manner until the capsule of the joint is reached and freely exposed.

2. The dislocated head is now completely freed of all structures which interfere with complete mobility. This is accomplished by freely and completely cutting away all the thickened capsule and by dividing all fibrous bands. Muscle attachments which interfere, particularly those to the greater trochanter, are preserved as far as possible by stripping up their periosteal attachments. Generally, it is necessary to divide the tendon of the iliopsoas which is usually markedly shortened; no ill effects have followed this. The importance of completely freeing the upper end of the femur cannot be overemphasized; attempts to preserve the capsule prevent this and are unnecessary as it regenerates later.

3. The head, neck, and upper part of the greater trochanter having been completely freed, traction on both legs is gradually increased. As the traction force acts, the elevated side of the pelvis is allowed gradually to sink until the patient is lying flat on the table. At this point a lever is placed behind the femoral head and neck and, if the upper end of the femur has been adequately freed, the head readily slips forward onto the ridge between the posterior and anterior planes of the pelvis into a position above, or above and slightly in front of, the acetabulum. Traction is then gradually increased until the head has been pulled down in its anterior position to a point beyond which it will not descend without the use of unjustifiable force; this is as a rule about an inch to an inch and a half. Both lower extremities are

* Dickson, F. D. The shelf operation in the treatment of congenital dislocation of the hip. *Surg. Gynec. Obst.*, 55: 81, 1932.

then gradually abducted and the traction is tightened to take up the slack which usually follows this maneuver. The head is now in the position in which, by turning down a flap or shelf of bone from the side of the ilium, it is to be held permanently.

4. The shelf is formed as follows: A wood-cutter's gouge, the size depending upon the size of the shelf to be formed, is used to turn down a flap of bone from the side of the ilium. This flap should be 1.5 to 2 inches in depth and at least 0.5 inch thick at its base. The flap should start well anterior to the head and be continued over it and well down posteriorly, so that when the shelf is completed it fits over the upper part of the head like a cap. It should be understood that the shelf turned down is not merely a ledge of bone projecting from the ilium but a modeled covering for the femoral head. A large wedge of bone is then removed from the crest of the ilium, or several wedges if so desired, and this is securely fixed between the turned down shelf of bone and the side of the ilium, filling the space between them. The wedge of bone acts as a brace for the turned down flap and provides a firm shelf above the head capable of resisting a fairly strong upward thrust without giving way.

5. At this point the condition of the adductor tendons of the thigh is examined; if they are under tension, an assistant does an open tenotomy of these tendons before closure of the wound is commenced.

6. Closure of the wound is made in the usual manner by layers. Drainage is rarely used and, if used, consists of a piece of rubber dam placed just under the skin and removed in twelve hours.

7. A plaster-of-Paris cast is now applied to include both hips and to extend down to just below the knee on the side which has been operated upon. The patient is transferred directly to bed from the operating table, strong traction on the extremity operated upon being maintained constantly by an assistant during this transfer and until the traction

apparatus attached to the bed has been arranged and is acting.

After-treatment: Traction is maintained constantly for six weeks. At the end of the fourth week, the cast is bi-valved and mild flexion and rotation movements are given daily. After six weeks traction is discontinued and physiotherapy continued with gradually increasing range of motion insisted upon. Weight-bearing is started at the end of six weeks with crutches and at the end of eight weeks unrestricted weight-bearing is permitted. It is necessary to maintain supervised exercises for several months following operation in order to secure full range of motion.

In 1927 Hey Groves * suggested that mobility and stability with an actual reduction of the dislocation might be accomplished if the capsule surrounding the head be placed in a reamed-out acetabulum located at its original site. He suggested perforating the floor of the newly formed acetabulum with a drill, and passing by means of a suitably curved aneurysm needle, a stout tendinous ligature over the pelvic brim through the hole in the acetabulum and out into the thigh, to be attached to the capsule covering the head. This ligature was then to be tightened and the free margin of the capsule firmly attached to the brim of the pelvis or to Poupart's ligament. Colonna has carried out this idea in the following operation:

Colonna's Operation.† "Preliminary stretching and tenotomy is done and a long plaster spica applied to the opposite side. Several weeks of heavy skin traction permit the head of the femur to be drawn down near the level of the original acetabulum. When this is accomplished, the child is prepared for open operation and an incision similar to that used in the Whitman reconstruction operation is employed.

* Groves, E. W. H. Treatment of congenital dislocation of the hip, with special reference to open operative reduction. Jones Birthday, Vol. 1., 1928, pp. 73-96.

† Colonna, P. C. Congenital dislocation of the hip in older subjects. *J. Bone & Joint Surg.*, 14: 277, 1932.

The greater trochanter with its attached muscles is chiseled through and turned upward, and the capsule covering the head is rather easily dissected free from the surrounding tissues. When the isthmus of the capsule is reached, it is cut through and the head of the bone inspected through this aperture to note the shape of the head and the appearance of the ligamentum teres. The aperture in the capsule is then closed with several chromic sutures. The rectus femoris tendon at its origin from the anterior inferior spine is identified and divided. With the Doyen reamer a capacious acetabulum is formed as near the original site as the preliminary traction has made possible. The head of the bone with its covering of capsule is then placed in the newly formed acetabulum and, with the limb in abduction, the greater trochanter is sutured back into place. After the wound is closed, a long plaster spica with the limb in complete extension and moderate abduction is applied. Care is taken not to remove the moleskin from the thigh and leg at the time of open operation, so that immediate postoperative traction can be applied."

It is felt that this type of operation in children between the ages of three to ten years is worthy of a more extended trial.

Putti's Method. "A straight incision is made beginning about 2 inches above the anterior superior spine of the ilium and carried along the crest down to and beyond the anterior superior spine. The muscles, rectus femoris, and tensor fascia femoris are separated and well retracted by blunt dissection. The capsule is exposed. An incision is made through the capsule. Special retractors are used to expose the head of the femur to full view. The capsule is examined for constrictions. It is usually shaped like a funnel and this occasionally prevents reduction. A special instrument in the form of a dilator is inserted through this narrow constricting portion of the capsule forcibly dilating it. A special instrument in the form of a skid, similar to that of a Murphy skid, is introduced into the dilated portion of the capsule and into the normal acetabular cavity. The knee is grasped and the femoral head abducted and inverted over the sliding

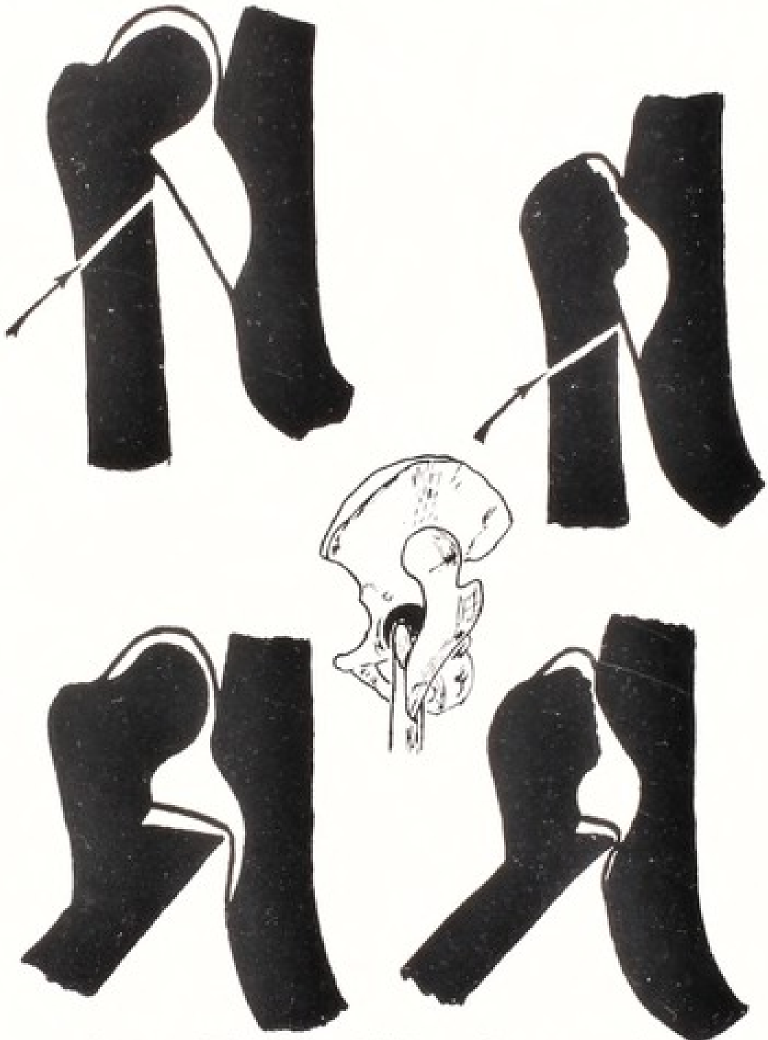


FIG. 50. Diagram of bifurcation operation.

instrument into the acetabular cavity. Dressings are applied and the thigh is placed in right angle abduction and slight internal rotation similar to that used in the closed method." *

Bifurcation Operation. The bifurcation operation of Lorenz is limited in adults to use in a small number of selected cases of traumatic, pathologic or congenital dislocations of the hip, in inflammatory processes involving the hip-joint, and rarely in Charcot's disease. It is claimed that the advantages of the operation are relief of pain, a good func-

* Putti, V. Congenital dislocation of the hip. *Surg., Gynec. Obst.*, 42: 449, 1928.

tional and cosmetic result, relative simplicity of the operation and a short period of recumbency. The danger of injury to the femoral vessels by the distal fragment and of non-union should be emphasized. The operation lacks all semblance of surgical precision (Fig. 50).

Hibbs' Osteotomy for Anteversion of the Neck of the Femur.* Many cases of anteversion are due to a twist in the shaft of the femur which Hibbs corrects by an osteotomy on the lower third of the shaft before attempting to reduce the dislocation. 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 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 perfect control. When the dislocation and consequent anteversion of the neck is bilateral, double osteotomy is performed at one sitting.

Schede controls internal rotation by driving a long nail through the greater trochanter and neck of the femur, using it as a handle. Bradford uses a knitting needle in like manner for the same purpose. Both Schede and Bradford first do an osteotomy.

A subtrochanteric osteotomy, either circular or transverse linear (see Chapter IX, Coxa Vara), may also be used to correct the anteversion of the neck of the femur.

Swett's Open Reduction.† When confronted with the impossibility of reduction at operation, Swett has reduced the head after osteotomy just below the lesser trochanter. There

* Hibbs, R. A. Anteversion of the neck of the femur in connection with congenital dislocation of the hip. *J. A. M. A.*, 65: 1801, 1915.

† Swett, P. E. The operation for reduction of certain types of congenital dislocation of the hip. *J. Bone & Joint Surg.*, 10: 75, 1928.

is always shortening from the overlapping position of the fragments, but this is less than before reduction. Although there is anatomical distortion, function is said to be good, and the patient is spared the prospect of increasing pain caused by use of the dislocated hip. Swett suggests that better alignment and increased length might be secured by suitable measures, such as redressment and traction.

Swett admits a certain feeling of anxiety in performing this operation. Fractures in this region have been responsible for so much anxiety that one hesitates to induce a solution of continuity, if such is avoidable. I would prefer either the construction of a new acetabulum at a higher level on the ilium, or a two-stage operation consisting of shortening of the femur by mortise and subsequent reduction of the dislocation.

Steindler, Kulowski and Freund,* in summarizing the end results of the treatment of congenital dislocation, say: "We can say that the extreme optimism concerning results in the closed method, as it is shown by some German and Italian authors, does not seem to be entirely justified. Results become definitely worse with the duration of the observation period. A systematic after-care and long lasting follow up of the patients is absolutely necessary (roentgenograms should be taken at least twice a year in the first five years after reduction, and at least once a year in the following years). Results of definite significance are given only by patients who, after reduction in childhood, are grown up to manhood and womanhood.

"The fact that beyond 5 years of age the satisfactory result rapidly decreased would indicate that the upper age limit for open reduction in general would be about 8 years. This agrees with Dickson, who recommends open reduction for all patients between 4 and 9.

"The significance of the palliative methods lies in their

* Steindler, A., Kulowski, J., and Freund, E. Congenital dislocation of the hip. *J. A. M. A.*, 104: 302, 1935.

preventive effects on the functional difficulties coming on during and beyond puberty and on the late sequelae seen in unreduced dislocated hips in middle age, the secondary arthritis due to the static insufficiency.

"It seems to us that from this point of view the simple shelf operations will undoubtedly gain in favor because of the lesser danger of operative failure and of postoperative complications. In view of the increasing evidence of late degenerative sequelae of the unstable, unreduced hip, it may be assumed that the future will find the indication field of the palliative operation extended rather than restricted. Functionally available statistics show an encouraging percentage of acceptable results for shelf operations."

Traumatic Dislocation

The fundamental guiding principles in treatment of traumatic dislocation are the same as for congenital dislocation, with a marked difference, however, in the length of time required for immobilization. In the congenital cases one is dealing with an elongation of the capsule existing since birth, whereas in traumatic dislocation it is a tear of the capsule which will rapidly unite if the hip is reduced and held in position for a period of three or four weeks. Immobilization should not be prolonged beyond this period unless there is some urgent indication to the contrary, such as an extensive fracture of the rim of the acetabulum that would jeopardize the hip staying in place.

Traumatic dislocation constitutes only about 2 per cent of all dislocations of the hip,* and is of rare occurrence in children. Wilson and Cochrane, who have clearly described the salient features of this condition, state: "All dislocations of the hip are either anterior or posterior in type. This is easy to understand when it is remembered that the acetabulum lies on the summit of the ridge formed by the junc-

* Wilson, P. D., and Cochrane, W. A. Fractures and dislocations. Ed. 2, Phila., Lippincott, 1928.

tion of the anterior and posterior planes of the pelvis and that these slope away sharply on either side. When the head of the femur leaves the acetabulum, it therefore tends to seek a position of equilibrium in the anterior or posterior direction.

"*Mechanism.* Dislocation of the hip results almost always from the action of indirect violence or leverage, usually with the hip flexed to 90 degrees. Bigelow was the first to call attention to the important role played by the iliofemoral or 'Y' ligament in the mechanism of dislocation and to the possibility of utilizing it as a fulcrum for securing reduction. Owing to its great strength, it is practically never torn, and by its action in limiting displacement it gives rise to the characteristic attitudes of deformity by which the various types of dislocation are recognized.

"*Anterior Dislocation.* The anterior type of dislocation is usually produced by violent hyperabduction of the hip. The neck and greater trochanter are forced against the outer rim of the acetabulum, a fulcrum being thus provided, and the head is pried out through a rent in the anterior and inner portion of the capsule. Primarily the head lies in the low position at the thyroid foramen, but, if the thigh is rotated outward, it rises to the high or pubic position. If, on the other hand, the thigh is rotated inward by a continuance of the original force, the low anterior dislocation may be converted into a posterior one.

"*Posterior Dislocation.* The posterior dislocation is the result of force applied to the leg when the hip is in the position of flexion, adduction, and internal rotation. Leverage is again brought into play, but this time in a different manner. Internal rotation of the thigh tightens the 'Y' ligament and winds it around the neck of the femur. The ligament thus becomes the fulcrum, and as the movement continues, the head is forced out through the lower part of the capsule posteriorly. Primarily it lies in the sciatic notch or the low position, but, if the movement continues, it may lodge in the high position on the dorsum of the ilium. A common accident by which this mechanism is produced is an automobile collision in which the passenger is thrown forward from his seat, the thigh being flexed and adducted and the knee striking the back of the forward seat with an inward twist.

"*Pathology.* Dislocation of the hip is always accompanied by considerable injury to the structures surrounding the joint. The capsule is torn. The adductor muscles and the obturator externus are usually lacerated in the anterior luxation, while in the posterior type the short external rotators and particularly the obturator internus muscle are liable to injury. The tendon of the latter may become interposed between the neck and the acetabulum and interfere with reduction (dislocation below the tendon—Bigelow).

"The sciatic nerve, on account of its close relation to the head, may be injured in dorsal luxations. It has twice been found at autopsy completely torn across. It may be hooked up over the neck when attempting reduction, and this is particularly likely to happen when converting a dorsal into an anterior position. Wide movements of circumduction are especially to be avoided.

"Contractures of the pelvic femoral muscles soon take place in the untreated case. As time goes on a new capsule of scar tissue forms around the head of the femur fastening it securely to the side of the pelvis. Within four weeks' time ligamentous shreds, fat, and new connective tissue fill the acetabulum. This mass of tissue adheres firmly to the cartilage so that, after six weeks, sharp dissection is necessary for its removal.

"*Diagnosis. Anterior Dislocation.* Anterior dislocation is characterized by abduction and external rotation of the leg, the knee being flexed. If the head lies in the thyroid foramen, the external rotation and eversion of the foot are less marked, while the abduction is increased. If the head lies in the high or pubic position, there is less abduction but more external rotation. In both cases there is moderate flexion of the hip as well. It is impossible to extend or adduct the limb. There is absence of shortening, and in the thyroid position there is even slight lengthening, but it is difficult to make accurate comparative measurements, and they are, therefore, of little value. In the high position the head can be felt in front of the pubis, but in the thyroid type it is difficult to locate. The greater trochanter is absent from its usual position, being displaced inward, and a depression remains instead. Occasionally there is pain and numbness in the distribution of the femoral nerve.

"*Posterior Dislocation.* Posterior dislocation, on the other hand, is characterized by adduction and internal rotation of the thigh, combined with moderate flexion of the hip. With the patient recumbent, the knee is directed inward and forward, the foot is inverted, and the heel often rests on the dorsum of the opposite foot. Flexion of the hip is usually more marked when the head is in the low rather than in the high position. Passive movements are possible to a certain extent, but abduction and external rotation are prevented, while active movements are completely abolished. The head of the femur can be felt indistinctly in its posterior position through the gluteal muscles, while the trochanter lies anteriorly and above Nélaton's line. There is shortening, which can be recognized when both knees are flexed. Dislocation into the vicinity of the great sciatic notch (dislocation below the tendon) presents the same general features as dislocation onto the dorsum of the ilium, but the deformity is not so marked. In stout subjects it may be overlooked.

"Dislocation of the hip presents such a typical clinical picture that there is practically no other condition with which it can be confused. However, a roentgenogram should always be made, partly in order to verify the position, but chiefly for the purpose of demonstrating the presence or absence of an associated fracture of the articular surfaces."

Dorsal dislocation is the type usually encountered, and roentgenographic examination frequently reveals fragments of bone torn away from the rim of the acetabulum by the strong ligaments, or broken off by the impact of the dislocating head.

CLOSED REDUCTION

"*Treatment.* Immediate reduction is indicated in all cases and the earlier this is attempted the less the difficulty of replacement. It must necessarily be postponed when the patient is in a state of shock from other associated injuries.

"A general anesthetic is always necessary in order to secure complete muscular relaxation. The patient should be placed on folded blankets on the floor in order to obtain a firm support and to permit the surgeon to work above him in a position to perform the necessary manipulation and utilize his strength to the best advantage. An assistant fixes the pelvis with his hands in order that the force may be applied directly to the hip-joint. . . .

"All methods begin with flexion of the hip. This converts high into low dislocations, brings the head down to the acetabulum, and relaxes the 'Y' ligament. The knee is likewise always flexed for greater ease in the control of the manipulation and the more efficient application of traction. In this position the 'Y' ligament is then put under tension to provide a fulcrum and by leverage and traction the head is replaced."

Bigelow's Method. a. Anterior Dislocation.* "Flex the limb toward the perpendicular and abduct it a little to disengage the head of the bone, then lift upward, rotate the shaft strongly inward, adducting it, and then extending the leg.

"In simpler terms, the leg should be flexed and abducted, then while exerting traction in the axis of the limb, circumduct inward, that is, move the knee in a circular direction inward and extend the leg.

* Bigelow, Mechanism of Dislocations and Fractures of the Hip. Boston, Little, Brown, 1900.

"*b. Posterior Dislocation.* With the knee bent and the hip flexed adduct and internally rotate to disengage the head from behind the socket. 'If the bone can now be abducted beyond the perpendicular, the capsule and other tissues are probably so torn or relaxed that reduction may be accomplished without much difficulty; the thigh need only be forcibly lifted or jerked toward the ceiling with a little simultaneous circumduction or rotation outward to direct the head of the bone toward the socket.'

"The essential is to exert strong traction in the axis of the thigh, while the hip is flexed, adducted, and internally rotated. If reduction does not occur, circumduct outward while maintaining the traction; that is, abduct, externally rotate, and then extend."

OPEN REDUCTION

The patient is placed on the fracture table and traction applied to both legs to bring the head of the femur down to as near the level of the acetabulum as possible. For anterior dislocations the Smith-Petersen approach is used. For posterior dislocations I prefer the incision described by Miltner.* An incision is made from the postero-inferior spine of the ilium to the base of the greater trochanter, or on down to the insertion of the gluteus maximus. The fibers of the gluteus maximus muscle are split longitudinally, exposing the secondary capsule which surrounds the head of the femur and holds it to the pelvis. The secondary capsule is opened and by forceful internal rotation the head and neck of the femur are swung anteriorly and away from the acetabulum. In the ordinary dorsal dislocation the scarred obturator internus, gemelli, and pyriformis muscles are now exposed. These muscles may lie between the neck of the femur and the pelvis and stretch across the upper and outer aspect of the acetabulum. Myotomy of these muscles is usually necessary to

* Miltner, L. J., and Wan, F. E. Old traumatic dislocation of the hip. *Surg., Gynec. Obst.*, 56: 84, 1933.

give full access to the socket of the hip joint. After the removal of all of the scar tissue from the acetabulum, the head of the femur is replaced by circumduction and traction.

While complete reduction by open arthrotomy is the goal sought in all cases of old dislocation, the surgeon may be forced to accept certain alternative procedures, such as the "shelving" operation, resection of bone, arthrodesis, or, in exceptional instances, he may be content with simple osteotomy to correct the deformity.

Following reduction a plaster-of-Paris double spica cast is applied for four weeks if no fracture of the rim of the acetabulum was found at operation.

Occasionally the entire superior rim of the acetabulum is carried upward by the head. When reduction is attempted, the fragment of the rim may enter the acetabulum in advance of the head and thus render reduction of the dislocation impossible except by *open operation.*

After the rim is lifted from the acetabulum, the head of the femur is easily skidded into the cavity. Johnson * of Nebraska fixes the fragment in its proper position by a temporary steel drill driven through it and into the ilium. An autogenous bone-peg is much more satisfactory and physiologically sound. In this type of case the double plaster-of-Paris spica cast remains on for eight weeks.

The prognosis must be very guarded in these cases as changes in the head of the femur occur almost routinely as a result of disturbance of the blood-supply plus the original trauma or the pressure forces which follow dislocation. If a piece of the femoral head has been crushed or broken off during the dislocation the late findings are those of roughening and partial disappearance of the cartilage—changes simulating advanced arthritis. In the very old cases, the head may be flattened or roughened because of weight-bearing in

* Johnson, H. F. Unusual bony injuries about the hip joint. *Surg. Gynec. Obst.*, 49: 630, 1929.

a deformed position and the aseptic necrosis which follows the disturbance of blood-supply.

Paralytic Dislocation of the Hip

METHODS OF TREATMENT IN ORDER OF PREFERENCE

1. Closed reduction;
2. Keystone bone-graft operation;
3. Shelf operation;
4. Arthrodesis.

The indications for open operation in paralytic dislocations of the hip are: 1. the inability to replace the head of the femur, owing to contracture of the soft parts, and 2. repeated dislocation after reduction, owing to faulty development of joint structures (shallow acetabulum), or extreme relaxation of the capsule. When thorough stretching of the contracted structures and reduction of the dislocation by the closed method fails (see p. 96), I use an autogenous keystone bone graft * to deepen the overhanging rim of the acetabulum, and reef the ballooned portion of the joint capsule, thus gaining a stable and satisfactory joint without sacrificing any of the joint elements.

Keystone Bone Graft in Treatment of Congenital and Acquired (Paralytic) Dislocation of the Hip (Albee). All existing contractures having been overcome by forcible manipulation or open division, and the dislocation made easily reducible by long continued weight and pulley traction or manipulation under general anesthesia, the hip-joint is reached by a Smith-Petersen approach or an incision is made from the anterior superior spine of the ilium to the great trochanter, then backward 1 to 2 inches in the direction of the ischial tuberosity. The skin and subcutaneous structures are dissected back and the trochanter exposed. The trochanter tip, with its attached muscles, is turned upward, giving a free exposure of the superior and posterior portions of the

* Albee, F. H. Bone-graft Surgery. Phila., Saunders, 1915.

capsule of the joint, together with its attached portion of the superior and posterior acetabulum 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, as well as the degree of laxity of the capsule, can be very easily determined at this stage by direct palpation through the overlying capsule and manipulation of the limb. Above the capsule attachment to the acetabular rim, the bone surface at the ilium is cleared of soft tissue, and with a thin osteotome the bone is incised just above the insertion of the capsule in a semicircular line in this posterior superior anterior surface, to conform to the natural curvature of the superior rim of the acetabulum. This semicircular bone incision produces a strip of the upper curved bone margin of the acetabulum with its attached and undisturbed capsular segment. This curved acetabular bone segment is pried outward and downward with the osteotome to deepen the acetabulum sufficiently to offer an obstruction to displacement of the femoral head, *i.e.*, it is made to overhang and more securely grasp the head of the femur (Fig. 51). The downward and outward prying produces still more laxity and wrinkling of the capsular ligament. The slack is taken up by reefing the capsule with a row of mattress sutures of kangaroo tendon placed at right angles to the long axis of the neck of the femur. 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 helps hold the new-formed acetabular rim in position.

To fill in the bone gap produced by the prying downward and outward of the curved bone rim segment, and further to secure the permanent fixation of the new-formed acetabular rim, a segment of bone having a triangular or keystone cross-section is obtained locally from the crest of the

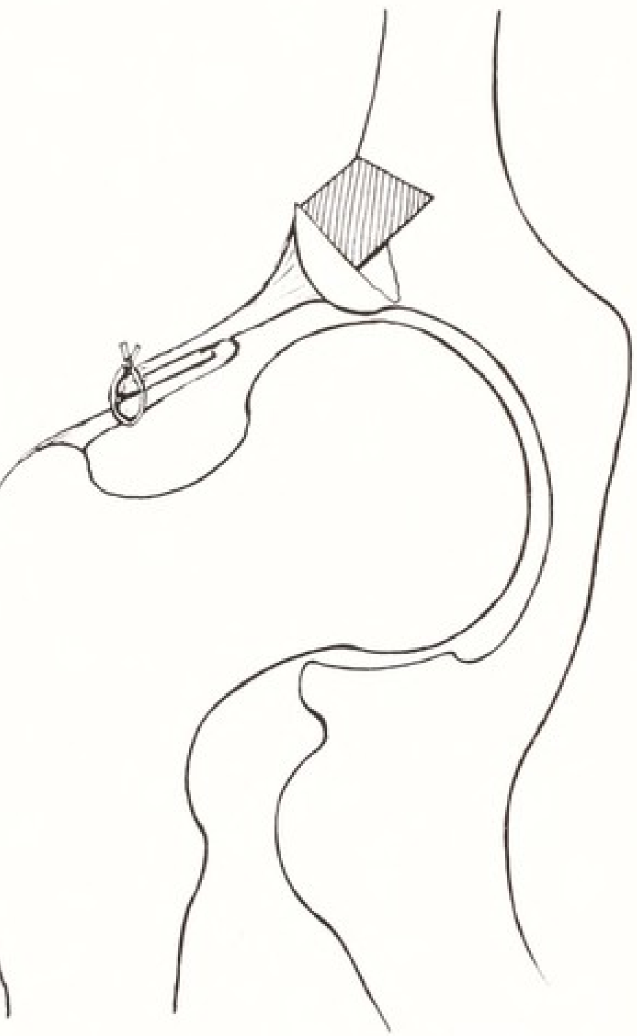


FIG. 51. Deepening of acetabulum by building out rim with bone grafts.

ilium or from the crest of the tibia, long enough (when cut into three or more portions) to fill in this gutter.

The keystone type of graft is self-retaining, and is held in place automatically and needs no pegs or sutures.

The limb is placed in an abducted position and fixed by a long double plaster-of-Paris spica reaching from the thorax to the toes on the operated side and to just below the knee on the other side. This spica is left on for six weeks, after which passive and active exercises are instituted, together with massage and guarded functional use of the limb.

Shelf Operation (Albee). The keystone graft operation is preferable to the shelf operation, except for those cases in which it is unwise to bring the head of the femur down to the level of the acetabulum (see p. 120 for technique).

Complete Paralysis of Hip Muscles, Arthrodesis. If general paralysis of the muscles controlling the hip demands it, an arthrodesis may be trustworthily done in cases over eight years of age by providing large grafts from the outer table of ilium or elsewhere, and generously contacting them to both femur and pelvis on each side of the joint (see Chap. VI, Tuberculous Disease of the Hip Joint, p. 176).

CHAPTER VI

TUBERCULOUS DISEASE OF THE HIP JOINT

Definition. Tuberculous disease of the hip-joint is a chronic destructive process caused by *B. tuberculosis* which results in various degrees of loss of function and deformity.

ETIOLOGY

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 vertebrae. 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 in the age period of from three to six years.

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).

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 semipurulent 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 becoming detached in flakes. The *bones* are, as a rule, bare, of worm-eaten appearance, or present definite cavities and sequestra.

The *contour* of the head and neck of the femur 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 pressure by the femoral head on a diseased acetabulum, extending its cavity upward and backward.

The capsular ligament is soft and relaxed, and the round ligament eroded. Ichor from the joint often traverses the periarticular 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; this is eventually succeeded by ankylosis, usually of the fibrous type, or by dislocation.

Symptoms and Physical Signs

SYMPTOMS

The disease is insidious in its onset. Pain and limp are the important symptoms, though several other subjective phenomena are encountered.

Stiffness. Stiffness of the joint in the morning is an early symptom and is possibly due to diminution in the amount of synovial fluid.

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.

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.

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.

Night Cries. These are due to sudden relaxation of muscular immobilization from the effect of sleep and may signify ulceration of the articular cartilages.

Constitutional Disturbances. General debility is the rule from the onset. Malaise, irritability, restlessness, loss of appetite, lassitude and decrease in weight are noted. An evening rise in temperature usually 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 underweight 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: 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.

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 fossae 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 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. 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 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 vertebrae touch the table. Have the leg held in this position by an assistant. The degrees of flexion can then be estimated.

Estimation of Abduction and Adduction. 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 the anterior 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.

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:

1. Outward—under attachment of rectus femoris muscle.
2. Inward.
3. Backward—following internal circumflex artery.
4. Upward—along sheath of psoas muscle.
5. Inward—through floor of acetabulum.
6. Downward—by gravity.

Roentgenography. 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.

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.

Soft Parts. An ichor pocket may sometimes be detected by a clear area resistant to the x-rays.

The x-ray study 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 only from the crushing and destructive influences of motion but also from weight-bearing and muscle-pull.

A careful x-ray study will aid in determining when the

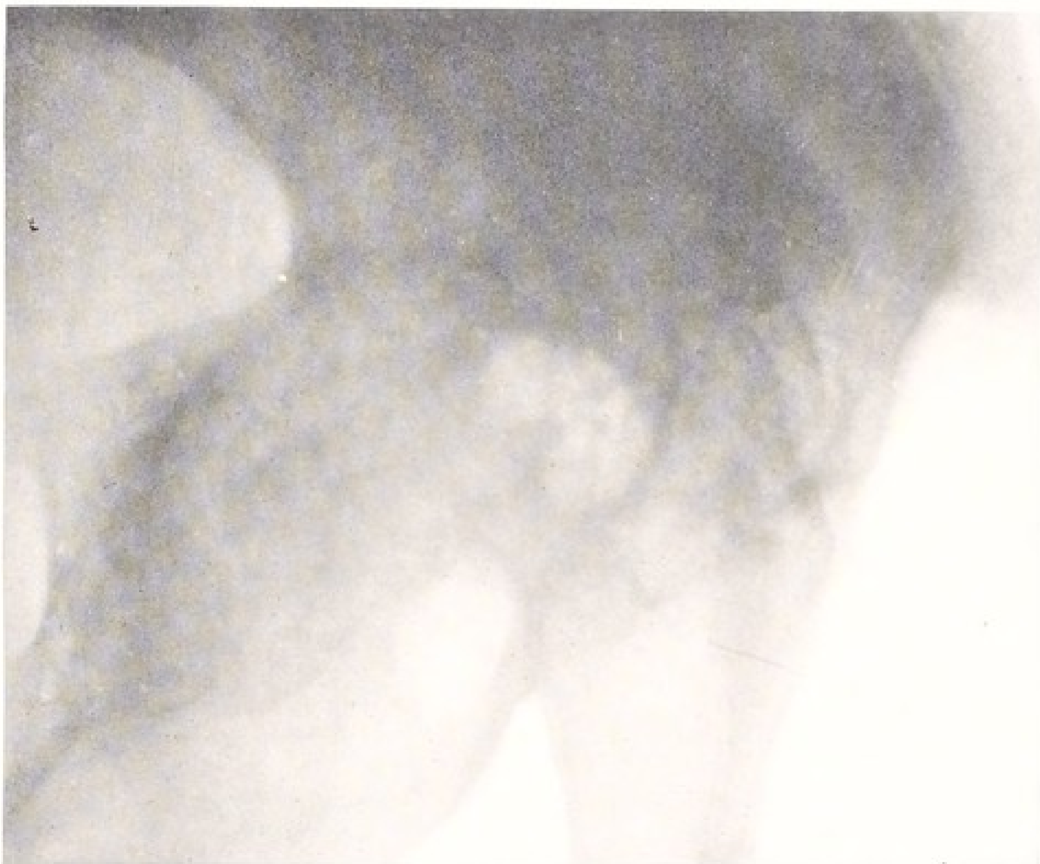


FIG. 52. Old tuberculous hip, ankylosed in marked flexion and adduction.

density of the osseous elements of the joint is restored sufficiently to allow weight-bearing; when 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.

DIAGNOSIS

ABSOLUTE DIAGNOSIS

The following history and physical signs are practically pathognomonic of tuberculous hip disease:

History. Chronicity of the affection and its restriction to one joint (monarticular); intermittent but progressive increase of signs and symptoms.

Attitude. (1) Early in the disease, flexion, abduction and eversion of the limb; (2) late in the disease, flexion, adduction and inversion.

FIG. 53. Same case as Figure 52. Adduction flexion deformity overcome by circular osteotomy.

Gait. Irregularity, a long step alternating with a short one. Flexion at all joints of the affected limb, with flexion of the toes.

Joint Outline. Wasting of the limb, particularly the buttocks, with alteration in the normal folds in buttocks and groin.

Limitation of Motion and Muscle Spasm. The most valuable of all physical signs. The most important restriction of motion is that of rotation and hyperextension (patient on face).

Deformity. Distortion of the affected limb by abduction, adduction, external, and internal rotation.

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:

DIFFERENTIAL DIAGNOSIS

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. Polyarticular. Gonorrheal urethritis. If of

DIFFERENTIAL DIAGNOSIS (CONT.)

Disease	*Points of Resemblance*	*Points of Difference*
		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. Periarticular disease	Symptoms resemble those of tuberculous hip	No muscle rigidity or limitation of rotation. *X*-ray
12. Perinephritis 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

DIFFERENTIAL DIAGNOSIS (CONT.)

Disease	*Points of Resemblance*	*Points of Difference*
		when using limb. *X*-ray
16. Atrophic polyarthritis	Childhood. Severe pain. Muscle spasm. Distortion of limb	Successive involvement of other joints. *X*-ray
17. Sacroiliac 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
19. Disease of the bursae 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

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.:*

(1) The pathology of the joint when treatment was instituted;

(2) Nature of the treatment employed;

(3) The severity of the tuberculous process;

(4) Individual resistance;

(5) 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 indirectly due to secondary infection:

(1) Miliary tuberculosis.

(2) Tuberculous meningitis.

(3) Pulmonary tuberculosis.

(4) Amyloid disease.

(5) Exhaustion.

(6) 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 vertebrae, which should have operative treatment. A tuberculous bone lesion which has been shown by the x-rays to be definitely localized, should, however, be excised providing that it is surgically accessible, whether the patient be an adult or a child.

Much discussion has taken place relative to the proper attitude of the surgeon toward operative interference with a tuberculous hip. Between the school of conservative abstinence from all operative interference and the school of radicals who advocate early surgical intervention, a middle course is desirable. Conservative measures should be given a thorough trial in every case in young children and be supplemented by surgery when indicated. In older children, adolescents and adults, the pendulum in later years has swung rightly toward operative intervention whenever bone destruction of any degree is shown by *x*-ray. The type of operation must be selected to meet the exigencies of the particular case at hand.

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 there is 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*, 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.

In the severest cases of tuberculous osteitis of the hip the desideratum is bony ankylosis and in the severest cases a short plaster spica extending to the knee is applied, and early walking permitted. The rarefied femoral head thus undergoes mechanical crushing, followed by firm ankylosis. The author attains the same results in adults by surgical intervention (arthrodesis), 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.

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. The child's body should be secured by some means; a Bradford frame or sand-bags are effective. Apply adhesive strapping to the affected leg (long lateral strips, reinforced 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.

Recumbent Treatment. The following methods may be employed:

(1) *Long Plaster-of-Paris Spica.* 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.

Traction can be supplemented by placing moleskin straps with their lower ends coming out through the plaster just above the ankle.

(2) *Thomas Hip Splint.* This consists of a main brace of flat malleable iron, $\frac{3}{4}$ inch wide and $\frac{5}{16}$ 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 molded 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.

Ambulatory Treatment. 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.

Plaster Splint 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.

2. *Short Plaster Spica (Lorenz).* 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. A high shoe worn on the opposite foot, and the use of crutches are advised. Weight-bearing by the affected limb is advised.

3. *Phelps' Traction Hip Splint.* 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. *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 molded 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.

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:

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 3 inches from the ground and a piece welded to its inner part, extending 2 inches below the sole of the boot and terminating in a bulbous tip 3/4 inch in diameter. The upright extends from the anterior superior spine to a point 1 1/2 inches beyond the bottom of the heel, the foot being held at right angles.

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.

THE TREATMENT OF DEFORMITIES

A tuberculous hip may become deformed in several directions, usually in (1) flexion, (2) adduction (rarely abduction), (3) flexion and abduction, (4) 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.

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.

The affected limb can be supported by a pillow or by an adjustable wooden triangle. In heavy patients 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.

OPERATIVE TREATMENT

Indications for operation are briefly as follows:

An age at or beyond adolescence. (As a rule, operation is contraindicated in young childhood and infancy except as an emergency, or when the disease is uncontrolled by conservative treatment.) An extra-articular arthrodesis should be recommended in all children over ten years of age where the disease is progressing in spite of conservative treatment. The resistance of the patient should be built up by heliotherapy and diet before and after the operation.

Abscess formation, with steady advance of the disease as disclosed both by x-ray and physical examination.

Persistent loss of health.

Ungovernable pain.

Whenever there is constant relapse of the adduction deformity in spite of conservative measures to overcome it, such as traction in bed, braces, etc., after long periods of such treatment.

If the adduction deformity recurs following Gant's osteotomy, because of the hip not being completely ankylosed.

In adults even if the bone destruction is moderate.

Uncontrolled poor hygienic surroundings.

Procedures. The operative possibilities consist principally of extra-articular arthrodesis by bone grafts, excision of focus when well localized and extra-articular, local curetting when sinuses secondarily infected exist, and amputation and arthroplasty rarely. Intra-articular arthrodesis is obviously inadvisable because of the danger of exacerbating the infection and its untrustworthiness if used alone.

Extra-articular arthrodesis. Tuberculosis of the hip is a condition most unfavorable to intra-articular arthrodesis, either spontaneous or operative. The reasons for this are obvious: (1) Inhibition of osteogenesis by the tubercle bacillus; (2) the peculiar anatomy of the joint frequently causing recession of bone surfaces from each other as bone destruction progresses, or following intra-articular removal of bone by the surgeon for arthrodesis purposes, because of the ball and

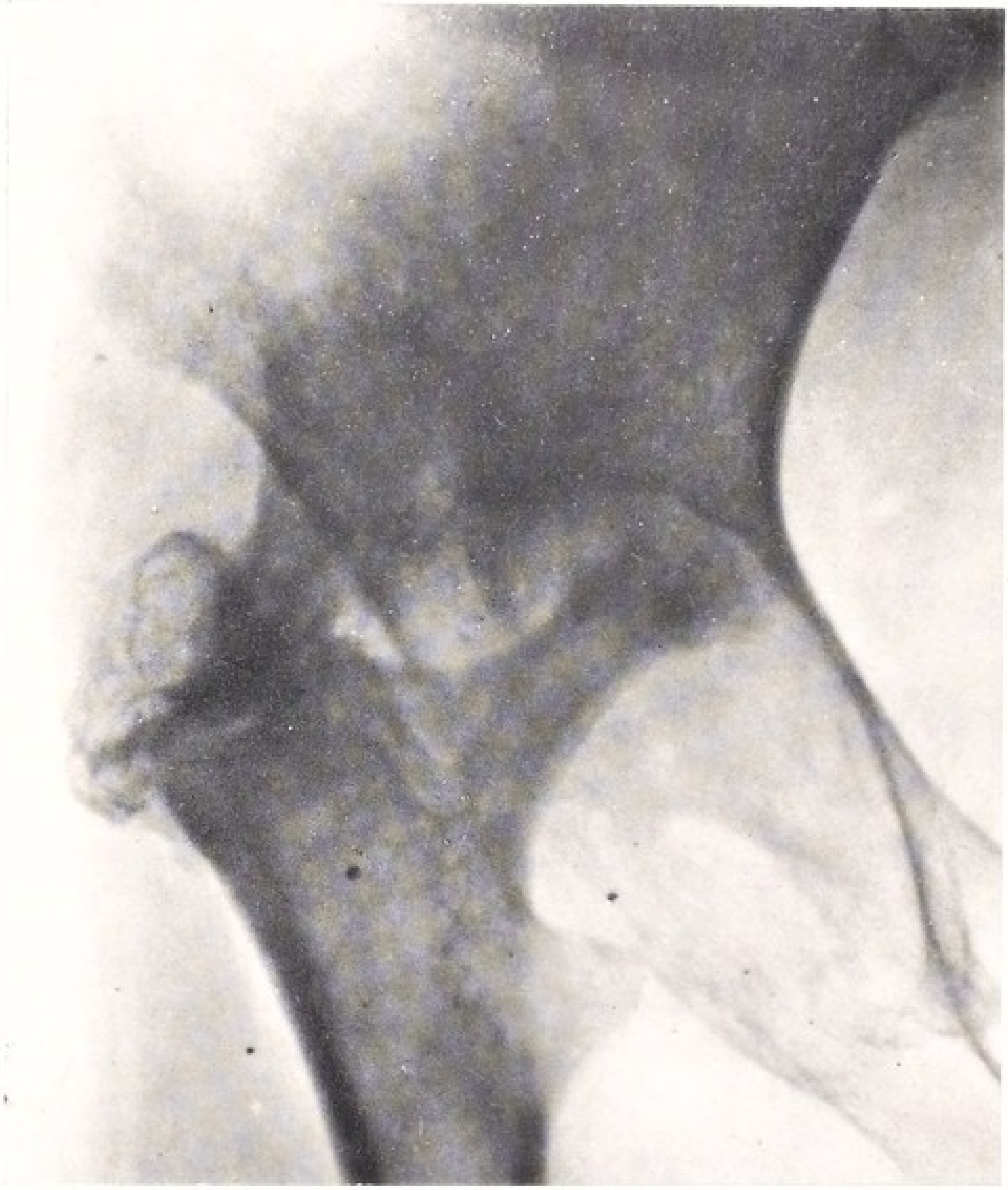


FIG. 54. Advanced tuberculosis with complete destruction of head and partial destruction of neck. This case resisted all conservative treatment. Symptoms were relieved by extra-articular arthrodesis by tibial graft.

socket contour of the hip joint (peripheral destruction of the femoral head causes it to become smaller, whereas peripheral destruction of the acetabulum causes it to become larger). Also, because of the anatomy and mechanical relationships of the hip and pelvis, as extensive destruction of bone pro-

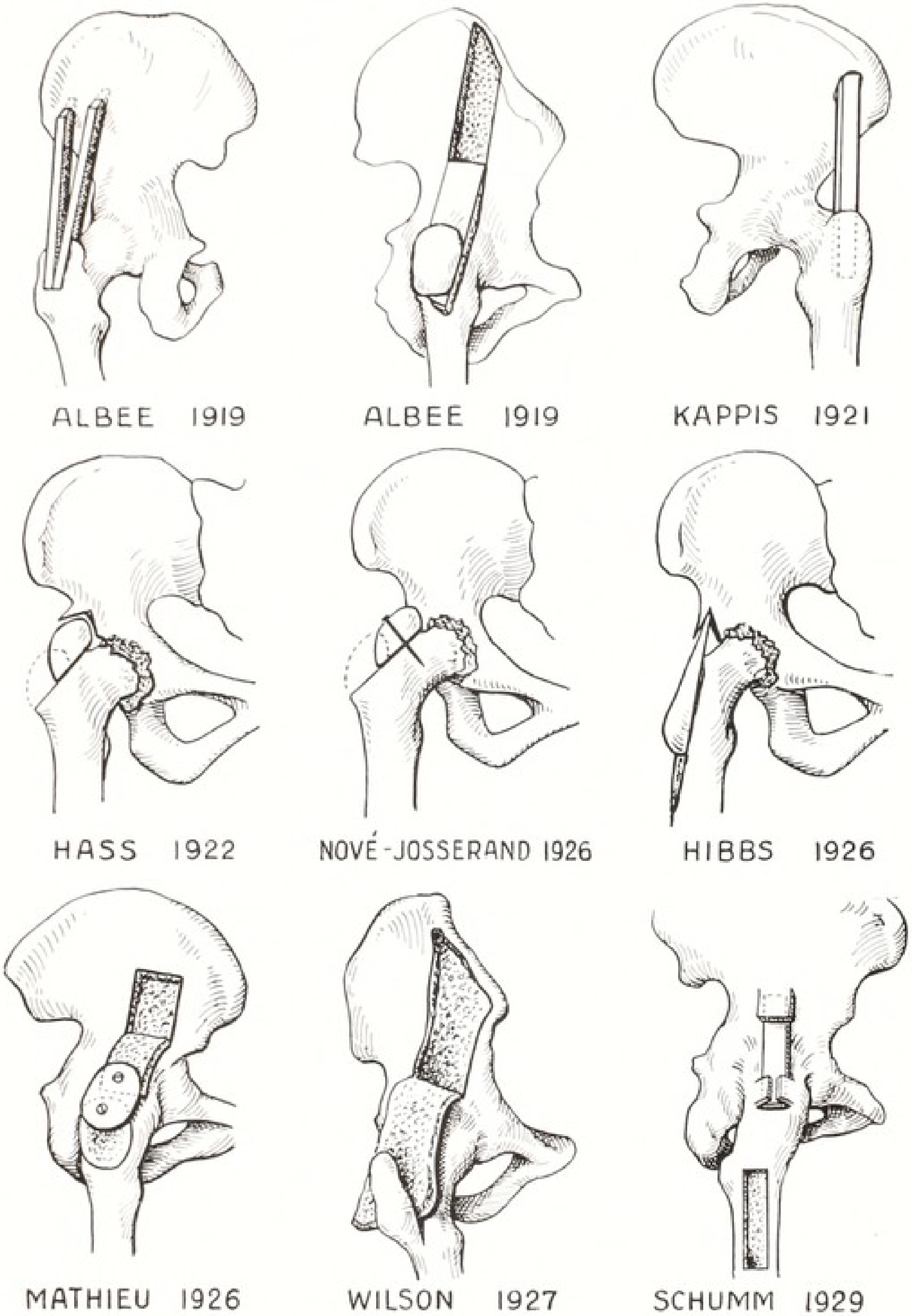


FIG. 55. Some of the more important methods of extra-articular arthrodesis of hip. The purpose of illustrating various methods is to give the surgeon a choice of procedure in individual cases.

gresses the diseased bony surfaces of the femur and pelvis do not tend to approximate because of impingement of the inside of the trochanter against soft parts at and above the rim of the acetabulum. Since the tubercle bacilli inhibit the active osteogenesis which would normally take place, dead spaces filled with caseous material are left between the bony elements, and spontaneous ankylosis and cure become improbable. Even if intra-articular arthrodesis is attempted, the impossibility of removing all tuberculous material, and the possibility of causing metastatic infection or sinuses with secondary infection, the low osteogenetic potentiality of the bony elements of the joint, and the consequent failure to secure fusion render the operation untrustworthy (Fig. 55).

Bracing in cases of extensive destruction and caseation, largely for the same reasons, has been signally unsuccessful.

Extra-articular arthrodesis is a most satisfactory alternative. By strongly bridging the joint with a tibial, femoral or iliac graft or grafts mortised into the bone elements on both sides of the joint, complete fixation is secured. The immobilizing influence of union of the femur to the pelvis makes it unnecessary to enter the infected area.

AUTHOR'S TECHNIQUE

Four Variations of the Author's Technique Adapted to Varying Degrees of Destruction. In an extensive experience with extra-articular arthrodesis of the hip during the past fifteen years, I have been convinced more and more that it is distinctly advantageous to the surgeon to have more than one type of operation to select from in meeting the variety of mechanical requirements which I have above discussed. Any proposed extra-articular arthrodesis is best brought about between the great trochanter on one side of the joint and the side of the ilium just above the rim of the pelvis on the other, and since the proximity of the trochanter to the side of the pelvis and the rim of the acetabulum varies widely in accordance with the degree of joint destruction and telescoping, limb adduction and flexion, the operative technique must vary accordingly. As in every surgical procedure, the simplest technique associated with the minimum of trauma and shock to the patient should be chosen, and also one which will interefere the least with a future arthroplasty, should the latter be desired and prove feasible.

From the technical standpoint cases suitable for extra-articular arthrodesis of the hip can be divided into two groups, on the basis of pathological findings, and each of these subdivided into two types, as to the character of operation.

Group 1. In the first group the destruction is moderate in amount and the great trochanter remains widely separated from the side of the pelvis, so that a bone graft cannot be obtained from the side of the ilium or the immediate locality in sufficient length and strength to serve as a bridge for the extra-articular arthrodesis. Therefore, the surgeon is compelled to go to the tibia or the outer portion of the upper end of the femur for graft material, because of the necessity of obtaining not only long but strong grafts (Figs. 56 and 57).

Technique for Group 1a. The patient is anesthetized to muscular relaxation and placed upon the fracture orthopedic table. The surgeon forcibly corrects the adduction of the diseased hip by manual counter-pressure, placing one hand against the buttock and the other against the inner aspect of the knee. His assistant at the same time, by adjusting the fracture orthopedic table, places the well leg in the limits of physiologic abduction, and cautiously swings it into a position of abduction the traction arm of the table holding the diseased leg. The amount of abduction in which the latter is placed depends upon the amount of bony shortening. This method of correction, partly by the mechanics of the table and partly by manual pressure, is adopted in order to guard against overstretching the lateral ligaments of the knee-joint.

A somewhat curved incision starting at the crest of the ilium, 2 inches posterior to the anterior superior spine and carried down below the great trochanter, is made through the skin. The gluteal muscles are separated suffi-

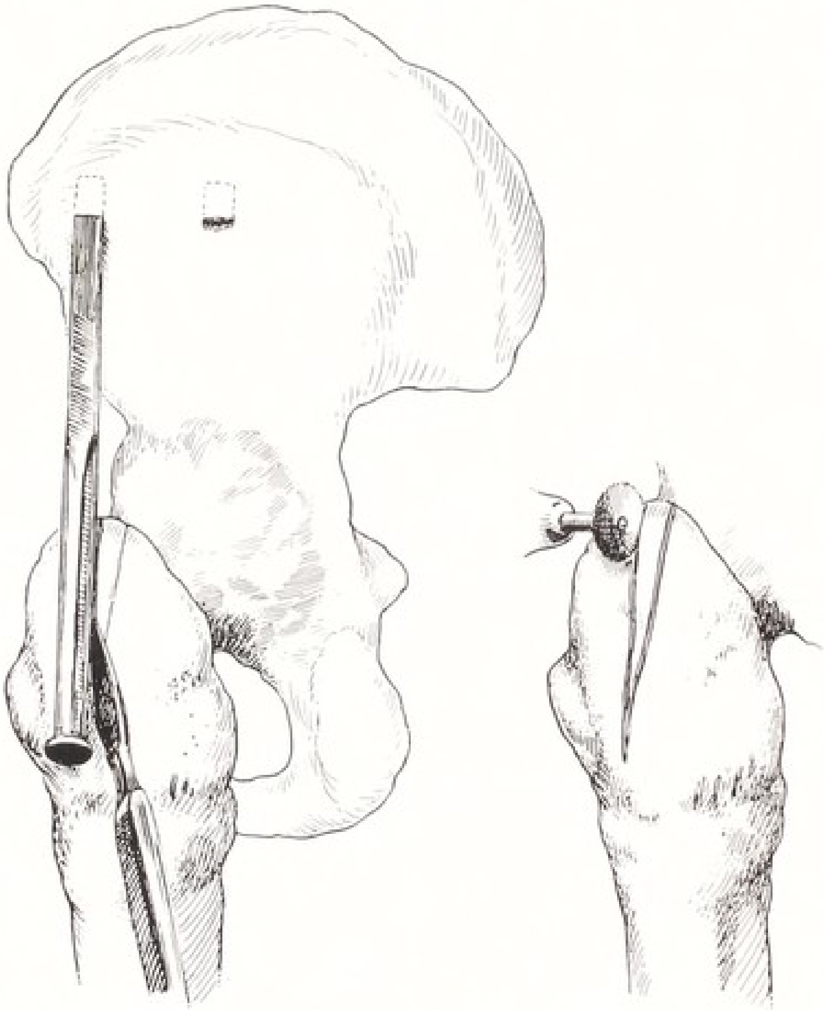


Fig. 56. Technique of arthrodesis of tuberculous hip with tibial grafts. First step.

ciently to expose the side of the ilium at the points of mortise for the insertion of the proposed tibial grafts.

Because of the thinness and elasticity of the bone comprising the outer table of the ilium, a mortise suitable to receive the grafts can be satisfactorily made with a ½ inch chisel driven through the outer table of the ilium obliquely upward between it and the inner iliac table, with the handle of the chisel in close proximity to the trochanter. With the cutting end of the chisel still in the mortise prepared by it, located 1 inch posterior to the anterior superior spine, and

1 inch below the crest of the ilium, the handle is depressed onto the outer surface of the trochanter at its anterior border, and used as a guide for some cutting tool, such as the scalpel,

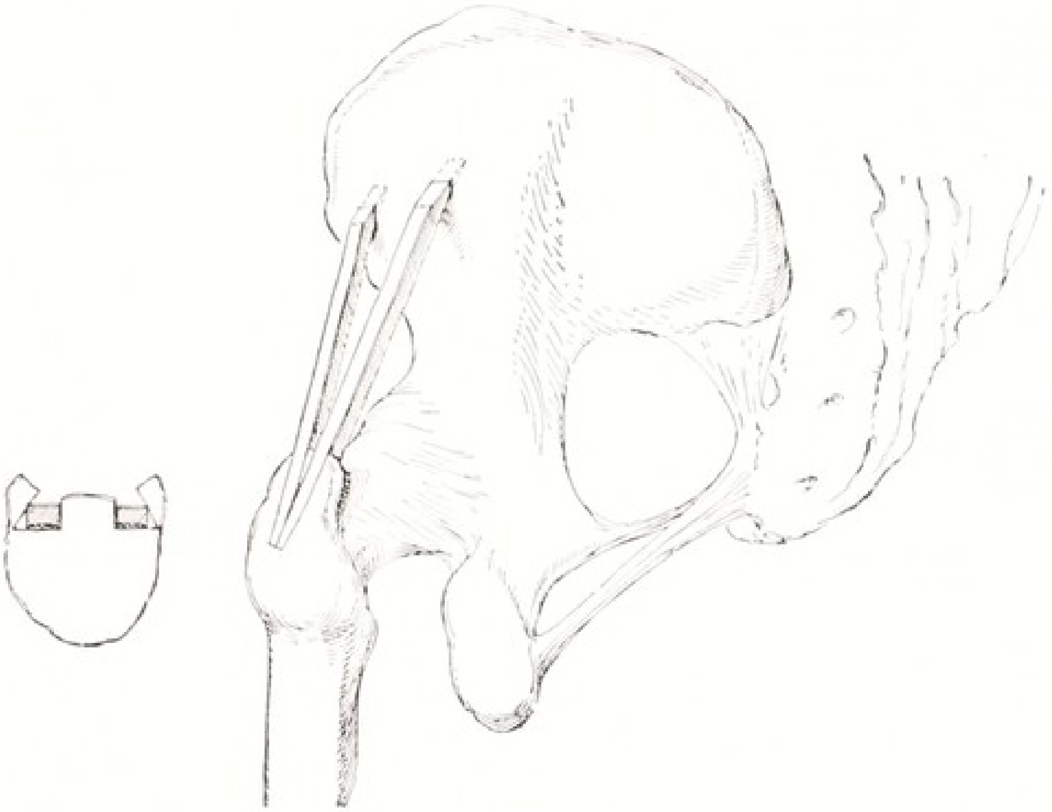


FIG. 57. Second step.

to mark on the periosseous structures the line where the motor saw is later to prepare a gutter for graft No. 1.

The same preparation is made for graft No. 2, except that the mortise in the ilium is made about 1½ to 2 inches posteriorly to the first one, and the scalpel mark is made on the posterior outer surface of the great trochanter.

Saw cuts are now made ½ inch in depth with the motor saw, following the scalpel marks just made on the trochanter. With an osteotome driven into these saw cuts, fragments of the trochanter are displaced with the periosseous soft parts as hinges, anteriorly from the saw cut for graft No. 1 and posteriorly from the saw cut for graft No. 2, so as to produce gutters to receive the two grafts.

The anterior internal surface of the tibia is then laid bare from the tuberosity of the tibia downward. With the motor twin saw set with the blades approximately 5/8 inch apart, a graft is removed by saw cuts made downward from the tuberosity of the tibia about 9 inches. With a small motor saw, this strip of bone is then cut into two segments. The upper ends of the grafts are cut in an oblique way like the end of a chisel.

The upper end of graft No. 1 is inserted into the mortise of the ilium with its lower end lying in the anterior gutter prepared in the trochanter. The oblique surface at the upper end is outward. With the author's bone drift or set (of which the carpenter's nail set is the prototype) placed on the trochanteric end of the graft, the graft is now driven into the iliac mortise by blows of the mallet upon the bone set. In this manner its trochanteric end is made to slide along the trochanter gutter and its proximal end to fit snugly into the mortise of the ilium.

Graft No. 2 is put in by precisely the same technique. The firmer the grafts are driven into the iliac mortise, the closer do they hug the bottom of the trochanteric gutter because of the obliquity of the cut end of the iliac end of the graft. This plan of operation automatically immobilizes the grafts at both ends in a most gratifying way and makes immobilizing bone ligatures unnecessary (Fig. 58).

The soft parts with fragments of the trochanter are drawn over the ends of the graft by means of interrupted strands of medium kangaroo tendon. The gluteal muscles are carefully drawn about the grafts by means of chromic catgut sutures.

The skin is closed with continuous suture of 0 catgut. Suture holes and the edges of the wound are puddled with 3½ per cent tincture of iodine.

Technique for Group 1b. The upper portion of the approach for this procedure is very similar to that described when tibial grafts are used. In this instance the incision must extend generously downward 5 inches from the tip of the trochanter so as to give free exposure of the antero-external aspect of the upper end of the femur. The soft structures are separated, leaving the periosteum on the femur. With the

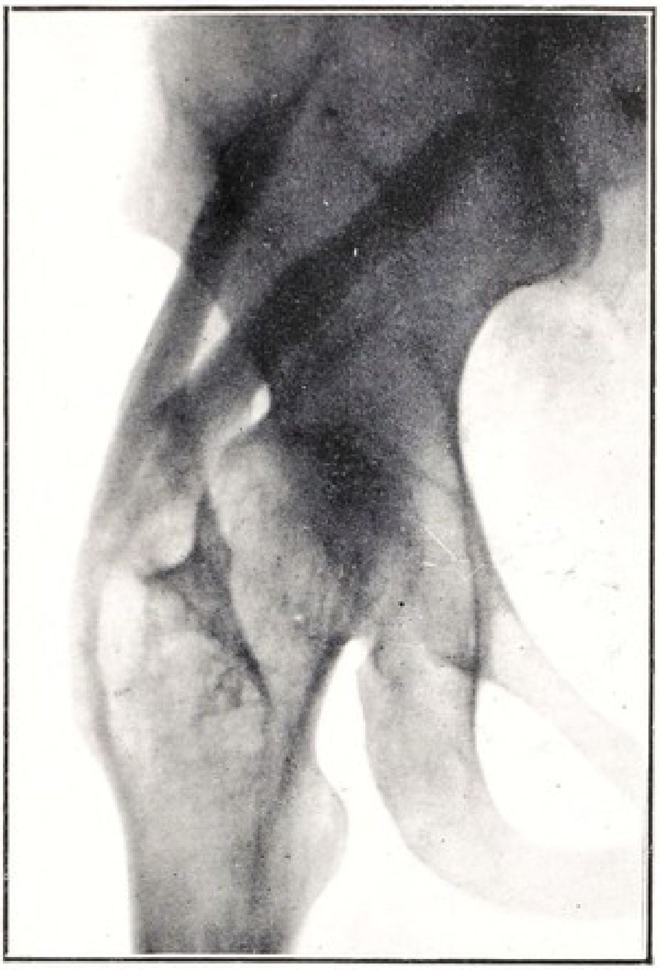


FIG. 58. Postoperative result eight years after operation. Influence of mechanical stress on graft may be noted. Joint has been completely ankylosed by bone.

motor saw and sharp ½ inch osteotome, a strong graft about 5 inches long and comprising about one-fifth the diameter of the shaft of the femur from the tip of the great trochanter downward is obtained with a pedicle of muscle at its upper end. The lower end of the femoral graft is now swung anteriorly on the muscle and soft tissue pedicle at the upper end as an axis until its anterior end comes in contact with the side of the ilium. When the desired location on the ilium is thus determined a flap or door of the outer table of the ilium is turned slightly upward and backward by means of the motor saw and ½-inch osteotome, so that the upper end of the graft (formerly the lower end) can be thrust backward beneath it (Fig. 59). Bone fixation ligatures are not necessary,

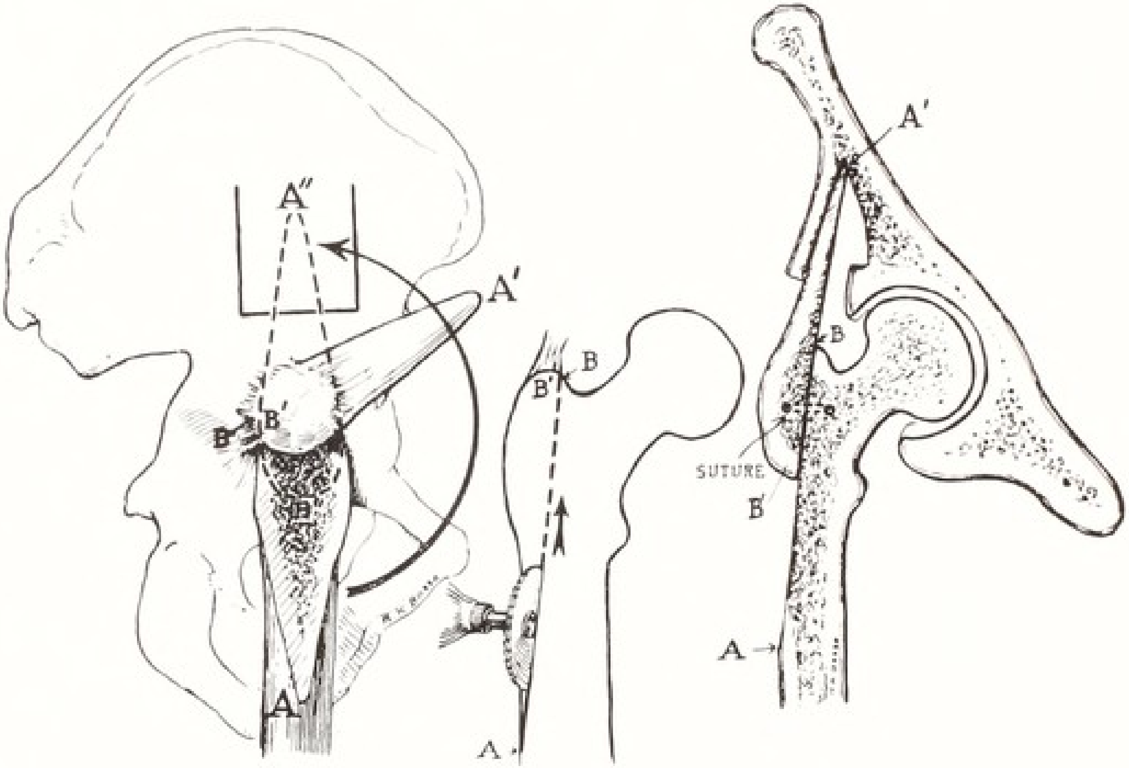


Fig. 59.

as when the graft is jammed with a few blows of the mallet and bone drift it is firmly placed and will not be displaced. The muscles and fasciae are now replaced over and around the graft with continuous suture of chromic catgut and the skin closed in the usual way.

The Hass or Hibbs procedure is somewhat similar to this method, except that Hibbs' method is not truly extra-articular, as both his diagrams and the description of his technique show that the neck of the femur is exposed and the cortex removed. The operation is therefore necessarily within the tuberculous area, which is to be avoided. Furthermore, it requires an extensive operative field, wide resection of muscles, and much shock. The procedure is the most difficult of the four types of technique presented. I have so modified this operation that it is extra-articular, but the great trochanter and attached muscles are much more damaged than when the tibial grafts are used, and it leaves more unfavorable conditions for a future arthroplasty—a possibility which should

Fig. 60.

always be borne in mind in planning an arthrodesis (Fig. 60).

Postoperative Dressing. Extensive dressings of gauze and sterile cotton are applied, and then a plaster-of-Paris spica from above the costal margin to the base of the toes on the operated leg, and to below the knee-joint of the opposite leg, in a posture of abduction sufficient, if possible, to overcome practical shortening.

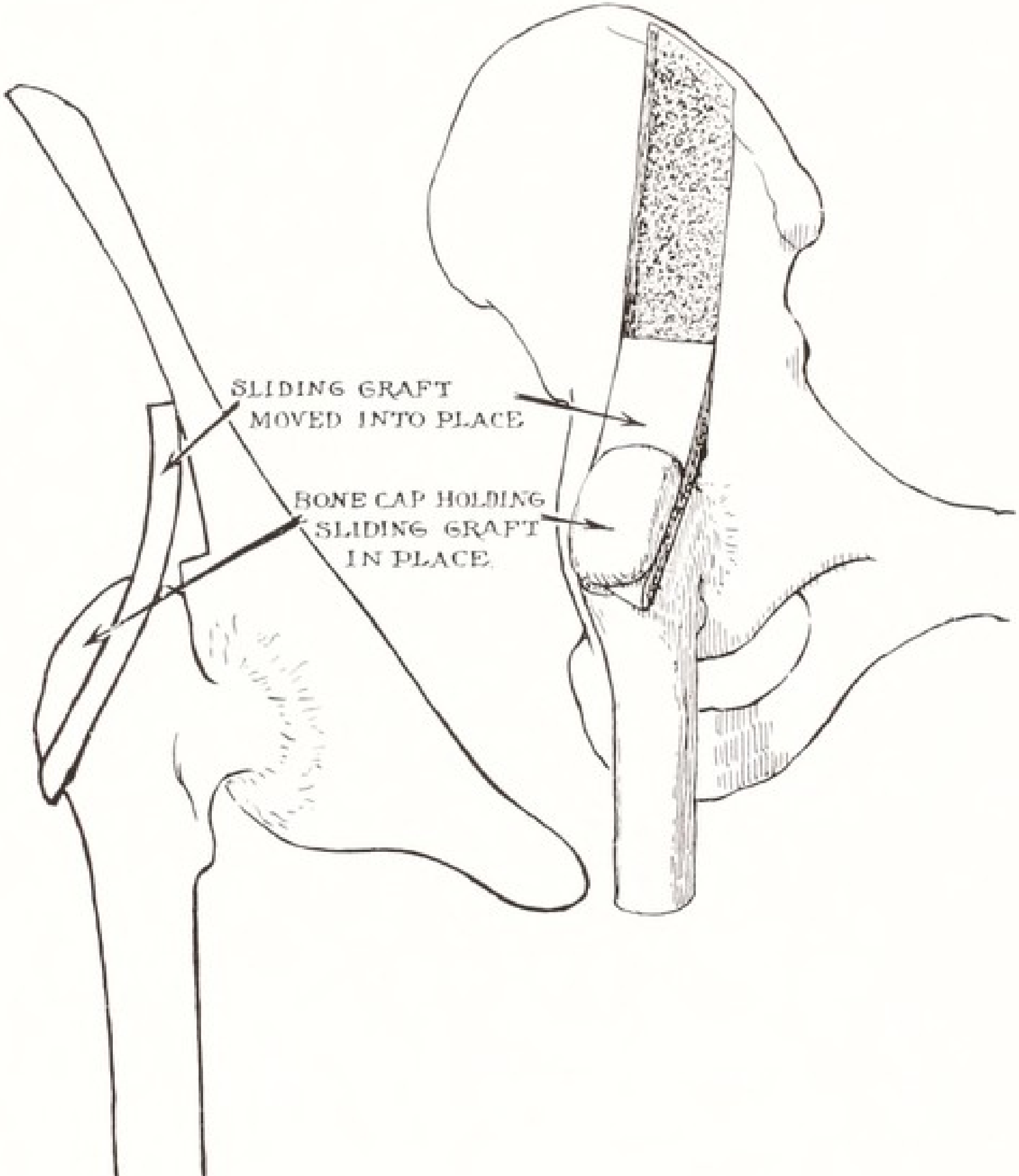


FIG. 61. Sliding graft from ilium in place.

With the plaster still in a semiplastic state, it is carefully molded over the operated area, for two purposes: to favor immobilization, and to aid in the control of bleeding.

The plaster on the uninvolved leg is removed at the end of five weeks. The remainder of the plaster is left alone until ten weeks from the time of operation.

Group 2. The operative technique for this group is illustrated by Figures 61-64. The head and a large portion of the neck of the femur have been disintegrated with telescoping, causing the trochanter to become more or less closely approximated to the superior rim of the acetabulum and the side of the pelvis.

For convenience in discussing the operative technique this group may be subdivided into two types:

Technique for Group 2a. Group 2a comprises those cases in which the destruction has been so extensive that the trochanter has approximated the rim of the acetabulum to a sufficient degree—within ½ inch or less—so that a sliding graft from the outer table of the ilium including the crest (Fig. 61) is adequate to reach from the side of the ilium into the trochanter and also furnish adequate contact with these bony elements and still allow the surgeon to keep outside the tuberculous joint. The side of the ilium has already been laid bare by the Smith-Petersen approach and furnishes a very satisfactory graft in that this outer table is not only curved so that it approximates the trochanter and ilium satisfactorily (Fig. 62), but also enables the surgeon to secure as broad a graft as he wishes. This technique is somewhat less difficult of execution and consumes less time than obtaining a graft from the tibia or femur, as described under Group 1. The surgeon, after sizing up the mechanical conditions, may therefore choose this type of technique rather than the other two already described.

Technique for Group 2b. In certain extreme cases, Group 2b, in which the trochanter is practically resting against the side of the ilium, and in which an intra-articular arthrodesis has been previously attempted, with complete removal of all tuberculous tissue, the following simple technique may be used: The trochanter may be denuded of its periosteum and periosseous structures, both on its outer and inner surfaces (Fig. 63). The outer table of the ilium just above the acetabular rim is then lifted externally, and the denuded trochanter implanted beneath the latter by swinging the hip into the abducted posture which automatically elevates the trochanter into the crevice thus made (Fig. 64). It may be neces-

Fig. 62.

sary to supplement this procedure by implantation of a graft obtained from the outer table of the ilium, higher up near the crest. These very extreme cases are rare; I have encountered only two of this type. This technique is partially intra-articular.

In any event one should design the operative procedure so that the graft used will be firmly mortised into both femur and pelvis without entering the tuberculous joint, and it will

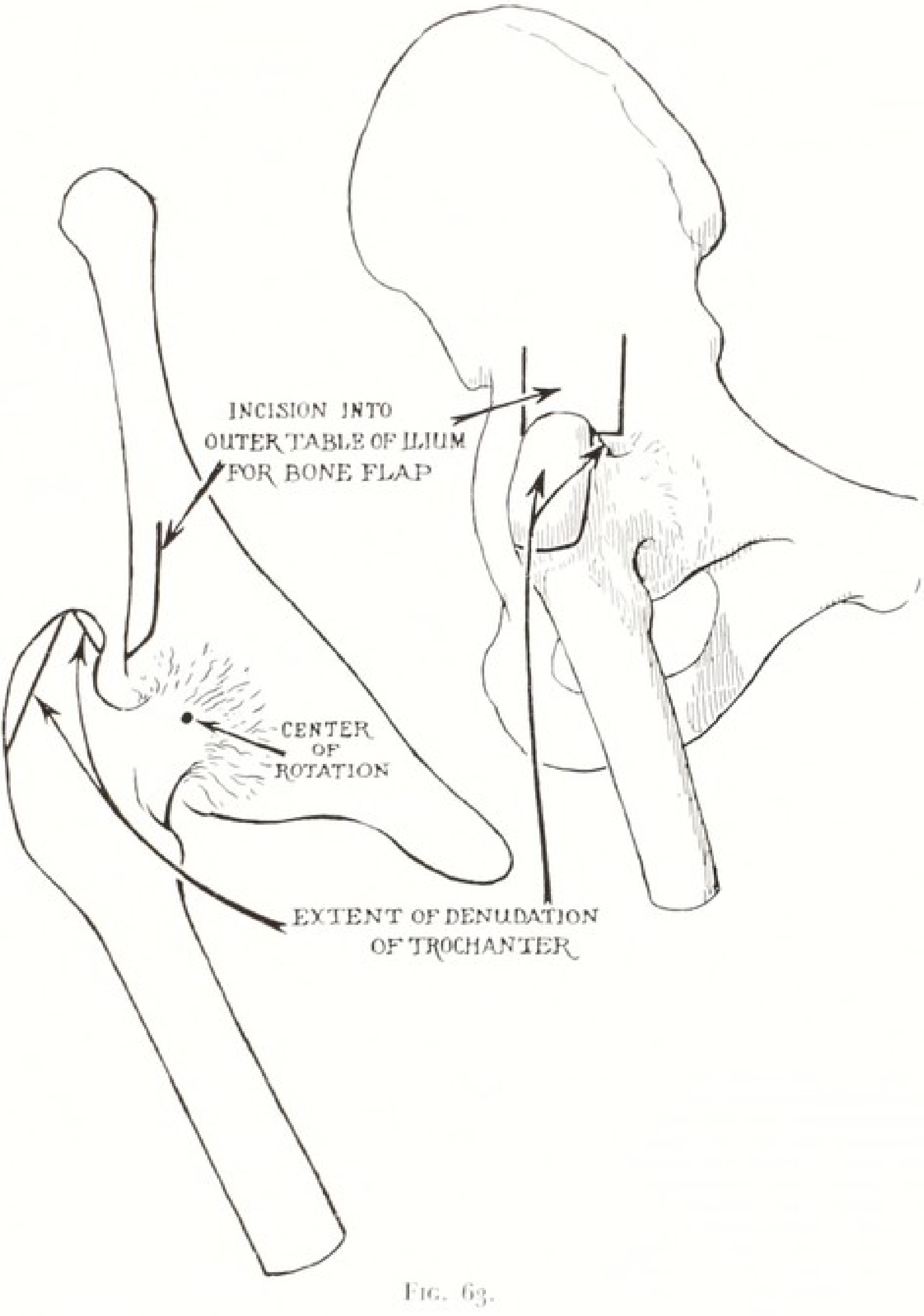


Fig. 63.

have to be left to the judgment of the surgeon as to just what technique should be chosen, always remembering that the simplest technique feasible will be most satisfactory.

Either of the procedures described under Group 2 is easier of execution than those for Group 1, providing the trochanter is near enough to the side of the pelvis so that it can be well carried out.

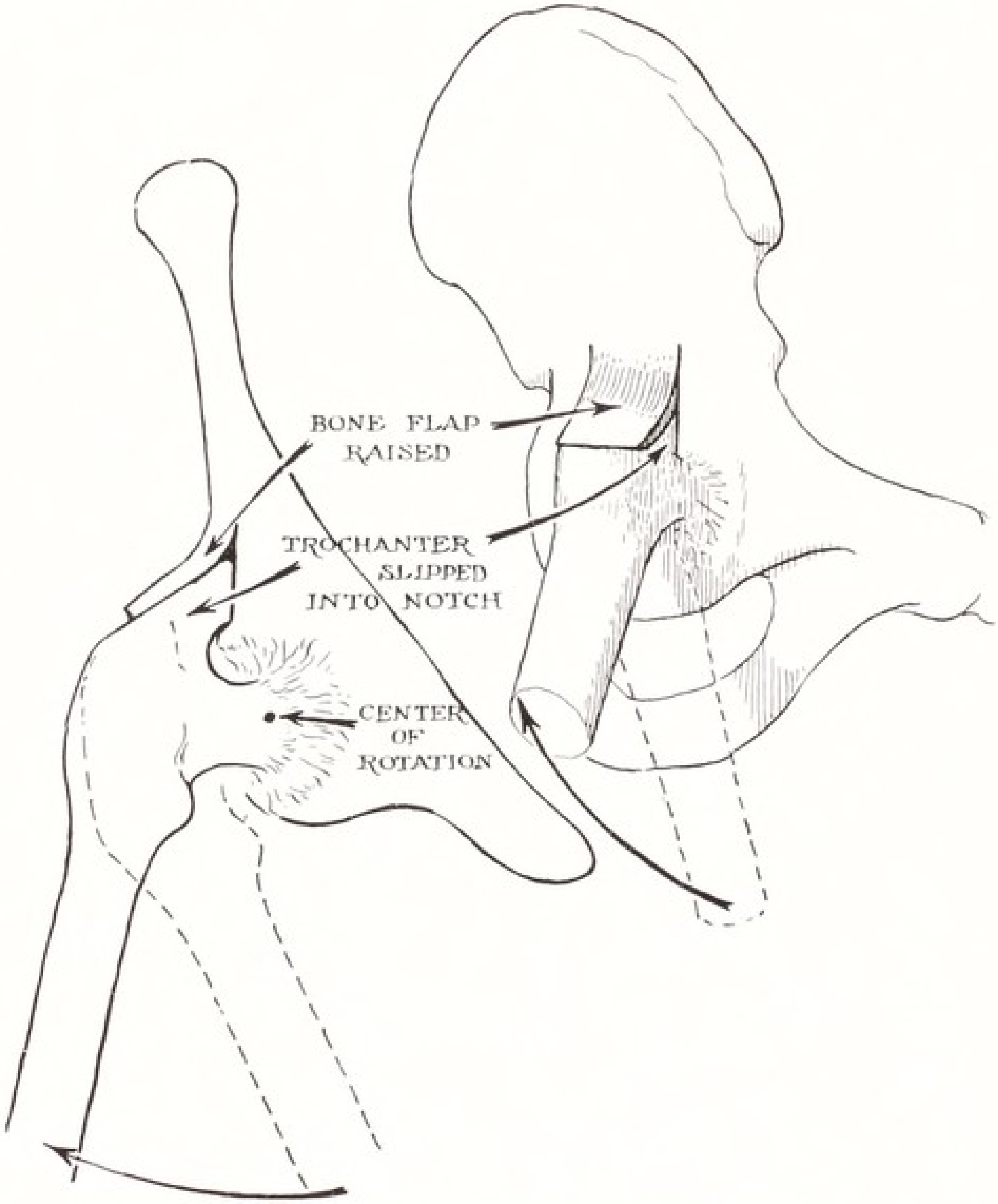


FIG. 64. Implantation of denuded trochanter under an osteoperiosteal door from outer surface of ilium.

Relative Difficulties of Technique. The simplest technique is 2b, but for the reasons already discussed it is applicable only in rare instances.

Where the great trochanter is in close proximity to the rim of the acetabulum, the simplest bone-graft operation possible for extra-articular arthrodesis is applicable: the sliding down of a broad graft from the outer table of the ilium into the split trochanter (2a).

The tibial grafts (1a) are next in order of difficulty.

The most difficult operation, particularly as to extent of operative field and tissues involved, is 1b, the modification of the Hass-Hibbs technique. The original Hass-Hibbs operation is not extra-articular, but about 4 or 5 inches of the outer portion of the great trochanter and the shaft of the femur can be used to accomplish an extra-articular arthrodesis. This, however, is an operation of great magnitude in that an incision has to be made from just below the crest of the ilium to nearly one-third down the thigh in order to rotate the graft into position (Fig. 55).

Caution. A word of caution concerning the execution of bone-graft technique is stimulated by recent publications of postoperative x-ray findings, in which it was claimed that extra-articular arthrodesis of the hip had been accomplished, but with unsatisfactory results in a considerable percentage. The x-rays showed that the same inadequate and imperfect technique had been practised as has been so frequently observed during the past twenty years when certain surgeons have drawn unfavorable conclusions from their attempts to accomplish extra-articular arthrodesis of tubercular spines, although the operative technique was inadequately carried out. I wish to emphasize the necessity of the graft being of sufficient strength, ample length, accurate fit, and carefully mortised on either side of the joint, if good results are to be secured.

HASS-HIBBS TECHNIQUE

In the Hass-Hibbs operation as described by Hibbs:* "An incision is made through skin and subcutaneous tissue from 2 inches behind and above the anterior superior spine, down

* Hibbs, R. A preliminary report of twenty cases of hip joint tuberculosis treated by an operation devised to eliminate motion by fusing the joint. *J. Bone & Joint Surg.*, 8: 522, 1926.

over the great trochanter, 3 inches on the shaft of the femur. The deep fascia is split, the tensor fascia femoris retracted medially, and the fiber of the gluteus medius and minimus separated by blunt dissection, exposing the capsule. The periosteum of the femur is incised along the line of the base of the trochanter, elevated and retracted medially; the anterior three-fourths of the trochanter with 2 inches of the cortex of the femur is separated with a chisel, leaving the muscle and periosteal attachments undisturbed (Fig. 55).

"The capsule is split, the superior aspect of the neck exposed and the cortex removed. A mass of the ilium including the upper rim of the acetabulum is elevated without disturbing the muscle or periosteal attachments or breaking loose the mass above. The trochanter is now transposed by turning its lower end up under the elevated mass of the ilium, its base making snug contact with the cancellous bone of the neck, the cortex having been removed. The periosteum of the transposed bone is sutured to that of the iliac mass above and to that of the femur below. The mass is also caught by the tip of the remaining one-fourth of the trochanter; when the thigh is abducted 15 degrees and flexed 30 degrees, it is held securely in place. The muscles and fascia are closed with sutures of plain catgut, the subcutaneous tissues with plain gut, and the skin with silk. A double spica plaster is applied, which has already been prepared and bivalved. By this means direct and massive bone contact has been secured between the ilium and the femur, with continuous periosteum which produces a situation favorable to bone growth, and essentially similar to the situation produced by spine fusion, where the continuity of bone and periosteum is primarily of healthy bone which first becomes fused; ultimately, however, fusion of the diseased bodies takes place. It was hoped that in the case of the hip the primary fusion would be of the transposed trochanter, ilium and femur and ultimately of the head and acetabulum as well, finally showing a massive area of fusion which is necessary to stand the force exerted upon it by the long femur."

Ghormley * claims the following advantages of using the crest of the ilium: it is easily obtained in any exposure of the hip, and the cancellous bone of the iliac crest furnishes ideal bone for grafting purposes. The graft lies in position in close contact with the surface of the neck and the ilium. In many cases it seems made to fit accurately in this position. It acts as a "flying buttress" which is mechanically as strong a structural support as possibly can be made. The simplicity of the procedure makes for speed in operation and lessens the danger of shock.

* Ghormley, R. K. Surgery of the hip joint. *J. Bone & Joint Surg.*, 13: 784, 1931.

Chapter VII

SYNOVITIS, INFECTIOUS AND GONORRHEAL ARTHRITIS, SUPPURATIVE ARTHRITIS, INCLUDING OSTEOMYELITIS AND ACUTE EPIPHYSITIS

Synovitis

IT is not easy to detect the presence of fluid in the hip-joint because of its deep situation, surrounded by large muscles. It is usually impossible to palpate any distention of the capsule. The diagnosis is made from the absence of roentgenographic changes and the characteristic physical findings—painful limited motion with marked muscle spasm and the tendency of the patient to hold the limb in flexion and adduction.

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 roentgenology.

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 a 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 a 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 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.

Infectious or Rheumatoid Arthritis

Infectious or rheumatoid arthritis is primarily a disease of the synovial membrane and the soft tissue surrounding the joint. Cecil * states that the clinical course and laboratary findings indicate that the rheumatoid type of arthritis is a chronic inflammatory process.

The clinical features are infiltration of the periarticular tissues, flexion deformity, restricted motion and local pain and discomfort. Roentgenograms show distention of the capsule of the hip joint and a varying amount of decalcification of the head and neck of the femur. Very rarely cartilage destruction is seen.

With the exception of those cases caused by infectious processes elsewhere in the body rheumatoid arthritis is frequently caused by focal infection or metabolic disturbance and the elimination of the foci of infection is the chief therapeutic indication. Physical and mental rest is very important. The diet should have a low carbohydrate and a high vitamin content. Good elimination and a copious water intake are necessary. Colonic irrigations may be given in cases of intestinal toxemia. Heat, exercises and massage are valuable. In cases showing no improvement under treatment by these measures, the hot climate of Florida may have a

* Cecil, R. L. Rheumatoid arthritis. *J. A. M. A.*, 100: 1220, 1933.

good effect. The only drugs of value are colloidal sulphur, iron for anemia, arsenic and strychnine as tonics, and salicylates for the relief of pain.

Fixation of the joint by a short plaster-of-Paris spica or rest in bed may be necessary in the more severe cases. Usually the use of crutches with no weight-bearing on the affected limb for a few weeks is sufficient.

GONORRHEAL ARTHRITIS

Gonorrheal infection invades the hip with far less frequency than the knee-joint, although it is not uncommon in adults.

Etiology. The process is part of a systemic, hematogenous infection with the gonococcus, usually originating in the urethra or its adnexa. It complicates from 2 to 10 per cent of gonorrheal urethritis. It affects women as well as men, and is not uncommon in children.

Pathology. The following pathological conditions are encountered:

1. *Hydrops Articuli:* This is often monarticular. 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 periarticular 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.

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 is swollen, exquisitely tender to pressure and to jarring 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 of or the presence of a urethral discharge. In *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 in the urethra, bladder, seminal vesicles, is essential. Rest in bed, support of the joint, and local applications of heat or cold are necessary.

Immobilization with weight traction should be done immediately. The hip joint should be aspirated and the fluid obtained examined both microscopically and culturally to determine the character of the infection. In aspirating the hip the trocar may be inserted from the front or the side. It may be thrust into the joint just above the greater trochanter, passing directly inward. If the anterior approach is desired the joint may be reached from a point on the same level, but in front of the thigh. 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. As soon as the most acute symptoms have subsided a short plaster-of-Paris spica cast should be applied. The duration of immobilization varies with the pathological state of the joint, but should

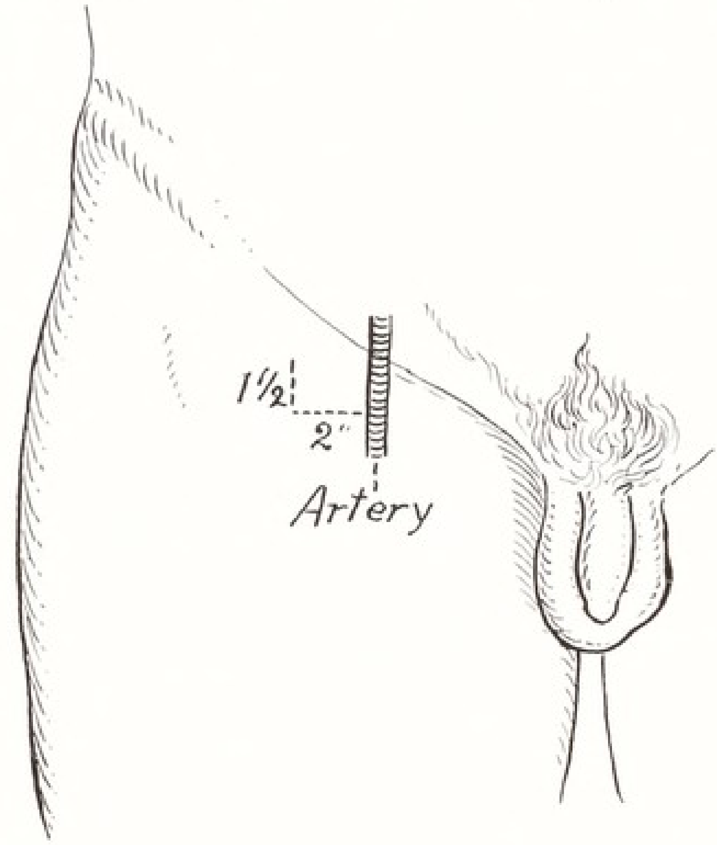


Fig. 65. Landmark for aspiration or injection of hip joint. In an adult, needle is introduced at a point 1.5 cm. below horizontal plane of pubic spine and 2 cm. external to femoral artery.

not be too protracted in any case. As soon as the infection subsides active and passive exercise and massage should be cautiously started. If suppuration occurs the joint should be incised and drained. Vaccines are of debatable value.

If contractures or ankylosis has occurred surgical methods will be necessary to mobilize the joint. (See Chap. VIII, p. 212.)

Suppurative Arthritis

PYOGENIC ARTHRITIS: OSTEOMYELITIS

Pyogenic arthritis, acute osteomyelitis (or epiphysitis) is not an uncommon event in infants, in whom it is manifested as an acute epiphysitis. Separation of the epiphysis of the femoral head may follow, with disintegration of that structure and dislocation. 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.

Of 217 cases of pyogenic osteomyelitis treated by Bisgard * there was associated arthritis in 51 cases, an incidence of 23.5 per cent. Of these 51 cases, 42 (19.3 per cent) arose by direct extension from an adjacent diaphyseal infection. The large weight-bearing joints constituted 92.5 per cent of this group.

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. Osteomyelitis of the ilium in children frequently extends into the hip-joint. Young † states that the diagnosis of acute osteomyelitis of the ilium is by no means easy. This is perhaps partly because the physician fails to remember there is such a disease. On the other hand, the patient may present such a preponderance of constitutional symptoms that little attention is paid to the initial local complaint.

If a child complains of pain in the region of the hip following a trauma to the region, and on examination is found to be acutely ill with high fever, leucocytosis, tenderness, and increased local heat about the hip, but relatively free motion of the hip-joint, then osteomyelitis of the ilium should be suspected. This, we believe, is so because: (1) The pain of infection in the hip-joint is often, although not always, referred to the knee. In osteomyelitis of the ilium, the pain is always about the hip with oftentimes inability on the part of the patient to localize the site of discomfort definitely. In none of the cases reported or in our cases has pain been

* Bisgard, J. D. The relation of pyogenic arthritis to osteomyelitis. *Surg., Gynec. Obst.*, 55: 74, 1932.

† Young, F. Acute osteomyelitis of the ilium. *Surg., Gynec. Obst.*, 58: 201, 1934.

referred to the knee. (2) Flexion and abduction contracture occurs very early in septic involvement of the hip-joint; in osteomyelitis of the ilium no contractures are present until later. (3) Pyogenic infection in the hip-joint manifests itself early by almost complete fixation of the joint due to muscle spasm; but in osteomyelitis of the ilium in the first few days of the disease, motion in the hip is free. (4) If osteomyelitis of the pelvic bones is suspected then the ilium is the bone by far the most likely to be affected. Acute osteomyelitis of the pubis and of the ischium is so rare that it is hardly necessary to give it consideration.

By far the most frequent complication of osteomyelitis of the ilium mentioned in the literature is invasion and destruction of the hip-joint. Treatment should be directed toward saving the patient's life and, secondly, preventing destruction of this joint.

Following incision the extremity should be kept in traction with the hip abducted and slightly flexed to prevent deformity of the acetabulum and possible dislocation of the hip. This occurs due to the upward pull of the hip muscles forcing the head of the femur upward and inward into the softened ilium.

The convalescence is long and oftentimes complicated by recurring abscesses. The patient should be protected from bearing weight on the affected side until there is x-ray evidence that the ilium has fully regenerated and the hip-joint is as normal as one thinks it will become.

Besides being more dangerous as regards life, the disease is also quite disabling if the patient survives. This is not only due to the sinuses and recurrent abscesses common to all osteomyelitis, but also to the frequent involvement of the hip-joint resulting in painful limited motion and, at times, complete ankylosis.

Santi * states that osteomyelitis of the hip frequently starts

* Santi, E. Osteomyelitis in the first years of life. *Internat. Abst. Surg.*, 60: 241, 1935.

as an infection of the synovial membrane and spreads into the bone secondarily. In nurslings purulent arthritis may occur without involvement of bone. Osteomyelitis of the hip is most common at the age of six months, but may become manifest very soon after birth. The lesion commonly produces a deformity of the head and neck of the femur and of the acetabulum with resulting dislocation of the femur. The dislocation may be confused with congenital dislocation of the hip. While the epiphysis is the most frequent site of osteomyelitis in the first years of life, the body of the diaphysis is a common site of bacterial emboli because of its abundant blood-supply. Involvement of the metaphysis is frequent both in infancy and after the second year of life. Roentgenography is of the greatest value in the diagnosis of osteomyelitis.

Treatment. The first consideration is treatment of the generalized septicemia which is always present in these cases. Transfusions are of great help. Prompt incision is imperative for the evacuation of the pus from the hip-joint, femur, or ilium. Traction with weights or a spica cast are applied immediately to prevent dislocation of the hip.

The treatment of a group of cases of osteomyelitis about the hip, with or without complications, entails a multitude of considerations. In most of these cases, we have deep wounds extending into the bone through thick muscles, with varying degrees of infection. The ideal wound dressing must, therefore, have a degree of solidity sufficient to restrict the tendency of the orifice at the dermis to close earlier than the depths of the wound. At the same time, this tampon should be such that it can be inserted in practically a fluid state, in order to flow uninterruptedly to every recess of the wound; it should then become semi-solid, thus tending to conserve the original contour of the wound, avoid adherence to the bone, and, bit by bit, extrude automatically as granulations fill up the depths of the wound, or as the contractions of healing and cicatrization demand.

If the consistency of the tampon can be altered by changing the relative amounts of the ingredients composing it, too early extrusion can be avoided in wounds of great depth, and, conversely, rapid extrusion can be favored in shallow wounds where earlier closure is desirable and possible. With these requirements in mind, I am now using, instead of the vaseline and vaseline gauze (Orr treatment) applied in earlier cases, different mixtures of paraffin and yellow vaseline, the proportions depending on the nature of the wound. In deep wounds, paraffin and vaseline are used in a strength of ten to one; in suppurative wounds, where early closure is desired, the mixture is four parts of paraffin to one part of vaseline. The mixture is always put into the wound in a melted state, at about 110° F., this being accomplished by immersing the jar containing the mixture in a water bath for some time before the mixture is used. It is then inserted into the wound by means of a large syringe.

I do not favor the vaseline, vaseline-gauze dressing for several reasons:

1. It is impossible to control satisfactorily the consistency of the vaseline, vaseline-gauze tampon. Due to the ingredients comprising it, this tampon cannot, at best, be uniform in its consistency.

2. Later experience has shown that, even when an excess of vaseline is added with the vaseline gauze, the gauze is still apt to become adherent to the bone at the bottom of the wound and so resist extrusion of the tampon and delay healing.

3. The wound granulations are likely to strangulate through the meshes of the gauze.

None of these complications ever arises with the paraffin and vaseline dressing, which, because of its proper degree of solidity for the particular case, the uniformity of its consistency, and its slippery surface, will always extrude much more satisfactorily than the vaseline, vaseline-gauze dressing, acting in a manner apparently somewhat similar to the bipp tampon. Furthermore, it has been found that laboratory-bred phage, when introduced, acts favorably in the presence of the tampon. I have been unable to find any shortcomings of this dressing as compared with either the bipp or the vaseline, vaseline-gauze dressing. Bipp, however, may be contraindicated because of the possible unfavorable chemical action of the iodoform upon the bacteriophage.

Technique. The usual sequestrectomy and saucerization are completed, and a culture is taken. (If a specific phage has already been found from a culture previously taken from an existing sinus, two-thirds of a test tube of this phage is poured into and over the wound, so that the whole surface is bathed.) The wound is then packed with a paraffin and vaseline mixture, usually 90 per cent paraffin to 10 per cent vaseline. The paraffin and vaseline are heated to 110° F. and poured in as a liquid, or forced in by pressure through a large syringe. In most cases, the syringe is the method of choice, in order to insure penetration of the mixture to the innermost recesses of the wound.

One end of a rubber catheter is inserted through the paraffin-vaseline wound tampon to the bottom of the bone cavity. The other is allowed to project through the dressings and cast (which are applied as usual), with a sterile gauze or cotton over the end. If the laboratory examination of the culture reveals that it is possible to develop a bacteriophage specific for the organism presented, 10 c.c. of this phage are injected through the rubber catheter each day. Care should be taken when making these injections not to infect or contaminate the end of the tube. Should the bacteriophage appear spontaneously in the wound, injection of the laboratory-bred phage is still of advantage in that it accentuates the action of the native phage, and may be a more specific one. This practice is of still further advantage because, if an original phage does not completely destroy a culture, the organisms that survive give rise to a resistant strain which may be pathogenic for its host but is not affected by the old bacteriophage. In large wounds, several catheters may be inserted, some of which are multifenestrated. Inasmuch as the catheter is firmly imbedded in the paraffin-vaseline tampon, the injected phage fluid cannot flow backward between the catheter and the tampon. It must, therefore, make its way *inward* between the tampon and the wound granulations, and thus, by reason of its own bulk, spread widely. Furthermore, since the phage is, by nature, a multiplying organism it will thus automatically spread over the wound surface.

At the end of eight weeks the plaster spica is removed and the wound dressed, great care being taken not to traumatize the granulating surfaces. The discharge around the edges of the wound is wiped off very gently with sterile gauze and the skin cleansed with benzin.

If the wound is not entirely healed when the cast is removed, it is again bathed with a test-tube of the prepared specific phage fluid and a catheter or catheters inserted to the depths of the wound. A paraffin-vaseline tampon is used as before and a cast applied for eight weeks. A culture is also taken at this time to determine whether the bacterial flora of the wound has changed, and also whether a more specific race of phage can be obtained. Periodic injections through the catheter are given as before.

Those cases in which a native phage develops usually do very well without the insertion of a laboratory-bred phage. However, in view of our latest investigations, we feel it is wise to inject periodically a race of phage of the highest potency, in order to have at work for a maximum period of time a phage of the highest specificity. In this way, any possible decrease in potency of the native phage is offset.

We have done extensive research to determine the relative effectiveness of plain and irradiated vaseline, and have established that there is no difference in their effect upon either bacterial cultures or different races of the bacteriophage.

The method described has the following advantages:

1. It is simple in its application, requiring a minimum amount of labor on the part of the surgeon and his staff.

2. It does not interfere with the immobilization of the part, nor does it favor edema of the granulations or the soft structures because of inequality of pressure at or in the immediate neighborhood of the wound, since there is no window in the cast. This is quite contrary to the Carrel-Dakin or maggot method of treatment, both of which must, of necessity, have a window in the cast. I believe that a uniform pressure over the wound and neighboring tissues (such as this method affords) will avoid exuberant granulations and edema—an important consideration in the healing of a wound, as is exemplified in the case of varicose ulcers.

3. The paraffin-vaseline tampon automatically yields to the encroachment of granulation, healing, and closure of the wound, thus gradually extruding and keeping up a constant physiological pressure upon the surface of the wound at all times. This is more effective than frequent dressings by the surgeon, and, in addition, avoids the possibility of reinfecting the wound by a foreign flora of bacteria.

4. This dressing is favorable to the appearance of the native bacteriophage and to the periodic introduction of a laboratory-bred phage.

5. It requires a very short period of hospitalization.

The Uses of Bacteriophage. In addition to its application to infected joints and bone wounds, the bacteriophage has proved a most efficacious specific agent in combating lesions such as furuncles, boils, carbuncles, and phlegmons. For these conditions it may be applied in two ways:

1. It may be thoroughly rubbed over the surface of the wound and the lesion covered by sterile pads soaked in bacteriophage; or, if the lesion is of extensive size or depth, it may be dressed with the paraffin and vaseline tampon with a catheter incorporated for periodic introduction of bacteriophage.

2. It may be injected subcutaneously into the soft parts by means of a hypodermic needle about the periphery of the lesion.

In bacteriemia, particularly with *Staphylococcus aureus*, a bacteriophage prepared with asparagin as a medium and injected into the blood stream, has, in the hands of Dr. MacNeal * reduced the mortality from practically 100 per cent to less than 50 per cent, even when there have been two positive blood cultures (*Staphylococcus aureus*). Not only is the bacteriophage a successful local therapeutic agent, but it has the added advantage of helping to establish a possible general immunity on the part of the patient. Also the bacteriophage is, to some degree, effective in experimental animals when injected at a site distant from the infected focus.

Certain cases of septic hip disease are followed by fistulae and sinus formation, destruction of the epiphysis and the production of a loose, flail-like pseudarthrosis, the "pseudoarthrose flottante" of the French.

The ultimate condition is frequently difficult of differentiation from congenital dislocation of the hip by means of physical examination alone; the x-ray diagnosis is final in such cases.

Remodeling the Hip Joint in Healed Cases. 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-Petersen 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 there by means of brace grafts, also obtained from the outer table of the wing of the ilium (Figs. 66 and 67).

* New York Post-Graduate Hospital.

The end results in cases of suppurative arthritis of the hip are very unfavorable.

Reschke * reports on a series of 26 cases of osteomyelitis

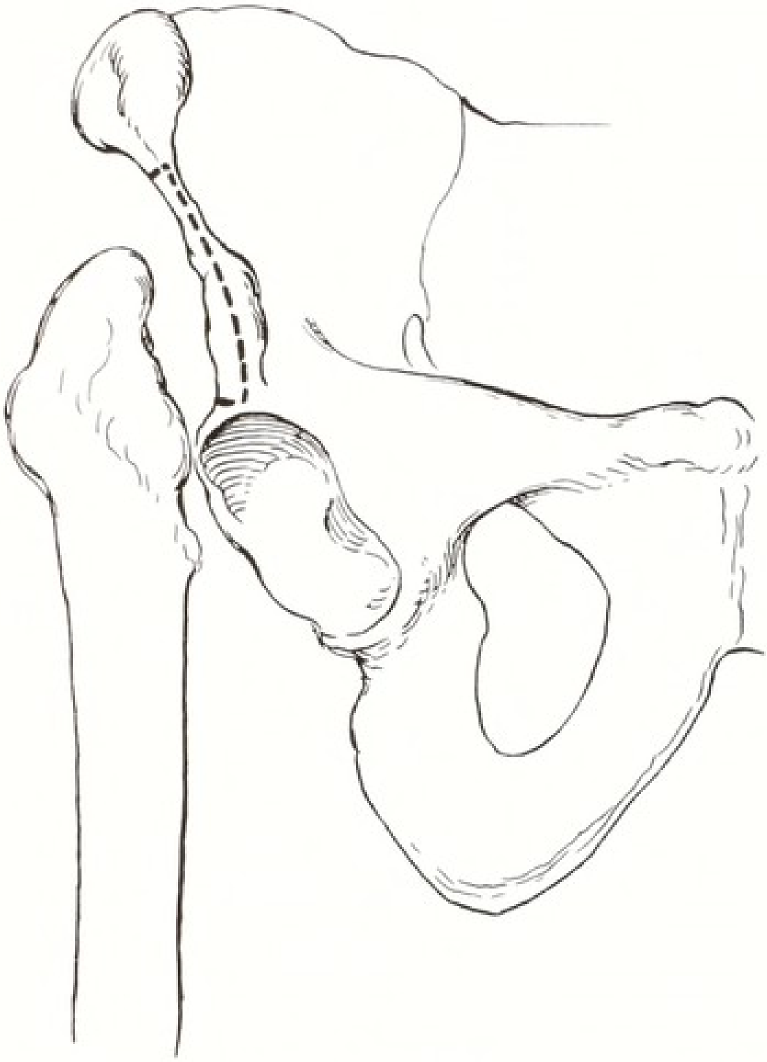


FIG. 66. Old acute epiphysitis, with destruction of head and neck and dislocation upward of trochanter.

of the hip-joint region in which there were 8 deaths. In all of the surviving patients, healing was obtained with ankylosis but without fistulae.

Ankylosis is more frequent in the cases complicated by osteomyelitis of the ilium and femur. Six to nine months after the healing of all sinuses, an arthroplasty (see p. 212) can be done.

* Reschke. Die akute Osteomyelitis der Hüftgelenksgezend. *Arch. f. klin. Chir.*, 173: 208, 1932.

If there is marked scarring of the soft tissues, which frequently occurs in these cases, arthroplasty is usually not done because the scar will not permit active muscle control of the new joint.

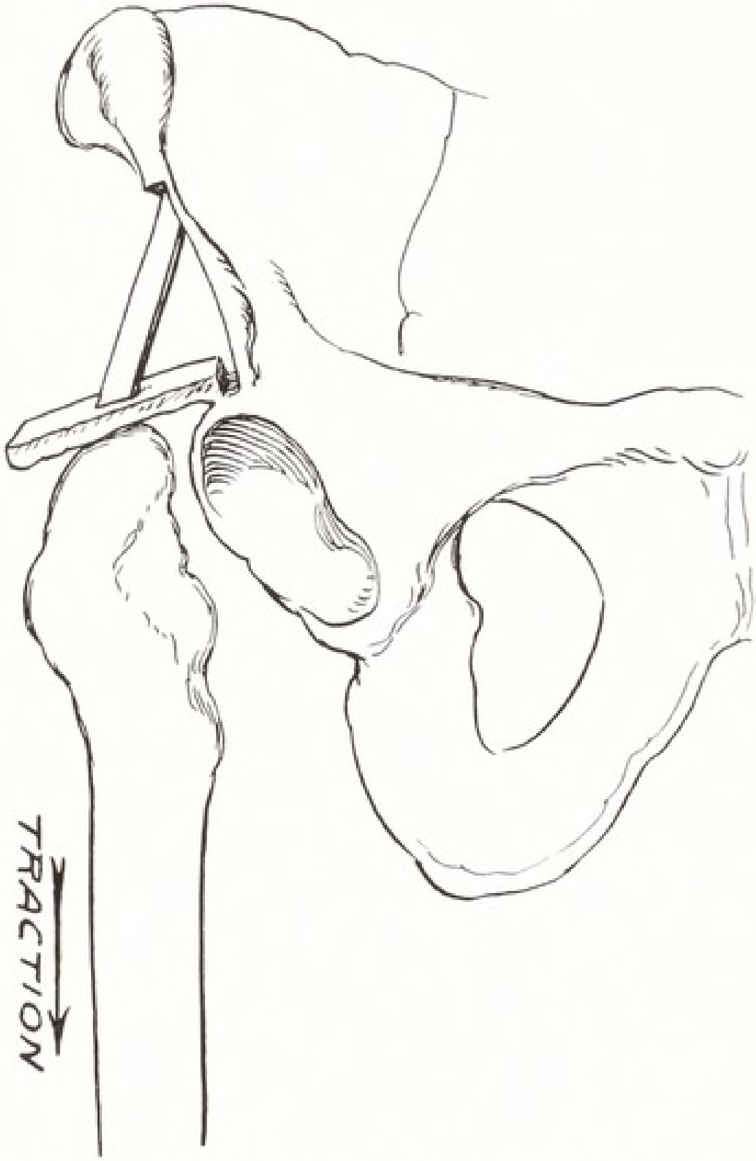


FIG. 67. Erection of bone graft shelf over top of trochanter.

SYPHILITIC ARTHRITIS

In *acquired syphilis*, along with the rash of the secondary stage, a characteristic synovitis may appear. The hip may become painful on motion and the capsule distended. This condition may disappear with the rash or may become chronic with continued painful motion of hip, synovial thickening, and increased joint fluid. This lesion may be confused with early tuberculosis of the hip. In the tertiary stage of syphilis gummatous synovitis may develop. This condition resembles tuberculous synovitis but is less prone to suppuration and is free from pain and limitation of motion. Chondroarthritis may develop, characterized by gummata near the articular surface.

In *congenital syphilis*, the characteristic lesion is epiphysitis accompanied by a serous effusion into the joint. Chondroarthritis and pyarthrosis are occasionally seen.

Diagnosis may be made by the Wassermann or Kahn blood and spinal fluid tests.

Treatment of the syphilis by the specific medication appropriate for the particular stage of the disease manifested by the patient is the most important therapeutic measure.

During the stage of acute synovitis, weight-bearing and motion of the hip should be restricted by spica cast or crutches. The presence of gummata near the hip joint necessitates protection from weight-bearing to prevent crushing and fracture.

Neurotrophic Arthritis

In the course of tabes dorsalis and syringomyelia Charcot hip may develop. The characteristic lack of pain in the presence of marked joint destruction differentiates this condition from other lesions. The condition starts with swelling and distention of the capsule. Two distinct processes are present at the same time: A marked destructive influence which leads to the solution of the head of the femur and acetabulum, and an attempt at repair. The hip joint may become a loose bag of semi-fluid detritis.

Diagnosis. Tabes dorsalis shows Romberg's sign, Argyll-Robertson pupil, lost knee-jerks, positive Wassermann reaction and characteristic colloidal gold spinal fluid reaction.

Syringomyelitis characterized by lack of pain sense and of temperature sense, with preservation of tactile sense in the same area.

Treatment. The most important therapeutic indication is the protection of the hip from weight-bearing with a spica cast and crutches. In the syphilitic cases cautious treatment of the tertiary syphilis followed by arthrodesis of the hip with a massive bone graft from the side of the ilium is a satisfactory procedure. Arthrodesis is not satisfactory in the cases due to syringomyelia.

CHAPTER VIII

ARTHROPLASTY TO OVERCOME LIMITED MOTION AND ANKYLOSIS

ANKYLOSIS of the hip may be fibrous or bony from 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 the joint does not necessarily indicate ankylosis, *e.g.*, muscular contraction in joint disease, or joint immobility from shortened muscles, tendons, fasciae, and skin from any cause. 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.

TYPES OF ANKYLOSIS

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.*, dislocation and fracture of a joint) also by pyogenic infection, gonorrhea, tuberculosis, rheumatic or gouty diatheses.

2. *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.

3. *Ankylosis in the proliferative type of non-tuberculous arthritis* (arthritis deformans), as described by Nichols and Richardson. According to these investigators, ankylosis is

produced in three ways, *viz.:* Proliferation of the perichondrium which is readily transformed into cartilage or bone; in other instances, new bone is formed from osteoblasts arising in the bone-marrow; rarely, fibrous tissue is transformed into bone.

Etiology

The causes of true ankylosis are acute and chronic inflammation of a joint from any cause 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 ankylosis. 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. Fibrous ankylosis is often made worse rather than better by forcible manipulation.

Treatment

The limb should preferably be fixed in a position of abduction, sufficient to compensate almost completely for bony shortening of the limb with the thigh flexed 10 or 15 degrees, and the foot slightly rotated outward. The usual 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 limp. 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. The gait is more natural if the foot is rotated a little inward rather than straight forward. Unfortunately, these precautionary measures are often neglected, and it is the rule rather than the exception to find ankylosis in the position of deformity, namely, flexion and adduction.

For the technique of osteotomy for correction of deformity see page 233.

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. When to manipulate requires judgment based upon a great deal of experience. Massage should precede and follow manipulation. In conditions resulting in marked osteoporosis an excess of massage should precede manipulation because of danger of crushing the bony elements of the joint or fracturing the neck of the femur. Adjuncts to manipulation are baking and vibratory massage. Various forms of electricity and electric light baths may also be tried.

Forcible stretching under anesthesia is a reprehensible practice if promiscuously performed. Unless it can be apprehended 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.

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 construct 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.

Formerly it was the opinion of the author, as well as that of others, that in the case of bony ankylosis, if the position of the limb was good (slight flexion and abduction), it was better let alone, unless the condition was bilateral or the patient insisted upon mobility by operation. However, since bone reconstruction methods have made possible the providing of leverage for the abductor and other muscles with marked increase of function, stability and weight-bearing, the pendulum has swung strongly toward arthroplasty.

In analyzing the reason for skepticism on the part of some regarding the wisdom of mobilizing ankylosed hips, one finds considerable difference of opinion among the best of surgeons. In most instances, however, the failure to secure active muscular stability, which many times results from the usual type of operation, is the reason. Henderson, reviewing the end results of arthroplasties of the jaw, elbow, knee and hip, found those for the hip the poorest. The problem is obviously more complicated in weight-bearing joints. The occupation and social status of the patient, as well as his temperament, are often determining factors in deciding whether or not to operate, where the relationship of the femur to the pelvis is favorable. The patient must be a mentally stable individual who is willing to go forward with the necessary prolongation of postoperative physiotherapy. When the hip and knee on the same side are both ankylosed, the advantages of arthroplasty are much enhanced.

Stability by muscle action is very important at the hip, and, although the rotary nature of the joint lends itself to arthroplasty, unfortunate results have followed arthroplasty when stability was not obtained.

Arthroplasty in cases of tuberculosis should be approached with a great deal of conservatism; and only when the bony ankylosis is complete and the roentgenogram shows evidence of complete disappearance of all disease and a complete homogeneity of bone structure throughout the operative field, should operation be advised (Fig. 68).

Murphy in 1904 reported his technique for arthroplasty of the hip, and in 1906 Hoffa reported five arthroplasties of the

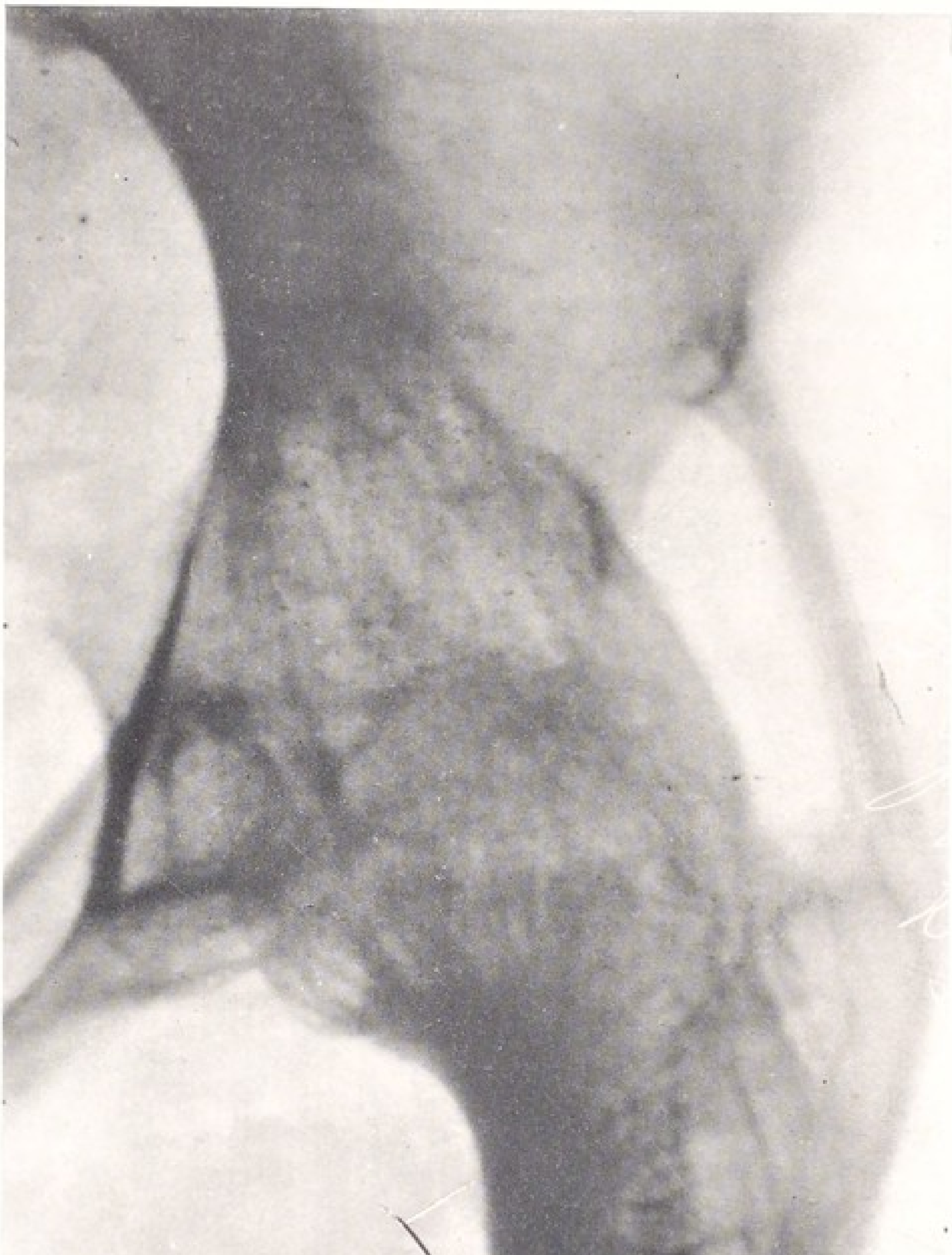


FIG. 68. X-ray to illustrate a common occurrence in tuberculosis of hip. Case failed to respond to conservative treatment over a period of six years, with resultant knock-knee and knee laxity. Extra-articular tibial bone grafts relieved symptoms, fused hip and cured condition.

hip. From that time on, an increasing number are found in the literature. In fact, in my hands arthroplasty of the hip has become so dependable and well regarded that whenever

Fig. 69. Same case as Figure 68 after removal of most of tibial grafts and an arthroplasty restoring motion to within 20 degrees of normal. Stumps of grafts were left to increase length of lever at top of femur for trochanteric muscles to pull upon, thus increasing strength of abduction and weight-bearing. Great conservatism should be exercised in selecting such cases for mobilizing operation.

doing an operation to stiffen a joint, if that case is a possible favorable one for future arthroplasty, I so plan my arthrodesing operation as to make it as favorable as possible for the future mobilizing operation. The points in favor of a future restoration of motion to a joint are: Favorable age and temperament of patient; satisfactory degree of preservation of overlying soft parts and muscles; and satisfactory general condition of limb, including bone at the site of the proposed operation. Therefore, in doing an arthrodesis, in a case which is favorable for a future mobilizing operation, I prefer to take bone for the graft elsewhere, rather than to disturb unduly periarticular structures or important surrounding muscles by obtaining the bone-graft material locally. At the hip, tibial or iliac grafts are preferable, because of their adequacy of length and strength, thus making it unnecessary to

FIG. 70. Same case as Figures 68 and 69, showing satisfactory, painless motion at left hip.

incorporate them in the joint itself. If there has been an approximation of the great trochanter to the rim of the acetabulum, because of telescoping from bone destruction, then graft material from the outer table of the ilium can be obtained of sufficient dimensions. Obtaining bone from the great trochanter has, besides the disturbance of the hip musculature, an additional disadvantage in that it shortens the trochanter-femoral-neck leverage, an important item in muscle control of the hip. At the knee, for the same reason, I no longer employ the patella as a source for arthrodesing material. After its diseased portion has been removed, the patella is left as intact as possible for the future arthroplasty.

To be classed as a good result in arthroplasty of the hip, there should be a minimum amount of voluntary flexion of at least 35 degrees. Everything being considered, a hip that possesses 35 degrees of painless, active motion, is far superior to a stiff hip. Not only should the hip joint have motion to allow proper sitting, but it should be painless and function in locomotion, particularly in bearing the weight of the body. It is far better to have a stiff, immobile hip than one accompanied by weakness and lack of satisfactory weight-bearing or abduction. One author goes on to say that "the more nearly the joint is similar in size and shape to the original joint, the greater will be the stability. Hence, arthroplasty is not a resection!" This statement should be challenged. A ball-and-socket joint situated at the hip cannot have *per se* a desirable amount of motion and still be stable, because passive stability could only result from the capsule acting as check ligaments to motion, and this, in itself, would prevent adequate motion. Desirable stability with a large range of motion must come from muscle control. One frequently sees excellently functioning hip-joints when there has been, from disease, an extensive destruction of bone and no semblance of a ball-and-socket joint remaining. The reason for this is muscle control which is the all important consideration as to whether a hip is stable and whether there is a satisfactory amount of active motion and weight-bearing.

The mechanics of the hip can be resolved into simple terms. The hip joint itself is a fulcrum point situated at the end of a lever (namely, the neck of the femur). The distal end of this lever (the great trochanter) is controlled by means of powerful muscles that are able, because of this mechanical setup, to pull or actively lift the limb at an angle with the pelvis. This active abduction is a most important feature of locomotion in that it is the essence of weight-bearing. In other words, it is impossible for an individual to bear weight satisfactorily on a limb when the hip is mobile unless the muscle control is such that the limb can be held so that it will not swing into adduction. This is brought about by the mechanical action of the abductor muscles of the hip pulling on the distal end of this lever.

If this statement, used as a premise, is true and if it is possible to maintain this muscular control, then careful modeling with the head of the femur fully filling a deep new-made acetabulum (with the difficulty of securing a free range of motion incidental thereto) is not necessary or desirable. The deeper the new acetabulum is made, and the corresponding femoral head fitted to it, the less the chance of securing a good range of motion. Therefore, in selecting cases for arthroplasties of the hip, one should be sure that the muscles about the hip are reasonably preserved. Formerly, it was my practice to rule out cases in which there had been extensive shortening of the neck of the femur, either from bone destruction or from a telescoping of the head and neck of the femur into the pelvis, for the reason that even if the abductor muscles were intact one could never expect satisfactory function in active abduction because the trochanter-femoral-neck lever would be still further shortened by the modeling of the new-formed hip, and thus furnish inadequate leverage for the abduction or weight-bearing muscles to pull upon.

This was fully realized twenty years ago when designing my reconstruction-arthroplasty for ununited fractures of the hip with removal of the head of the femur, and placement of the denuded trochanter in the acetabulum; because of this, the leverage action of the neck of the femur that was lost was restored by lengthening the lever on the outer side of the long axis of the shaft of the femur by erecting, laterally and obliquely to the shaft, a bone muscle lever with the insertion of the hip abductors to its upper end undisturbed. Later, in order both to increase the length of this lever and to assure its maintenance, the removed femoral head was shaped as a wedge and placed so as to hold it outward. In this way, one is able in such cases, even in the complete absence of the head and neck of the femur, with the denuded trochanter placed in the acetabulum, to establish a lever equally as long as the normal trochanter-neck lever of a normal joint. Whether the resulting reconstructed joint follows a non-union, or a shallow modeled acetabulum of an arthroplasty for ankylosis, the mechanical conditions brought about in the above manner prevent dislocation when the limb approximates the midline, which is a real hazard, unless provided against. The *modus operandi* is as follows: As the limb seeks the midline, the upper end of the erected bone-graft lever travels farther and farther away from the rim of the acetabulum and the side of the pelvis, and thus not only puts an increasing tension on the short abductor muscles but also on the surrounding fascial structures, thus holding the head of the femur securely in the acetabulum.

Because of the very satisfactory experience with this mechanical setup in a large number of cases of ununited fractures of the hip, I began ten years ago to apply the same principle to cases of paralysis of the abductor muscles and also to cases of arthroplasty where, because of bone destruction, the trochanter-neck lever is practically absent or much shortened, and a satisfactory result by arthroplasty alone not possible. Therefore, in recent years, the destruction of the head and neck of the femur (with telescoping) has not been considered a contraindication in selecting cases for operation, in that I have found in doing an arthroplasty that a hip-joint could be modeled with the head of the femur much smaller than the acetabulum, with sufficient fascia and fat to fill in the interspaces, and that the mechanical influences brought about by the provision of leverage action for muscle control on the outer side of the trochanter not only prevented dislocation, but allowed active abduction and satisfactory weight-bearing.

Author's Technique. The patient should be placed on a fracture orthopedic table. The Smith-Petersen approach affords such satisfactory exposure that it is the incision of

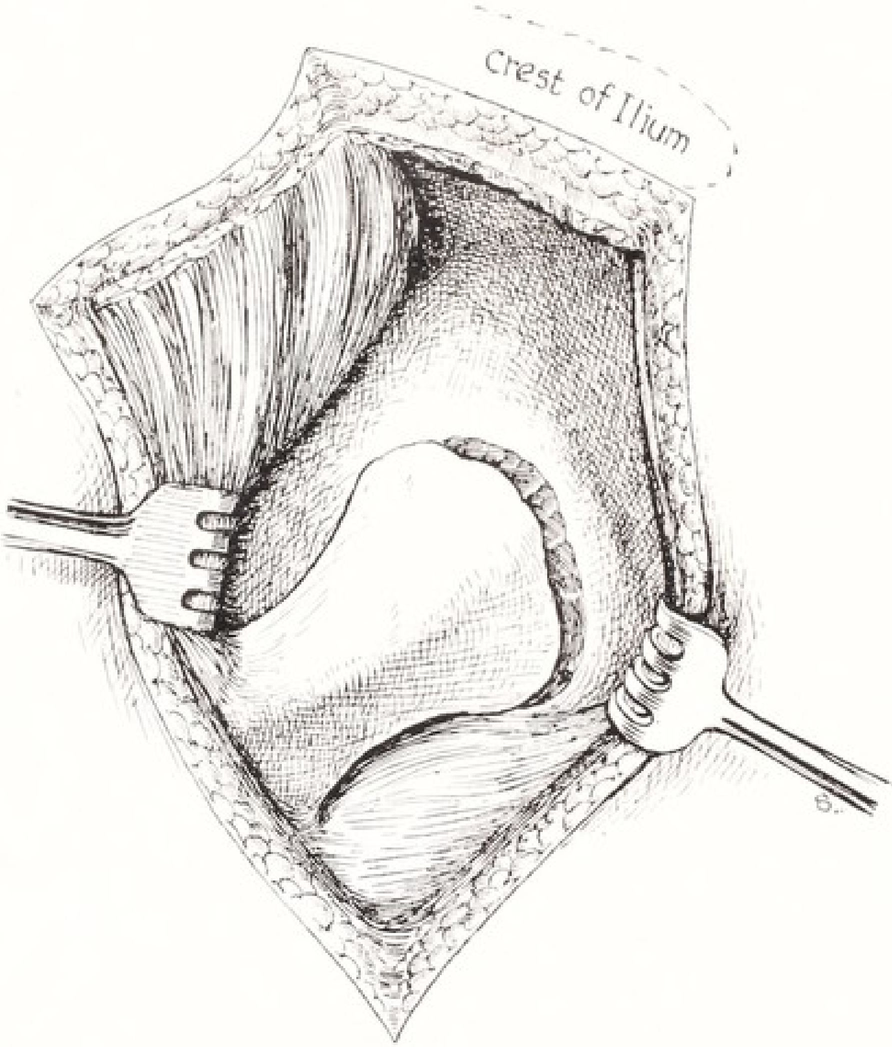


FIG. 71.

choice for all intra-articular operations. The incision begins at a point about 4 inches below the anterior-superior iliac spine, and is carried along the outer border of the sartorius muscle, upward to the anterior spine and 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 a large carver's or Murphy's gouge, the femur is separated from the pelvis (Fig. 71), care being taken to

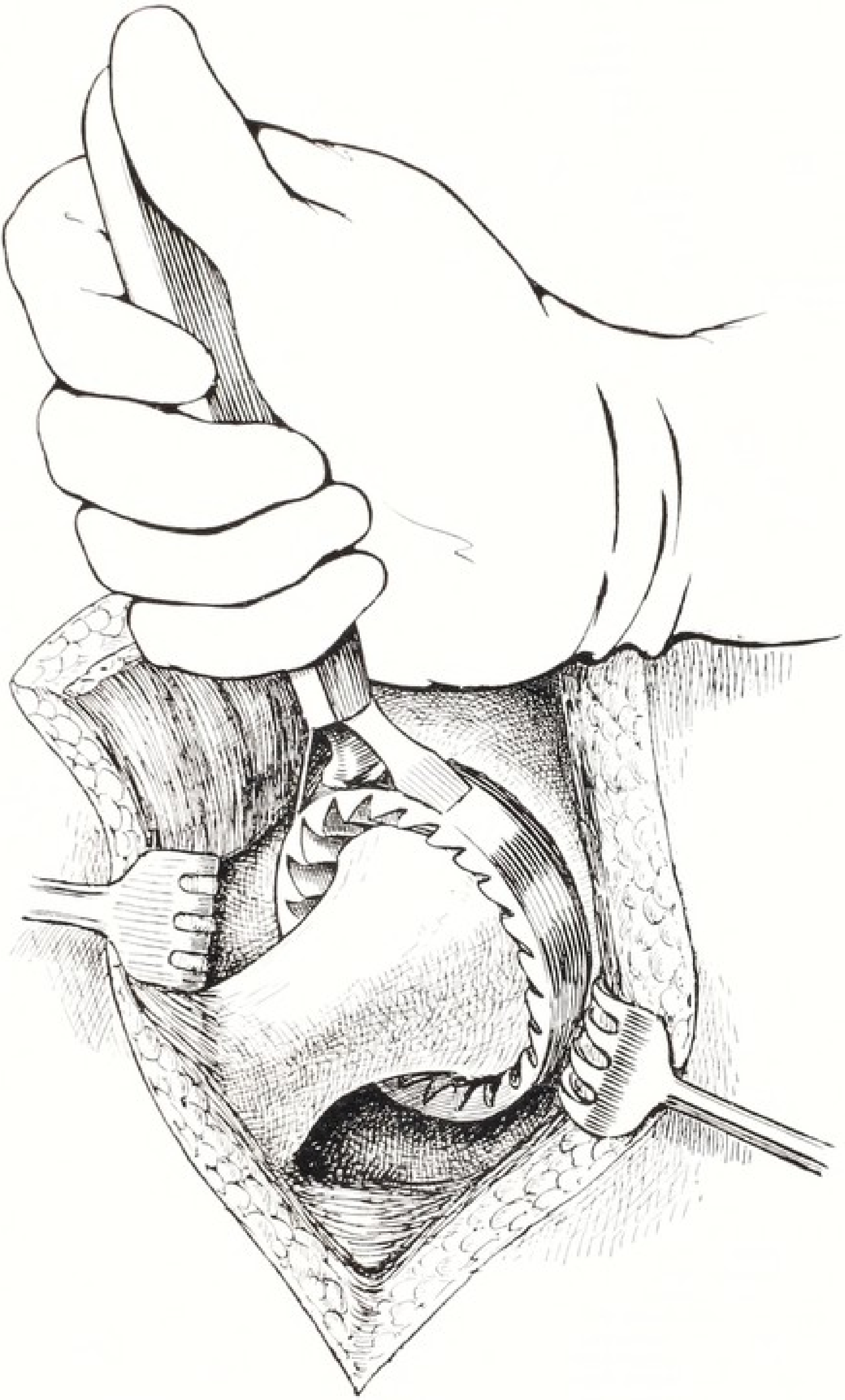


Fig. 72.

make the bone incision in such a way that a rounded femoral head and a corresponding acetabular cavity are shaped. The acetabulum is not shaped nearly as deeply as formerly, be-

Fig. 73.

cause of the fact that I find the present technique obviates the danger of dislocation, and further that this is a very satisfactory influence in bringing about a greater degree of ultimate motion. The various carver's gouges and chisels are of great service in plastic bone work, especially in arthroplastics. The large variety of cutting edges and curvatures of the chisel

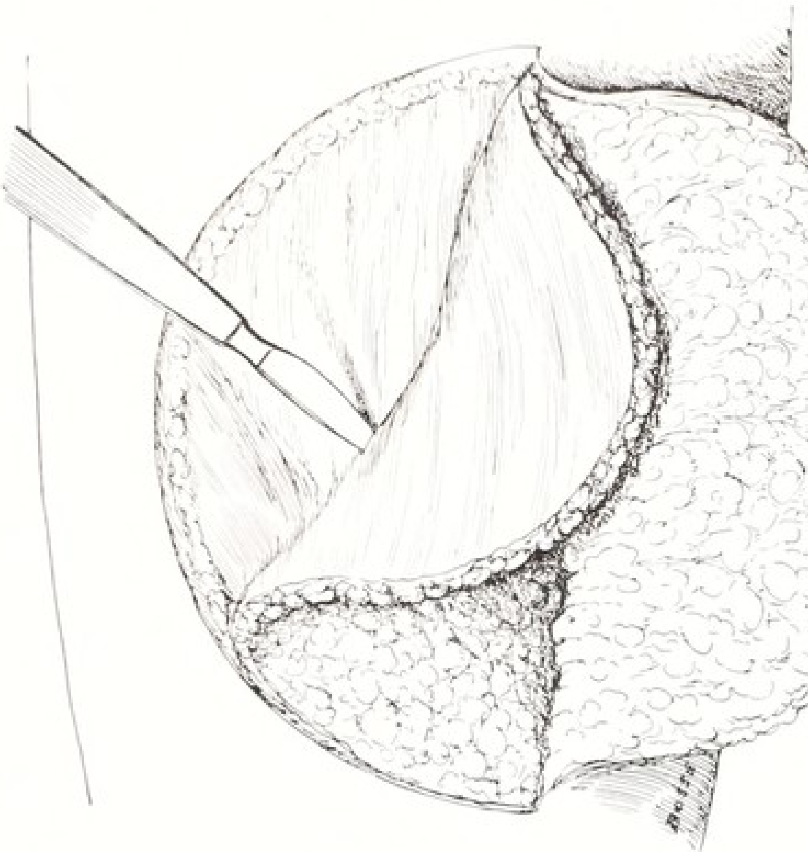


FIG. 71. Flap of fascia and fat being freed from underlying muscles of thigh. (From Albee's "Orthopedic and Reconstruction Surgery," Saunders.)

or gouge 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 spherical convex and concave surfaces by arthroplastic hip rasps, modified from Murphy's (Figs. 72 and 73). 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 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 an 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

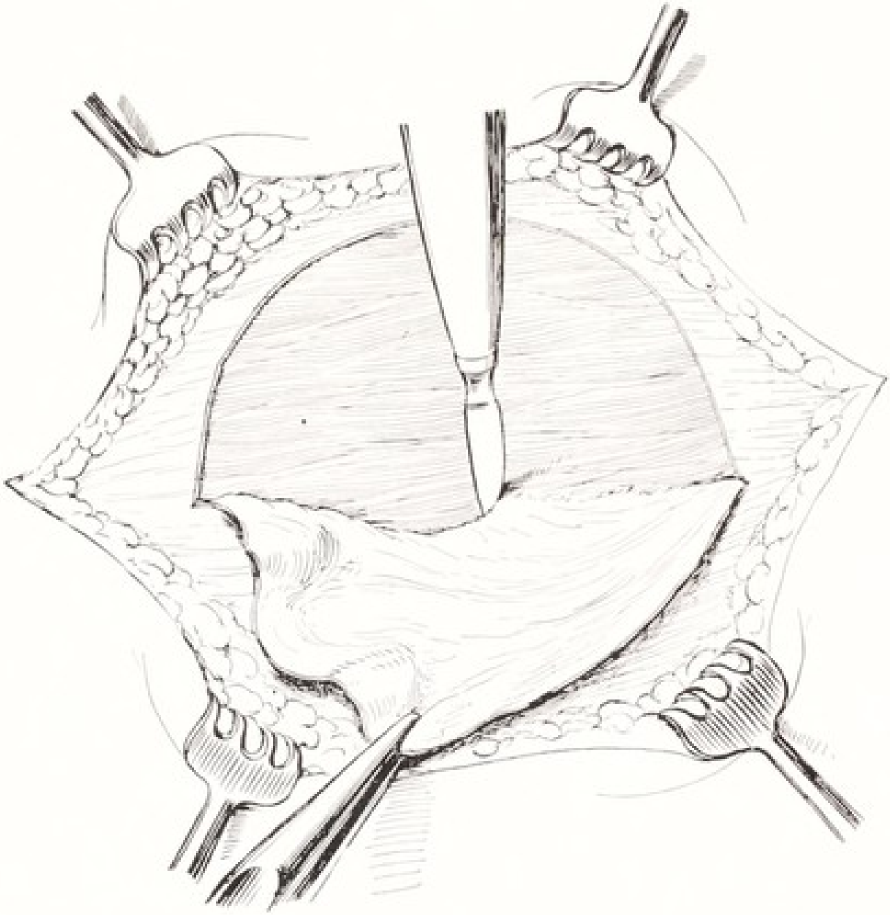


FIG. 75. Improper method of dissecting-out a fascial transplant. By this method no fat is left adherent to fascia. (From Albee's "Orthopedic and Reconstruction Surgery," Saunders.)

with a fountain of saline solution over the table, and to allow the easy insertion of the fascial flap, about to be obtained from the thigh, lower down. A semicircular skin incision is made on the outer side of the thigh, midway between the hip wound and the knee, and a quadrilateral piece of fascia lata with as much fat as is obtainable, about 4 inches long by 3½ inches wide (in adults) is secured. The subcutaneous layer of fat is divided in equal halves, one-half being left attached to the skin and the other half to the graft, which is subsequently to be removed (Figs. 74 and 75). 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.

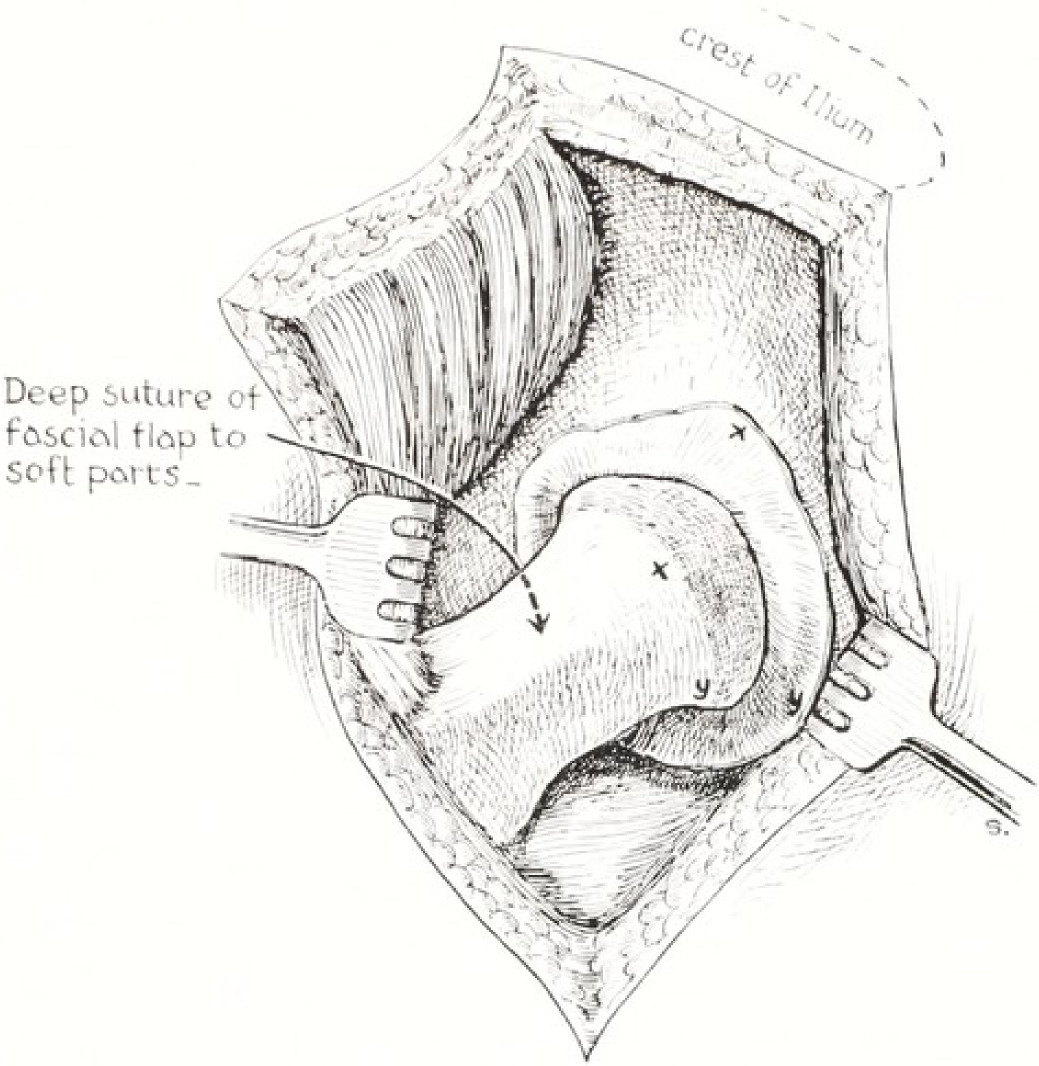


FIG. 76. Fascial and fat transplant in place.

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.

If, at this point, it is thought that the leverage action of the neck of the femur is not sufficient, a bone fragment, consisting of the tip and the outer surface of the trochanter of a varying length (approximately 3½ inches) is separated with a broad thin osteotome, with the insertion of the abductor muscles intact, and swung outward from the shaft of the femur from 20 to 35 degrees, by producing a green-stick fracture at its lower end. Into this triangular space, between the remaining portion of the shaft of the femur and the bone fragment, a segment of the crest and outer table of the ilium

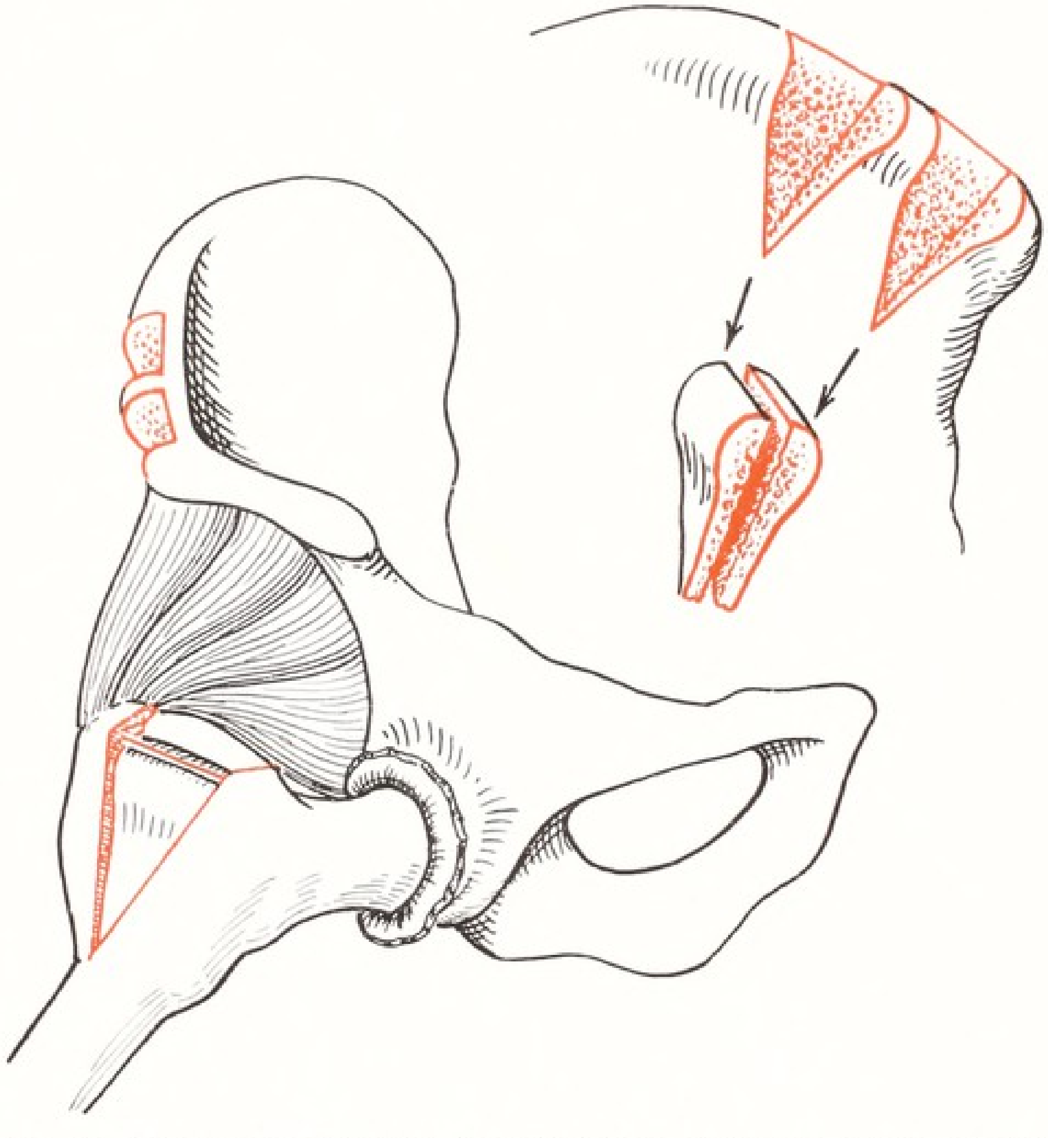


Fig. 77. Diagram to illustrate lengthening of lever arm at top of femur where it has been shortened following arthroplasty to restore motion. Loss of bone may be from destruction by disease or trauma plus necessary removal of bone at operation. This same principle and operation are also applied in lengthening of this lever beyond its anatomical length when the abductor muscles have been weakened by infantile paralysis or other cause.

is fitted (Fig. 77). This graft may be supplemented by fragments of cancellous and cortical bone, also obtained from the ilium. This bone-muscle lever operation may be done at the same time as the arthroplasty or at a later date, as the surgeon thinks best. Dressings and stickers to the thigh are applied. With the limb in moderate abduction, a plaster-of-Paris spica is applied from above the costal margins on the opposite side to the toes, with stickers coming out through the plaster, above the ankle. From 15 to 20 pounds of traction with pulley and weight is applied immediately and maintained for three weeks after the removal of the plaster spica (three weeks postoperatively), 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, during which time, or longer, daily massage and active and passive motion are carried out. Traction is most necessary and should be applied before the patient comes out from under the influence of the anesthetic, because of the devitalizing and crushing effect that would otherwise be produced on the fascial graft by the involuntary contraction of the powerful thigh muscles. I have found that with a pulley and rope erected over the bed, fastened to a sling beneath the knee, the patient is able to help very materially in mobilizing the joint by constantly pulling the hip into flexion. This engages the patient's attention, and is a real help as a part of the postoperative physiotherapy.

A ball-and-socket joint, particularly the hip, with its anatomic provision for muscular control, cannot be stabilized by modeling of the joint contours alone; the fit of a ball-and-socket joint in machinery may be so accurate as to be within a few microns and still the motion be as free as with a loose fit.

The stability of a freely movable hip-joint, particularly in weight-bearing, which is the most important consideration, must be through the medium of muscle control, especially the short trochanteric muscles and their pull upon the trochanter-femoral-neck lever. In most arthroplastic procedures, this lever is either shortened to such a degree that it no longer functions, or it may be entirely obliterated. Hence, the necessity for its elongation or restoration by surgical means, either at the primary operation or later at a second operation (see Chap. VIII, p. 218).

*Murphy's Technique.** Murphy used three incisions; the original one was U-shaped, beginning 1½ inches above the trochanter and 1 inch behind it, extending down 2 inches below and passing under and in front of it up to a point opposite the commencement. Sometimes the skin was divided down at the lowest point of the U to form the large interposed flap. The second incision was along the iliotrochanter line 1 inch below and in front of the trochanter and upward for about 5 inches in a straight line with the anterior superior spine of the ilium. The third was a modification of the second, in that the incision was curved and convexed backward behind the trochanter. His next step was to free the trochanter by a chain saw and retract it upward with the attached muscle.

The ankylosed head of the femur was severed from the ilium, as near the anatomical line as possible, with a carpenter's curved chisel. It was driven obliquely into the acetabular cavity for 1 inch. The head was fractured out and the acetabular cavity fashioned with a special globular burr. A corresponding cup-shaped cavity was made to conform to the femoral head.

A flap of fat and fascia lata, and subcutaneous fatty tissue (¼ inch thick) was inserted behind the head and neck of the femur, and the edge was sutured to the acetabular margin and to the capsular ligament with phosphor bronze wire. The head was replaced. The trochanter was nailed in place. The fascia was re-approximated by chromic catgut and the skin sutured with silkworm or horsehair. No drainage was used.

The field operated upon was dusted with bismuth subiodide powder and the wound sealed with gauze saturated with collodion. A pad of plain sterile gauze, moistened with

* Murphy, J. B. Arthroplasty of the hip. *J. Bone & Joint Surg.*, 8: 769, 1926.

95 per cent alcohol and 61 per cent phenol, was placed over the hip 4 or 5 inches beyond the line of incision on either side. A Rainey splint and Buck's extension with 20 to 35 pounds were applied. Both legs were dressed in an abducted position.

Passive motion was instituted in three or four weeks.

In the majority of cases of ankylosis of the hip reported by Murphy, there resulted a good range of motion and ability to walk without support.

*Baer's Technique.** "The hip is exposed by the Ollier-Mikulicz incision. The trochanter, with its attachments, is turned back and the neck and head of bone, as well as the part of the ilium immediately above the acetabulum, are exposed. The capsule is split parallel with the neck and stripped from the underlying bone. With a wood-carver's gouge, the head is separated from the acetabulum. Quite often, one can find no line of demarcation between the femoral head and the acetabulum. One must then chisel through the bone where one supposes the old articulation to have been. The head is now delivered completely from the acetabulum. It is rounded off and then filed down, making it as smooth as possible. The acetabulum is now curetted and reamed out, making it large enough to receive the head. The smallest possible amount of bone should be removed. Indeed we should cleave to the old lines of the joint, both head and socket, if possible. The head of the bone and the acetabulum should be kept as near the normal size as possible. Remember we are doing an arthroplasty and not a resection. All fibrous tissues in the neighborhood of the joint should be sacrified. All tissues which tend to form bone should be handled with the greatest care.

"The pig's bladder membrane, which has been previously immersed in salt solution for ten minutes, is now placed about the newly formed head and sewn with forty-day chromic catgut to the fibrous covering at the distal portion

* Baer, W. S. Arthroplasty of the hip. *J. Bone & Joint Surg.*, 8: 769, 1926.

of the femoral neck. Thus the head and the neck of the bone are covered by a sac, as it were. Care must be taken not to tear or perforate the membrane.

"The covered head is now replaced in the newly formed acetabulum. The trochanter is nailed to the shaft, at the point from which it was removed. The fascia lata is brought together with forty-day chromic catgut. This skin is sewn with subcutaneous silver wire. Great care should be used to ensure complete haemostasia, as no drainage is used in these cases. The leg is now encased in plaster, from the nipple line to the toes, the position being one of 25° abduction and slight internal rotation.

"*After-treatment.* The leg remains in the plaster cast for forty-eight hours, so as to control, by pressure of the bandage, any possible hemorrhage. The cast is then removed, and the leg placed in a Thomas traction splint, with a pull of 20 pounds.

"In this manner the leg is left absolutely alone until the twenty-first day. The splint is then removed and the silver wire pulled out. For one more week the patient is allowed to remain in bed and to use voluntary active movements of his own hip. At the end of the fourth week he is given crutches and allowed to bear weight on his affected leg. Voluntary motions and active exercises are encouraged. Massage and passive motion are instituted. Shortly afterwards, mechanical therapy and thermotherapy are started. As soon as possible, a cane is substituted for the crutch. From now on the range of motion gradually increases. One should not forcibly try, under anesthesia, to hasten matters, but by gentle massage and mild passive motion, progressively stretch the peri-articular tissues. Limitation of motion is not generally due to a poor arthroplasty, but is due to the stiffness and unstretchableness of the peri-articular tissues incident to the pathology which caused the ankylosis. Care should have been taken preceding or at the time of operation, to remove all scars and thick fibrous tissue."

Chapter IX

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.

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. 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

Anatomical Types. Bending of the femoral neck may occur at any one of three portions. Thus, the following anatomical types are recognized (Fig. 78):

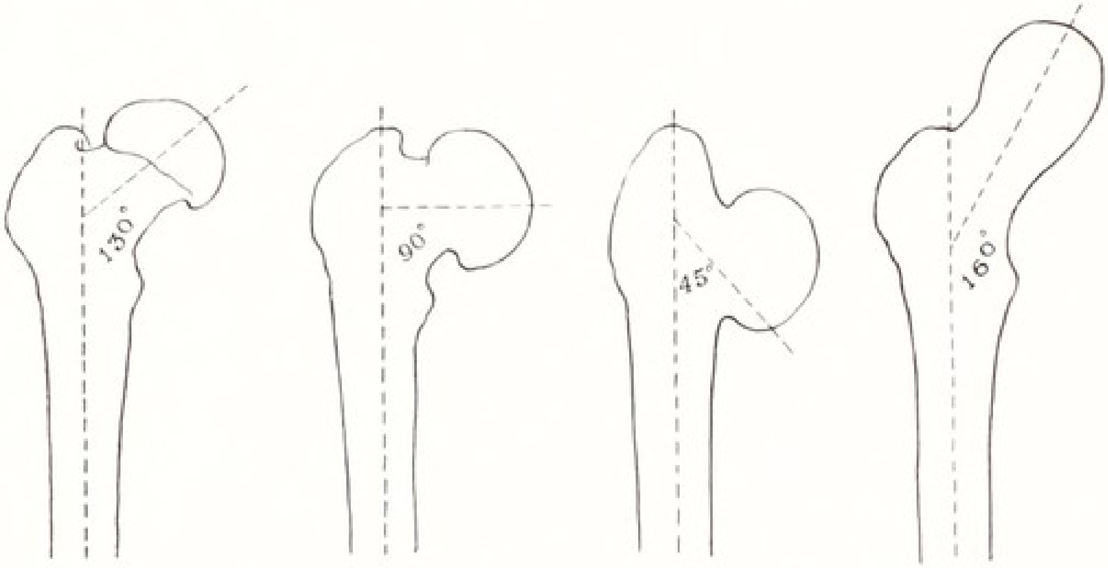


Fig. 78. Angles of inclination of femoral neck from normal to two stages of coxa vara. Last drawing indicates coxa valga.

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.

2. *Epiphyseal Coxa Vara.* This 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: it is frequently due to rickets.

Beside the angle of inclination (between neck and shaft), the femoral neck also points forward on an angle of declination (appreciably 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. 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.

Etiology

Coxa vara is not an uncommon affection. 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 the structures and relatively greater length of the femoral neck predispose 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:

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.
        (a) Rickets.
        (b) Osteomalacia.
        (c) Senile osteoporosis.
    (b) Due to inflammatory processes.
        (a) Osteomyelitis.
        (b) Tuberculosis.
        (c) Arthritis deformans.
    (c) Traumatic coxa vara.
        (a) Separation of the epiphysis of the neck in children and adolescents.
        (b) Fracture of the neck of the femur in children and adolescents.
        (c) 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

CERVICAL AND TROCHANTERIC COXA VARA

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 one 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.

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.

In *unilateral coxa vara,* 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 * 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.

In bilateral coxa vara, the *gait* and *attitude* are striking phenomena. The gait is characterized by swaying of the body to overcome the adduction 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 † 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.

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

* Whitman, R. A treatise on orthopedic surgery. Ed. 2, Phila., Lea, 1903, p. 541.

† *Loc. cit.*, p. 547.

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.

CONGENITAL COXA VARA

The congenital form of coxa vara was first described in 1896 by Kredel.* 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 other 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 in 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 clinically.

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.

* Kredel, L. Coxa vara congenita. *Centralbl. f. Chir.*, 23: 969, 1896.

1. *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.

2. *Tuberculous coxitis*, or tuberculous hip disease, may be confused with coxa vara if the latter is in an acute state clinically and no *x*-ray study is made (*i.e.*, spasm, fixation and pain). 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

The objectives to be gained from operative procedures in coxa vara are primarily to restore motion at the hip, particularly in abduction, which has been lost because of the change in the angle between the neck and the shaft of the femur; to a lesser degree, to restore rotation and overcome shortening at the hip.

CERVICAL AND TROCHANTERIC COXA VARA

Methods of treatment for cervical and trochanteric coxa vara in order of preference are:

1. Forcible abduction and fixation in plaster-of-Paris;
2. Circular osteotomy (Brackett);
3. Cuneiform osteotomy (Whitman);
4. Cuneiform osteotomy (Mayer);
5. Linear osteotomy (Gant).

Forcible Abduction and Fixation in Plaster-of-Paris. On the assumption that the affected neck is malleable in coxa vara occurring in young children with acute rickets where the symptoms have rapidly increased in extent and severity, forcible abduction of the thigh may be effective in restoring the angle of inclination of the femoral neck. In this maneuver, 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).

Author's Comment. 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 effective treatment.

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: circular osteotomy and the cuneiform osteotomy.

Circular Osteotomy. Credit is due Brackett * for perfecting the technique of circular osteotomy. His operation resembles that of Sir Robert Jones. It is mechanically excellent and produces no shortening. Brackett describes 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, the higher on the femur is the point of origin

* Brackett, E. G. A study of the different approaches to the hip-joint. *Boston M. & S. J.*, 166: 235, 1912.

of the incision. If flexion deformity is marked, the vertical (anteroposterior) line of osteotomy is deflected slightly backward to produce a slight overhanging of the anterior edge of the upper fragment.

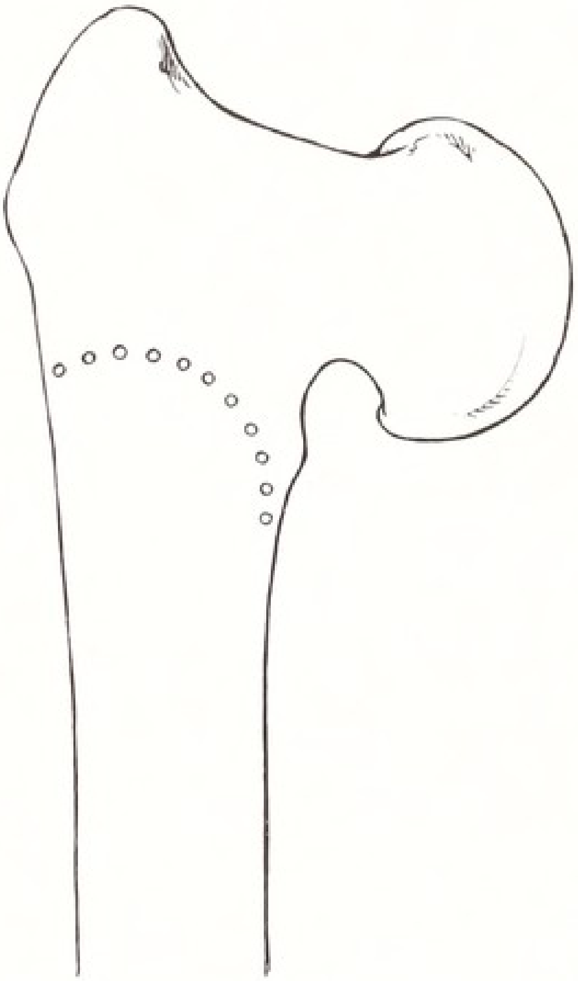


Fig. 79.

Author's Comment. I almost invariably employ circular osteotomy in preference to linear osteotomy, not only because the latter is not mechanically sound, 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. 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.

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.

Modification of Brackett's Technique. I have modified Brackett's technique by prolonging the inner portion of the 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 additional safeguard against sliding-by and possible displace-

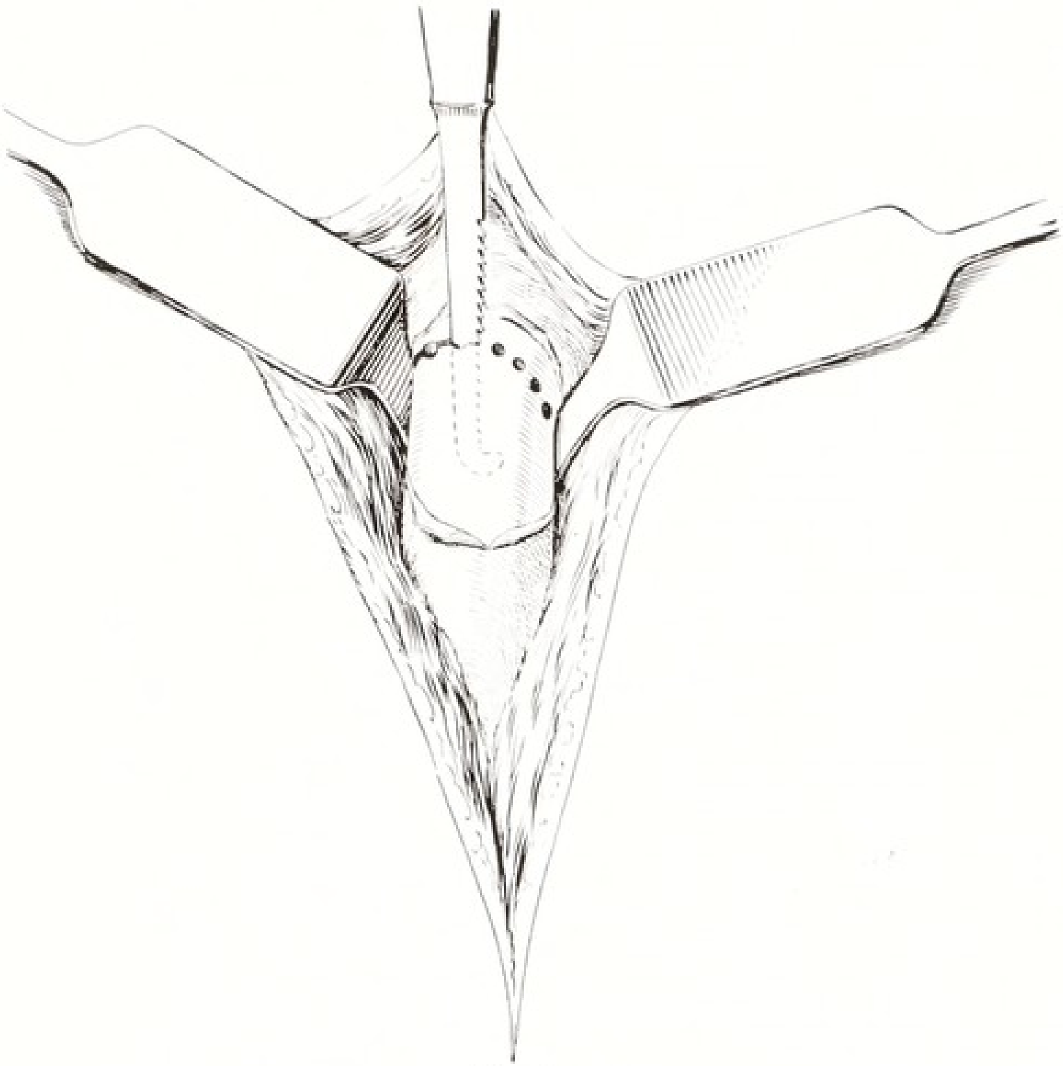


FIG. 80.

ment of the two fragments and a broader surface of contact. The motor drill is used in making the circular osteotomy, the holes being connected with Jones's saw (Figs. 79 and 80).

Circular osteotomy possesses definite advantages over other methods as follows:

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, 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 (Fig. 81).

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.

Cuneiform Osteotomy. Whitman 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 technique, as follows:

Vigorous preliminary stretching and massage of contractured muscular and ligamentous structures which limit abduction should be practiced. 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, as obtained from the roentgenogram, 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 130 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 operat-

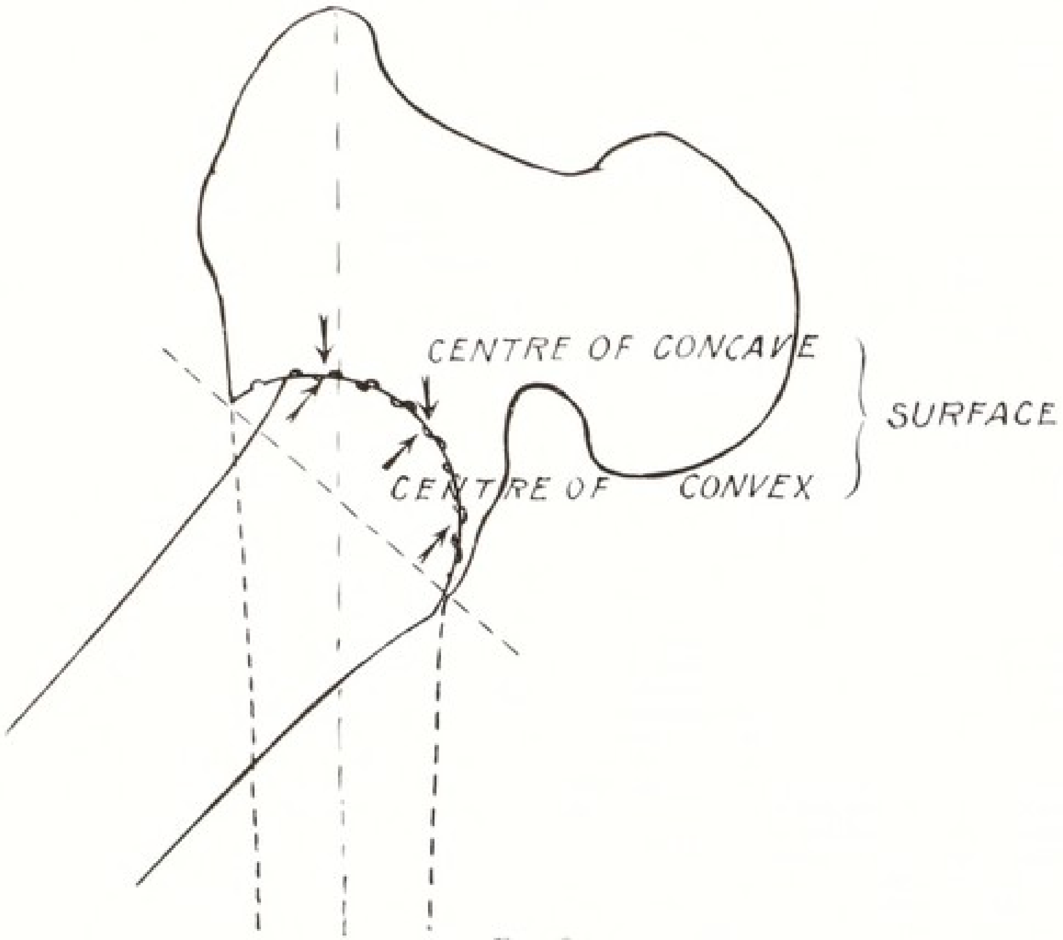


FIG. 81.

ing 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 (Fig. 82), the lower section is cut at right angles to the shaft of the femur, while the upper section is made more oblique. After removing the wedge, the limb is strongly abducted; this 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 the 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. The normal angle between the neck and the shaft is

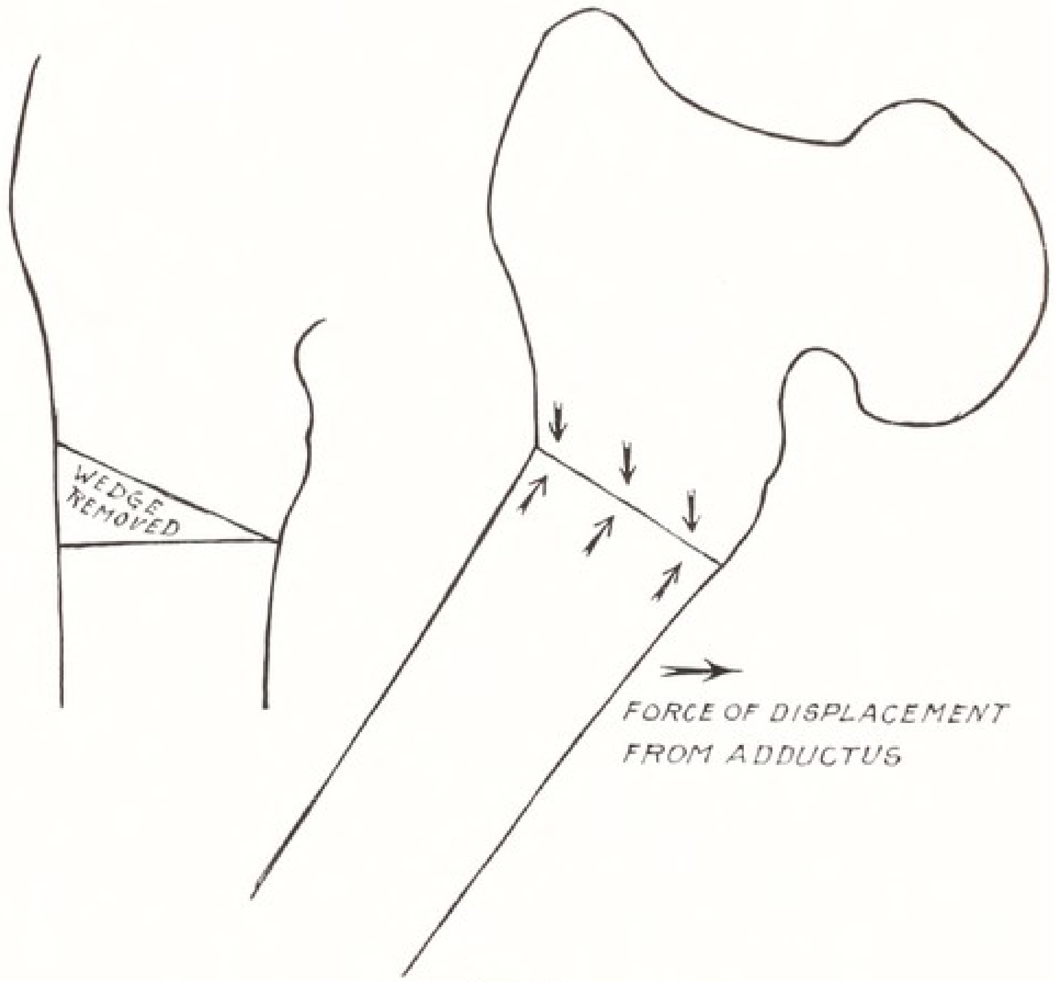


Fig. 82.

thus restored. 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

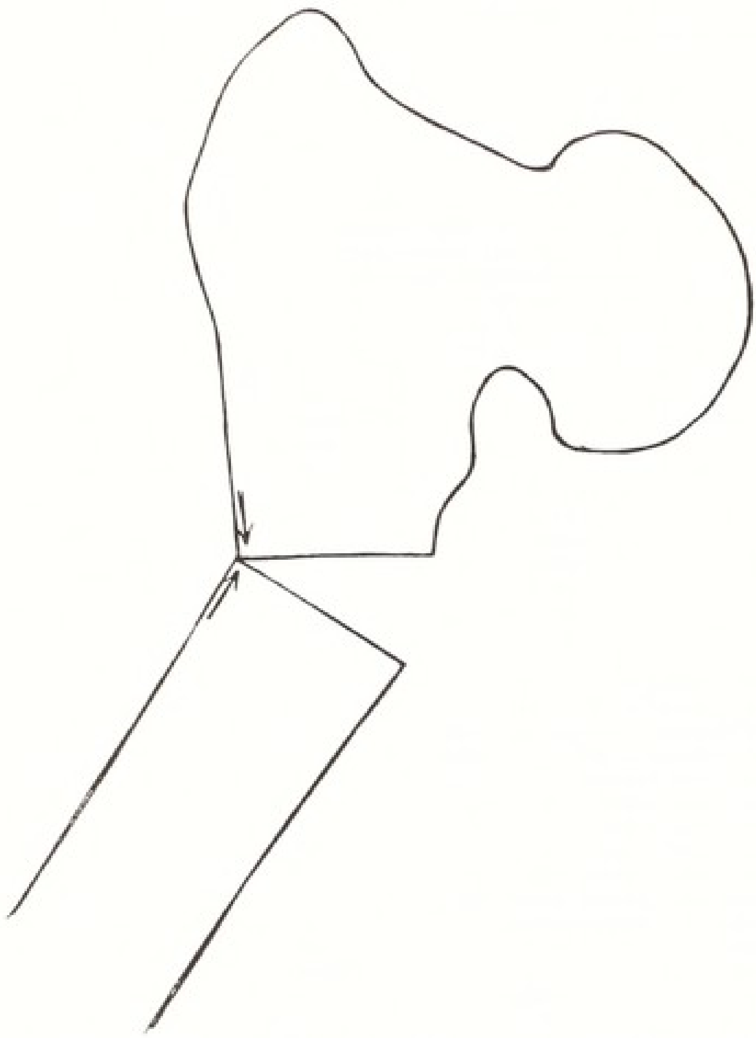


FIG. 83. Transverse osteotomy best done when there is ankylosis at hip joint, thus allowing better control of upper femoral fragment. Danger of slipping and possible displacement is emphasized by corner-to-corner contact of fragment in cases where upper femoral fragment is mobile.

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 medial 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.

Linear Osteotomy. In the method of linear osteotomy described by Gant, 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 (Fig. 83).

Author's Comment. I believe that this operation is not mechanically sound. Its only claim to attention is the fact that when subcutaneous osteotomy was in vogue it was the only procedure available. When the hip is not firmly ankylosed a great deal of consideration should be given before this procedure is done. It should be employed only when subcutaneous osteotomy must be performed, a circular or cuneiform section of the femur being impossible by the subcutaneous route.

EPIPHYSEAL COXA VARA (ADOLESCENT—TRAUMATIC)

Wardle * divides cases of slipped epiphysis of the head of the femur into two groups. In one group he places the cases with disordered glandular function in which epiphyses other than the epiphysis of the head of the femur are also involved. In discussing this group he cites the theory advanced by

* Wardle, E. N. Slipped epiphysis of the head of the femur. *Surg., Gynec. Obst.*, 58: 255, 1934.

Kocher in 1894 that the slipping of the epiphysis of the head of the femur may be due to a localized osteomalacia which, tending to occur in the areas of most recently formed bone, weakens the attachments of the epiphyseal cartilage and metaphysis.

The other group of cases are those in which indirect trauma has involved the epiphysis and no joints other than the hip joint are involved. In both groups the body-weight and muscular action are secondary factors increasing deformity. The process *always* starts in *adolescence;* there may or may not be a history of slight trauma or slight strain; quiescent periods alternate with recurrence 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 osteoarthritis of the hip (see Chap. XI, section on Arthritis Deformans). The clinical course of the affection conforms very closely to that observed in juxta-epiphyseal fracture of the upper end of the femur.

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 from symptoms for possibly many years, when from some cause (trauma or osteoarthritis) the symptoms again recurred. If no intercurrent disease is in evidence, the only signs on physical examination are as follows:

Very slight shortening of the limb. Slight limitation of abduction and rotation. X-ray examination shows a flattened and somewhat "mushroomed" femoral head, especially its superior and inner aspects, with giving away of the head at the epiphyseal line (Fig. 84).

FIG. 84. Epiphyseal separation (fracture) at upper end of femur. Note giving away of bone in region of epiphyseal line. This is a case of adolescent coxa vara (epiphyseal type) in a man of eighteen years. (From Albee's "Orthopedic and Reconstruction Surgery," Saunders.)

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 resilient cartilage, during this period, acts as a "shock absorber" and is less liable to disruption.

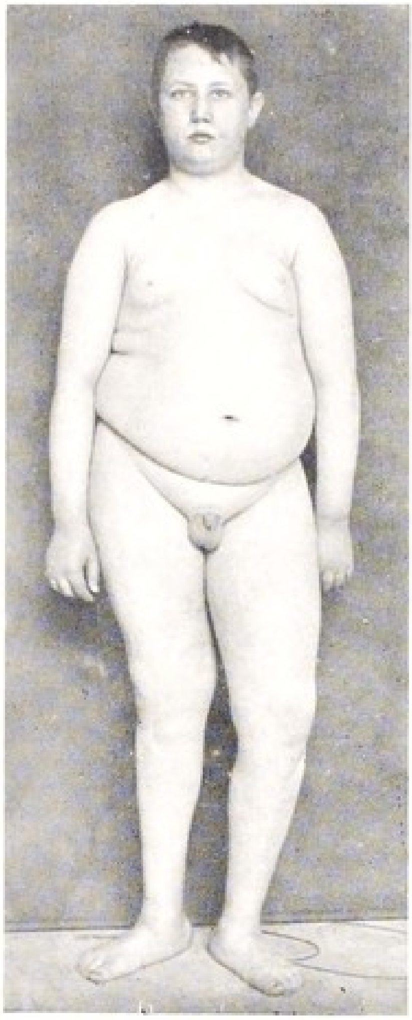


Fig. 85. Dyspituitary type of individual particularly prone to separation of capital epiphysis of femur. This patient had suffered slipping of capital epiphysis of both femora prior to time of this photograph. Eversion of feet is characteristic. (From Albee's "Orthopedic and Reconstruction Surgery," Saunders.)

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 (Fig. 85). Macausland * stated that obesity and endocrine disturbance were observed in at least 19 of his 45 patients and possibly these factors were present in other cases. The majority of his cases were around twelve years of age.

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."

The symptoms or physical signs of this condition are those of fracture of the neck of the femur, with the following additions and exceptions:

Trauma may be very slight. Crepitus, which, however, is rarely obtained, is soft. There is marked fulness at the front

* Macausland, A. R. Separation of the capital femoral epiphyses. *J. Bone & Joint Surg.*, 17: 353, 1935.

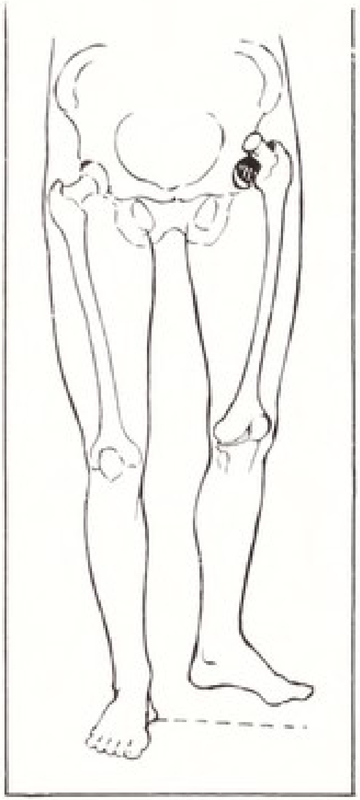


Fig. 86 a.

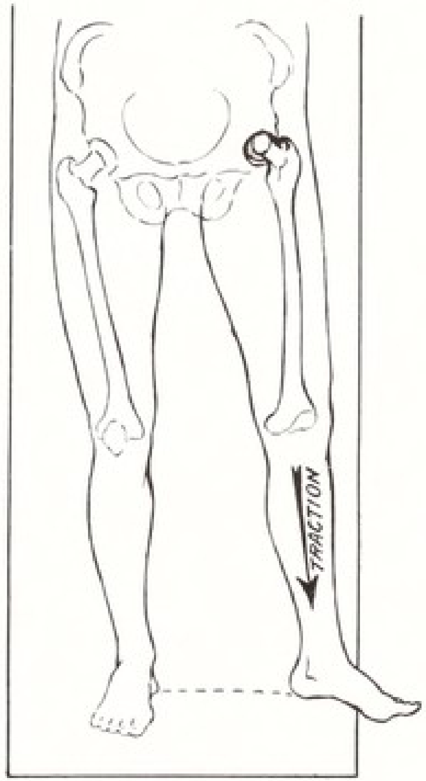


Fig. 86 b.

Fig. 86. Epiphyseal separation (fracture) at upper end of femur. Maneuvers of reduction:

a. Head is free in acetabulum and lies behind and below neck, its epiphyseal (cervical) surface looking directly forward. Neck is dislodged from acetabulum, everted and dislocated upward. Shortening of lines and eversion of foot are marked.

b. First maneuver of reduction. Traction to pull neck down below rim of acetabulum. Eversion (external rotation) still persists.

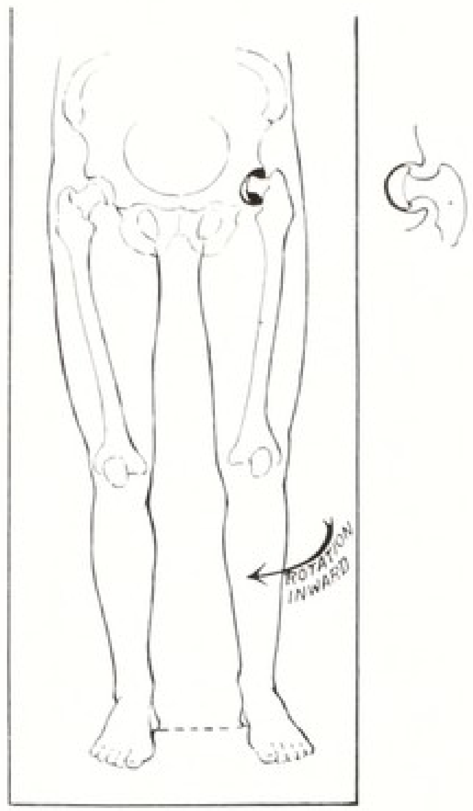


FIG. 86 C.

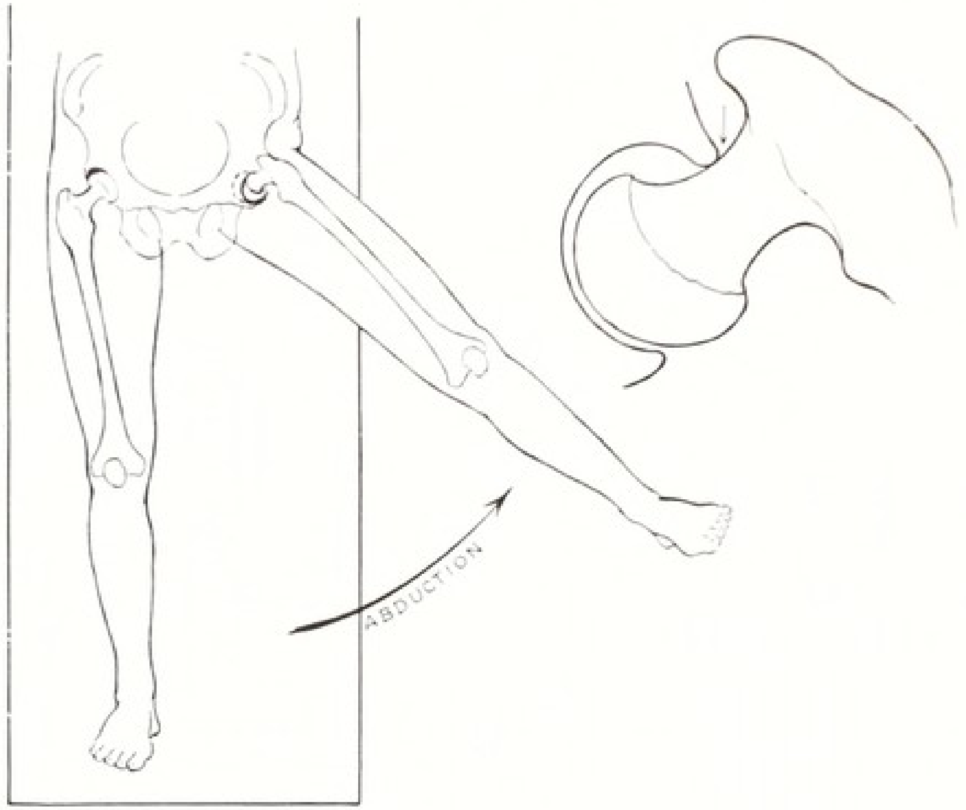


FIG. 86D.

C. Second maneuver of reduction. Inward rotation of femur to throw neck back into acetabulum (correcting eversion) and into contact with head.

D. Third maneuver of reduction. Abduction, to cause femoral neck to impinge upon rim of acetabulum, thus fixing fragments and preventing powerful thigh muscles from pulling femur upward. (From Albee's "Orthopedic and Reconstruction Surgery," Saunders.)

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

Fig. 87. Epiphyseal separation (fracture) at upper end of femur. Perfect reposition of parts by maneuvers shown in Figure 86. (From Albee's "Orthopedic and Reconstruction Surgery," Saunders.)

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

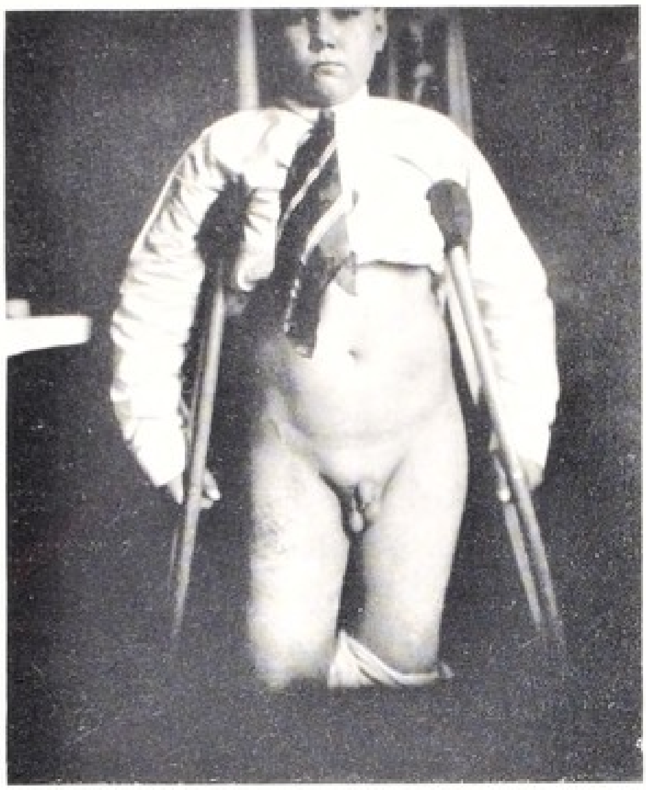


Fig. 88. Type of individual particularly prone to this injury—an adolescent of muscular and obese physique—the dyspituitary type. (From Albee's "Orthopedic and Reconstruction Surgery," Saunders.)

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.

In these cases 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.

Treatment. The methods of treatment in order of preference are:

1. Closed reduction;
2. Open reduction with the insertion of autogenous bone-graft peg;
3. Partial arthroplasty.

1. *Closed Reduction.* If the sliding of the capital epiphysis is of recent origin, manipulation, under an anesthetic, consisting of strong traction, abduction and marked inward rotation obtained by means of a traction table, should be tried. The limb is fixed in this position in a long plaster-of-Paris spica, and 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 operation is usually necessary.

In either event, if the fragments are replaced they can be held in perfect apposition by employing the position of abduction and internal rotation as pointed out by Whitman; * but because of faulty blood-supply to the epiphyseal fragment, I have, in later years, been inserting the autogenous bone-graft peg in selected cases, and have realized improved results.

2. *Open Reduction with or without the Insertion of an Autogenous Bone-graft Peg (Smith-Petersen approach).* The fractured end of the femoral neck (lower fragment) usually presents in the wound. This may be very puzzling on account of the head lying far behind and being entirely obscured by

* Whitman, R. Further observations on injuries to the neck of the femur in early life. *Med. Rec.*, 75: 1, 1909.

the neck (Fig. 89). If the fracture has existed for some time, there may be firm malunion. If so, the neck is separated from the head by means of a chisel which is then used to pry the fragments into position at the same time that strong traction and inward rotation are applied to the limb. Good apposition is secured and the parts are put in a long spica in abduction and marked inward rotation (Fig. 90). In order to hold the forced inward rotation, the leg is flexed on the thigh to a right angle (Figs. 91-93). In this way, the strong inward rotation forces the anteriorly displaced neck back into apposition with the head and causes the posterior parts of the capsule and the unruptured soft parts to become tense, thus acting as a splint.

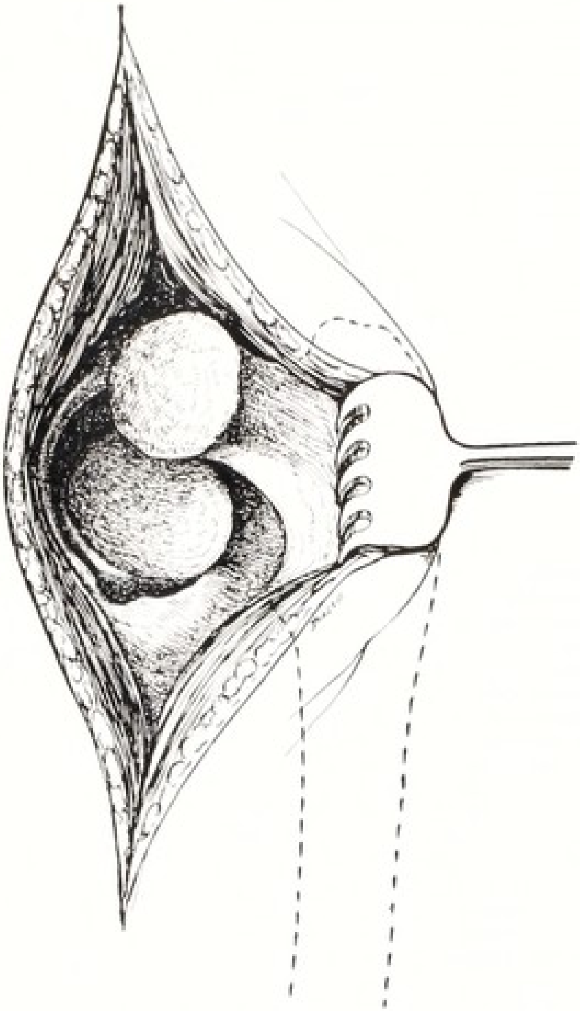


Fig. 89. Epiphyseal separation (fracture) at upper end of femur. Head lies free in acetabulum, behind and below neck, its epiphyseal (cervical) surface looking directly forward. Neck is dislodged from acetabulum, everted and dislocated upward. (From Albee's "Orthopedic and Reconstruction Surgery," Saunders.)

The 20 and 30 degrees of abduction rotates the upper edge of the fractured end of the neck under the lip of the acetabulum, as shown in Figure 86, thus preventing any possibility of an upward displacement from the muscular spasm or otherwise. Through a short trochanteric incision, a tibial bone-graft peg may be inserted, as for fracture of the neck to favor the establishment of blood-supply to the head and stimulate repair. At the end of three weeks, the part of the plaster which is over the leg is removed and the leg extended. An extension of plaster is applied from the knee over the foot. This is changed to a short spica at the end of six weeks. The

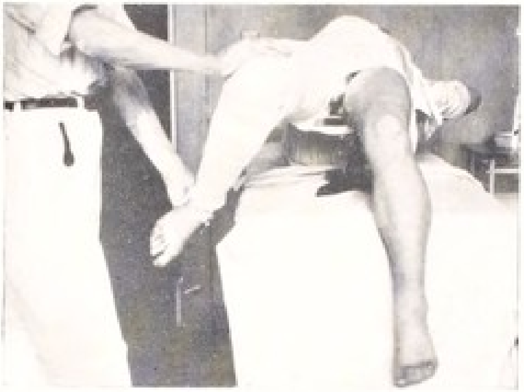


FIG. 90. Author's method of applying plaster-of-Paris spica to hold strong inward rotation, also abduction. (From Albee's "Orthopedic and Reconstruction Surgery," Saunders.)

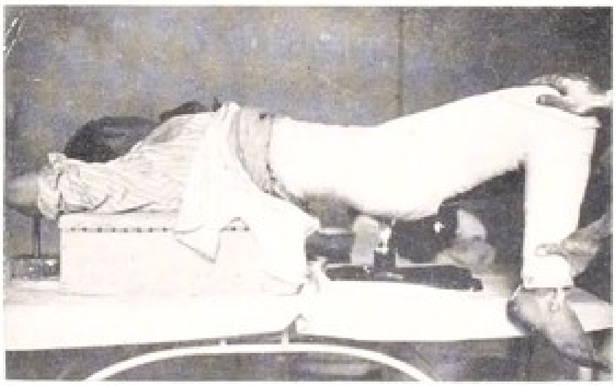


FIG. 91. Side view, showing application of spica over flexed knee. (From Albee's "Orthopedic and Reconstruction Surgery," Saunders.)

short spica is continued until five months after the operation. The motion of the hip is only slightly limited in all directions.

3. *Partial Arthroplasty.* In *traumatic coxa vara of long duration*, where displacement is considerable and union firm, I do not correct the malunion by chiseling the bone fragments apart, but perform a *partial arthroplasty* in order to remove any bone that blocks free motion at the hip. In many cases this necessitates the removal of a considerable amount of bone due to the forward projection of the neck of the femur. By extensive removal of bone, inward rotation of the limb is largely restored.

A double plaster-of-Paris cast is applied which remains on for three weeks. The patient is then permitted to exercise and begin weight-bearing. Vigorous manual massage and

Fig. 92. Epiphyseal separation from jumping off street car while in motion. Patient did not fall, but landed on his right foot with great force. (From Albee's "Orthopedic and Reconstruction Surgery," Saunders.)

manipulation is carried on each day to aid in restoring active muscular control of the hip throughout its new range of motion.

Author's Comment. The majority of patients with old traumatic epiphyseal separations come to operation because of a complaint of pain on weight-bearing. They are usually in early middle age and have been content to get along since adolescence with marked limitation of motion at the hip. Many of them have been able to indulge in sports. As they grow older, there is a gradual onset of pain with bone proliferation and further limitation of motion at the hip. A typical osteoarthritis develops. Following the partial arthroplasty there is no complaint of pain, and these patients are usually able to resume nearly normal activity.

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.

Fig. 93. Skiagram taken six weeks after open reduction of fracture, showing position of united fragments. (From Albee's "Orthopedic and Reconstruction Surgery," Saunders.)

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

Congenital Coxa Valga. Congenital coxa valga may be associated with congenital dislocation of the hip. It is then 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.

Congenital coxa valga may also occur not associated with other abnormalities. Young has reported several instances of coxa valga in which no other deformity was present.

Acquired Coxa Valga. Acquired coxa valga may be due to: 1. Traction by a pendant limb plus absence of the body-weight above plus abeyance of action of the pelvifemoral muscle group, as in the following conditions:

(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.

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 bi-

lateral 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.

It may be mistaken for tuberculosis of the hip; but in coxa valga pelvic inclination does not compensate for lengthening of the limb.

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, circular osteotomy (see treatment of coxa vara in this chapter) will effectually restore the mechanical relationship of the bony parts.

Chapter X

PARALYTIC DEFORMITIES

I. Abduction-Flexion Contractures

CONTRACTION of the hip in flexion and abduction is most likely to occur where the hip flexors retain some degree of power and the gluteus maximus is weak. This contracture is often overlooked. The presence of this deformity is most easily detected by laying the patient on his back over the edge of the table and hyperextending the thigh while the pelvis is held. The hip must not be allowed to abduct or rotate out during the examination. Unilateral fixed flexion of the hip causes the body to be pulled forward when the affected extremity is placed on the ground in walking. When the deformity is bilateral it prevents walking.

TREATMENT

The methods of treatment of this deformity in order of preference are:

1. Fasciotomy at the anterior superior spine (Soutter);
2. Mayer's operation.

Soutter's Fasciotomy. All methods of stretching the contracted tissues are ineffective. A very satisfactory and, at the same time, a simple procedure is an operation devised by Soutter.* The technique of the operation is as follows:

A longitudinal incision 2 or 3 inches in length is made with the anterior superior iliac spine at its center. With an osteotome, the tip of the cartilaginous spine with the perios-

* Soutter, R. A new operation for hip contractures in poliomyelitis. *Boston M. & S. J.*, 170: 380, 1914.

teum and the underlying superficial portion of cancellous bone is chiselled away for 3/4 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 fasciae 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 lateral 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.

Mayer's Operation for Paralytic Abduction Deformity. Mayer points out that, in solving the problem of correcting this deformity, the process of its development has to be reversed by the operation; in other words, all those structures which have gradually shortened on the outer aspect of the hip have to be lengthened until the leg can be adducted, and then some means devised to replace the pull of the paralyzed adductors.

*Mayer's Technique.** "A 14 inch incision is made along the outer aspect of the right thigh. The skin is dissected back sufficiently to give a wide exposure of the fascia lata. A transverse incision through the fascia is made a little below the level of the great trochanter. This removes the first obstacle to the adduction of the limb, namely, the contracture of the fascia lata and at the same time permits the retraction of the gluteus maximus muscle and the exposure of the trochanter. The tip of the trochanter is then cut off with the chisel, liberating the shortened abductor muscles. It is then possible to adduct the limb to within 10 degrees of the vertical line. It is evident, however, that shrinkage of the hip capsule prevents the complete adduction of the limb. A transverse in-

* Mayer, L. An unusual type of paralytic abduction deformity of the hip—an operation for its cure. *Surg., Gynec. Obst.*, 40: 421, 1925.

cision is, therefore, made through the capsule of the joint near its attachment to the neck of the femur.

"Immediately after this the leg can be swung well over to the left side of the body and the right heel brought into contact with the left. The abduction contracture, thus having been overcome, the next problem is how to keep the limb in the adducted position.

"To do this a 2 inch strip of the fascia lata is dissected away from the lower half of the thigh. Above, the fascia is left attached by a broad pedicle. This strip of fascia 2 inches wide and 8 inches long is then drawn upward and inward through a subcutaneous channel, and fastened under tension to the spine of the pubis and to the inner portion of Poupart's ligament by means of strong chromic gut sutures. At the point of reflection the pedicle of the fascia is reinforced by means of several sutures so as to prevent tearing of the tissues. The wound is closed, no attempt being made to suture the tip of the trochanter to its original site. A plaster spica is applied holding the leg in adduction of 15°.

"After 4 weeks this is removed and active and passive exercises begun at once."

By means of this operation, Mayer has been able to overcome entirely the abduction deformity. The lumbar curve disappears and the limp is scarcely perceptible. There is slight power of voluntary adduction. In spite of the fact that the tip of the trochanter has been chiseled off, the abductors recover almost normal strength. No unpleasant sequelae, due to the removal of the strip of fascia, develop.

II. Adduction Contractures and Paralysis of the Glutei

The methods of treatment in these cases in order of preference are:

1. Tenotomy of adductor tendons;
2. Substitution of vastus externus or erector spinae for paralyzed glutei (Lange-Kreuscher);

3. Transplantation of tensor fasciae femoris into femur (Legg);
4. Transplantation of tensor fasciae femoris into the posterior superior spine of the ilium (Dickson);
5. Transplantation of tensor fasciae femoris and erector spinae (Hey Groves).

Tenotomy of the Adductor Tendons for Adductor Contracture from Spastic Paralysis. In the usual case of spastic paralysis the hip is somewhat flexed and internally rotated and adducted, the knee adducted and flexed and the foot in equinus. If both limbs are involved, and in cases with any degree of adductor spasm, the patient will cross one leg over the other when an attempt is made to walk (scissors gait). Muscle training, braces, and stretching have not proven to be of value in treating this type of contracture at the hip. The only satisfactory treatment is the lengthening of the muscles which are responsible for the deformity.

With the patient on the fracture orthopedic table and 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 ¾ 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 marked abduction in a long plaster-of-Paris spica.

PARALYSIS OF THE GLUTEI

The gluteus medius is very frequently affected in infantile paralysis. This muscle is one of the most important stabilizing forces in weight-bearing and in walking. Its principal function is to hold the pelvis steady or abduct the pelvis when weight is placed on the limb and to abduct the limb when the weight is placed on the opposite limb. The gait associated with weakness or paralysis of this muscle is perfectly characteristic. When the patient bears weight on the affected limb the opposite side of the pelvis sags and he must lurch to the affected side to maintain his balance. The treatment of this condition presents one of the most difficult problems in hip surgery.

Paralysis of the gluteus maximus is not so frequently found in infantile paralysis. When the patient bears weight on the affected side the trunk shifts quickly to that side and back and the patient hurries to get the other foot in position for weight-bearing. Apparatus is entirely ineffective in the control of these deformities. A number of operative procedures have been devised to substitute other muscles for the paralyzed glutei.

*Substitution of Vastus Externus or Erector Spinae for Paralyzed Glutei (Lange-Kreuscher Operation).** The vastus externus is used as a substitute for the paralyzed glutei. The origin of the vastus externus is detached from the base of the great trochanter and by a series of sutures is anchored to the crest of the ilium to assist abduction of the thigh.

If the vastus externus is paralyzed as well as the glutei, which is often the case, Lange substitutes the erector spinae after lengthening it with "silk sinew," by which attachment was made to the lesser trochanter.

The latissimus dorsi from the sound side can be substituted for the smaller glutei.†

Transplantation of the Tensor Fasciae Femoris into the Femur (Legg's Operation).‡ When power to abduct the leg has been impaired or lost because of paralysis of the gluteus medius, Legg transplants the tensor fasciae femoris into the

* *Am. J. Orth. Surg.*, p. 19 (Aug.), 1910.

† Wilkie, D. P. D. Treatment of fractures of the neck of the femur. *Surg., Gynec. Obst.*, 44: 529, 1927.

‡ Legg, A. T. Transplantation of tensor fasciae femoris in cases of weakened gluteus medius. *J. A. M. A.*, 80: 243, 1923.

femur. The fascia lata is exposed by an incision which commences at the anterior superior spine and extends backward and downward over the great trochanter and for about 3 inches down the femur. The fascia lata is incised downward from the anterior superior spine along the line where it thins out; this incision is carried to a point 3 inches below the great trochanter and then transversely backward for 1½ inches. The fibers of the vastus externus are now divided and the femur exposed about 2½ inches below the trochanter. A periosteal flap is turned down and a groove is made in the bone 1 inch long, ½ inch wide and deep enough to penetrate to the marrow. Drill holes are made through the lateral walls of this groove. A suture is run through the free end of the fascia lata and its end passed through these drill holes and knotted over the fascia lata. The flap of periosteum is replaced and sutured. With 20 degrees of abduction, in which the leg is to be held by plaster, there should be moderate tension on the fascia.

Transplantation of the Tensor Fascia Femoris into the Posterior Superior Spine of the Ilium for Paralysis of the Glutei (Dickson). When anterior poliomyelitis has caused paralysis of the gluteus maximus and medius, Dickson transplants the tensor fasciae femoris to the posterior superior spine of the ilium. Even if this muscle has been affected by the paralysis, the joint is stabilized. If the function of the muscle is intact, he has found an astonishing amount of abduction and extension of the hip possible after the transplantation.

*Dickson's Technique.** With the patient lying well over on the side, the skin incision is made. This starts at the anterior superior spine and runs posteriorly along the crest of the ilium to the posterior superior spine. Anteriorly, it is prolonged downward from the anterior superior spine onto the thigh for a distance of about four inches, passing along

* Dickson, F. D. An operation for stabilizing paralytic hip. *J. Bone & Joint Surg.*, 9: 1, 1927.

the inner border of the tensor fasciae femoris (lata). The skin and subcutaneous fat are reflected back, exposing the fascia covering the tensor fasciae femoris (lata), the gluteus medius and the gluteus maximus.

The tensor fasciae femoris is next separated from the sartorius and rectus femoris anteriorly for a distance of about 4 or 5 inches, and from the gluteus medius for about 3 inches posteriorly; care should be taken in this dissection not to interfere with the nerve supply to the muscle. The nerve to the tensor fasciae femoris, coming from the superior gluteal nerve, emerges from beneath the gluteus medius at about its lower third and passes into the under surface of the muscle.

The tensor fasciae femoris (lata), having been freed well down towards the knee, is separated from its origin at the crest of the ilium by chiselling off a shell of bone. As large a shell as possible is taken; usually a good substantial piece about 2 inches long can be secured.

The atrophied gluteus medius is now carefully lifted up and through the tunnel thus formed beneath it, the severed insertion of the tensor fasciae femoris (lata) is passed, to emerge through an incision in the fascia made at the anterior border of the gluteus maximus. This tunnel beneath the gluteus medius should be made close to its insertion into the greater trochanter to allow the transplanted muscle to pass as far posteriorly as possible.

The thigh is now strongly abducted to allow the insertion of the tensor fasciae femoris (lata) to pass well posteriorly and reach the posterior superior spine if possible. It will almost invariably reach this position if the abduction is carried far enough. At this point, a groove is made in the crest of the ilium into which the shell of the bone adherent to the origin of the tensor fasciae femoris (lata) is securely fastened with No. 3 chromicized catgut or silk suture. If, even with extreme abduction, the tensor fasciae femoris (lata) is too short to reach the posterior superior spine, a strong band of fascia attached to the crest of the ilium can be turned up, and by suturing the tensor to this, a firm attachment for the transplanted muscle can be secured. Occasionally, when unable to bring the muscle as far posterior as was desired, we have raised a flap from the side of the ilium below the crest and attached the muscle at this point. It is usually only in the older cases that we have found it necessary to resort to fixation below and slightly anterior to the posterior superior spine.

The posterior edge of the transplanted tensor fasciae femoris is then firmly sutured to the under surface of the gluteus maximus, the sutures through the gluteus maximus being placed as far posterior as possible, thus drawing the transplanted muscle back and anchoring it. If the muscle has been displaced as far posterior as it should be, it will, in its new position, pass over the anterior half of the greater trochanter.

The wound is closed, all dead spaces being carefully obliterated, and the limb put up in plaster in extreme abduction.

At the end of three or four weeks, the cast is cut down and daily exercises given. The exercises consist in placing the patient in a prone position and teaching him to extend the hip on the pelvis with the thigh abducted. The cast is removed and the extremity allowed gradually to come down from the abducted position at the end of six to eight weeks, and the patient allowed to use the extremity.

*Transplantation of Tensor Fascia Femoris and Erector Spinae (Hey Groves' Method).** Hey Groves has adopted a combination of Legg's and Kreuscher's operations.

"A long incision is made down the outer side of the thigh exposing the iliotibial band of the fascia lata from the level of the trochanter to that of the outer condyle. The fascial band is divided just above the knee and isolated from the deep tissues up to the insertion of the tensor fasciae femoris. It is taken backwards through the tendinous origin of the

* Hey Groves, E. W. Some contributions to reconstructive surgery of the hip. *Brit. J. Surg.*, 14: 486, 1927.

vastus externus just below the prominence of the great trochanter. At this stage the long incision in the thigh is closed except at the upper part. The lower part of the erector spinae muscle is now exposed through a separate vertical incision. About half the thickness of this muscle is isolated and divided from its origin at the angle between the iliac crest and sacral spinous processes. A tunnel is made beneath the skin and subcutaneous tissues connecting the two wounds, and the iliotibial band is drawn up to the back, pulled tense and its end is brought through the tendon of the erector spinae, doubled back on itself, and sewn by separate stout silk ligatures, the leg being held in abduction all the time and put up in this position after the closure of the wounds and the conclusion of the operation. The new muscle which now forms an abductor of the hip-joint is a digastric muscle having the erector spinae forming its posterior belly, and the tensor fasciae femoris its anterior, whilst the strong fascia lata forms the intermediate tendon. Acting together the two components of this muscle will be a pure abductor, whilst the anterior belly will also be a flexor, and the posterior an extensor of the thigh."

III. Paralytic Hip and Knee Flexion with Knock-Knee

In cases showing the triad deformity, hip flexion, knee flexion and knock-knee, Silver and Young divide the iliotibial band near the knee. Forbes * extends the idea underlying this procedure by separating the fibers of the fascia lata which can be proved to be acting as flexors of the knee and inserting them as a cylindrical cord into the quadriceps tendon and the patella, while the leg and thigh are held in extension.

* Forbes, M. The tensor fasciae femoris. *J. Bone & Joint Surg.*, July 1926, p. 589.

IV. Paralytic Dislocation

(See Dislocation of the Hip, p. 119.)

Author's Comment. Each case of paralysis of the hip is an individual problem. A careful preoperative survey of the contractures and remaining muscle power usually reveals that none of the above procedures alone is adequate to correct the disability. It has been my custom to use these procedures as a basis for the modifications necessary in each case.

Chapter XI

OSTEOARTHRITIS

OSTEOARTHRITIS (arthritis deformans) 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 coxae 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. This lesion is never suppurative, but is a degenerative process. There is never any indication of satisfactory self-repair, and fixation and immobilization for years would be of no avail in advanced cases. The femoral head becomes markedly flattened or cylindrical in shape at its upper aspect, and the motions of the joint become altered from a ball-and-socket action to that of a hinge 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

FIG. 94. Advanced osteoarthritis. Hip has become dislocated because of acetabulum filling up with bone.

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 osteoarthritis often becomes engrafted upon a former healed arthritis of a tuberculous or pyogenic type.

Symptoms and Diagnosis

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 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 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 a 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.

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 (see Chap. VI).

X-ray appearances of osteoarthritis 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 osteoarthritis (arthritis deformans) of the hip are:

1. Insidious onset.
2. Symptoms manifested only during locomotion.
3. Motions of the hip change from those of a ball-and-socket joint to those of a hinge joint.
4. 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.
5. Muscle spasm, on passive motion, may be entirely absent.
6. Marked contrast of the *x*-ray appearance to other conditions which simulate it clinically.
7. 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

NON-OPERATIVE TREATMENT

Occasionally some relief may be experienced in early cases 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. Physiotherapy in the form of heat and massage is indicated to overcome pain, contracture and limitation of motion. A prolonged course of treatment with thymus and pituitary extracts is also indicated. Occasionally deformity may be counteracted by traction, rest, or reduction under anesthesia followed by a 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 osteoarthritis 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.

OPERATIVE TREATMENT

Resection of the upper extremity of the femur (an operation which I believe has outlived its usefulness) was practiced 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 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 is best to aim for an immediate firm ankylosis by means of an arthrodesis operation. 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.

Intra-articular Arthrodesis with Supplementary Extra-articular Graft. The production of surgical ankylosis of the adult hip-joint is indicated for the following conditions: (1) Marked pain; (2) fibrous ankylosis following previous operation, trauma, or from other causes; (3) rarefaction of the femoral head and neck in the adult, with inevitable or actual crushing of these structures.

Author's Technique. Since I first reported the technique of arthrodesis for arthritis deformans (1908),* I have modified the technique in several respects, principally by the addition of either intra-articular or extra-articular grafts.

The hip joint is reached by the Smith-Petersen approach. The capsule becomes visible and is incised. A part of the osteophytes about the acetabulum are turned upward with the soft tissues adherent to them, since it is considered advisable to preserve as many of these as feasible on account of their potential bone-producing power. With the head of the femur *in situ*, approximately one-third of its upper hemisphere is removed with a long osteotome or chisel, $5/8$ inch in width, in a plane nearly parallel with the long axis of the neck of the femur. 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.

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.

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

* Albee, F. H. Arthritis deformans of the hip joint. Report of a new operation. *J. A. M. A.*, 50: 1553, 1908.

into contact by simply abducting the thigh. In my 1919 text book, the intra-articular mortising operation supplemented by chip grafts around the periphery of the joint was described. However, I was occasionally disappointed in the failure of arthrodesis or a delay in the occurrence of the ankylosis. This experience plus the realization that well-mortised massive grafts are more trustworthy induced me to modify the operation by sliding an inlay graft from the outer table of the ilium just above and including the rim of the acetabulum, downward into the cleft produced by the splitting *in situ* of the trochanter from above downward and outward with a 1½ inch osteotome, with a minimum amount of periosseous and soft parts separated. The superior surface of the neck of the femur is at the same time freshened by removing with an osteotome sufficient bone to make a flat surface against which is contacted the under surface of the iliac graft.

Since changing the technique in this manner, the early fusion obtained and the absence of failure to secure ankylosis have been most gratifying. The comparative experience with the old intra-articular arthrodesis supplemented with chip grafts as compared with the massive inlay graft bears upon all such operations performed upon any joint or location in the body; that is, it proves the untrustworthiness of small chip grafts as to their osteogenesis and their ability to fuse, and emphasizes the trustworthiness of the massive graft well incorporated by inlay or mortise into the elements of a joint to be fused.

Soft tissues are sutured with continuous suture of chromic catgut No. 1; skin, with continuous suture No. 1 plain catgut.

A double plaster-of-Paris spica cast extending to the toes on the operated side and to the tubercle of the tibia on the other side is applied, which remains on for a period of eight weeks.

Following the removal of the cast, if roentgenograms and physical examination reveal solid bony fusion of the hip, massage is started and the patient is allowed to bear weight as soon as his strength permits, usually at the end of five to seven days.

GENERAL DISCUSSION OF ARTHRODESING OPERATIONS

In ankylosis from suppurative arthritis, trauma or tuberculosis, if the conditions of the joint and periarthritic structures are favorable, as well as the age of the patient, for future arthroplasty, I so plan my arthrodesis that conditions are favorable for an arthroplasty at a later date. This is particularly true of the knee and the hip, both joints being favorable to arthroplasty, and the latter operation being of great advantage to the patient.

At the hip, instead of using local bone-graft material, I prefer to use tibial grafts so as not to destroy or impair the future function of the trochanteric muscles, which is essential to the success of an arthroplasty. And from a second standpoint, I do a true extra-articular arthrodesis so that the grafts can easily be removed at the arthroplastic procedure and will not interfere with the execution of the operation. Further, a varying amount of trochanter ends are left in place with the gluteal muscles into which they are inserted, attached so that their functional control of the femur will be accentuated, particularly in active abduction of the hip and weight-bearing.

PARTIAL ARTHROPLASTY

In certain cases of osteoarthritis, particularly those in young and middle-aged patients in which the arthritis has come on following an adolescent slipping of the femoral epiphysis, a partial arthroplasty may be done to restore motion. The indications for the choice of this procedure are very definite, as follows: (1) The hip must be almost entirely painless with no evidence of active inflammation, the chief complaint being the limitation of motion. (2) The patient's occupation must allow him to sit a great deal of the time while at work. (3) The patient must have the mental and financial resources to permit him to go through a long period of massage postoperatively.

The Smith-Petersen incision is used and the capsule is opened widely. With the large gouge, used in arthroplasty of the hip, the osteophytes surrounding the head of the femur are removed and the head reduced to such size that it is able to move freely throughout its normal range of motion. The articular surface of the acetabulum is not disturbed. The osteophytes surrounding the rim of the acetabulum are not removed unless they block the free range of motion of the newly formed head. The subcutaneous tissues are closed in layers with No. 1 chromic catgut and the skin sutured with No. 0 plain catgut. A double plaster-of-Paris spica cast is applied extending to the toes on the operated side and to the tubercle of the tibia on the opposite side with the operated hip in slight hyperextension, moderate internal rotation and abduction. At the end of three weeks the cast is removed and daily massage and exercise given. The patient begins to bear weight after a week or ten days.

The results of this procedure in a large series of carefully selected cases has been most gratifying. The deformity remains corrected. After four to six weeks of massage and exercise a good range of active, painless motion is secured. Many of these patients are able to resume active sports following this procedure.

Chapter XII

MISCELLANEOUS CONDITIONS

1. Neoplasms

MALIGNANT GROWTHS

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 of Sarcoma. 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, 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 aneurysm.

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.

Gordon-Taylor and Wiles * have performed the "hind-quarter" amputation in 5 cases with death in 2 of them. There have been 20 of these cases reported in the literature since 1910 with a mortality of 40 per cent. They believe it probable that in the future such an extensive surgical procedure will be undertaken less and less frequently because of the more conservative irradiation therapy now possible.

The amputation involves the entire gluteal mass, the os innominatum, and the entire lower extremity. It is performed under general anesthesia supplemented by spinal block. The incision is made along the crest to the antero-superior spine, thence downward and inward 1½ inches below Poupart's ligament toward the middle of the origin of the abductor brevis. Poupart's ligament is divided at each end and the spermatic cord retracted downward. The rectus abdominis muscle is then cut from its insertion on the pubic crest, the pubis denuded on both sides, and the symphysis divided. Next, a skin incision is made from the center of the iliac crest to the gluteal fold and along this fold to meet the lower mesial end of the first incision. The ilium is sawed through into the sciatic notch. The innominate bone and lower extremity can then be drawn away from the pelvic peritoneum. The psoas muscle is sectioned above the pelvic brim, and all other muscles attached to the disengaged os innominatum are divided near the bone. After hemostasis and injection of nerve trunks, the remains of the muscles are

* Gordon-Taylor, G., and Wiles, P. Interinnomino-abdominal (hind-quarter) amputation. *Internat. Abst. Surg.*, 61: 376, 1935.

sutured to reinforce the peritoneum and the skin flaps are sutured. Blood transfusions should always be given.

CYSTS OF THE UPPER END OF THE FEMUR

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.

Clinical History. Fracture is a very common sympton, 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 osteoarthritis 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. Trabeculae subdividing the translucent area are of common occurrence.

Differential Diagnosis. Simple traumatic fracture can be eliminated by the x-ray findings.

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 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 new growth* containing one or more cysts, and occurring at all ages. The solid mass contains cartilage (hyaline or fibrous), spiculae 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, a few years ago, encountered one of these echinococcus cysts of the head of the femur in a patient from New Zealand upon whom he operated.

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 technique as when bone is broken) through the weakened area.

2. Osteochondritis Deformans Juvenilis
(Legg-Calvé-Perthes' 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. Hoffman * summarizes the various opinions as to the exact etiological factor responsible for this condition and comes to the conclusion that the deformity is due to deficient blood-supply to the epiphysis and that weight-bearing or trauma have no connection.

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 micro-

* Hoffman, R. Epiphyseal pseudotuberculosis—osteochondritis juvenilis, *Internat. Abst. Surg.*, 61: 559, 1935.

scopic appearance of the diseased portion of the femur. Perthes,* in his original communication described the pathological change as an overgrowth of abnormal cartilage extending down into fairly normal bone. Legg, 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.

X-ray Appearances. 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, including inefficiency of the pelvitrochanteric 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 attempted, it continues a variable number of months or years, when it disappears and recovery occurs with very slight derangement of the joint function.

Shortening of the leg occurs as the result of atrophy of the femoral neck and epiphysis. *Pain* is slight or entirely ab-

* Perthes, G. Ueber Osteochondritis deformans juvenilis. *Verhandl. d. deutsch. Gesellsch. f. Chir.*, 42, pt. 2: 140. 1913.

sent. Exaggerated movements at the hip-joint are accompanied by pain of slight degree. 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*.

Differential Diagnosis. 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.

From *tuberculous coxitis*, differentiation is easy except in the very early cases of Perthes' disease.

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 tuberculous hip disease, and the diagnosis can always be confirmed by x-ray examination.

Infantile Coxa Vara: Both this and Perthes' 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.

Acute or Chronic Articular "Rheumatism": The onset with fever is different from that of Perthes' disease; likewise the accompanying emaciation and the relief afforded by salicylates and other antirheumatic drugs may be characteristic of "rheumatism."

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 Perthes' disease and the *x*-ray appearances will permit differentiation to be readily made.

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 Perthes' 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. In accordance with the confusion as to the etiology of this condition there are wide differences of opinion regarding the proper method of treatment. Danforth * and Brailsford,† believing that the changes in the head and neck are due to crushing caused by weight-bearing, recommend rest until all evidences of bony change are gone. At the present time the majority of observers believe that the deformity is due to a lack of adequate blood-supply to the epiphysis. Bozan ‡ recommends conveying a fresh blood-supply to the epiphysis by means of multiple drill holes through the trochanter and neck. It has been my practice, in the cases with marked deformity, to place an autogenous bone peg through the neck and head by the same method used for intracapsular fracture of the neck of the femur.

The more mild cases are protected from weight-bearing for a few weeks until all muscle spasm is gone, after which they are permitted to resume cautious weight-bearing. These cases are examined each week and if there is any evidence of

* Danforth, M. S. The treatment of Legg-Calvé-Perthes' disease without weight-bearing. *J. Bone & Joint Surg.*, 16: 56, 1934.

† Brailsford, J. F. Osteochondritis. *Internat. Abst. Surg.*, 61: 50, 1935.

‡ Bozan, E. J. A new treatment of intracapsular fractures of the neck of the femur and Calvé-Legg-Perthes' disease. *J. Bone & Joint Surg.*, 14: 684, 1932.

muscle spasm their activities are restricted. Massage seems to have a favorable effect and shorten the period of convalescence.

3. Snapping Hip

Intra-articular Type. In children, the term snapping hip 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.

Extra-articular Type. Both in adults and children snapping hip of the extra-articular type 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. 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 evidences of hysteria can usually be obtained from the personal history and by careful examination and scrutiny of the subject. Roentgenography and examination under anesthesia will remove all further doubt.

5. Hemophiliac Disease

Children and adolescents of hemophiliac 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.

Differential diagnosis must be made from tuberculous and syphilitic arthritis; this is usually done by the family history (see Chap. VI).

Treatment. Prophylactic protection of the joints from trauma and strain should be carried out. Operative interference is not indicated.

For combating the hemophiliac tendency, calcium chloride is of less value than fresh animal serum or human serum given in the form of small whole blood transfusions.

6. Phocomelia

Phocomelia is a congenital absence of the femur or its proximal portion. No treatment has proven satisfactory in these cases. An artificial leg offers the best solution to this most difficult problem.

7. Intrapelvic Protrusion of the Acetabulum

There may be a non-traumatic, chronic, progressive arthritis of the hip-joint with intrapelvic protrusion of the acetabulum and head of the femur * (Otto pelvis; arthrokotadysis). The etiology is unknown.†

The chief complaint in the average case is a slowly progressing painful coxitis which has been present for months or years.‡ When the deformity is great and the condition has been present for a long time, all movements of the hip are restricted.

Even in early cases the diagnosis may be made by roentgen-ray examination. The protrusion of the acetabulum varies from a few millimeters to 4 or 5 cm. As the acetabulum migrates, it inclines upward, inward and forward, so that it may project above the ramus of the pubic bone and extend toward the obturator fossa.

As it extends into the pelvis, a low-grade osteoplastic process is initiated and the yielding joint is splinted by the formation of a dense wall on the inner aspect of the acetabulum parallel with its projecting margin. The external margins of the acetabulum project outward over the neck of the femur as irregular serrated vegatative formations.

In the typical deformity the integrity of the femoral head is maintained. As the head of the femur is submerged within the acetabulum the trochanters approach the lateral margins of the pelvis and incline posteriorly. The greater trochanter impinges on the lateral margins of the ilium in the region of the acetabular shelf, and the lesser trochanter approaches

* Pomeranz, M. M. Intrapelvic protrusion of the acetabulum (Otto pelvis). *Internat. Abst. Surg.*, 55: 457, 1933.

† Cary, A. Arthroplasty of the hip joint. *J. Bone & Joint Surg.*, 14: 687, 1932.

‡ Reed, E. N. A case of arthrokotadysis of the hip joint. *J. Bone & Joint Surg.*, 15: 803, 1932.

the ischium. This explains why the femur cannot be rotated outward or backward.

In cases where the submerged hip-joint remains reasonably intact, pain can be relieved and motion largely restored by radical removal of the impinging bone about the rim of the acetabulum. In the more advanced cases with severe pain on weight-bearing, arthrodesis is the most satisfactory treatment.

Overgaard * reports another type of protrusion of the acetabulum which he calls juvenile osteoasthenic protrusion. This condition develops at the age of puberty in girls in the absence of signs of arthritic or traumatic changes in the hip-joint, probably as the result of weakness of the bone tissue. The treatment consists of guarded weight-bearing as long as there are any signs of progression of the lesion.

8. Coxa Magna

Ferguson and Howard † have described a condition characterized by enlargement of the femoral head and neck in children. They suggested that the cause of this enlargement is a disturbance of circulation produced by sclerotic changes in the soft tissues about the femoral neck following infectious arthritis. There was a gradual onset of pain and limp in all cases. Examination showed a varied amount of limitation of motion in different cases, each motion of the hip being subject to limitation. Tenderness, spasm and pain on motion are present in all cases. The treatment consists of removal of foci of infection and rest of the hip as long as there is muscle spasm. Deformities must be prevented by a plaster-of-Paris spica cast. If, after all the acute signs have disappeared, motion is limited, manipulation or arthroplasty must be done.

* Overgaard, K. Otto's disease and other forms of protrusio acetabuli. *Internat. Abst. Surg.*, 61: 376, 1935.

† Ferguson, H. B., and Howard, M. B. Coxa magna: a condition of the hip related to coxa plana. *J. A. M. A.*, 104: 828, 1935.

INDEX OF PERSONAL NAMES

INDEX OF SUBJECTS

Paul B. Hoeber, Inc., 49 East 33rd St., New York
Medical Book Department of Harper & Brothers