FRACTURES

BLAKE

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BEING A MONOGRAPH ON

"GUN SHOT FRACTURES OF THE EXTREMITIES"

BY

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WITH FORTY ILLUSTRATIONS

D. APPLETON AND COMPANY
NEW YORK LONDON
1919

Printed in the United States of America

PREFACE

This little manual is the outcome of a request made to me by the late Dr. Lewis A. Stimson to write a chapter on fractures for a book he was compiling for the Council of National Defence but which did not materialise because of his sudden death.

In it I have attempted to put in as concise a form as possible the conclusions formed as a result of my experience and observation since the beginning of the war in hospitals largely devoted to the treatment of fractures, with the hope that the manual may be of some aid to members of the Medical Corps who have not had equal opportunities in war surgery, and that it may help to alleviate the sufferings of our soldiers and diminish the number of cripples who will become a charge upon our country. Perhaps, also, suggestions arising from it may lead to the realisation of further progress and thus assist our surgeons to continue the advance so brilliantly begun by our French and British colleagues.

Joseph A. Blake.

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GENERAL

GUN-SHOT FRACTURES
OF THE EXTREMITIES

CHAPTER I

MECHANISM AND VARIETIES OF GUN-SHOT FRACTURES

Definition:

A fracture is a solution of the continuity of a bone. Fractures are divided into two groups: fractures of the diaphyses and fractures of the epiphyses. In diaphyseal fractures the false point of motion is more evident than in epiphyseal fractures; there is a tendency to overriding and shortening, which is most marked in the case of fractures of single bones, such as the humerus and femur. In epiphyseal fractures the articulations are frequently involved. Because of the difference in the process of repair, and in the treatment necessitated, the two groups will be described separately.

Wounds of bones:

A distinction should be made between *fractures* and *wounds of bones*. A bone may be perforated, or a portion of it broken off or removed by a missile, and its continuity still remain intact (Fig. 1). Such a condition is more often observed in an epiphysis than in a diaphysis. It frequently occurs that a missile penetrates or even perforates an epiphysis without causing a true fracture; but usually, when a diaphysis is perforated,

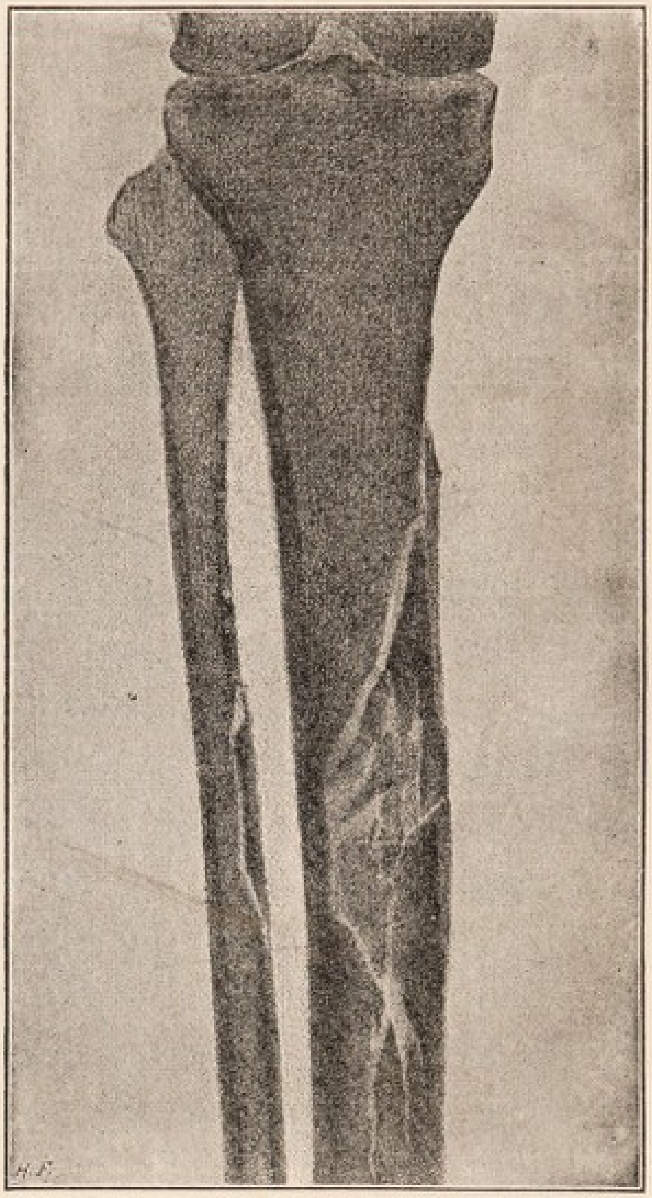


FIG. 1.—Extensive wounds of tibia and fibula by rifle ball without complete fracture.

any slight indirect violence is sufficient to break the remaining bone. Nevertheless, shrapnel balls have perforated the shaft of the humerus without producing a fracture.

As regards the epiphyses, it is often difficult to differentiate between wounds and fractures, but it is better

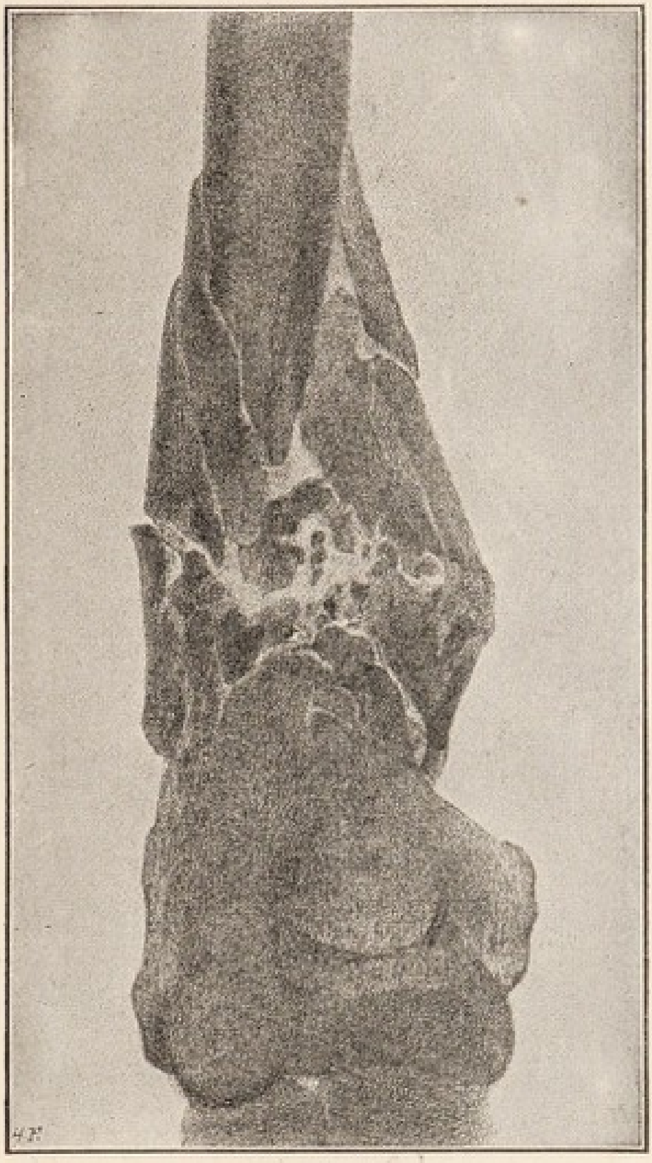


Fig. 2.—Fracture of humerus by ball. Large and small fragments. This fracture united in 23 days.

to confine the term "wound" to those injuries which do not produce solution of continuity between important parts of the bone. Wounds of the epiphyses frequently occur without implication of the joints.

Varieties of fractures:

All varieties of fractures are met with in war. Simple fractures occur as often as in any other violent occupa-

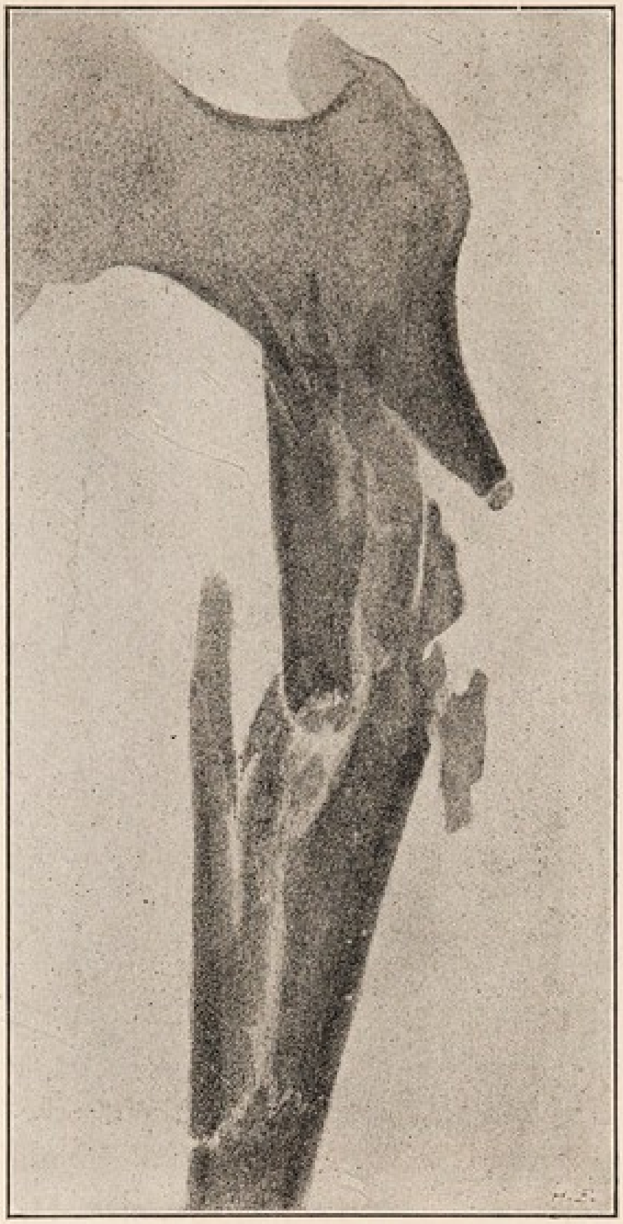


Fig. 3.—Fracture of femur by shell. Large fragments. Faulty position, due to lack of abduction of the limb.

tion, but they are caused more particularly by the explosion of mines and shells. The essentially *war* fracture

Fig. 4.—Extensive comminuted fracture of femur by rifle ball. Small fragments. Bad position. Had been treated with a plaster splint. Illustrates the flexion, abduction and rotation outward of upper fragments observed in high diaphyseal fractures of the femur.

is produced by the impact of relatively small missiles traveling at a relatively high velocity and penetrating or perforating the body or limbs. Such a fracture is always compound, and, unless made by a rifle or shrapnel ball (which do not, as a rule, entrain clothing), is *à priori* infected.

The effects produced by missiles upon bones are extremely diverse, and it is idle to try to classify them too minutely. Occasionally a bone is broken transversely or obliquely into two fragments, but it is much more usual to find comminution. Such comminution may extend for a short distance only, the pieces being large or small; or the bone may be shattered for a great part of its length (Figs. 2, 3 et 4). Not infrequently the fissures extend far enough to involve articulations.

It often happens that the bone is broken up into tiny particles to which the velocity of the missile is imparted; these in turn tear their way through the soft tissues, thus producing the so-called "explosive" effect. It is largely to this destruction of the soft tissues that war fractures owe their peculiar danger and their need of special treatment. In fractures of the thigh, for instance, there may be relatively small apertures of entrance and exit in the skin; yet when these openings are enlarged the hand may be introduced and freely moved around in a pulp of muscle filled with gritty fragments of bone. This effect is seldom seen in an epiphysis, however it may be shattered, because of the less dense character of the bone.

Effects produced by different missiles upon the bones cannot be classified arbitrarily. The lesions caused by rifle balls depend in character upon the velocity of the ball. Unless it is distorted or tumbling, as a result of hitting some other object before wounding—when it acts like a shell fragment—it usually produces a splitting fracture, or, in the case of the epiphyses, a simple perforation. Yet rifle balls may cause extensive minute comminution. Fragments of shell, on account of their lesser velocity, are more apt, when causing fractures, to become lodged in the bone; although they frequently stop short at its surface and produce fracture by impact instead of by penetration. As a rule, such fractures are not comminuted.

Double fracture:

Double transverse fractures of a single bone, only one of which communicates with the wound (Fig. 5), are not infrequently observed. In these cases there is often a history of a fall, suggesting a combined direct and indirect violence.

Fractures by impact and fractures by penetration or perforation:

As has been pointed out by Leriche, the question as to whether the missile breaks the bone by impact simply, or whether it enters or passes through the medullary cavity, possesses great clinical importance. In the first instance no infectious material is carried into the bone, and the wound may be considered as a wound of the soft parts so far as infection is concerned; in the second, if the missile penetrates the medulla or perforates the bone, any foreign matter upon it is generally caught between the fragments. Cases in which the opening

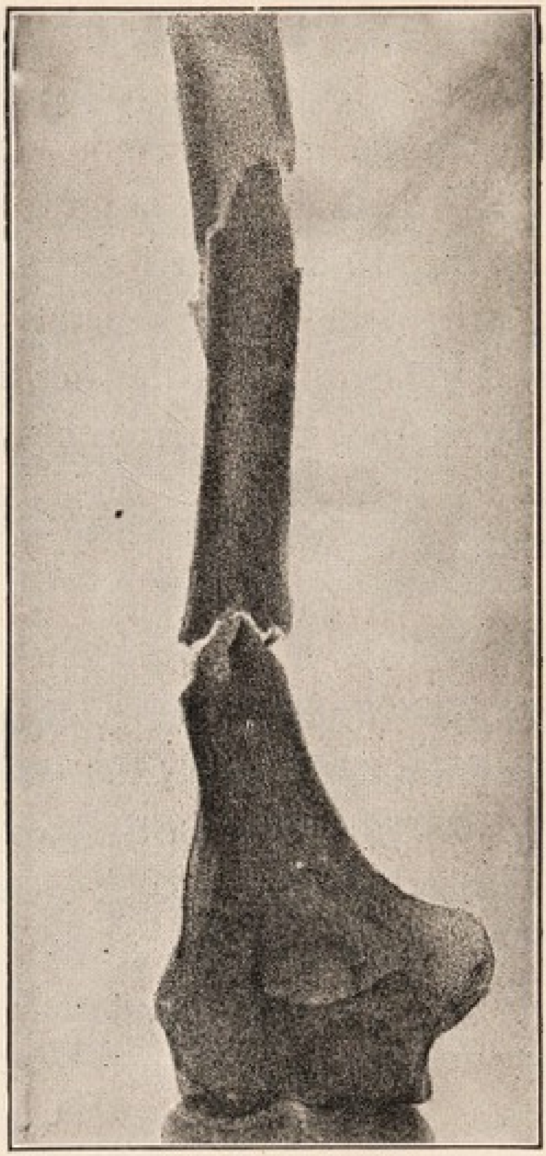


Fig. 5.—Double fracture of humerus by shell, suggesting a combined direct and indirect violence.

into the medulla is small are particularly dangerous in that, on account of retention of the products of infection, extensive osteomyelitis is apt to be caused. The difference between the treatment of fractures by impact and fractures by penetration will be considered later.

Infection:

Fractures produced by rifle balls, if the orifices of entrance and exit are small, are considered as uninfected; when caused by shrapnel balls, judgment must be used as to whether to consider them infected or not. Generally, when the orifices in the skin are small and punctate, they may be taken to be uninfected; but if proper conveniences are at hand for the performing of an aseptic operation no doubtful case should be allowed to pass.

All fractures produced by shell, bomb or grenade fragments must be regarded as infected. In the great majority of cases clothing, hair, skin or other foreign bodies are entrained by the projectile. This foreign material is often found entangled in the bone splinters.

CHAPTER II

REPAIR OF FRACTURES

The process of repair in fractures produced by missiles does not differ in principle from that observed in the ordinary fracture in civil practice; but with the former, on account of extensive comminution and displacement of small fragments, results having a far-reaching effect upon the ultimate function of the member may occur. Infection markedly influences repair, and it is therefore well to consider the uninfected cases first.

In the absence of infection there is no death of tissue, at least in mass, and new bone is produced to a varying extent by all the osteogenetic tissue, whether attached to periosteum or bone fragments, or contained within them. If there is no comminution the repair does not differ from that of a similar simple fracture caused by indirect violence, except that, as the periosteum has usually not been stripped from the ends of the bones, the repair takes place more normally and more rapidly. In cases of extensive comminution (Figs. 2 and 3) the new bone forms around and between all the fragments as if cement had been poured in between them, and, as the broken surfaces present a far greater area than those of a non-comminuted fracture, the formation of new bone is much increased and the site of union correspondingly enlarged; the size and irregularity of the callus depending upon the separation and distribution of the fragments. Osteophytic processes often extend into the muscles, interfering greatly with their function

Fig. 6.—Fracture of tibia and fibula, infected; united with exuberant callus and osteophytes. Had been treated without traction in a bridged plaster splint.

(Fig. 6). Nerves may be surrounded and included. Pieces of bone entirely detached from the others and projected into muscles do not, however, produce new bone, but, as has been shown in cases of experimental,

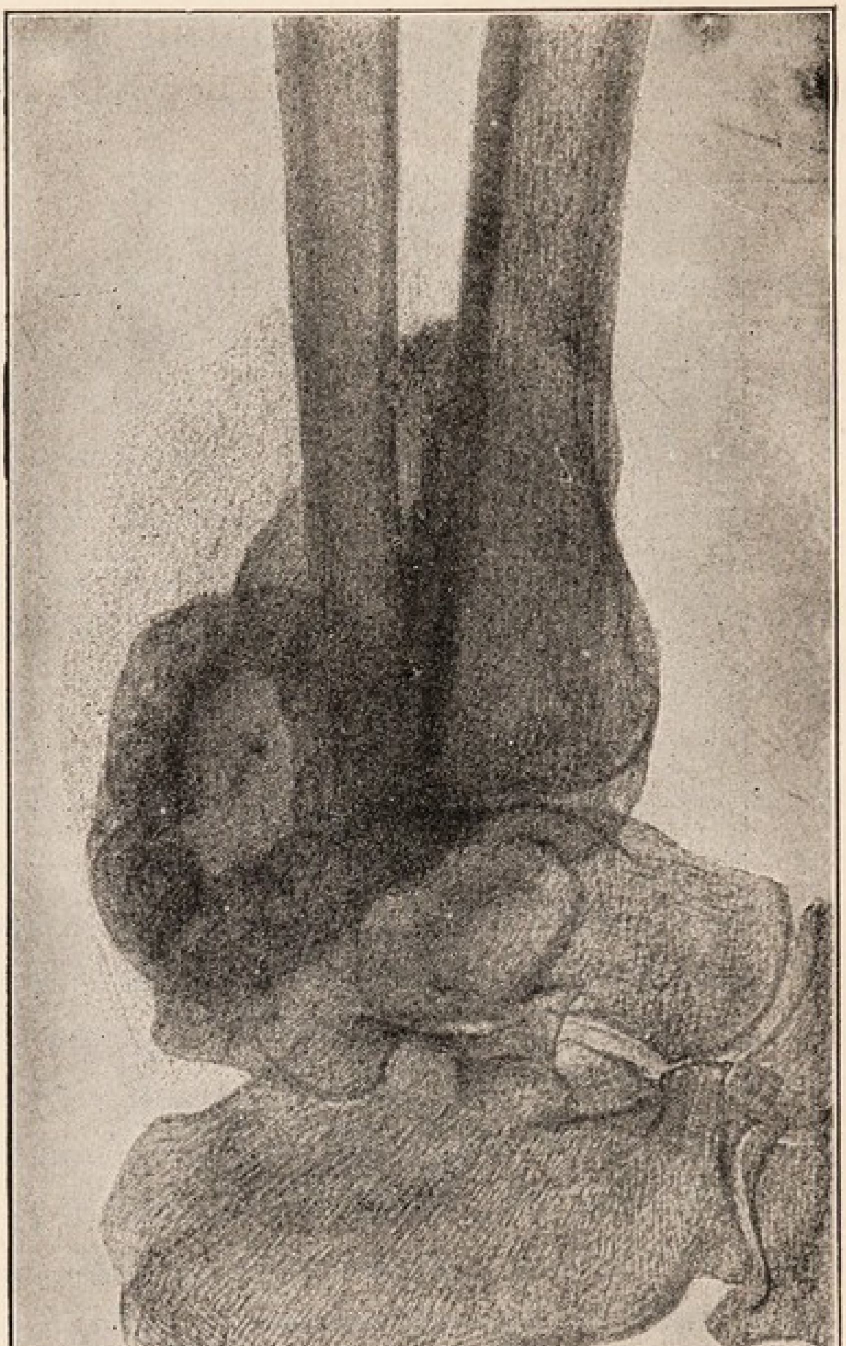


Fig. 7.—Fracture of tibia and fibula: partial resection. Large callus with opening through it caused by persistent use of through and through drainage tube.

implantation of bone into tissues distant from bone, are gradually absorbed. The tendency to excessive bone production can be controlled to a certain degree by proper treatment. Traction by stretching the muscles tends to confine the fragments to normal limits, and no drainage tubes or packing should be introduced between them. Fig. 7 shows an opening produced through a callus by a large drainage tube. Such holes and cavities close but slowly, if they close at all.

Union of uninfected comminuted fractures usually takes place very rapidly. Fractures of the humerus are not infrequently united in three weeks and fractures of the femur in from four to five weeks.

Infection not only delays union as a rule, but also, by causing the death entirely or in part of fragments, gives rise to obstinate sinuses leading to the dead fragments or sequestra, which do not close until the dead bone is removed and then often very slowly on account of the irregular cavities left in the callus. Mild infection stimulates bone formation to a certain degree, and the excessive growth of the involucrum about the necrossed bone, thereby caused, frequently results in the production of irregular and exuberant callus which interferes greatly with the function of muscles and joints in proximity to them. Furthermore, long-continued infection kept up by the presence of dead bone and the abscesses caused by the blocking of drainage by reparative tissue leads to infiltration of the surrounding soft parts by scar tissue, and this, added to the incisions which have to be made to afford drainage, has most deleterious effects upon the function of the member.

Typical osteomyelitis is exceptional in comminuted fractures on account of the free drainage afforded to the medullary cavity. Not infrequently a limited osteomyelitis is observed in transverse fractures and results in the death and separation of the entire ends of the fragments. This is particularly true of fractures in which the periosteum is stripped from the ends of the fragments, thus depriving them of their nutrition and at the same time allowing infection to enter. Destruction of the medullary artery is a frequent cause of extensive necrosis. Occasionally a missile engenders fissures which, on account of the elasticity of the bone, close, entrapping foreign material and thus producing osteomyelitis. Fissures that close, however, rarely cause extension of infection. It is rather the open fissure, along which infection may extend but which does not afford sufficient drainage, that gives rise to extensive infection of the marrow cavity. Such fissures, extending through the epiphyses into the joints, may lead to infection of the latter, necessitating amputation in order to save life.

Insufficient drainage of the medullary cavity is a cause of grave spreading of infection resulting in extensive death of bone, and this is why typical osteomyelitis is more common in slight wounds and injuries of the bones than in severer ones. Even deficient drainage of the wounds of the soft parts increases the infection and therefore prepares the way for the death of bone.

When necrosis of fragments situated centrally to the forming callus occurs (as, for instance, the ends of the main fragments), a flask-like callus is apt to form containing the sequestra in its cavity. As time goes on this callus is added to peripherally and excavated centrally, on account of the absorption going on about the

Fig. 8.—Production of exuberant irregular callus about the necrosed extremity of fragment in compound fracture of the femur. Note the absorption of the interior of the callus about the sequestrum. (By the courtesy of M. le Médecin-Major R. Leriche).

sequestra, and the flask is thus increased (Fig. 8). This produces a very troublesome condition, necessitating resection of one side of the flask to permit closure of the cavity[1].

[1]Page 32.

Repair in injuries of the epiphyses and in the short bones differs from that observed to take place in the diaphyses. There is no medullary cavity, and true osteomyelitis does not occur. On the other hand, infection leads to a troublesome osteitis, characterized by fragmental death rather than necrosis *en masse*.

The peculiarly obstinate infection and suppuration noticed in cancellous bone can be explained by the character of the lesions produced by projectiles. Such tissue, when penetrated, has a tendency to close behind the missile, which may either lodge or perforate. Along the tract thus closed are scattered minute fragments of infectious material, and about it is an extensive zone of hemorrhagic contusion. Into this area the infection may extend, giving rise to scattered foci of necrosis. In continued infection the bony trabeculæ become absorbed and the fatty tissue increases, so that the entire epiphysis becomes softened. This softening is frequently mistaken by the surgeon for necrosis, and he may do irreparable injury by curetting out tissue which, with the subsidence of infection and the resumption of function, would again become firm. These cavities do not fill with new bone, and may have to be levelled up by the implantation of soft tissue such as fat.

Besides causing death of bone, injury to the nutrient vessels of a bone has a marked influence upon repair, especially in infected fractures. This is evidenced by a rarefaction of the bone deprived of its nutrition and a lack of new bone formation, and not infrequently by non-union. Bone grafts do not take well in such cases.

Non-Union:

Non-union rarely happens in comminuted fractures, and should not occur in non-comminuted fractures properly treated. The author has never observed it in comminuted fractures in which the fragments were not removed; but it occurs frequently after improper resection of the fragments.

Union almost invariably occurs by means of the involucrum, even in the presence of extensive necrosis of the ends of the bones, if the fragments are kept in a reasonably good position. If by mischance the involucrum should break, union usually recurs rapidly; but occasionally, particularly in old cases in which efforts toward repair seem to have exhausted themselves, definite non-union results. In such cases the extremities of the fragments are found to be rounded and the medullary cavity to be plugged by eburnated bone. In such cases union will never take place until the ends of the fragments are resected or the continuity of the medulla re-establishd by an inlay graft.

CHAPTER III

TRANSPORT AND OPERATIVE TREATMENT OF FRACTURES IN GENERAL

TRANSPORT

The first treatment to be applied to a gun-shot fracture is the cutting away of the clothing, the painting of the wound and skin about it with iodine and the application of the first aid dressing. Then comes the most important (and often greatly mismanaged) part, namely, the transportation of the wounded man to the dressing station and thence on toward the rear.

The question of transportation, so far as distance and stages are concerned, depends largely upon the exigencies of the military situation; but it has been amply proved during this war that the less the transportation the better for a fracture.

In every case traction should be applied to the limbs in order to avoid laceration of muscles, vessels and nerves by the sharp fragments, and to prevent over-riding and stripping of the periosteum. If traction be efficiently applied harmful angulation at the site of fracture cannot occur.

For the treatment of fractures during transport splints and apparatus must be light and non-cumbersome, for otherwise they cannot be taken to the advanced posts. Moreover, they should be of such a nature that they may be easily and quickly applied and not interfere with the dressing of wounds. They should be designed to produce reduction and maintain alignment of the bone fragments; treatment may then be continued with the same apparatus. It is difficult, however, to find an apparatus combining all these desiderata, and usually another is substituted at the hospital in which the treatment is carried out. The various splints will be described under the headings for each fracture.

OPERATIVE TREATMENT

Primary operations:

No operation should be performed until the wounded reach a place where formal aseptic surgical treatment can be given—except in case of hemorrhage, for which neither a tourniquet nor a tampon should be used, but the bleeding point caught by a forceps. The tourniquet is provocative of gas gangrene and the tampon of infection. When either has to be used the patient should be a rush case for operation.

Every fracture should be operated with the exception of those caused by a bullet in which both wounds are punctate. The operation should be performed at the earliest possible moment; it is not a question of days but of hours, even minutes. Gas gangrene has been known to set in three hours after injury, and the earlier the operation the surer the prevention of this, tetanus and the ordinary suppurating infections.

The operative technique is extremely important, for upon the success of the primary operation in removing the causes of infection depend the entire aftercourse of the wound and perhaps the life of the patient. With the exception of special procedures in the case of wounds and fractures of certain joints which will be treated later, the operative treatment resolves itself into two categories: that of the soft parts and that of the bones.

In general, wounds of the soft parts complicating fractures are treated in the same manner as those of the soft parts alone. The region is prepared by dry shaving and cleansing with ether followed by a 3-5 per cent. solution of iodine in alcohol. After excision of the edges the wound is enlarged superficially so that the whole of the deeper recesses are laid widely open to view. The deep surfaces are then pared with scissors or scalpel until healthy, unlacerated tissues are reached; the proper depth is determined by their color, and especially by their contractile response. Some surgeons employ a fixative stain, consisting of 5 per cent. methyl blue and 20 per cent. formalin (i. e., half the commercial 40 per cent., a weaker solution not being sufficient), to color the devitalized parts, but equally good results are reported by those who use nothing. If the operation is methodically and correctly performed it is obvious that when the whole of the superficies of the wound surfaces is removed all foreign materials are removed as well, so that theoretically there is no need of X-rays to determine the presence of missiles; but practically, an accurate localization by the X-ray gives valuable information in helping to determine the course of the projectile and the approach, especially if counter incisions have to be made.

Wounds treated in this way may be closed by primary, delayed primary, or secondary suture. The term *primary suture* is applied to the immediate closure of wounds. When suture is performed after a delay of two or three days because of doubt as to the removal of contamination or because of the evacuation of the patient (i. e., removal from observation), the term *delayed primary suture* is employed. If the operation to close the wound has to be postponed, on account of infection, until the formation of granulations, the term *secondary suture* is used. In the latter case a second excision of the wound, entailing a further sacrifice of normal tissue, is necessary; if this is not done the operation seldom succeeds, or results in the production of an inordinate amount of cicatricial tissue. Primary or delayed primary suture is therefore obviously preferable to secondary suture, and should always be done if possible.

Uncomplicated wounds of the soft parts may be successfully closed by primary or by delayed primary suture in 98 to 99 per cent. of cases; the structures involved are, as a rule, of minor importance, and risks may be taken that would be unwarrantable were the wounds complicated by fractures. Nevertheless, most fractures may also be closed in this way if certain points in the operative technique are carefully observed; indeed, in many cases, as will be shown, they may be sutured primarily with as much impunity as wounds of soft parts alone. It is, as a general principle, however, more prudent to practise delayed primary suture when a fracture is present, on account of the difficulty of removing foreign materials from among the bone fragments. Herein lies the importance of distinguishing between fractures by impact and fractures by penetration.

In the former case the projectile does not enter the medullary canal, and the wound may be sutured as though it were an uncomplicated wound of the soft parts. The stitches should be interrupted and spaced sufficiently to permit a certain amount of drainage and yet accurately approximate the tissues. A few strands of silkworm gut are inserted to serve the double purpose of draining the wound and providing a tell-tale as to the bacteriological flora it may contain; they are removed at the end of the second or third day and cultured to determine whether the wound may remain closed or should be re-opened.

If the missile has penetrated or perforated the bone, however, the medullary canal must be considered to be contaminated, and must be laid open and explored. To do this it is nearly always necessary to remove some of the fragments. Absolutely detached fragments should always be removed, since they have become foreign bodies and will surely necrose should infection supervene. Unhappily their removal seldom affords sufficient exposure of the medulla, and therefore fragments still attached to their periosteum must also generally be cut away. The greatest care must be exercised in excising them, and only enough and no more should be removed. Care should be taken to leave at least one or more, if possible, to preserve the continuity of the shaft. In other words, if a resection is done it should be lateral and not transverse in character. When a piece has to be removed it must never be torn or pried away; it must be cut out, leaving its outer layer adherent to the periosteum. This can only be done by one instrument, namely, the cutting periosteum elevator of Ollier (Fig. 9). The edge of this rugine must be kept as sharp as a

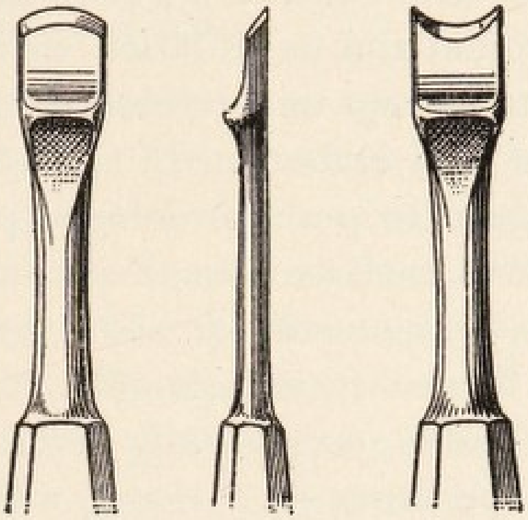


Fig. 9.—Cutting Periosteum Elevator of Ollier.

razor, and several may have to be used during an operation; a number of them, of various sizes, should be at hand. The fragment to be separated must be held firmly in a bone forceps while its outer layer is sliced off by lateral movements of the rugine. The medulla having been sufficiently exposed, all loose fragments and pulpified medulla should be removed, as the latter is apt to be filled with particles of clothing.

In the case of fractures in which the missile has perforated the bone, comminution is frequently more marked at the side of the bone opposite to the wound of entrance and the soft parts there are more likely to be filled with contaminated bone fragments and therefore to need more careful treatment than those on the side of entrance. Consequently, in such a case it is wise to approach the medullary cavity from both sides of the limb.

For fractures by penetration great judgment must be exercised in practising primary suture, the nature of the missile, the time elapsed since wounding, the character of the wound and its situation, as well as whether the patient is to be kept under observation or evacuated, must be taken into account. It is wiser for an inexperienced surgeon to practise delayed primary suture. Certain fractures, such as those of the femur, which are surrounded by thick muscles in which the anaërobic bacteria are apt to proliferate, should not be closed primarily except under exceptionally favorable conditions. If infection supervenes in a closed wound it is much more violent in character than in an open one, and results in a far greater setback to convalescence.

If there is grave doubt as to whether the wounds are infected (as, for example, in the case of delay before operation exceeding eight hours—the period during which bacteria remain latent) it is better not only to leave the wounds widely open but also to use a complete Carrel installation so as to remove the wound secretions as completely as possible during the first few days following the operation.

A fracture which is transported after operation is more likely to become infected than one retained in the service of the operator, and, consequently, as many fractures as possible should be kept in the hospital where they have been operated. If they must be evacuated, delayed primary suture may be done at the hospital in which the patient is ultimately retained. It is extremely important that the series of hospitals through which fractures pass should be in close relation with one another so that the results of operations may be closely followed.

Operations in infected cases:

In obviously infected cases successful primary suture cannot be hoped for. Tissues which have already developed protection should not be excised, but all dead and foreign material must be removed and free and efficient drainage afforded. The incision should be free enough to enable inspection of the entire wound by sight, but the operation must be gently done and no indiscriminate rooting with the fingers is permissible.

In cases of gas infection (B. Welchii), the incision should be very free and all dead muscle removed. In exceptional cases the entire muscle may have to be excised. In any case, the incisions should reach into freely bleeding muscle. It is to be remembered that the gas infection extends along a muscle and is often limited by the muscle sheaths. Incisions should, therefore, be longitudinal, in the axis of the muscle, and never transverse.

In infected fractures it is usually unwise to resect or remove any attached fragments; it is better to wait until the dead or dying portions of bone are sequestrated.

All such wounds should be left freely open, with gauze laid lightly in them. Paraffined gauze does not stick and may be used, but ordinary gauze drains better and should not be removed until it is loosened. It is sufficient to keep the exposed parts of the wound well cleansed with soap and water, and hydrogen peroxide if obtainable, afterward washing with alcohol or ether. The use of drainage tubes is bad practice, for they only drain locally and allow the surface of the remainder of the wound to adhere and form pockets. If drainage is indicated it is advisable to employ the Carrel method of using many small tubes and intermittent irrigations. It is obvious that an infected fracture must not be secondarily sutured until all dead bone is eliminated.

Resection:

Typical resection (i. e., removal of all the fragments) of diaphyseal fractures is, in general, to be condemned. Good results have been obtained by surgeons skilled in the technique of resection, but it is not a procedure to be recommended. The resection should be confined to the removal of only sufficient bone to expose the medullary canal (*vide supra*).

On the other hand, certain fractures of the joints should be resected, so that every surgeon must familiarize himself with the rules governing the operation or his results will be failures. The greatest care must be taken to preserve the periosteum as a continuous sheet in so far as possible, or the consequences will be disappointing. The elevator or rugine of Ollier (Fig. 9) should be used for the purpose. The periosteum is separated but a thin shaving of bone is left adhering so that the osteogenetic layer is well conserved. In using the instrument the hand must be controlled so as to avoid slips and tearing of the periosteum. The greatest care should be exercised in removing the muscular attachments.

As a rule, the resection should not be unilateral; that is, the cartilage, at least, should be removed from the other bones forming the articulation with the exception sometimes of the glenoid cartilage in the shoulder. The classical incisions should be made unless the wound affords abundant access.

The wound is lightly packed with gauze; some surgeons prefer iodoform gauze, although it is not indispensable, especially in clean cases. The packing is arranged so as to keep the periosteal tube from collapsing, and is used for two or three weeks, being changed as infrequently as possible. Tubes have to be used in some resections—such as resection of the hip by the anterior method, in which dependent drainage through a posterior opening is necessary.

In infected cases the aim is to keep the ends of the bones separated (even in the knee when ankylosis is desired), until the infection has subsided. Too much stress cannot be laid on removing all the cartilage in infected cases, because it prevents repair and prolongs suppuration. The after-care is most important and will be considered with the treatment of fractures of special joints. In general, where a return of function is sought for, very early motion should be instituted, particularly active motion by the patient, in order to maintain the function of the muscles, and, by their contraction, to pull out and mold the new bone to its proper shape.

The indications for and technique of resections of the various joints will be considered under the heading of each.

Internal fixation:

Systematic plating, banding and wiring of compound fractures of war have had an extensive trial and are almost universally condemned. In exceptional cases this procedure may be practised when a fracture cannot be retained in reduction by other means, but such cases are rare. It is often a temptation to band or wire long splintering fractures, but equally good results can be obtained otherwise without the risks of the operation. Internal fixation of an infected fracture is, as a rule, bad surgery.

Operations for sequestra and bone sinuses:

Nearly every case of infected war fracture unites with sequestra in the callus. The sinuses resulting therefrom are difficult to close and often keep a soldier, who is otherwise perfectly well, from active duty for months and even years. They will not definitely heal until the necrosed bone is removed, and this should therefore be done at the earliest possible moment, not only to enable the sinus to close but to avoid osteitis and excessive formation of callus.

Judgment must be exercised as to when to operate. If the operation is performed before the dead bone has become separated it will be a failure, because the traumatism provoked in removing the necrotic portion leads to further necrosis. There is also great danger of refracturing weak unions.

The moment to operate is when the dead portions have been detached from the living, at which time they can be picked out of the sinus with the least traumatism. Usually this occurs in six weeks, but the time is influenced by the amount of blood supply to the parts. In weak unions it may often be wise to wait for the growth of more callus, but it must be remembered that an area of absorption is being created about the sequestrum and the operation should not be postponed until disagreeable cavities are formed.

The best way of determining the presence and location of sequestra, if they cannot be felt by the probe, is by X-rays. Stereoscopic plates should be taken by which the sequestra can be localized standing out by themselves surrounded by a clear interval between them and the less dense callus. In this way their exact number and location can be determined and everyone subsequently accounted for at operation. The trouble and expense of stereoscopic plates are far less than those of several operations and the cost of months of treatment thereby entailed.

Operations for sequestra possess none of the excitement of abdominal surgery but are even more difficult and require the most painstaking care. As a rule the sinus and scar are excised and the opening thus made used as the approach—unless the sequestrum has been located on the other side of the bone, when an incision over it should be made. The dissection is carried out along the sinus and if the necrotic bone is within the callus the periosteum should be carefully lifted. The callus should be interfered with as little as possible. By efficient sponging the dead white sequestrum can be seen and removed. Others, if present, should be sought for in the same way; the stereoscopic plates being on view so that their relations with one another may be compared. Blind curettage of a bone sinus is bad practice.

The aniline antiseptic dyes—methyl blue, gentian violet, flavine or brilliant green—may be used to stain the sinuses and are of help, but they are not so reliable as stereoscopic X-ray plates. It is difficult to obtain penetration of the stain throughout the sinuses.

After removal of the sequestra, in the presence of a reasonably clean field the ends of the incision may be approximated, and drainage may be dispensed with unless evidently needed, when light gauze packing should be employed.

Sometimes when the operation to remove sequestra is deferred for too long a period, particularly when large portions of the main fragments necrose, large cavities are formed more or less completely surrounded by an irregular callus. Such cavities, unless operated on before the medullary cavity of the main fragment is plugged by new bone (thus stopping all regeneration of bone from that source), are almost incurable and sometimes demand amputation or wide resection of the whole area including the condensed bone closing the medullary cavity. A resection of this extent produces crippling shortening, as a rule, unless a bone graft can be used. If, however, the operation is performed at an early date it will suffice to resect one wall of the cavity, preserving the periosteum covering the resected callus and thus allowing the soft parts to collapse and obliterate the dead space. In such operations all the old granulations and cicatricial tissue lining the cavity should be carefully excised so as to allow the periosteum of the side removed to come into direct contact with the callus remaining on the opposite side.

Vicious union:

Many cases of vicious union demanding correction come to base hospitals. They are often complicated by dead bone and fistulæ, and it is usually advisable to get rid of the latter before revising the union. In some cases with quiet sinuses showing no signs of active infection, the dead bone may be removed and the fracture revised at the same operation; but the wound, under such circumstances, must not be closed.

The methods employed to revise fractures obviously depend upon the site and the nature of the mal-union.

Internal fixation is seldom necessary. If the fragments cannot be maintained in good relation by fixing the limb in proper position, an inlay graft may be of value. Repair of fractured callus is very rapid if it is fairly recent. After several months, however, it loses its vascularity and repair is slow, so that operation on these cases should not be deferred.

Non-union:

In true non-union the ends of the bones become healed over and the medullary cavity plugged with dense callus. Union will not take place unless this bone plug is cut away and the medullary cavity made continuous. Non-union is generally caused by loss of substance (i. e., removal of a section of bone either by the projectile or by the surgeon), and therefore, if all the dense material forming the ends of the bones is cut away, considerable shortening results. Hence bone plating should not be used, for it is decidedly unwise to put on a plate and leave a gap between the bone ends. The treatment for these cases is an inlay graft by the Albee method. The channel cut to receive it passes through the dense ends and thus the medulla is made continuous by means of the medullary surface of the graft. The ends of the fragments are not removed, and the bone is therefore not shortened by the operation.

Delayed union:

Delayed union is best treated by use of the member. An ambulatory apparatus such as the Delbet (Figs. 34, 36 et 37) may be employed in the case of the lower limbs. Injections of blood between the ends of the fragments should be made in refractory cases.

CHAPTER IV

MECHANICAL TREATMENT

Since the beginning of the war mechanical treatment (i. e. the external fixation of fractures) has passed through several phases. The tendency has led steadily and progressively away from the methods of absolute fixation by splints of wood, metal and plaster of Paris toward methods in which the main principle is traction (extension of the member in what may be called the physiological direction and position). With this latter method the old rule of fixation of the adjoining articulations has passed into obscurity.

It by no means follows, however, that plaster of Paris and other splints should be done away with entirely. They are of the greatest value for certain conditions, more particularly in some stages of convalescence and for late transportation.

The inadequacy — even harmfulness — of plaster, especially the circular forms, for *fresh* fractures, became evident very early in the war. It constricted the limbs, causing sometimes œdema, sometimes gas gangrene; or, on account of the rapid atrophy of the muscles, the splints became so loose as to afford little support. Pressure sores were common. Filth collected under the plaster and abscesses hidden from sight were formed. Dressings were difficult, even with the most skillful bridging. The joints stiffened, and, in short, the condition of the fractured member became deplorable.

The treatment which is finding greatest favor and gradually becoming generalized is *suspension of the member combined with traction.* A simple form of splint acting as a cradle (such as Hodgen's for the lower extremity) is used or no splint at all, and the limb is suspended to an overhead frame with or without a trolley attachment. Traction is applied by a weight attached to a cord running over a pulley, or simply by utilizing the weight of the patient. The limb is suspended in a position of flexion, rotation or abduction which as nearly as possible coincides with that of physiological rest for the opposing muscles, i. e. those tending to cause deformity. This position of physiological rest is a most important object to attain, for with it little force is necessary to keep the fragments in place. Unfortunately, on account of wounds, infection and other complications, it is often impossible to accomplish it, but it should always be the goal aimed at.

The great advantages of this system become at once apparent to one who has struggled with other methods —the circulation is better, the wounds are accessible, union is if anything more rapid, and, greatest boon of all, the patient has no pain. Furthermore, the articulations are seldom fixed and the muscles are always accessible for massage.

Suspension apparatus:

In order to suspend fractured limbs some sort of overhead frame or apparatus is necessary. The original

Balkan frame consists of a single horizontal bar, longer than the bed, supported by two posts set on foot pieces in order to make the apparatus stable and allow it at the same time to be moved from one bed to another. This frame has the disadvantage of having only one bar, of being too low, of being heavy and clumsy and only suitable for the lower extremity.

The frame shown in Fig. 10 by itself, and in use in the figures illustrating the method of suspending the different fractures, is free from most of the above defects and has proved its practicability. It has the disadvantage of being difficult to attach to beds that are not supported on legs at the corners; but this can be overcome by nailing longitudinal bars of the length of the bed to the feet of each pair of frames, and thus fastening them together under the bed, or by simply nailing the feet to the floor. The frame is furnished by the Red Cross and described in the Army Splint Manual, but in case of delay in obtaining a supply it can readily be made by anyone having the slightest knowledge of carpentry.

The apparatus consists of two similar frames, one of which is tied to the foot and the other to the head of the bed. Each frame is composed of two uprights united by two cross members; the lower one at the level of the top of the mattress, the upper one far enough below the upper ends of the uprights to avoid splitting of the ends of the latter by the screws or bolts which are used to fasten them together. The upper cross member is notched, as shown in the diagrams, to receive the longitudinal bars, which are also notched. Several extra notches, two outside and two inside of each upright, are made in the cross member to receive the longitudinal bars in the proper position over the limb to be suspended. Only two notches are made in the longitu-

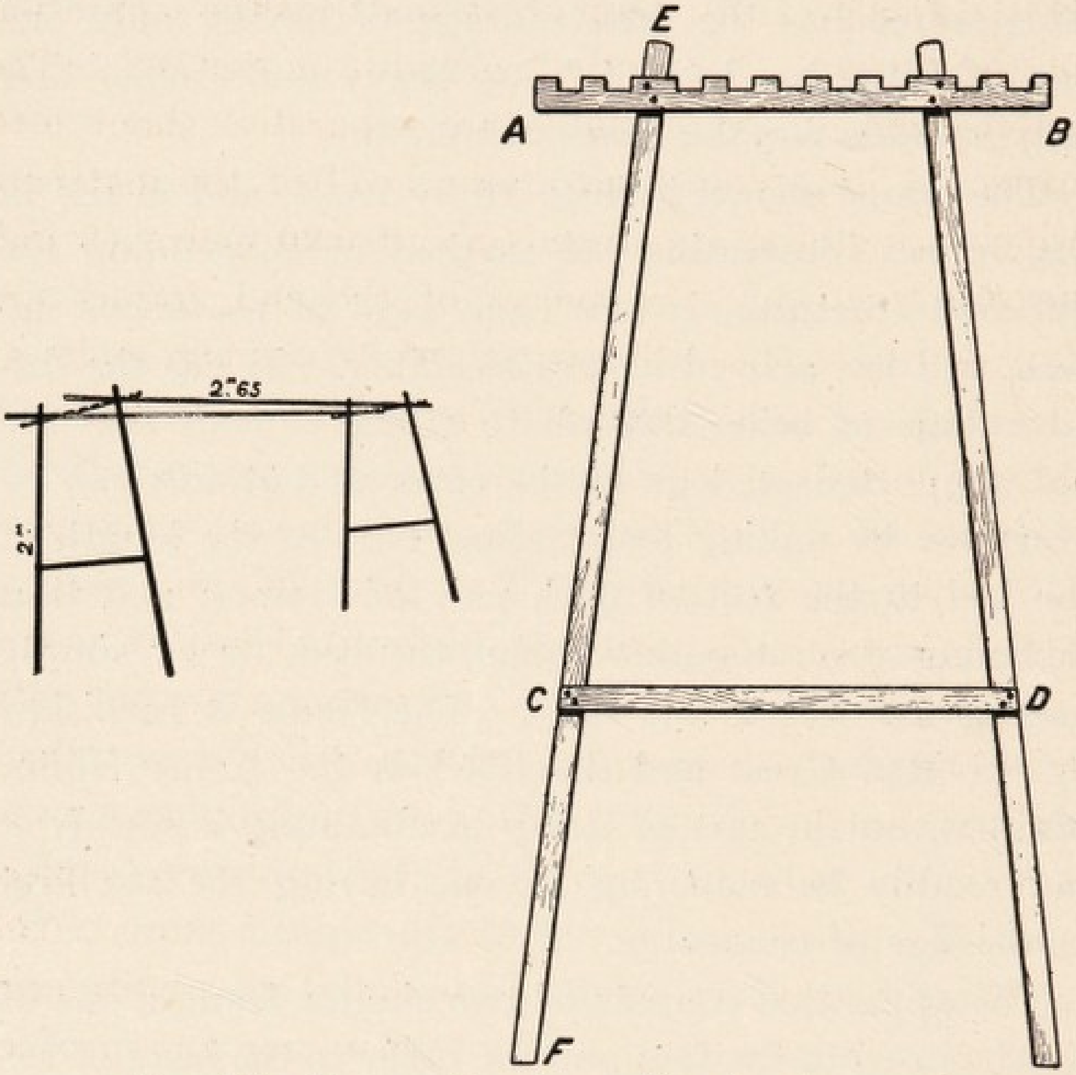


Fig. 10.—Suspension frame for fractures.

dinal bars, the distance between them being the exact length of the bed. The interlocking of the notches prevents the longitudinal bars from slipping and makes the entire frame rigid.

The end frames, as will be seen by the diagrams, are made in the shape of a truncated "A", the uprights below being separated slightly more than the feet of the bed, while the upper ends are closer together. Each upright, E-F Fig. 10, is 2 metres (80 in.) long. The upper cross piece, A-B, is 1 metre (40 in.) long. The lower cross piece, C-D, is as long as the bed is wide, so that at the level of the top of the mattress the separation of the uprights is exactly the width of the bed. The lower ends of the uprights are separated about 0.10 metre (4 in.) more than at the level of the mattress, which brings the upper ends about 0.20 metre (8 in.) nearer together. The pieces of the end frames are fastened together with two screws or carriage bolts at each point. Bolts are better for frames to be knocked down for transportation.

The best material for the purpose is soft white pine free from knots; this does not split and the eyes or screws of the pulleys are easily inserted into it. Any wood may be used, however. Using soft pine the author has found material 0.021 metre (7/8 in.) thick and 0.05 metre (2 in.) wide for the uprights and lower cross piece sufficient, while for the upper cross piece and the longitudinal bars slightly wider material, 0.06 metre (2½ in.), should be used. The longitudinal bars are 2.65 metres (10 ft. 4 in.) long and project over the ends of the frames so as to allow the weights to hang beyond the head and foot of the bed.

Suspension is effected by strong cord passing through pulleys. The pulleys used are the ordinary iron ones found in any hardware shop, furnished with a screw to fasten in the wood or with a hook which is hooked into a screw eye.

To permit the patient to move longitudinally in the bed, as in the change of posture from lying down to sitting, it is advisable to have a short bar to which the limb and weights are hung, and which moves on a trolley attached to the longitudinal bar of the main frame. This bar is made of a piece of wood 0.30 metre to 0.45 metre (12 in. to 15 in.) long (Fig. 11), in the bottom

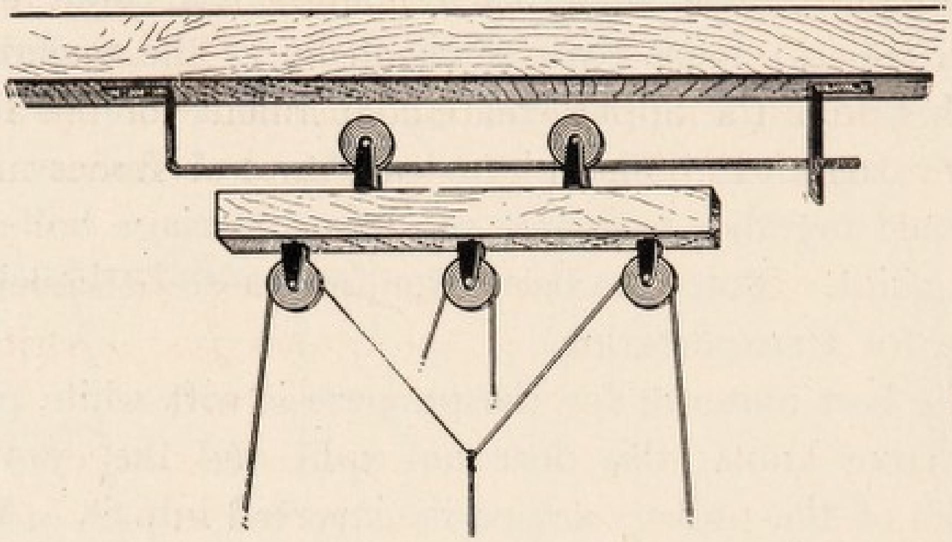


FIG. 11.—Detail of trolley bar for suspending the lower limb.

of which are screwed the pulleys through which the cords for the suspension pass. Two pulleys are screwed into its upper side and run on an iron rod 10 millimetres (3/8 in.) thick. One end of this rod is bent and tied to the main longitudinal bar, while the other is straight in order to allow it to engage the pulleys and is passed through a hole in a piece of strap iron bent at right angles, which is in turn fastened to the longitudinal bar by two screws. In default of screw pulleys the iron strap hooks furnished by the Red Cross and figured in the Army Splint Manual may be used for attaching the short bar (trolley) to the long longitudinal bar.

In practice it has been found that the trolley attachment is very important for suspending the lower, but is superfluous for the upper extremity.

The best weights are cast from lead, weigh 500 grammes each, and are strung on an iron rod, but when they hang over the patient in such a position that he or the attendants may strike against them it is better to use small bags of shot, each holding 250 grammes, placed in a larger bag of strong muslin. These smaller weights permit a more delicate adjustment for the arm and forearm. Failing shot or lead, sand or stones may be used.

For suspension of the arm a simple post with a horizontal arm may be used, but the frames just described are adapted for the treatment of all fractures.

In some of the English fracture services installed in barracks an overhead frame is constructed as part of the building. It consists of a pair of longitudinal bars, of about 0.10 metre × 0.075 metre (4 in. × 3 in.) square section. These pass over the beds at the level of the eaves on each side of the barrack and extend the entire length of the building. The bar nearer the wall is at about 0.85 metres (2 ft. 6 in.) distance from it, and the other at 2.25 metres (7 ft. 6 in.); the latter thus passes directly over the bottom of each bed. Across these, other bars, about 2.40 metres (8 ft.) in length, may be placed for suspension of limbs. To provide for traction, such as that required for a fracture of the femur, a post is used, the lower end of which is fitted into a step in a board nailed to the floor in front of the foot of the bed, and the upper pinned to the longitudinal bar over it. A number of steps are cut in the board so that the post may be put into the position requisite to obtain the desired abduction of the limb. The foot of the bed may also be suspended from the bar, in order to obtain the necessary traction if the foot is attached directly to the post, or counter-traction if a weight and pulley are used.

This overhead construction is to be recommended for fracture services installed in barracks, but it must be lower than the eaves or it is impossible to arrange the suspensions without a stepladder. 2 metres (6 ft. 6 in.) is the most convenient height.

Methods of attaching suspension and traction apparatus to the limbs:

The several methods of suspension will be discussed under the headings of the different fractures.

For direct attachment of the apparatus to the limb several adhesive substances may be used. The most convenient have been found to be Sinclair's[1] glue or Heussner's[2] liquid glue, both of which are painted

[1] Formula for Sinclair's glue (from the *British-Medical Journal,* August 26, 1916, p. 301):

Glue	50	parts
Water	50	"
Glycerine	2	"
Calcium chloride	1	"
Thymol	1	"

[2] Formula for Heussner's glue:

Resin	50	parts
Alcohol 90 0/0	50	"
Venice turpentine	1	"
Benzine	10	"

directly on to the limb with a brush. Bands made of Canton flannel and furnished with straps of webbing for tying or buckling to the apparatus are then immediately applied. A supply of two sizes of these bands, one for the leg and the other for the arm, should be made and kept in stock; they are readily trimmed to the necessary size for any individual case and are more easily applied than straps made of diachylon plaster, although the latter is one of the best and least irritating of the materials that can be used. If the flannel and webbing bands are not at hand, however, stout muslin or several layers of gauze may be employed. Rubber plaster is liable to slip and should not be used.

Sinclair's glue, being an aqueous preparation, is well borne by the skin. It adheres firmly. Sinclair does not shave the skin but strokes the hairs upward in applying the glue, which should be as warm as can be supported. Heussner's preparation does not slip, but it occasionally irritates. When using either glue the skin, as for all impervious plasters, should be carefully cleaned preliminarily by scrubbing with soap and water and then removing all traces of the same with alcohol. No antiseptic other than alcohol or ether should be used.

Traction:

The most obvious object of traction is to overcome longitudinal deformation, i. e. overlapping. It also to a certain extent prevents lateral deformation, i. e. angulation; and if it is made in the proper direction, namely, in that of the axis of the proximal fragment, the tendency to angulation is so slight as to make ordinary fixation unnecessary. In fact, as has already been stated, the time-honored rule of fixing the adjacent articulations no longer holds and in most instances may be disregarded.

There are two main methods of producing traction; one by a force exerted continuously, as by weights and springs, the other by a force exerted momentarily, the resultant length being retained by fixation as in the ordinary application of the Thomas knee splint. In the latter method there is no way of estimating the tractive force, the only guide being the result obtained. Theoretically this would seem to be, and is thought by many to be, the better method. The objection to it is that it is difficult to maintain what has been gained without producing discomfort. For instance, taking the Thomas splint as an example, the length of the limb is maintained by attaching the traction straps to the distal end of the splint and consequently continuous pressure is exerted by the upper part of the splint against the pelvis. This pressure is sometimes insupportable. To avoid it a weight may be attached to the end of the splint by means of a cord running over a pulley, thus substituting active traction for the passive traction of the Thomas splint proper; or the same result can be accomplished by attaching the splint to a fixed point and using the weight of the patient (the bed being inclined), as practised by Sinclair. By using the Thomas splint in the manner described its great advantage of being a self-contained traction splint permitting the patient to be moved, as for operations or X-rays, is retained, and at the same time the objection of constant pressure against the pelvis is obviated. If the Thomas splint is used by itself, without traction on the whole splint, care should be taken, in tightening the traction from time to time, not to over-stretch the limb and thus ruin the knee-joint. This may easily happen on account of the impossibility of gauging the amount of traction employed. The loose, weak knees so often observed in convalescents after fracture of the femur can be largely avoided by due regard to the principles involved. Many surgeons commit the error, when using weights, of commencing with a comparatively small one and adding to it until the desired effect is produced; not realizing that, on account of the process of repair, each day makes the reduction increasingly difficult. In this manner the weight is increased to an inordinate amount and continued for an unnecessary length of time. Consequently, if the traction is made through a joint, the ligaments will be gradually stretched and the joint may be irreparably damaged. The correct method is to use a weight sufficient to reduce the fracture in the first two hours and to then decrease it to the amount just necessary to maintain the position. If traction is applied in this way little trouble will be experienced in regard to the joints.

Traction by means of elastics and springs is difficult to control, is not well borne, and is in general unsatisfactory.

Radiographic control:

It is impossible to treat fractures properly and intelligently without frequent radiographic observations. This is particularly true of gun-shot fractures because of the frequent dressings that are often necessary and that cause disturbance of the mechanical treatment.

Radiographs should be taken directly after the splints and apparatus have been applied and as often as is necessary to verify the position and observe the course of repair.

It is unwise and impracticable to move the patient to the X-ray room, and there should therefore be a portable apparatus in every fracture service. In hospitals where there are large wards near the radiographic department wires may be carried from the latter and extended throughout the length of the wards, and to these the X-ray tube may be directly connected.

Nerve lesions:

All cases of fracture should be carefully examined for injuries to the nerves before the anæsthetic is given for the primary operation, so that they may be sutured if possible at that time.

Due care must be taken in the after treatment of these cases to prevent deformation, contractures and trophic disturbances such as pressure sores.

When there is a lesion of the musculo-spiral nerve the hand must be kept in the position of dorsiflexion so that the flexor muscles may function. For this purpose, especially during convalescence, the Jones cock-up splint is excellent; it bandages to the flexor surface of the forearm. Another good cock-up splint may be made of thin sheet metal placed on the dorsum of the forearm and wrist and reaching just to the heads of the metacarpals. A narrow band at the end of this passes across the palm, holding the hand up. This band does not interfere so much in grasping objects as the splint placed on the flexor surface.

SECTION II

SPECIAL FRACTURES

CHAPTER V

DIAPHYSEAL FRACTURES

CLAVICLE AND SCAPULA

Fractures of the clavicle and scapula, when not involving the shoulder joint, are treated as in civil practice. Either the Sayre, or the sling and body bandage may be used. It is often impossible to use a typical method on account of the position of the wounds.

The chief complications of these fractures are injuries to the lung, brachial plexus and subclavian vessels.

HUMERUS

Transport:

Three splints are furnished by the Red Cross for splinting the humerus for transport. These are, in order of preference: Murray's hinged modification of the Thomas traction arm splint (Fig. 12 A), the Thomas traction arm splint (Fig. 12 B), and Jones' humerus traction splint (Fig. 13). The unmodified Thomas splint would be best were it not for the difficulty of transporting a man with his arm extended at right angles to his body.

Neither the Murray modification nor the Jones splint afford abduction, and this is an objection to their use for the continued treatment of high fractures. The

Jones is a right and left splint and, moreover, several sizes are necessary.

Failing these splints a fractured humerus may be transported satisfactorily for a short distance by using a sling and body bandage, provided that the axilla and

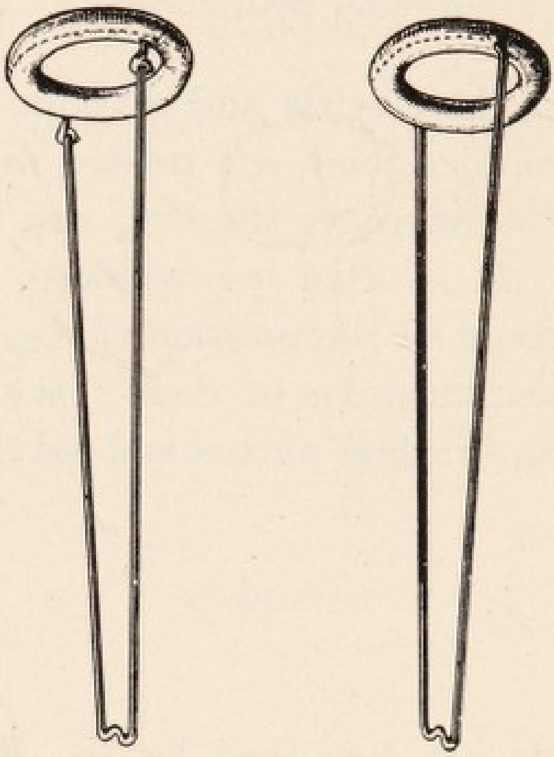


Fig. 12.

A. The Thomas traction arm splint.

B. Murray's modification of the Thomas traction arm splint. The bars are hinged to the ring, thus allowing the arm to hang by patient's side.

side are well padded and that some form of coaptation splint is used to prevent angulation.

In both the Thomas splint and Murray's modification traction is made with the arm and forearm in a straight line, i. e. with the elbow extended. It should be effected by means of adhesive straps attached to the skin of the forearm. In case these cannot be applied, as, for instance, when there are wounds of the forearm, a clove hitch may be taken with a bandage about a heavy dressing of cotton placed on the wrist. In either case

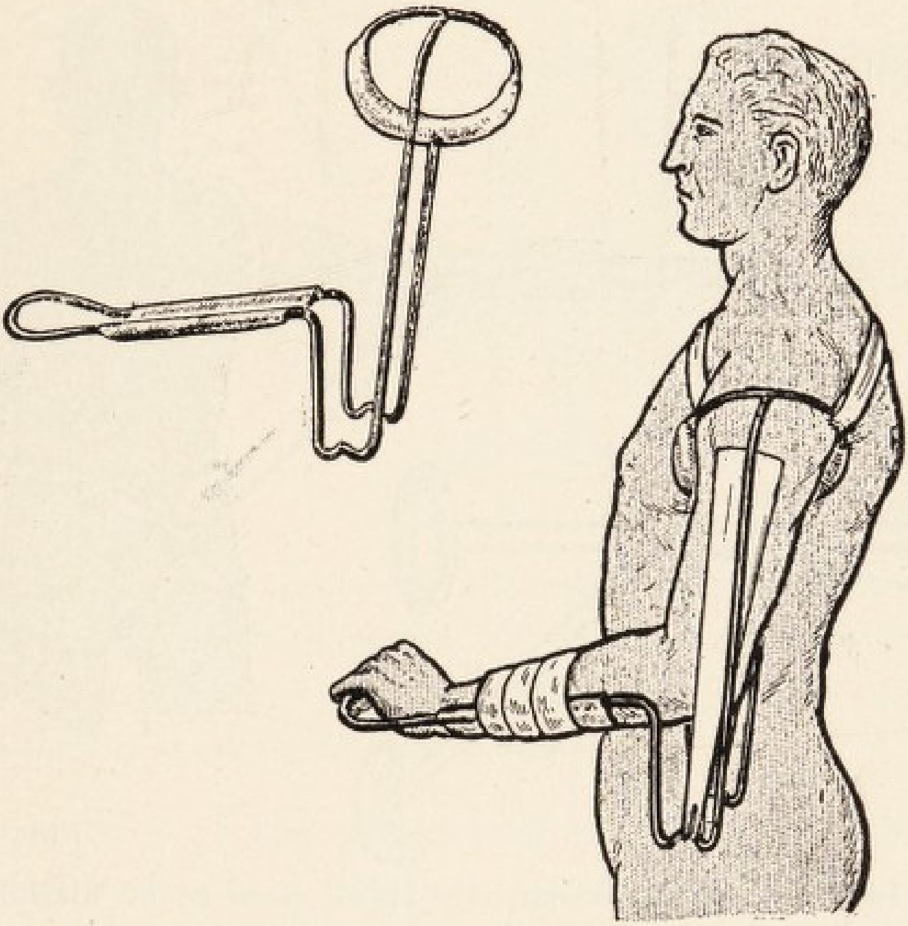


Fig. 13.—The Jones traction humerus splint.

the straps or the extremities of the bandage are tied to the end of the splint after having been first placed one over the other under the bars. Traction is then made by twisting, by means of a short stick (Spanish windlass).

In using the Jones humerus splint, traction is supposed to be effected by adhesive straps attached to the skin of the arm, the elbow being flexed; but in fractures of the lower part of the humerus the straps obviously cannot be used, and a hitch must be taken about the elbow with a bandage. All such hitches must be pinned in order to prevent their drawing tight and constricting the parts.

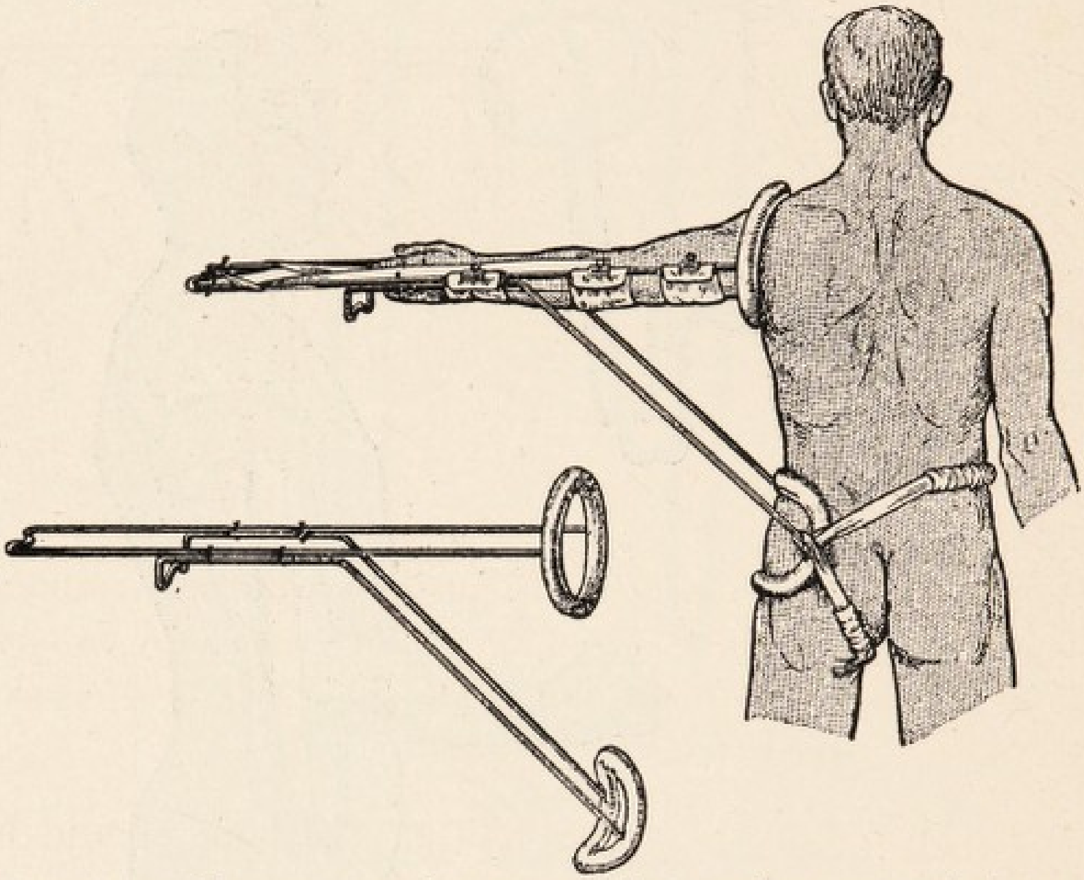


Fig. 14.—Thomas traction arm splint used as an ambulatory splint. Abduction is maintained by bending another Thomas splint to form a support.

Operative treatment:

Should be conducted as laid down for fractures in general. When operated on before infection is established, the musculo-spiral nerve, if divided, should be sutured.

Mechanical treatment:

Much ingenuity has been expended in devising ambulatory splints for fractures of the humerus, but none of them fulfill all the requirements, though they may render excellent service after union has commenced and deformation is no longer likely to occur.

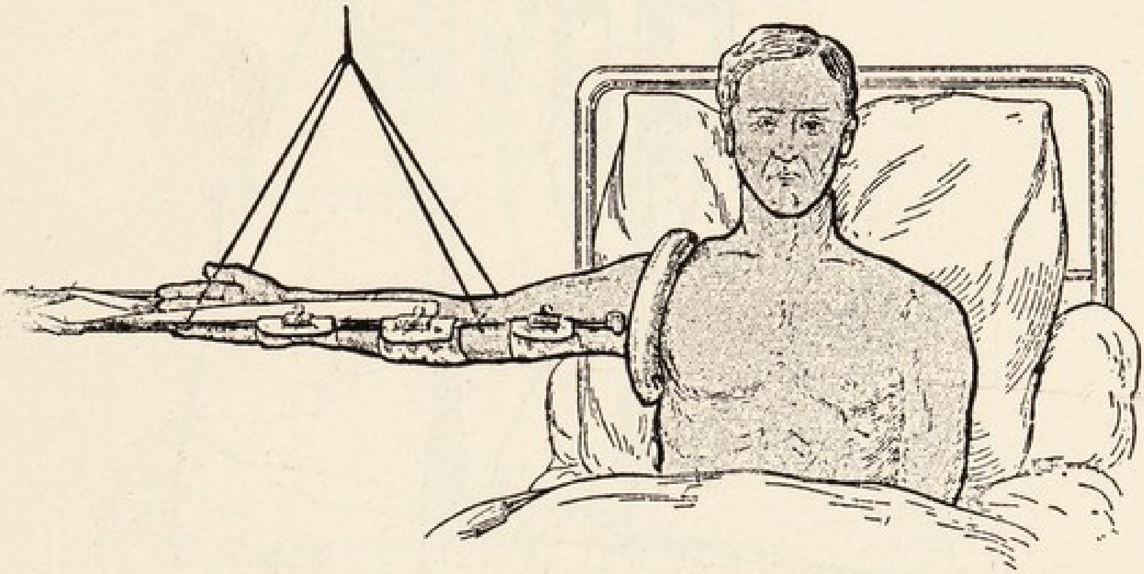


Fig. 15.—Thomas traction arm splint used for bed treatment of fracture of the humerus. Traction is made by twisting the bands by means of a nail. The splint may be suspended as shown, or at its extremity alone.

Fractures of the upper half of the bone should be treated by traction, rotation out and abduction, according to the site. Fractures of the surgical neck usually require extreme abduction and rotation out (Fig. 19). This position brings the hand to a level above that of the head—a position extremely difficult to maintain with an ambulatory apparatus.

Fractures of the lower half do not, as a rule, require abduction and external rotation, and could be satisfactorily treated with the Jones splint were it not for the difficulty of arranging the traction in presence of low wounds and of keeping the splint in place. The Thomas splint can be employed for any fracture, and may be used as an ambulatory splint when supported

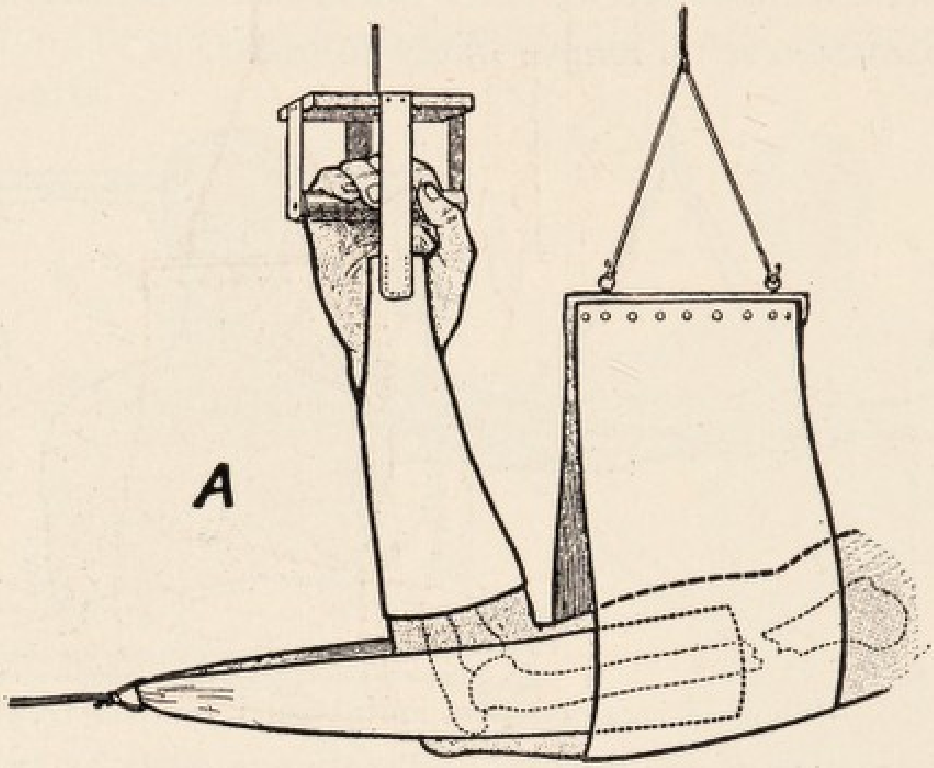
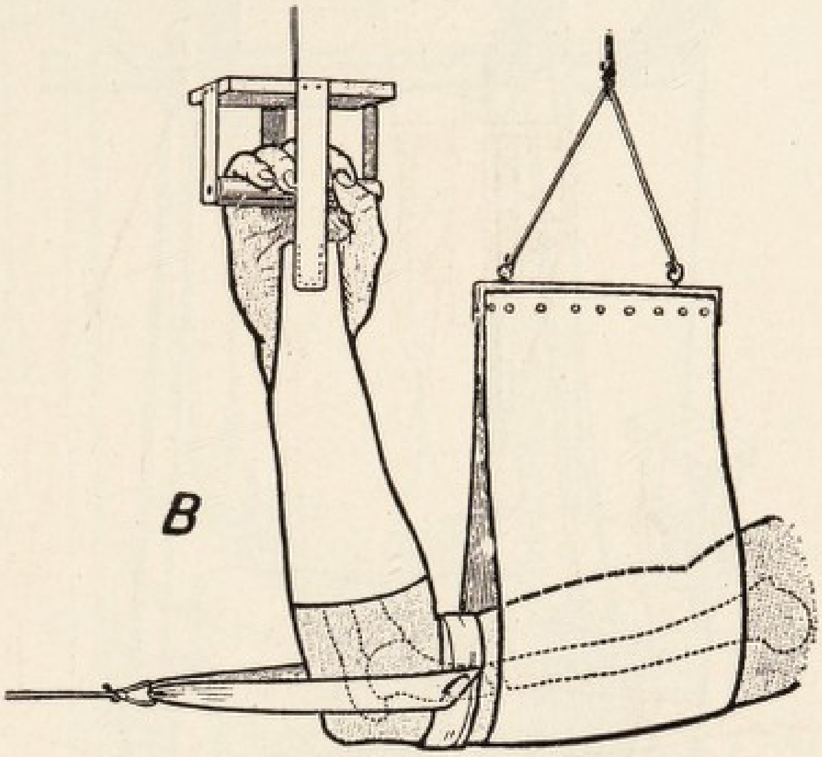


Fig. 16.—Principles of suspension and traction for fractures of the humerus:

A. High fracture of the humerus for which adhesive strips can be used for traction.

as shown in Fig. 14; but when it is utilized the patient is generally kept in bed and the end of the splint suspended (Fig. 15). The objection to the Thomas splint and its modifications is that the elbow is kept fixedly extended and traction made through it, and on account of the resulting stiffness the period of convalescence is greatly lengthened by the time necessary to restore the motion of the joint. Moreover, the ring interferes with the dressings when the wounds are in the neighborhood of the shoulder.

On the other hand, treatment by suspension and traction (without any splint), as carried out on the author's



Low fracture for which adhesive strips cannot be used. In this case a band is placed about the arm in the manner shown; in order to prevent its slipping, and to keep the traction in the axis of the humerus, the ends of the band are crossed over in front and pinned on each side of the forearm. It may be placed directly over the dressing covering the wound; when there is no wound dressing a thick piece of cotton should be placed under it, but for the sake of clearness neither dressing nor cotton has been shown in the drawing. The spreaders which should be used to prevent pressure of the band on the epicondyles have also been omitted from the drawing.

service during the past three years, is adapted to all fractures of the humerus, including those entering the

FIG. 17.—Method of suspension for fracture of the humerus or elbow.

Note the use of two bars over the arm, the external one being employed to support the forearm and to maintain the abduction and external rotation of the lower fragment. The traction has been omitted from the drawing.

shoulder and elbow (Figs. 16, 17, 18 and 19). As most cases require abduction of the arm, the forearm and arm are suspended in different planes in relation to the longitudinal axis of the bed, so that two longitudinal

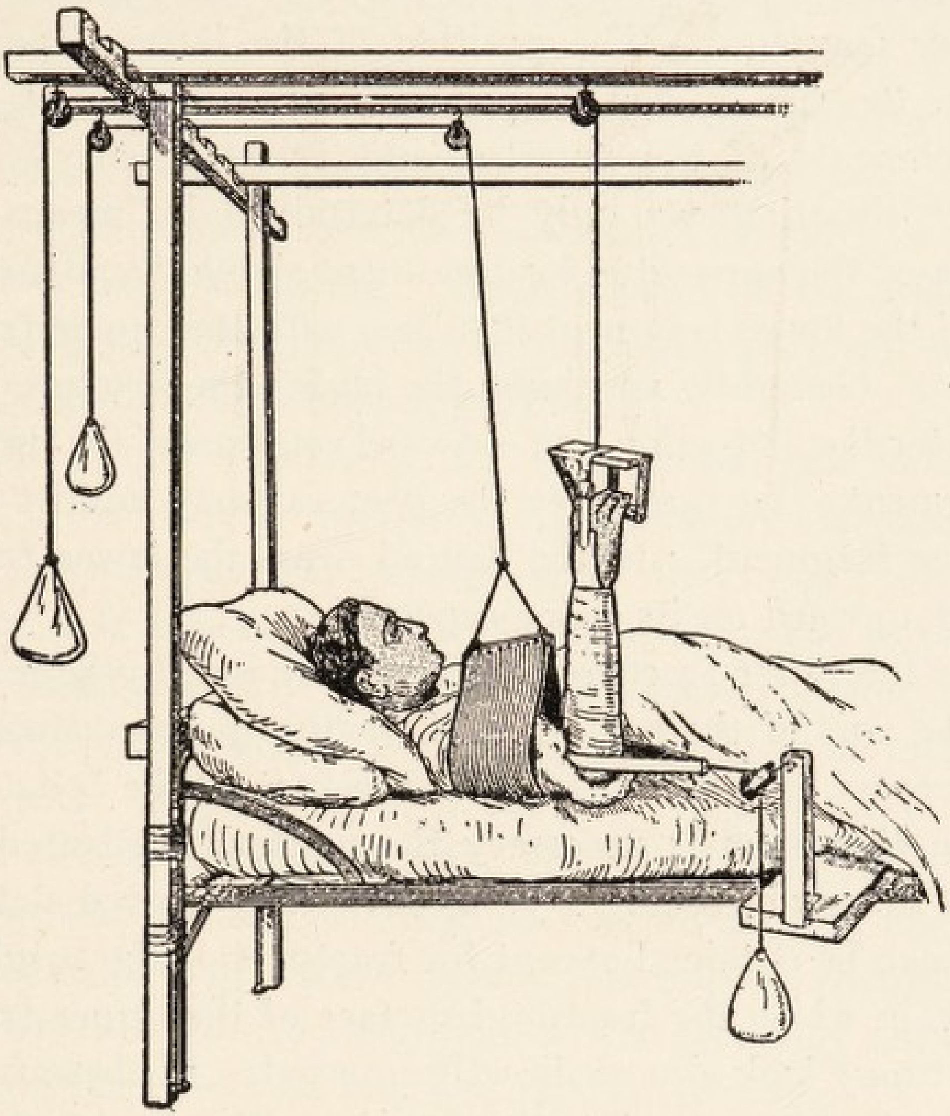


Fig. 18.—A simple method for producing traction and at the same time regulating abduction. The pulley for the weight is attached to an upright fixed at the end of a rough unplaned board which is slipped in under the mattress. The desired abduction is obtained by adjusting the position of the board.

bars must be used, the forearm being suspended to the outer. The distance between the suspending bars is regulated to conform with the desired abduction and the outward rotation of the lower fragment.

Traction must always be made in the axis of the upper fragment. The position of the latter depends upon the site of fracture and the preservation of the attachments of the muscles, and varies greatly. Its exact situation can only be determined by means of X-rays; the apparatus for treatment should be adjusted until the lower fragment is in line with the upper fragment. Generally speaking, the higher the fracture the greater the abduction and outward rotation of the upper fragment In rare cases the pectoral may adduct the upper fragment, and the deltoid draw the lower fragment upward on its outer aspect.

In the lower fractures traction may usually be made in the axis of the bed and the traction pulley attached to a cross bar on the frame at the foot of the bed. If more abduction is necessary the method illustrated in Fig. 18 may be used. By this device any desired abduction can be obtained except for fractures of the surgical neck, in which the fractured surface of the upper fragment may look almost directly upward. In these fractures the arrangement illustrated in Fig. 19 has been found efficient and surprisingly comfortable.

The weight necessary for traction varies with the musculature of the arm. It is generally from 1,500 to 2,000 grammes.

If no direct suspension of the arm is made the fragments tend to bow backward. To prevent this a broad sling, nearly equal in width to the length of the humerus, is placed under the arm, which is then suspended as shown in Figs. 17 and 18. By using two narrow slings it is possible to vary the suspending force on each fragment as desired; this is often an advantage, but it necessitates careful attention as regards the position of the slings and the weight attached to each, and for this reason a single, broad sling is more practical. This should be attached to a stick as long as its width to prevent it from wrinkling. Eyelets made in the ends of the sling slip over hooks on the stick and permit it to be easily undone for dressing purposes.

The weight attached to the sling should just balance that of the arm proper, while the amount attached to the forearm should correspond to the weight of the latter. If a heavier weight be applied to the forearm the fragments will tend to bow backward, and conversely, if the weight be lighter they will tend to bow forward About 1,500 grammes are necessary for each (i. e. arm and forearm).

The slings may be made of Canton flannel backed with muslin to give them rigidity and prevent wrinkling, but when continued irrigation or wet dressings are employed they are best made of rubber sheeting.

The method of arranging the adhesive strips for suspension of the forearm is shown in Fig. 16. The strips are applied to the sides of the limb and must not overlap (i. e. encircle it) on account of the danger of constriction in the event of swelling of the member. The pieces of webbing attached to them are fastened by buckles to a spreader made of thin board, 0.125 metre (5 in.) long × 0.10 metre (4 in.) wide, to the center of which a cord is fixed. To the ends of this spreader are attached bands of elastic webbing, 0.02 metre (¾ in.) wide; these support a round bar of wood at a height which puts

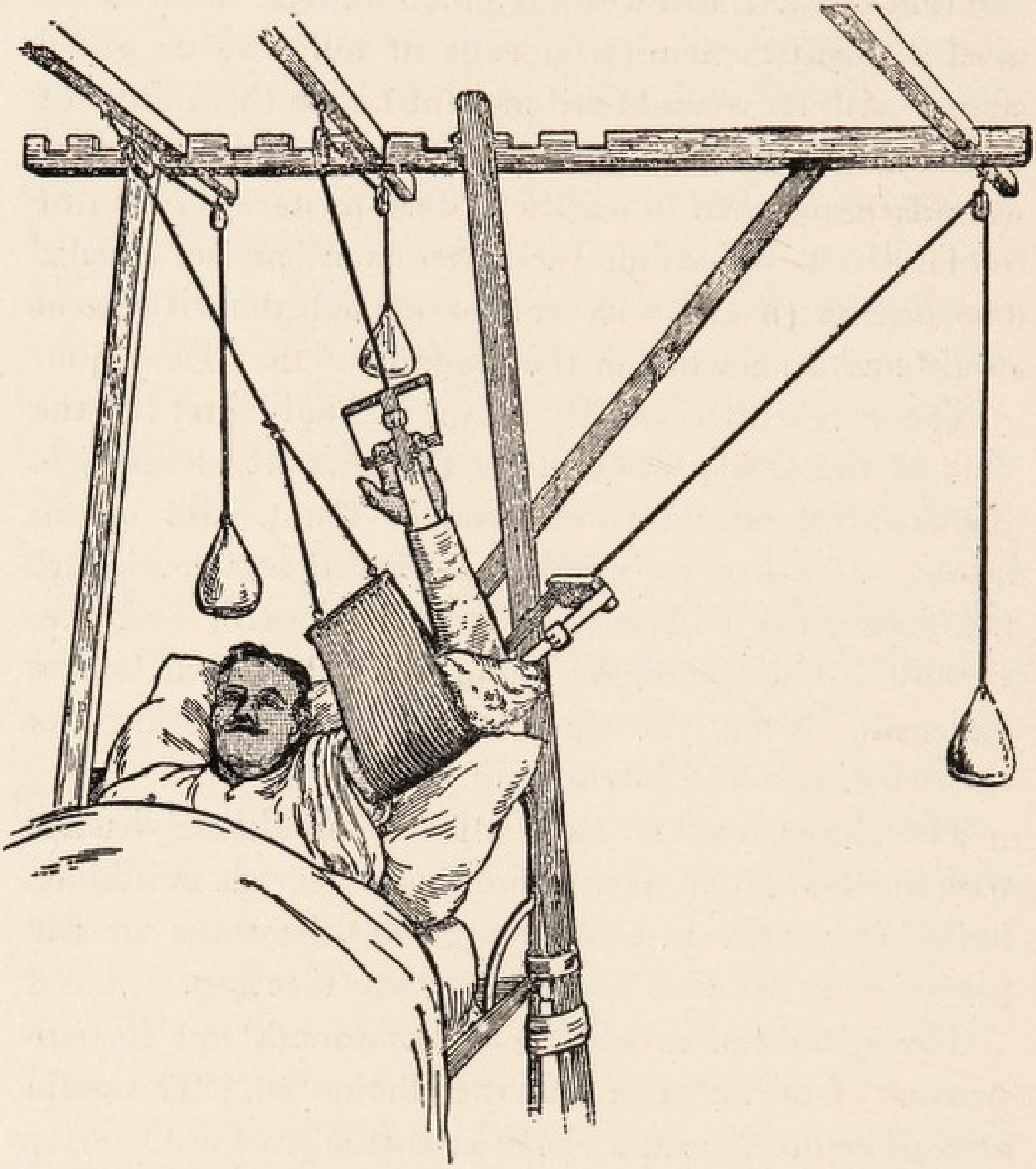


Fig. 19.—Position of extreme abduction and external rotation necessary in the treatment of some fractures at the surgical neck of the humerus.

it just within reach of the fingers, so that the patient can pull it down into the grasp of the hand and thus exercise the fingers—an arrangement which is of special value if the musculo-spiral nerve has been injured.

Traction to the lower fragment of the humerus is most efficiently made by means of adhesive or glued strips. When wounds are present below the middle of the arm, however, they cannot be applied unless such wounds happen to be in the antero-posterior plane of the limb. To overcome the difficulty a band of muslin 0.08 metres (3 in.) wide can be passed about the arm and elbow, somewhat in the manner of the Hennequin hitch for fractures of the femur. The center of the band is applied to the back of the arm just above the elbow, and the ends, after crossing in front, pass to each side of the forearm as shown in the illustration (Fig. 16); they are then pinned back to the middle portion of the band, so as to pass along the sides of the elbow and bring the traction into the axis of the humerus, as otherwise the band would tend to force the lower fragment forward. As an alternative, a band like a wristlet may be placed just above the elbow and side-straps attached to it; it is convenient to have these made so that they can be laced on. Either variety may be placed directly over the dressing on the wound, but if such dressing does not extend to the elbow the latter should be well padded with absorbent cotton.

Patients should be encouraged to move the elbow, wrist and fingers actively, and they should be passively moved and massaged daily.

No splints of any kind are applied to the arm, and although the patients move freely in bed, lying down and sitting up (even out of bed in a chair), there is no pain and union takes place rapidly without deformity.

As soon as union is firm the patient is allowed to get up with his arm in a sling; this must be removed several times a day, however, and the patient encouraged to exercise all the motions of the shoulder and elbow joints.

In fractures treated by suspension firm union has been repeatedly observed within 25 days in uninfected cases, and patients have been able to use their arms in four weeks from reception of the wound. In cases of delayed union caused by loss of bone or infection there has been no tendency to the production of pseudarthrosis, as might be supposed would result from the absence of fixation. On the contrary, union has appeared to be more rapid, which is explained by the preservation, during the treatment, of function and normal circulation.

RADIUS AND ULNA

Fractures of the forearm are extremely difficult to treat. In fractures of both bones, on account of the usual comminution and projection of splinters into the tissues, cross union or interference of callus is apt to occur. Moreover, because of the numerous muscles and tendons it is difficult to secure adequate drainage and infection may cause lamentable loss of function from sloughing of tendons and from cicatricial fusions.

Transport:

Murray's modification (Fig. 12 B) of the Thomas traction arm splint is the best splint for transport. Traction is applied by one of the methods illustrated in

Fig. 21 or by a hitch with a bandage over a cotton dressing about the wrist. The ends of the strips are simply passed about the bars of the splint and tied to its end (as already described for fractures of the humerus), and the traction is tightened by twisting the strips. The traction should be arranged so as to keep the hand supinated. A bandage is placed about the splint and arm.

Operative treatment:

Fractures of the radius and ulna, although not so dangerous to life as others, are the most dangerous of all as regards loss of function. The losing of the use of a hand is much more serious than that of a leg, and the surgeon must not only aim at preserving a forearm and hand but at preserving their functions also; this cannot be the case if all the tendons and nerves are embedded in a cicatricial mass, and such fractures should therefore receive the earliest possible attention in order to avoid infection. Rifle ball fractures with punctate orifices are the only ones which should not be operated upon.

Were it not for the fact that non-union of these bones is common after resection, primitive resection of their fractures would have fuller indications than in the case of breakage of any other diaphysis.

When operating before the establishment of infection the incisions should be free and the dissection carefully carried down between the muscles and tendons. All fragments driven into the muscles must be carefully sought for and removed, and those which have remained attached should be pressed back into place if possible.

The muscles and tendons should be trimmed and repaired, or cross sutured if long segments have been destroyed. Fine chromicized gut should be used; plain cat-gut will not hold, and heavy chromicized gut will have to be removed if suppuration should occur. Nerves should be sutured if possible. The wounds should be partially closed; tight suturing of the fascia must be avoided. Drainage tubes should never be used, as they produce sloughing of the tendons by pressure.

When infection is already established the operation should be confined to providing drainage and removing detached bone and foreign bodies, especially clothing. Projectiles themselves do not provoke suppuration unless clothing is attached to them, and therefore, if they are small and not easily located, the operation should not be prolonged to find them. For drains vaselined gauze should be used.

Mechanical treatment:

Traction is exceedingly important in the treatment of fractures of the radius and ulna, even when only one bone is broken. This is especially true of fractures of the lower part of the radius, as in these cases abduction of the hand due to shortening of the radius is apt to occur, causing marked loss of function.

It is wiser to treat these patients in bed until repair is well advanced, particularly if the fracture is infected. By keeping the patient in a reclining position, with the arm and forearm suspended, the circulation is greatly improved and repair hastened.

The entire limb may be placed in a Thomas arm splint and suspended. It will be found better to use independent traction by weight and pulley (Fig. 21) than to attach the traction strips to the splint, as in the

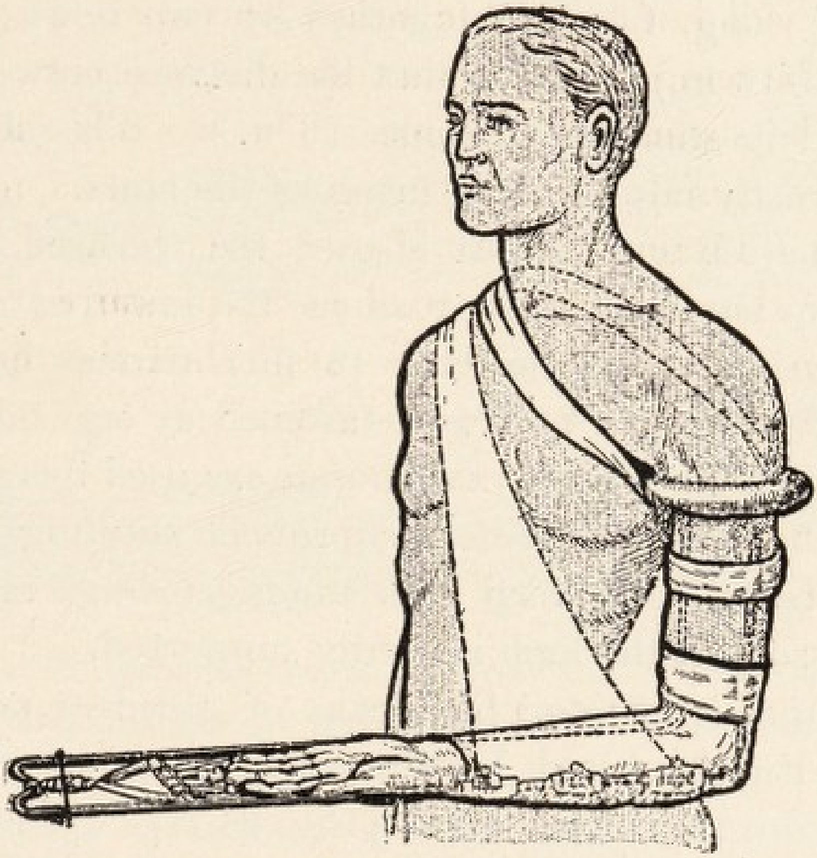


Fig. 20.—Method of using bent Thomas traction arm splint for treating fractures of the radius and ulna. Traction is made by a glove glued to the hand, and counter-traction furnished by a band around the arm and splint just above the elbow.

latter case the arm will have to rest at right angles to the body. On account of the carrying angle of the elbow, it is usually advisable to bend the Thomas splint at the elbow (Fig. 20). The Jones humerus traction splint may be used instead of the bent Thomas, but it generally needs considerable re-bending and adjustment.

The simple cradle shown in Figs. 21 and 25 C has been found satisfactory. It consists of two parallel steel rods, 0.009 metre (3/8 in.) thick and 0.40 metre (16 in.) long, fastened together by two bows of rod 0.004 (3/16 in.) thick, so that the distance between the parallels is about 0.15 metre (6 in.). This distance can be easily regulated by bending the bows.

No matter what splint is used the forearm is supported in the same manner as for the lower extremity, on pieces of 10 centimetre (4 in.) flannel bandage doubled across the bars and fastened at one side with clips or pins. When wet dressings are used these bands should be made of perforated rubber sheeting. Care should be taken to keep such bands or slings taut and smooth so that the limb is evenly supported.

Traction is effected by means of glued or adhesive strips (Fig. 21 A), or by Sinclair's method of gluing a cotton glove on to the hand (Fig. 21 B). This clever and very satisfactory arrangement consists of an ordinary cotton glove to which small curtain rings are attached at the tips of the fingers by means of cotton tape, the latter being sewed along the entire length of the fingers to reinforce them. A narrow cord is then laced through the rings and over a round stick which acts as a spreader and thus equalizes the tension on the fingers. The spreaders should be long enough to engage with the bars of the splint, so as to prevent the hand from turning and to maintain it in supination.

Counter-traction is provided for, when the bent elbow position is adopted, by a hitch about the forearm at the bend of the elbow and over a cotton dressing, as shown in Fig. 21; or, when a bent Thomas splint is used, by attaching the cord directly to the splint. A weight of

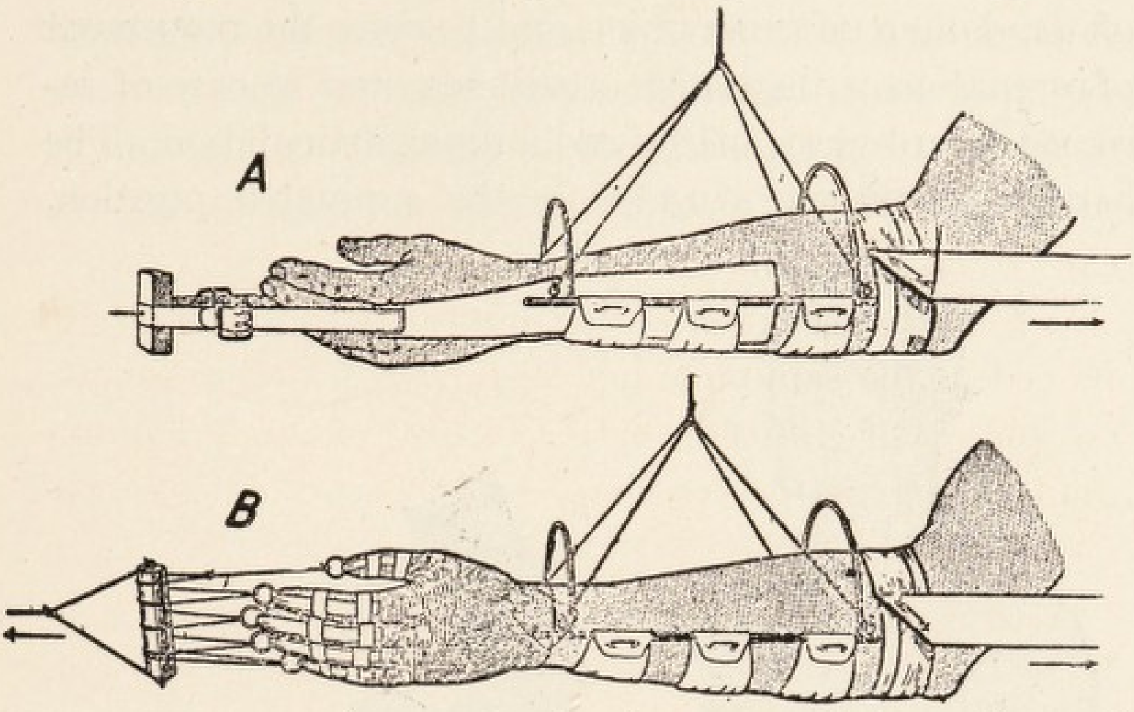


Fig. 21.—Suspension cradle for fractures of the radius and ulna, and methods of installing traction and counter-traction.

A. Traction by means of glued or adhesive strips for high fractures. A spreader is used, to which the traction strips are attached.

B. Sinclair's method of using a cotton glove glued to the hand. Note the manner of attaching the rings to the fingers of the glove by means of cotton tape, and the equalizing of tension by lacing the cord through the rings and over the spreader. Counter-traction is made by the band hitched about the forearm at the bend of the elbow. The dressing of cotton which should be placed under this band has been omitted from the sketch for the sake of clearness.

from 1,000 to 1,500 grammes is usually sufficient for traction.

The consensus of opinion is in favor of treating fractures of the forearm and particularly those of the radius, with the hand in full supination, both on account of the danger of cross union and because the movement of pronation is then more easily acquired in case of incomplete ankylosis of the radio-ulnar articulation. The hand is much more useful in the supinated position,

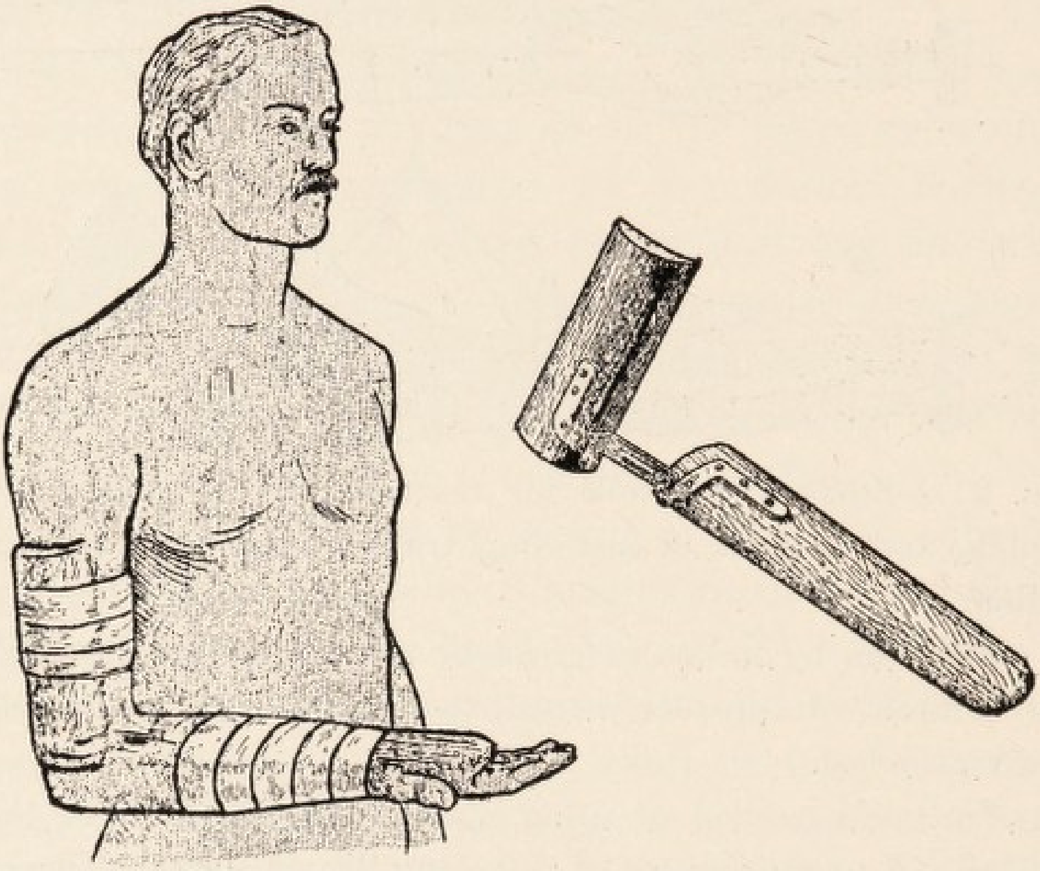


Fig. 22.—Van de Veld's splint for fractures of the forearm.

since it is brought into the pronated position by abduction of the elbow. This last point must be borne in mind during the treatment of the fracture in order that the mistake may be avoided of over-supinating the hand when suspending the arm with the elbow abducted from the body; for, when the arm is abducted to a right angle, the hand is in full supination when the thumb is pointing upward and the palm is directly mesally.

When repair is well under way and the condition of the wound permits, an ambulatory splint is desirable. If traction is still necessary a bent Thomas arm splint may be used and the traction cords attached to the end of the splint (Fig. 20). In this case it is well to use an elastic cord to take up the slack of the bandages

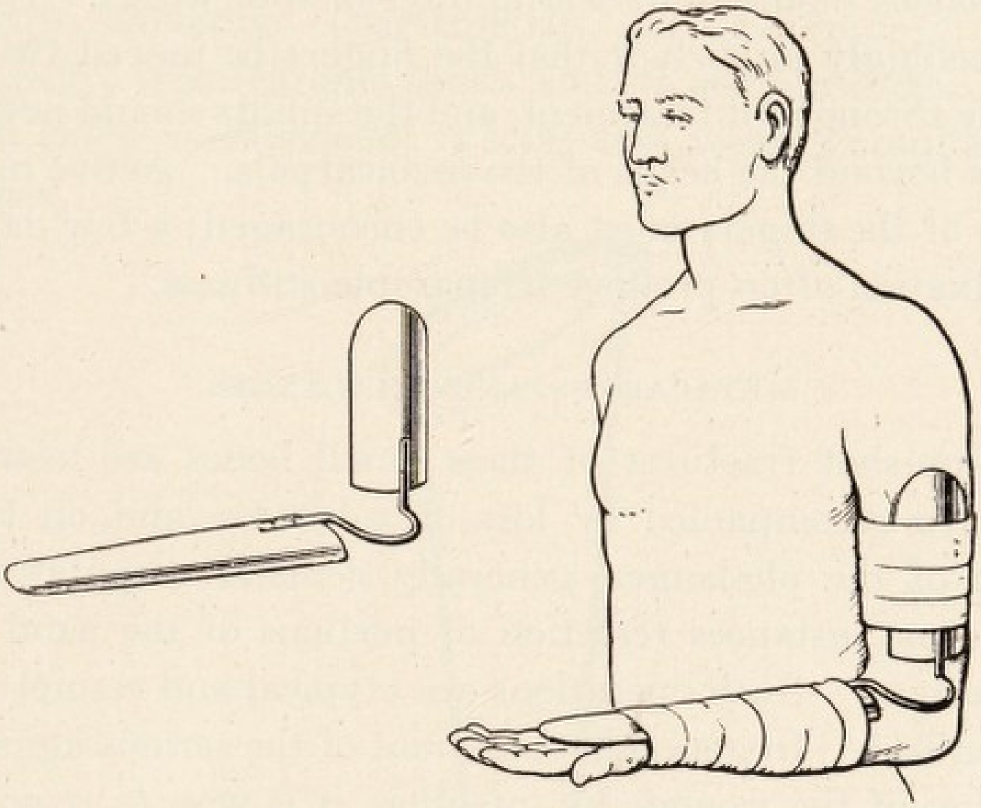


FIG. 23.—Sinclair's splint for fracture of the forearm.

which fasten the arm into the splint. When traction is no longer required the best splints are then the Van de Veld and Sinclair (Figs. 22 and 23). These are alike in principle. The Van de Veld consists of two pieces of wooden splint board, of which one lies on the palmar aspect of the forearm and the other on the lateral aspect of the arm, the two being connected by an adjustable metal hinge at the elbow. The Sinclair is made of metal, and the two pieces are fastened together by a curved rod. With both, pronation is prevented by the arm piece being on the outside of the arm.

Circular plaster splints should never be used for fractures of the forearm because the circular turns draw the bones together.

Repair is fairly rapid in fractures of the forearm, and the bones should unite within three or four weeks. It is exceedingly important that the fingers be moved twice daily throughout treatment, and the splints should never pass beyond the heads of the metacarpals. Active motion of the fingers must also be encouraged; a few days of fixation often produce irreparable stiffness.

METACARPUS AND PHALANGES

Gun-shot fractures of these small bones are nearly always accompanied by loss of substance and, in the case of the phalanges, generally demand amputation. In some instances resection of portions of the hand is necessary. Such operations are atypical and cannot be described. In general, on account of the serious aggravation of the wounds by infection, it is wise to remove all lacerated tissues and strive for asepsis; by acting in this way plastic operations and tendon sutures may be successful which could never be performed later.

In cases not needing resection, fractures of the metacarpals may be treated by bandaging the hand over a rubber ball a little larger than the ordinary tennis ball. Some cases are benefited by traction; this can be attached by gluing on glove fingers (Fig. 21) and placing the arm in one of the traction splints for the forearm. When traction is employed the hand should be supported on a ball in order to preserve the normal curve of the bone.

FEMUR

Gun-shot fractures of the femur are the most serious of all fractures of the limbs. The mortality is high: firstly, from hemorrhage and shock; secondly, from acute infection (particularly gas gangrene); and thirdly, from chronic sepsis and its complications. In all cases convalescence is long and average results are poor.

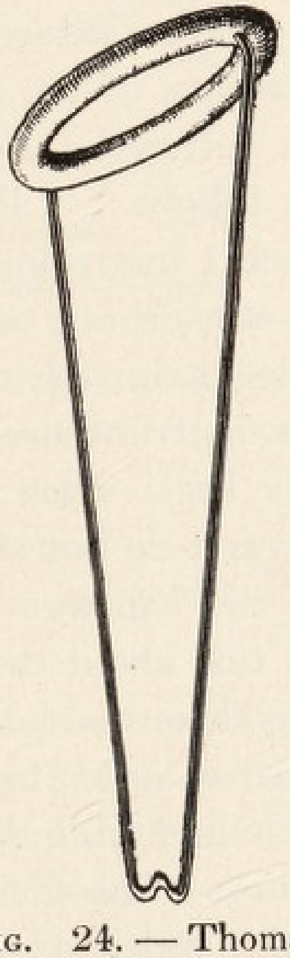


Fig. 24. — Thomas traction leg splint.

Transport:

Traction during transport is absolutely essential.

The Thomas traction leg splint (Fig. 24), or the half ring modification (Fig. 25 A) should be used. The ring of the regular Thomas splint is passed over the limb, and for this reason is made much larger than that of the ambulatory splint.[1] The half-ring model is applied to the back of the limb and is held in place by a strap which passes over the groin. Ordinarily three sizes of the regular Thomas splint are furnished, but only one size of the half-ring modification is supplied.

For transportation from the field the splints are applied over the clothing and before the wounds are dressed. Traction is then attached to the foot, over the boot, either by means of the gaiter which is issued with the splint, or, better, by Pouliquen's method of using a bandage, as follows:—2 lengths of 0.075 metre (3 in.) bandage, each 1 metre long, are applied to the ankle by the middle of each, one to one side of the ankle, the other to the other side; the ends are then carried across the foot, one in front over the instep and the other behind over the heel: when drawn upon the ends hug the foot snugly and do not slip. The ends of the gaiter straps or of the bandage are passed over and under the bars, and tied about the notch at the end of the splint. In tying them the full strength of the surgeon must be exerted in order to crowd the ring well up against the pelvis and pull the leg down into the splint. If the traction is insufficient a stick or nail a little longer than the width of the splint should be passed between the straps at the end of it and twisted in the manner of the Spanish windlass. The clothing is then cut from about the wounds and they are dressed.

[1]Page 94.

A piece of coaptation or wire splinting is placed behind the limb (Fig. 27), care being taken to pad it well at the back of the knee. By taking hitches with a bandage about the bars of the Thomas splint, a sort of sling suspension is formed and at the same time the leg is

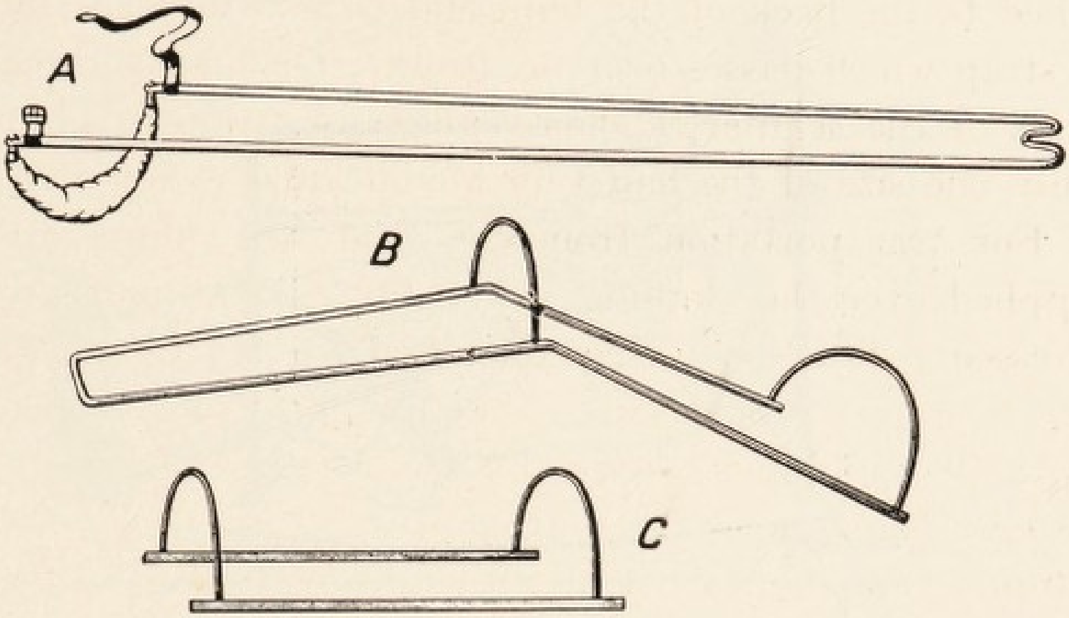


FIG. 25

A. Half-ring modification of the Thomas traction leg splint. On account of the hinge the splint can be used for either limb.

B. Hodgen's leg splint.

C. Frame used for suspension of fracture of the forearm.

prevented from moving forward in the splint. Several turns of the bandage should be passed around both splint and limb, as shown in the illustration, and a figure of eight made about the foot so as to support it comfortably. On the stretcher the limb should be suspended as shown in Figs. 26 and 27. If the patient is to be evacuated in a Ford ambulance the stretcher suspension must be placed over the middle of the leg in order to raise the foot enough to clear the tailboard of the car.

Traction by the gaiter or by a hitch over the boot is merely provisional, however, and only to be employed for short trips. The use of the gaiter, even with a

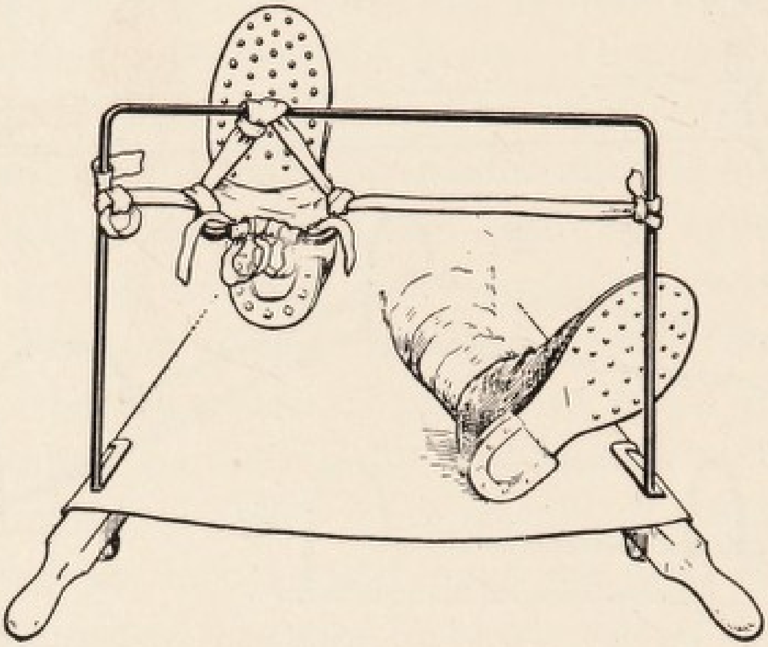


Fig. 26.—Method of attaching end of splint to stretcher suspension. If the patient is to be transported in a Ford ambulance the stretcher suspension must be placed over the middle of the leg so as to raise the foot above the tail board of the car. (From the British Army Instructions.)

heavy cotton dressing under it, is unsatisfactory for the strong tension necessary for fractures of the thigh, as it is apt to cause pressure sores, especially above the heel. At the time of operation permanent traction for treatment should be provided. This may be applied by means of adhesive or glued strapping, the Codavilla pin or the Ransohoff tongs; but if the patient is to be evacuated again strapping must be used.

If wounds preclude the use of the Thomas splint in the case of high fractures, the long Liston splint should be employed. There is no provision in the Liston

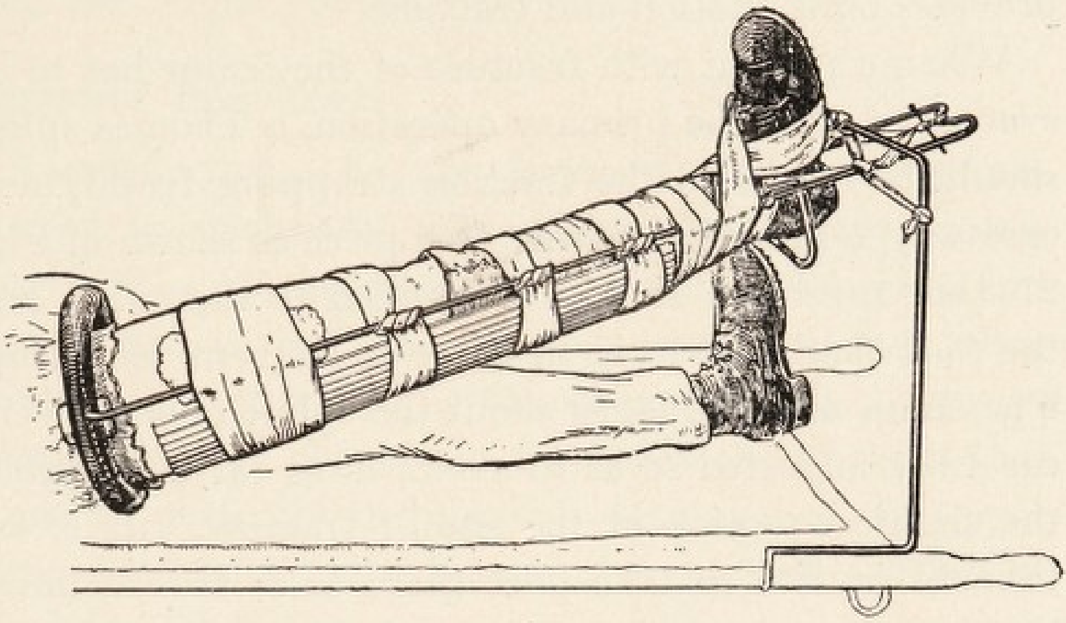


Fig. 27.—Method of applying the Thomas traction leg splint. The splint is passed over the clothing and the traction is applied before the wound is dressed. The clothing is then cut from the region of the wound; it is dressed, and a coaptation splint, well padded under the knee, is placed behind the limb. The bandage is then applied so as to prevent any motion of the limb either backward or forward, and to form a figure of eight about the foot. The end of the splint is hung to the stretcher suspension so as to prevent lateral swaying. (From the British Army Instructions.)

splint, as supplied, for traction, but this can be provided by attaching the foot to the lower end of the splint and then taking up the counter-traction by passing a padded cord from the upper end between the thighs as a perineal band. Failing the Liston splint, the same object may be attained by utilizing one side of a Bradford frame or a stretcher pole.

The combination of the long Liston splint and the Delorme aluminium gutter splint with traction, devised by Pouliquen, is extremely efficient for transport as it provides both fixation and traction.

When a patient with fracture of the femur has to be evacuated after the primary operation, a Thomas splint should be used and the traction strapping freshly and carefully arranged. A wire foot piece as shown in Fig. 27 (but reversed) should be applied to the splint and the foot bandaged to it, in order to prevent foot drop. The slings and bandages about the splint must be very carefully adjusted so as to avoid, in so far as possible, the slightest motion at the site of fracture. It is extremely unwise to transport these cases before union has commenced, as the slightest fresh traumatism (so easily caused) may light up infection.

Occasionally it may seem best to use plaster of Paris splinting for transport, particularly in cases of high fracture and fracture of the neck in which a position of abduction should be maintained. These splints are difficult to put on and must be accurate to be efficient. In order to maintain abduction the pelvis must be fixed and the sound limb therefore included in the splint, and the latter should also extend up over the lower ribs on each side of the body. To avoid the suffering caused to the patient by keeping him too long on the pelvic rest, it is wise to cut out forms of fifteen to twenty thicknesses of crinoline for the parts of the splint which must be strongest (i. e. one piece for the abdomen, groin and anterior parts of the thigh, and another and longer piece for the side of the body, outer side of the thigh and the leg). These forms should be impregnated with plaster cream and bandaged on with the ordinary plaster bandages. It is well to bandage in a cross stick to keep the thighs apart.

Operative treatment:

AMPUTATION.—As the function of the lower extremity is essentially that of weight bearing, unless there is hope of retaining a strong limb it is wiser to amputate than to run the risk of a prolonged and often stormy convalescence. Consequently the surgeon should not take chances in fractures of the thigh that would be perfectly justifiable in fractures of the upper extremity, the preservation of the slightest portion of which is of value.

The indications for amputation may be divided into two groups: the first, for immediate amputation; the second, for amputation after infection has become established. Immediate amputation should be done for (1) extensive loss of groups of muscles, especially if the sciatic nerve is severed, (2) division of both femoral and internal saphenous veins, (3) excessive comminution of the greater portion of the shaft—20 centimetres or more, (4) shock, when it is deemed that the patient will not survive the primary operation described below, since amputation is shorter and less shocking and the convalescence quicker. The indications for amputation in the case of established infection are (1) injury to the femoral artery or vein requiring ligation, (2) gas gangrene when more than one group of muscles is extensively involved, (3) extensive fracture of the diaphysis communicating with the knee joint when the latter is also suppurating, (4) multiple wounds threatening life, (5) incurable chronic osteomyelitis. The drifting policy should not be followed in septic cases; amputation should be done before visceral degeneration takes place.

PRIMARY OPERATIONS.—The primary operation is long and severe, and the patient must have recovered from shock before it is undertaken. Nitrous oxide oxygen anæsthesia should be used. The wounds should be enlarged so as to obtain free access to their deepest parts—transverse incisions should be avoided if possible. Flexion of the thigh on the pelvis relaxes the muscles and facilitates retraction. The danger of infection is largely due to the extensive destruction of muscles and consequently great care must be taken to remove all devitalized tissue. Greater attention than usual should be paid to the perfection of hæmostasis on account of the depth of the wounds and the consequent danger of retention of blood.

Dependent counter-drainage should be provided in all operated fractures. The drainage incision should be made at the outer border of the biceps and should extend to above the site of fracture, so as to avoid pocketing when the thigh is flexed.

Immediate suture of the wounds is not to be recommended except in selected cases. Up to the time of writing primary suture of the wounds has succeeded in only about 15 per cent. of fractures of the femur. They should be left for delayed primary or secondary suture.

Mechanical treatment:

Splints.—The splints furnished for treatment of fractures of the femur are the Thomas leg traction, the half-ring Thomas (already described) and the Hodgen's (Fig. 25 B). This latter is essentially a suspension splint, and is right and left. The angle at the knee may be changed by bending to suit the requirements of individual cases. The splint is shown in place in Figs. 28 and 33. The suspension cords are arranged in two sets; the proximal cord passes upward and across the patient to the head frame on the opposite side, preventing the patient from sliding and the splint from tilting. It is usually better balanced if the distal cords are attached one approximately opposite the malleoli and the other just proximal to the knee. The main cords should be attached to the bridles by knots that cannot slip, as otherwise the splint may rotate. Hodgen's splint is well adapted for treatment of high fractures of the femur in which the wounds preclude the use of the Thomas. It is more apt to become displaced than the Thomas and half-ring splints, in which the ring helps greatly in keeping the apparatus in position, and when in use much attention has to be given to the sling bands at the proximal end to keep them taut and in place.

Either the Thomas full ring or half-ring splints may be employed, though the latter will be found to be the more convenient. The bars may be bent at the knee to suit the requirements of the case. Even when treating a fracture in the straight position of the limb, as in Fig. 29, the bars should be bent a little (about 10°). This angulation aids in preventing the knee from sagging backward and in maintaining the normal anterior bowing of the femur.

The Thomas splints possess the great advantage of intrinsically maintaining traction. Ordinarily, during treatment, this feature is not made use of traction being applied to the end of the splint in order to prevent the painful counter-pressure of the ring and for other reasons to be mentioned later[1]; but if it should be necessary to remove the patient from his bed, as, for instance, for a radiogram when no portable apparatus is available, or for operation or evacuation, traction may be kept up by simply twisting the traction straps. The Thomas splint, therefore, should be used in preference to any other if the hospital does not possess a portable radiographic outfit or if there is a possibility of having to evacuate the patient before consolidation of his fracture.

The weight for suspension should just balance that of the limb and consequently varies with the case.

In some instances the sound limb may have to be suspended in abduction in order to maintain abduction in the injured one; although, ordinarily, the patient can be prevented from occupying a position in the axis of the fractured bone by a band about his body fastened to the opposite side of the bed. When both limbs are suspended, or when the patient has to be raised high up to give access to wounds of the buttock, a sling made of one of the bands for the Bradford frame should be

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passed under the body. A stick to act as a spreader is fastened to each end of the sling, and cords are at-

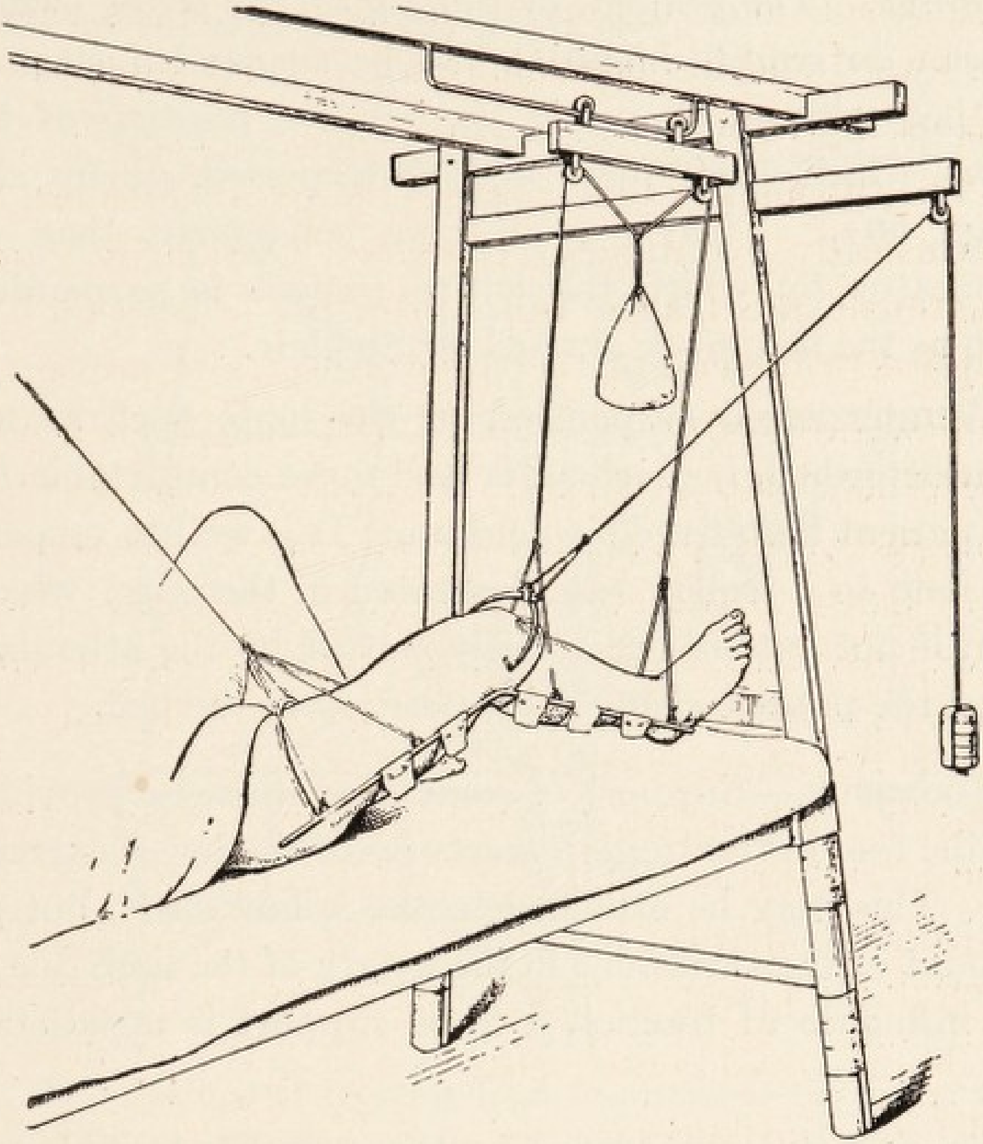

Fig. 28.—Method of treating high fractures of the femur with the Hodgen's splint and traction by the Codavilla (Steinmann) pin or Besley tongs. Abduction is obtained by placing the pulley for the traction cord on an outrider, and outward rotation by tilting the splint.

The suspension attachment for preventing foot-drop has not been drawn.

(The more proximal of the distal suspension cords should have been attached to the splint at the proximal side of the knee.

tached to the stick by means of stout hooks. These cords pass over pulleys on the longitudinal bars to counterpoises. The patient, by pulling on the latter (which he can do readily himself) can be suspended clear of the bed without changing the relative position of the limbs, which, since they are counterpoised, go up also (Fig. 30). This is even more convenient than an apparatus by which the entire patient is suspended, such as the hammock devised by Sinclair.

Counterpoised suspension of the limb, such as has been described, is much safer and more comfortable for the patient than fixed suspension. It is well to suspend the limb to a trolley (as illustrated in the cuts) which, even if not automatic, is easily shifted by the attendant when the patient changes his position in the bed.

Footdrop.—Support of some kind must be provided for the foot in treating all fractures of the lower extremity. This may be attached to the splint itself, but on account of the variations in the length of the limb due to the influence of traction a fixed support is unsatisfactory.

The arrangement shown in Figs. 29, 31 A et B, and 33 has given great satisfaction. It consists of a piece of Canton flannel, or several thicknesses of gauze, glued to the sole of the foot and extending beyond the ends of the toes. From this end a cord passes upward and cephalad over a pulley on the trolley to a weight of 500 grammes. This holds up the foot without fixing the ankle, which the patient is instructed to move at frequent intervals. When the limb is to be put in a position of outward rotation, the material should be glued on the sole obliquely, so that the cord passes up at the mesal aspect of the great toe.

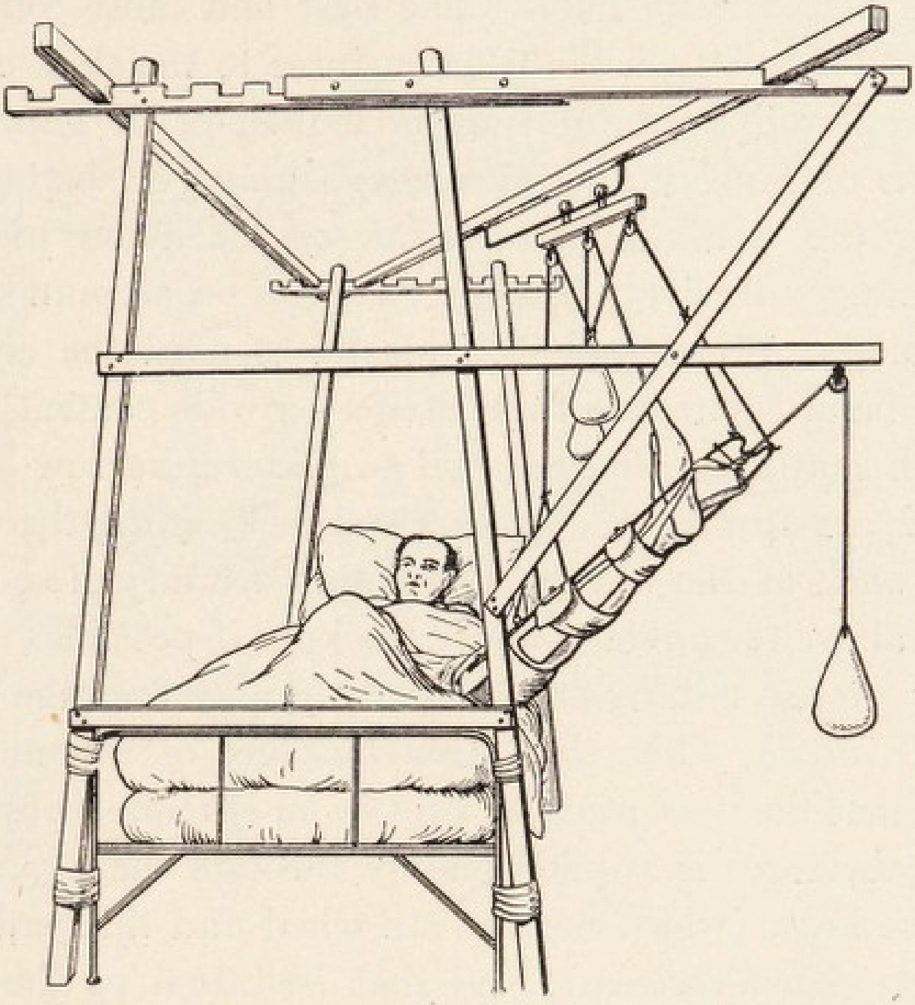

Fig. 29.—Method of treating high fractures of the femur with the half-ring Thomas splint. Note the manner of obtaining abduction and flexion at the hip, also the attachment to prevent foot drop. The traction weight is not applied directly to the traction straps but to the splint and consequently draws the latter away from the tuberosity of the ischium. The traction straps are also attached to the splint and hold it in place.

Traction.—One of the most important and vexing problems is the best manner of applying traction. Broadly speaking, there are three methods; the choice between which is generally limited by the position of the fracture, the size and location of the wounds complicating it, and the occurrence of other wounds or fractures in the same limb. The first and most common method is to attach the tractive force to the skin, either by applying bands of Canton flannel or of gauze by means of Sinclair's or Heussner's glue,[1] or, better, by using the well-known moleskin or diachylon plaster. Ordinary adhesive plaster is valueless on account of its slipping. When moleskin plaster is used the end of each band is cut into three strips—a wide central piece which is applied straight, and two lateral narrow bands which are applied in opposing spirals avoiding the front and back of the knee. The bands are adjusted from just above the ankle to above the knee if possible. Sinclair prefers gluing the strips only as far as the knee (*vide infra*). The chief disadvantages of this method are: that the knee must be kept in an extended position, that the force is applied mainly through the ligaments of the knee (which become stretched and thus entail a longer convalescence), and that irritation of the skin (more often observed in infected cases) is caused. The bands cannot be applied solely to the thigh above the knee because the tractive force is then chiefly transmitted by the skin and fascia to the pelvis. The advantages of bands are their cheapness, safety and ease of application.

The second method is to make traction on the bones themselves. This is accomplished directly by Ransohoff's tongs (Fig. 32) or the Codavilla pin (Fig. 28) through the condyles of the femur; and indirectly by the

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Codavilla pin through the head of the tibia or the os calcis, or by the stirrup of Finochietto (Fig. 31 C),

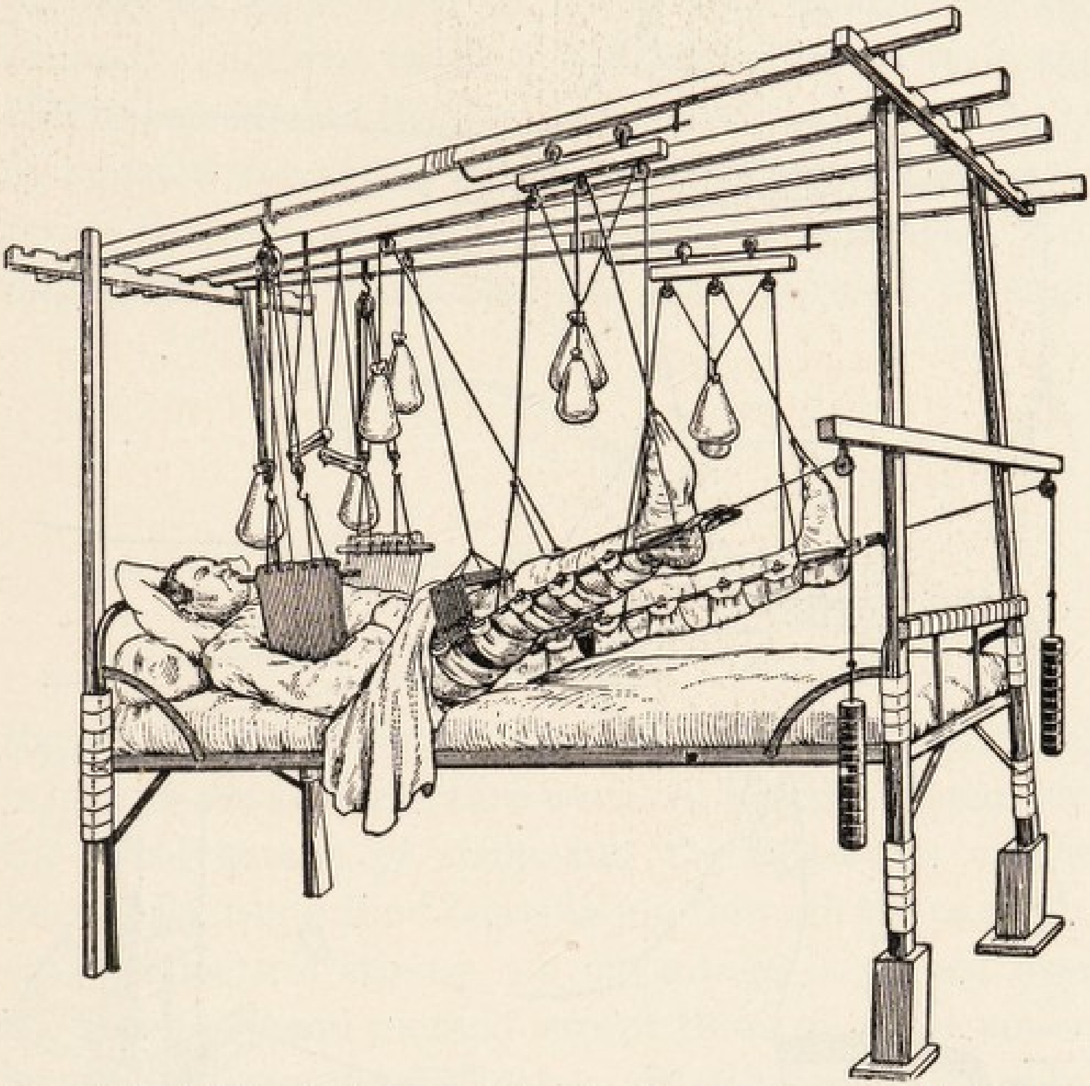

Fig. 30.—Method of suspension for fractures of both femora, showing systems of applying additional suspension at the site of fracture in order to prevent backward angulation of the fragments, and also a method of counterpoising the weight of the body of these cases.

which is a steel band passed over the os calcis in front of the tendo-achillis. The use of the Codavilla pin or the Ransohoff tongs through the condyles of the femur is the most perfect of all methods because it permits the placing of the limb in an absolutely correct position

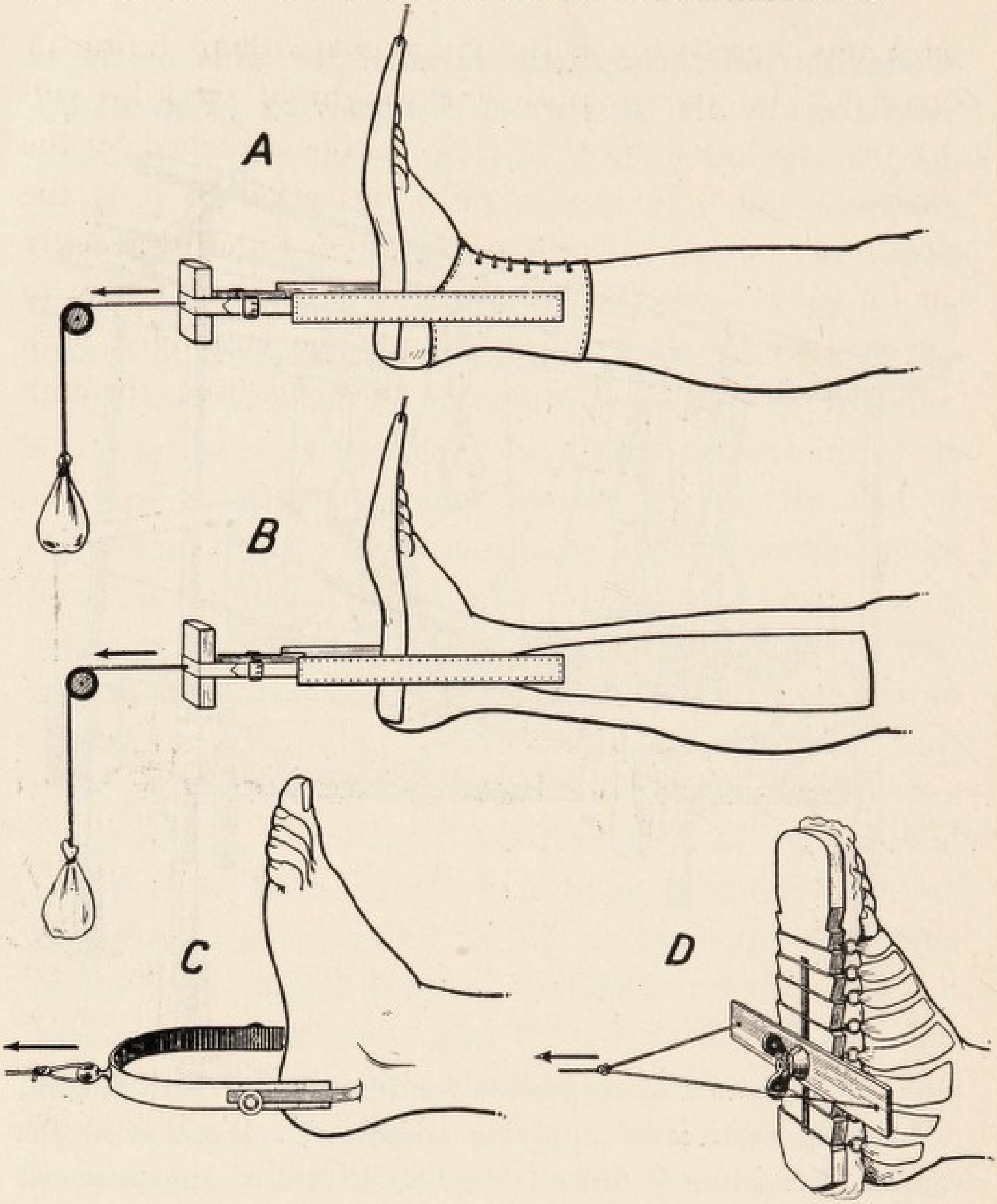

Fig. 31.—Four methods of installing traction for fracture of the leg:

A. With a gaiter. (For the sake of clearness, the cotton dressing, which should first be placed about the ankle, has been omitted.)

B. With traction straps.

C. With the stirrup of Finochietto.

D. With Sinclair's skate.

and acts directly upon the fragment without fixing or injuring the knee. With it a weight of six kilos will produce as much effect as fifteen kilos attached by the ordinary adhesive bands. The objection to it is the fear of infection at the site of the pin or tongs, especially in infected fractures, but present experience seems to prove that the tongs at least may be employed with impunity. The Codavilla pin may be used through

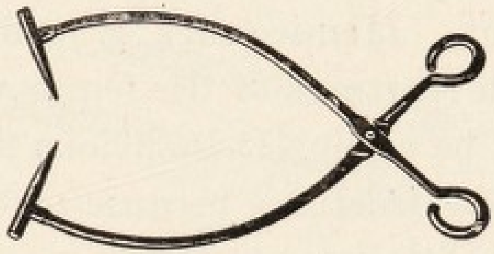

Fig. 32.—Ransohoff's tongs.

the head of the tibia with equal efficiency, and additional injury to the femur is thus avoided, but this system has the disadvantage of stretching the ligaments of the knee. By using the Codavilla pin through the os calcis, or Finochietto's stirrup, no advantage is gained over the adhesive band method except those of direct action on the skeleton and avoidance of irritation to the skin, but one of them may be employed when wounds of the leg prevent the use of any other method.

In the third method of effecting traction the knee is strongly flexed and the tractive force is applied about the latter or against the back of the calf. This is ordinarily accomplished in two ways. By Hennequin's method (Fig. 33) the limb is surrounded to the height of the middle of the thigh by a very thick dressing of non-absorbent cotton, bandaged on very snugly with a narrow bandage. The knee must be kept in flexion while the dressing is applied, and it is well to put a wet crinoline or very thin plaster of Paris bandage over all to keep the dressing in place. A figure of eight hitch is then made about the thigh and knee by means of a sheet folded several times so as to make a band 1.50 m. (60 in.) long and at least 0.15 m. (6 in.) wide. Hennequin cut away the mattress to allow a place for the foot, but this is not necessary when the limb is slung in a wide Hodgen's splint. Hennequin's is probably the best method for high fractures of the femur when the Codavilla pin cannot be used. It is obvious that it cannot be employed for low fractures because of the interference of the bandage with the wound.

The alternative manner is to bandage the leg to a well flexed Hodgen's splint and make the traction on the latter. This method affords access to wounds in the lower part of the thigh for dressing purposes, but it has a great disadvantage in that it is exceedingly difficult, when it is adopted, to make sufficient traction on the splint without causing unbearable pressure on the calf just below the bend of the knee, particularly in the early part of the treatment when it is necessary to exercise strong traction to overcome the spasm of the muscles. In the later stages, however, when only slight traction is required to hold what has already been gained, the system is fairly satisfactory. It will be referred to later in describing the treatment of low fractures. When strong pressure is made against the calf, the head of the fibula should be padded to avoid pressure upon the peroneal nerve.

In the case of coexistent fractures of the thigh and leg the traction has to be divided, because, if enough traction to reduce the fracture of the femur be applied below the fracture of the leg, the latter will be overstretched. If the fracture of the leg is low there may be room enough above it to glue bands by which traction for the femur can be made, while traction for the fracture of the leg may be effected by one of the methods described under that heading. In such a case the

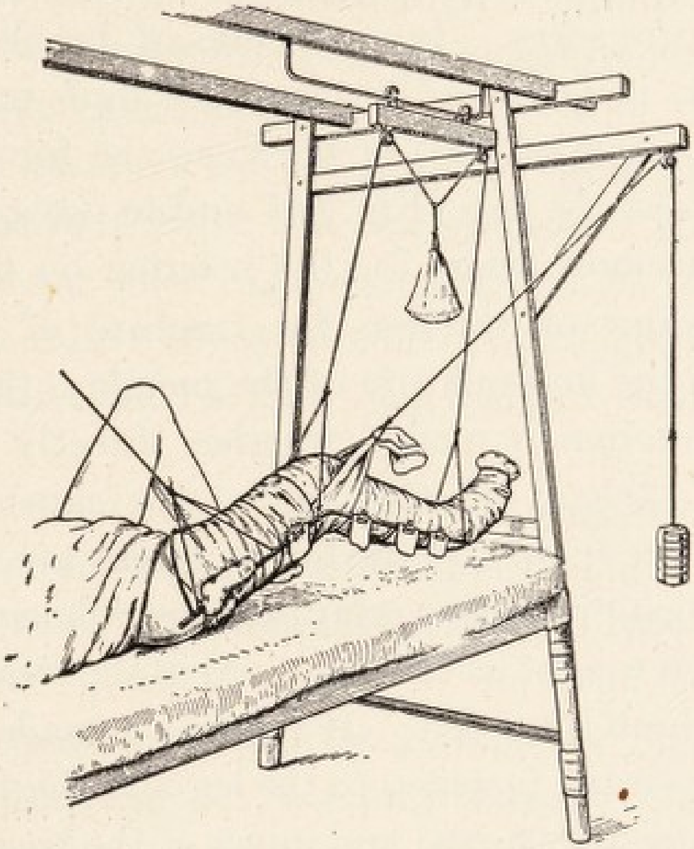

Fig. 33.—Hennequin's method in conjunction with Hodgen's splint in the treatment of fracture of the femur.

weight placed on the femur should be equivalent to the difference between the weight for the femur proper and the weight placed on the leg, the limb being in the straight position. For example, if 15 kilos were the weight to be applied for the fracture of the femur and 5 kilos for that of the leg, 10 kilos should be placed on the straps above the leg fracture. If there is not enough room on the leg for glued straps and there are no wounds on the lower part of the thigh, a collar of plaster of Paris may be placed around the latter, carefully modelled about the condyles of the femur, to which the traction for the femur may be attached. This plaster should be modelled directly on to the skin; if a bandage be placed under it it is apt to become wrinkled and cause pressure sores. In most cases of double fracture, it is better, if possible, to place the limb on a splint bent to an angle of 135° at the knee (as for treatment of fractures of the leg—Fig. 35) and to use a Codavilla pin or Ransohoff tongs for the traction on the femur.

The amount of traction for fracture of the thigh varies with the musculature of the member, the manner in which traction is made (whether directly upon the bone, i. e. skeletal traction, or on the skin), and the position of the limb. If the hip and knee are flexed the muscles which produce overlapping are relaxed, and not half as much weight as that required in the straight position of the limb is needed. If traction is made by glued or adhesive straps fastened to the leg and thigh the knee cannot be strongly flexed and much of the tractive force is transmitted through the skin and fascia. With the knee in the extended position a weight of 16 to 18 kilos is usually necessary for the first few days, while with the flexed position of the knee and with skeletal traction by means of the Codavilla pin or Ransohoff tongs, a weight of 8 to 9 kilos is generally sufficient and may be too much, particularly if the weight of the limb is more than counterbalanced by the suspension weights (Fig. 28).

As has already been said, the initial traction should be sufficient to overstretch the muscle in the first few hours or at least in the first day. A radiograph should then be taken, and if the overlapping has entirely disappeared the weight may be diminished by one-third. Two or three days later another radiograph should be taken, when, if the reduction has been well maintained, the weight may be gradually decreased to that just sufficient to maintain it, as determined by frequent radiographic examinations.

Counter-traction is furnished by the weight of the patient, the foot of the bed being raised. If traction is made with the knee extended, the foot of the bed will have to be raised about 30 cm. (12 in.); while if made with the knee flexed, half this distance will be found ample.

The patient's head and shoulders should be raised if possible, for there is distinct danger of pulmonary complications from hypostatic congestion in feeble and septic cases.

When traction is made by springs, by the use of the Thomas splint on the Thomas principle (i. e. by twisting the traction straps), or by attaching the straps to a post and utilizing the weight of the patient, it is extremely difficult, if not impossible, to gauge and regulate the amount of traction actually employed; the tendency is to use too much traction over too long a period and thereby to endanger the integrity of the ligaments of the knee.

Late treatment:

The normal length of time for consolidation of fractures of the femur is about eight weeks. Exceptionally this is reduced, especially in comminuted, non-infected fractures, such as those caused by rifle bullets in which the fragments of bone have not been removed. In these cases firm union may be accomplished in six weeks. There are many cases, however, in which, although consolidation may occur in the ordinary period, the union is weak either from loss of substance or insufficient callus. In other cases union is delayed, and, although apparently firm to the examining hands, the bone will angulate when weight is put upon it. This bending may be very gradual and increase during a period of several months; it is more frequently observed after secondary operations done to reduce mal-union. In such instances the callus may be very large and give a false sense of security.

Even if a fracture unites normally there is danger of the patient's falling and re-breaking it. Refractures of the femur have been so common as to make the French Service de Santé prohibit the use of crutches.

To avoid such accidents and deformations and to permit the patient to use his limb at the earliest possible moment, an ambulatory splint should be fitted to all cases. The most satisfactory is the Thomas knee splint. In the British army the fitting of these splints is termed "calipering," and all fractures of the femur are "calipered" before being sent home.

The Thomas splint used for this purpose differs from that employed for transportation and treatment in regard to the size of the ring, which is much smaller. The ring must fit closely to the thigh so that the weight, when the patient is walking, is borne on the tuberosity of the ischium. Eleven sizes of the splint are necessary to fit all cases, the internal circumference of the bare ring varying by inches from 16 in. to 26 in. The size for the average thigh has an internal circumference of 21 in., and ten splints of this dimension will be used as against nine each of 20 in. or 22 in., seven each of 19 in. or 23 in., five each of 18 in. or 24 in., three each of 17 in., or 25 in., and one each of 16 in. or 26 in. In measuring for a splint the circumference of the thigh is taken at the gluteal fold and two inches added to it, one for the obliquity of the ring and the other for the thickness of the padding. The latter should be four inches in circumference at the inner side of the ring and taken to nothing at the outer. The bars of the splint are made of three-eighths inch iron rod, and the inner bar is one-third of the internal circumference of the ring shorter than the outer. To caliper a patient the ring is slipped over the leg and forced firmly up against the ischium, and a mark is made on one of the bars at the level of the sole of the bare foot. The bars are then cut off $2\frac{1}{2}$ inches below this mark. The patient's boot having been re-soled and heavily re-heeled, the terminal $1\frac{1}{2}$ inches of the bars are bent inward at a right angle and fastened into holes bored into the heel, that on the inner side of the heel being 1 inch behind the one on the outer side in order to provide for the outward rotation of the foot.

If angulation has occurred during the late treatment of a fractured femur and the callus is not absolutely firm, the Delbet splint will be found to be of distinct value. This splint or apparatus (Fig. 34) consists of three metal uprights, two of which are welded to a pelvic ring resembling in principle that of the Thomas splint but incomplete, and the other attached to the ends of the ring segment by means of a strap. Each upright consists of a rod telescoping into a tube and

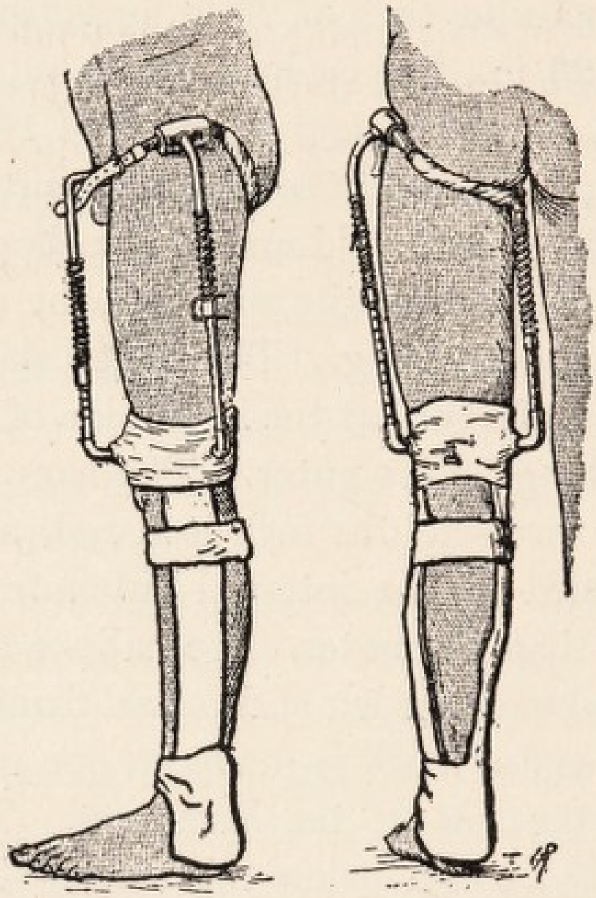

Fig. 34.—Delbet's apparatus for ambulatory treatment of fractures of the femur. (By the courtesy of M. le Médecin-Major R. Leriche).

fitted with a spiral spring and suitable stops for regulating the tension of the spring or blocking it. The lower ends of the rods are embedded into a plaster collar about the lower part of the thigh and bearing on the femoral condyles. This collar is connected, as shown in the illustration, by two lateral splints, with two other collars, one just at and below the tuberosity of the tibia, the other just above the ankle and bearing on the malleoli. The apparatus is essentially an ambulatory one, and Delbet's patients are up and walking within a few days from reception of their injury. It is used more commonly for late treatment, and the tendency to angulation (which is almost always outward) can be overcome by increasing the force of the spring on the adductor side of the thigh.

In cases in which the callus is soft, either the calipers or the Delbet apparatus may have to be worn for months.

Mechanical treatment of special fractures of the femur:

FRACTURE OF THE NECK OF THE FEMUR.—These fractures practically always involve the articulation, and will be considered later with fractures of the hip joint.

FRACTURE OF THE UPPER THIRD OF THE FEMUR.—Such cases are not infrequently complicated by injury to the pelvis. The wounds of the soft parts are large, or have to be made so in order to explore the fracture and to effect drainage; they are often situated posteriorly, which makes them difficult to dress, and it is frequently impossible to use the Thomas splint because of them. Antero-posterior wounds being in the region of the femoral vessels and of the anterior crural and sciatic nerves, large drainage tubes should never be used in such cases. If additional drainage is necessary the incision should be made behind the great trochanter, well to the outer side of the sciatic nerve. The position assumed by the upper fragment is that of marked abduction, rotation out and flexion, the flexion being more accentuated when the lesser trochanter remains attached to it. To bring the lower fragment effectively into line the limb should be suspended in marked abduction and rotation out, with the knee flexed. The best way of accomplishing this is to use the Codavilla pin or the Ransohoff tongs. In these cases the best arrangement of the suspension frame is that shown in Fig. 28. The necessary position for the limb is best grasped by flexing one's own hip and knee and rotating the limb outward, when it will be seen that the leg assumes a position midway between the antero-posterior and transverse planes of the body, and that when the limb is well abducted the foot lies in the median plane of the body. To maintain the splint and limb in this position of outward rotation, the bridles (i. e., the cords fixed directly to the splint and to the bights of which the suspending cords, are tied) must be arranged so that the parts attached to the inner bar of the splint are much shorter than those attached to the outer. It may even be necessary to fix a guy line to the foot and pass it over a pulley (fastened to the opposite longitudinal bar) to a sufficient weight. The weight for skeletal traction at the outset should be about 8 kilos (18 lbs.).

When the pin or tongs cannot be used the Hennequin method may be employed with the limb in the same position and a commencing weight of 10 kilos (22 lbs.)

(Fig. 33). If, for any reason, neither the Codavilla pin nor the Hennequin method can be used, the limb is put on a straightened Hodgens splint (traction being made by straps passing well above the knee or by the Finochietto stirrup) and placed in the position of abduction, rotation out and flexion at the hip, the knee of course being extended (Fig. 29). With this arrangement the initial weight must be at least 14 to 18 kilos (30 to 40 lbs.), because the hamstrings must be stretched and the weight of the limb overcome.

When a straight splint is used the other limb may have to be suspended in like abduction in order to maintain abduction in the injured one. This is seldom necessary, however, when the flexed position of the knee is employed.

With all the above methods the foot of the bed is elevated and the patient's head and shoulders should be raised on pillows.

Fracture of the Middle of the Femur.—In these the wounds are at the middle of the thigh and do not interfere materially with the use of any method except the Hennequin. The position assumed by the upper fragment is abduction if the fracture is above the adductor longus insertion; otherwise it is nearly straight, moderately flexed and rotated out. These cases are the easiest to treat because the position of the fragments is controlled by the lateral pressure of the muscles when strong traction is made.

As has been emphasized by Sinclair, due regard must be given, in treating all fractures of the shaft, to reproducing the normal anterior curvature of the femur. If traction is applied in the axis of the bone, the best result that can be hoped for is a perfectly straight bone; generally, however, a position of backward curvature will be obtained. This is particularly true in fractures below the middle of the shaft. The best way to overcome the tendency of the fragments to backward sagging, is to apply the tractive force in a line below the axis of the femur and to place a support behind the fragments so that the pull will be made against the support, thus forcing the fragments forward. This is accomplished by means of a bent splint, the bend being about 4 cm. above the knee joint. The angle varies slightly with the case, but should be about 160°. A Thomas splint will be found the most satisfactory. The ordinary muslin or flannel slings are used, but they should be doubled behind (particularly just below the point of fracture) so as to afford an unyielding support. The limb, when suspended in such a splint, is in a position of flexion at the hip and moderate flexion at the knee. Traction may be made in the axis of the leg by glued bands, in which case the splint does not have to be bent so much as when the tongs are used directly upon the femur. In the latter case the axis of traction must be higher in order to clear the leg, which in turn necessitates a position of greater flexion of the femur.

It is obvious that when traction is thus made against a supporting band attached to the splint, the fraction should not be applied to the end of the splint but rather directly to the limb, and that the splint should be held against the limb. The method of suspension should therefore be that shown for the Hodgens splint (Figs.

33 et 35). A supplementary sling, attached by a cord to a weight, may also be used to correct the position of the fragments (Fig. 30).

The Thomas splint thus used is merely a cradle for suspension, but should the patient have to be moved from his bed it is only necessary to attach the traction straps or cords to the end of the splint to bring the Thomas principle into play.

FRACTURE OF THE LOWER THIRD OF THE FEMUR.—In very low fractures of the shaft, if the method just described does not suffice to overcome the strong tendency of the lower fragment to become flexed backward by the pull of the gastrocnemius, the Ransohoff tongs have been used successfully in the following way. They are applied, as usual, to the upper part of the lower epiphysis, but instead of making traction below, the traction is made above the axis of the femur, thus actually tilting the fragment upward. Care should be taken to obtain the elongation necessary before raising the axis of traction, as otherwise the upper end of the lower fragment may engage behind the lower end of the upper and reduction be impossible.

If the tongs cannot be used on account of the proximity of infected wounds, and complete reduction of the backward angulation has not been obtained by the other method, the following procedure should be tried. While the union is still soft, the splint should be flexed to a full right angle and the leg bent to suit. The knee will have been somewhat stiffened by the long traction and the bending will therefore take place at the fracture. Traction is then made on the splint at the knee and transmitted to the back of the calf. If strong traction has been used from the beginning of treatment the muscles will have been stretched so that only moderate force will be necessary. This method has given satisfactory results during the last two years.

TIBIA AND FIBULA

Fractures of the fibula alone are of little consequence, as the tibia acts as an efficient support for the broken bone. Fractures of the tibia alone are splinted by the fibula, which prevents over-riding to any great extent, though it cannot obviate (especially in cases of loss of substance) a tendency to incurvation. Fractures of both bones tend to overlap and also be interlock in bad positions, and are often difficult to reduce; moreover, repair in the leg seems more indolent than elsewhere in the body, and these fractures sometimes unite very slowly and imperfectly. The lack of soft parts over the tibia possibly accounts for some of such cases of delayed union, sluggishly granulating wounds and disagreeable scars.

Transport:

The problem of transport is simple. The fragments are easily fixed by any splint, but it is advisable to use the Thomas on account of the traction it affords, which does much to prevent laceration of the muscles, tendon sheaths and skin as well as to obviate over-riding and interlocking. It is applied in the same manner as for fractures of the femur, except that the leg should be well bandaged into the splint. If the fracture is in the region of the ankle the boot should be removed and the anklet placed over the dressing. In these cases care should be taken to support the foot, and for this purpose the Cabot leg splint may be tied to the Thomas if a foot rest is not at hand.

At the initial operation the fracture should be reduced if possible, as these fractures, above all, need direct instrumental intervention to effect proper reduction; if done at once a secondary operation will often be avoided. All projecting fragments which might produce pressure necrosis of the overlying skin should be carefully pushed back in place; if it is not possible to do this it is better to remove them.

If the fracture has already become infected, however, an operative reduction should not be attempted, as very disagreeable suppuration of the muscle planes and tendon sheaths is apt to be provoked on the breaking down of the barriers to infection which have been formed.

Primary and delayed primary suture have been quite successful in treating fractures of the leg. On account of the better conservation of the tendons, primary suture is preferable to secondary suture, especially in low fractures.

Mechanical treatment:

All wounds and fractures of the leg repair far more quickly if the limb be suspended. Traction is necessary in fractures of both bones.

The best method is to suspend the limb in a Hodgens or Thomas splint bent to 135° (Fig. 35). The center of suspension should be below the knee. A cord attached by a bridle to the thigh part of the splint passes back to a pulley on the head frame on the opposite side from the fracture and provides counter extension. Traction is made in a straight line to the foot frame. Frome 6 to 7 kilos (13 to 15 lbs.) are sufficient to commence with for fractures of both bones; half this amount should be used for fractures of the tibia alone. The weight must be rapidly diminished. If there is no tendency toward overlapping half the amount, or less, is enough. The effect of the traction should be verified by X-rays.

In high fractures the weight may be attached to glued straps (Fig. 31 B). In low fractures the Sinclair skate (Fig. 31 D) or the Finochietto stirrup (Fig. 31 C) should be used. The gaiter method (Fig. 31 A) is not suitable for strong, continued traction even when a heavy dressing is placed beneath, for in spite of every care pressure sores will form at the dorsum of the foot and at the attachment of the tendo-achillis when it is employed. It is, however, valuable as a supplementary traction and can be used in conjunction with glued straps. The Sinclair skate consists of a half-inch board longer than the foot and 9 cm. wide. In this a central slot is cut (as clearly shown in the illustration) in which slides a bolt with a winged nut. The bolt passes through a hole in the center of a piece of strap steel 15 cm. long. This steel crosspiece serves for the attachment of the traction cords, and, resting on and across the bars of the splint, also acts as a regulator of the position of the foot. When it is clamped toward the heel the traction dorsiflexes the ankle, and conversely, when clamped toward the toes plantar flexion is produced. Moreover, as the bar rotates on the bolt, the rotation of the foot may be controlled. Eight or ten notches, 1 cm. apart, are cut on each side of the board and serve to prevent the slipping of the lacing cord

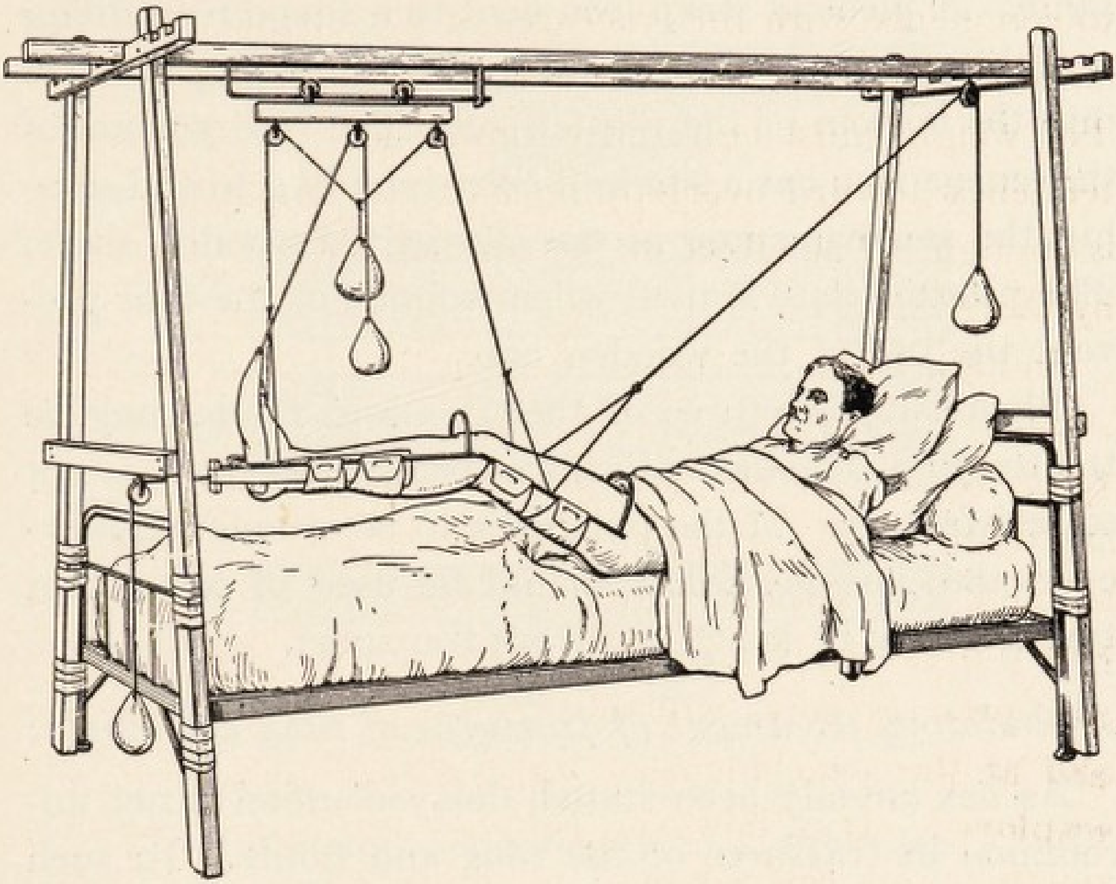

FIG. 35.—Method of treating fractures of the tibia and fibula by suspension and traction. The limb is suspended in a Hodgens splint bent to an angle of about 135°. Traction in this case is made (as shown) with straps glued on to the leg.

which fastens it to the glued straps. The straps are made beforehand of Canton flannel or tape with small curtain rings sewed to their ends. They are glued to the sides of the foot as shown in the illustration and must not overlap on the dorsum. The board is padded so as to conform to the sole of the foot and is laced on either by a continuous cord or by separate cords for each pair of opposed rings.

Another form of skate devised by Sinclair consists of a plaster sole lined with saddler's felt, which is accurately modelled to the sole of the foot and glued to same. A piece of strap iron bent to a shape resembling a right-angled letter omega is embedded by its feet into the bottom of the plaster sole. The free portion of the omega iron has a slot in it corresponding to and serving the same purpose as the slot in the wooden skate. The plaster skate is used when wounds of the foot prevent the use of the wooden one.

Obviously, fractures of the tibia and fibula may be treated in a Thomas splint, but being straight it is not so satisfactory. If the patient is to be evacuated, however, the Thomas splint should be used in order that traction may be kept up during transport.

Ambulatory treatment of fractures of tibia and fibula:

As has already been stated, delayed union is not uncommon in fractures of the tibia and fibula. In such cases it is important that the function of the leg should

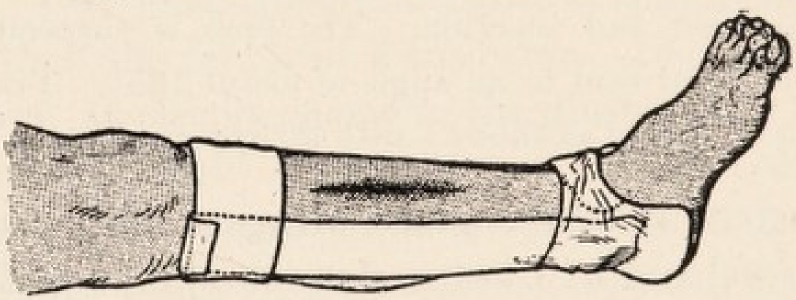

Fig. 36.—Delbet's ambulatory splint for fracture of the tibia and fibula. (By the courtesy of M. le Médecin-Major R. Leriche.)

be resumed, as the increased circulation and traumatism at the ends of the bones caused thereby greatly aids in hastening union. A certain amount of weight

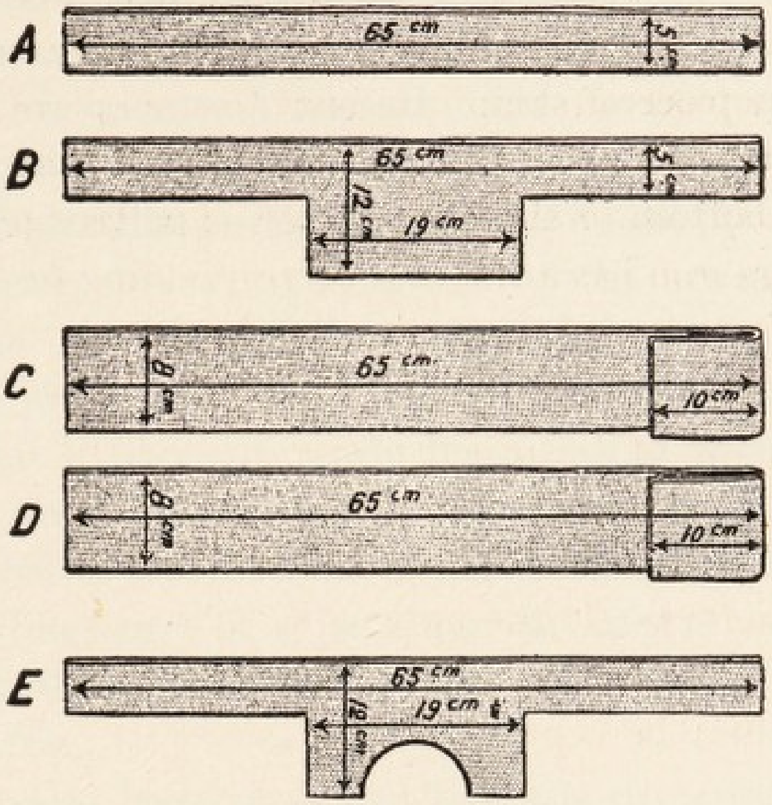

Fig. 37.—Method of cutting strips of crinoline to make the plaster bands for Delbet's ambulatory splint for fracture of the tibia and fibula.

A. Upper band.

B. Lower malleolar band.

C. and D. Lateral bands with folds 10 cm. long at inferior extremity.

E. Lower band for the malleoli with notch cut in heel piece for heel. (By the courtesy for M. le Médecin-Major R. Leriche).

should be borne on the leg, but the fracture must be supported and angulation prevented. The Delbet leg splint, the tibia and head of the fibula above and against the malleoli below, thus preserving the length of the leg. To be successful the splint must be skillfully applied. In such cases patients with simple fractures can walk in three or four days after reception of their injury. The plaster is put directly on the vaselined or talcum-powdered skin. Recent fractures are reduced by attaching a weight of 25 kilos to the foot, and the splint is applied while the traction is still attached.

CHAPTER VI

FRACTURES AND WOUNDS OF JOINTS

General:

Experience during this war has unequivocally proved that the ideas formerly prevalent concerning the extreme susceptibility to infection of the synovia were erroneous. At the present time most of the wounds of joints are being closed successfully, and it has been found that if they suppurate the infection is, as a rule, confined to the periarticular tissues or at least commences there. In proof of this assertion it is frequently observed that part of a joint may be infected while the rest of it, although continuous with the infected portion, remains free.

It has also been remarked that the presence of foreign bodies or materials in joints brings about infection and encourages its progress. This is not only true of carriers of infection, such as shell fragments and clothing, but also of objects considered surgically clean, such as drainage tubes. In support of this it has been found that cases of suppurative synovitis, which, by the older treatment of drainage by tube, would have ended in the loss of the joint, if treated by simple, free incisions and a mild irrigation to wash out the pus recover rapidly and satisfactorily.

The rules for treatment of wounds of the joints are, therefore, exceedingly simple. Recent, contaminated wounds should be treated as already described for wounds of the soft parts accompanying fractures. All foreign bodies should be removed, contaminated and injured synovia cut away, especial attention given to removing small, loose fragments and all infected bone, and perfect hæmostasis made. The synovia should then be closed by cat-gut sutures, and wounds of the periarticular structures either closed by primary or left for delayed primary or secondary suture. When there is injury to the bone communicating with the exterior through the joint, it is well to expose the bone wound by an incision over it so that in case of infection the bone will drain directly to the surface and not through the joint. The worst and most persistent suppurations of the joints are those caused by infection of the bones forming them, so that every precaution should be taken in the way of removing all causes of infection in the bone wounds and isolating them from the joint cavity.

In treating joints already infected free incisions so planned as to not only drain the joint but, above all, the wounds of the bones, should be made. No drains of any sort should be used, but the wounds leading into the joint should be kept open until all drainage from it ceases. At the time of operation the joint may be irrigated out. The value of subsequent irrigation is questionable. If made, the greatest gentleness should be observed so as not to injure the synovia. It is probable that normal saline or isotonic sodium bicarbonate solution is as good as any fluid for irrigating purposes.

The indications for radical operative procedures on the bones, such as excision, vary with the different joints and will be considered under the heading of each.

Post-operative treatment of wounds of the joints depends largely upon the extent of injury to their architecture and also upon their normal functions; for the elbow, for example, free movement may be desirable at the expense of strength, while stability at the cost of mobility is usually preferable for the knee. These questions will be discussed later, in detail, for each joint. A general line of treatment may, however, be mapped out for wounds implicating the synovia alone or accompanied by slight or moderate injury to the bones. Early mobilization is beneficial in these cases, as has been demonstrated by Wilhelm, who commences mobilization on the day following operation even when mild infection is present. The passive motion carried out for the first two or three days is at once followed by active motion, and patients with wounds of the knee or ankle are walking by the third or fourth day. When begun early and carried out consistently, motion and use of a joint are not painful. If it is infected it is of course left open, but without drains; Wilhelm claims that drainage is improved by the motion. The functional results of his method are far better and more rapid than those obtained by the old fixation treatment.

SHOULDER

In a large number of fractures of the shoulder all three bones—humerus, scapula and clavicle—are involved. Wounds at the point of the shoulder often present loss of substance with a wide laying open of the joint. In such cases the origin of the deltoid is frequently destroyed. Wounds involving chiefly the head of the humerus are deep, as the joint is here surrounded by heavy muscles; they are consequently prone to anaërobic infection.

The deltoid muscle is the principle abductor of the arm, as well as the one which supports its weight. If it ceases to act the humerus descends and the motions of the shoulder are lost or much weakened. Great care should be taken to preserve it and its nerve, the circumflex, which passes backward around the neck of the humerus in a line 5 to 6 cms. below the border of the acromion process.

Transport:

Traction is not indicated, and the sling and body bandage method is therefore the best for fixation for transport from the field. For transport after operation one of the methods described for ambulatory treatment (page 106) may be used. These cases, however, should not be transported until convalescent:

Operative treatment:

Punctate bullet wounds should not be operated on. All others should receive surgical treatment as early as possible.

If sufficient access for exploration is not afforded by enlarging the wounds, or if they cannot be enlarged on account of their position, the incision for typical resection should be made at the anterior border of the deltoid and the joint opened at the outer side of the bicipital groove and tendon. After this approach counter-drainage is made, if necessary, posteriorly above the circumflex nerve. The drains should be introduced only as far as the joint and should not enter it.

All missiles lodged in the humeral epiphysis, even if the wounds do not implicate the joint, should be removed—with the possible exception of rifle balls, which are usually innocuous. A diligent search for bits of clothing must be made, as, if such foreign bodies are not removed the joint is apt to become involved in the subsequent infection of the bone.

In cases of fracture typical resection should be avoided except when the head of the humerus is smashed into small pieces. Ordinarily the surgeon must be contented with the removal of spicular and irregular portions of bone which would be likely to interfere with the function of the joint. The cartilage should not be removed unless the joint is already infected.

In early operations, when there is every reason to expect an aseptic evolution of the wound, the latter may be loosely closed; but, as a rule, it is better to simply close the synovia and leave the wound of the superficial parts for delayed primary or secondary suture. In recent wounds, in which infection is already established—particularly in fractures extending into the diaphysis of the humerus with much comminution—the surgeon should, on account of the great danger to life and limb, be less conservative of bone and work for an absolutely free drainage. Large openings should be made, a free sub-periosteal resection done, all the cartilage of the articulation removed, and the wounds left open.

In later, suppurative cases, where the danger of an explosive infection is past but in which abscesses form from extension along the muscles, the surgeon should limit himself to free drainage of these extensions and not resect.

Mechanical treatment:

If the after-treatment is not carefully followed most resections of the shoulder will result in a flail articulation which renders the limb almost useless. The same condition is apt to follow any injury or treatment causing paralysis or over-stretching of the deltoid muscle. Temporary inhibition of the muscles activating the joints is a peculiarity of all joint injuries. The period of inhibition is usually proportional to the traumatism and may last for many weeks. In the case of the shoulder it is extremely important to keep the humerus in contact with the glenoid cavity and to support the arm until the muscles have regained their tone. Moreover, the danger of a flail joint being so great after resection, it is better to play for complete ankylosis which gives a strong and useful member if the ankylosis is good. The position to be sought is one of abduction to 90° and rotation out. The movements of the scapula on the thorax will then allow the arm to be approached to the side and the hand to pass the median plane. If, on the other hand, ankylosis takes place with the arm at the side, the movements of the scapula will not compensate in the slightest degree, and the arm will remain fixed to the side of the body. Furthermore, if ankylosis is not complete, a range of motion from abduction to adduction is far more easily acquired, on account of the greater power of the adductor muscles and because the weight of the arm does not have to be overcome. Hence the adducted (i. e., arm at side) position is absolutely contraindicated.

During the first weeks after reception of the injury the arm should be suspended as for high fracture of the humerus, but no traction should be employed. The correct position for suspension is for the humerus to be at 90° with the body and midway between the coronal and sagittal planes. For the later stages of treatment an aeroplane splint may be used, or the arrangement of Thomas splints shown in Fig. 14. If wounds at the shoulder interfere with the ring of the arm splint a Thomas leg splint may be used, the ring being slipped over the opposite arm and the chest being between the bars. Traction must not be employed. It is better, however, to keep the arm suspended until ankylosis or return of function takes place. Suspension allows of a certain amount of motion continuously at the articulation and favors a return of normal movement. It also facilitates massage, and the patient, being able to move the arm, regains control of it much more rapidly.

These cases should never be allowed a sling. If the patient must be up before function has returned he should wear a corset and a hinged support for the arm.

ELBOW

Fractures of the elbow joint, even if infected, are not, as a rule, dangerous to life, but are difficult to treat on account of the tightness and irregularity of the articulation.

Transport:

Murray's modification of the Thomas arm splint (Fig. 12 B) or Jones' humerus splint (Fig. 13) may be used. With the former, the arm being in the straight position, a slight amount of traction is indicated, but with the latter none is required.

Operative treatment:

Any fracture involving the joint surfaces is apt to result in ankylosis more or less complete. The loss of the movements of flexion and extension is not so serious as the loss of pronation and supination of the forearm. The worst result that can happen is a flail articulation, and this often follows injudicious resection.

In deciding upon the treatment to be adopted in any individual case, the surgeon must not only consider the extent of the injury but also the occupation of the patient in civil life and the result which will be most desirable for him.

Complete resection of the elbow, performed by surgeons who are familiar with the technique and the very important after-treatment, generally gives excellent results as regards motion and to a certain extent as regards power; but occasionally it fails, producing a flail articulation. It is therefore exceedingly doubtful whether complete resection should be recommended to the average surgeon who does not follow the after-treatment himself. Partial and atypical resections are often sufficient to prevent infection, and as they generally become ankylosed during repair they are probably better operations for laborers or others needing a powerful arm.

It is very difficult to lay down strict rules. When possible, the question should be put before the patient; and the surgeon, after explaining the situation fully to him as to probable and possible results, both good and bad, should be led by his wish.

Early operations:

NON-INFECTED CASES.—(a) Perforating bullet wounds with punctate orifices should not be operated upon, no matter what the extent of fracture.

(b) In wounds opening the joint but without fracture or lodged foreign bodies, the synovia should be sutured and the soft parts closed by primary or delayed primary suture.

(c) In wounds with lodged foreign bodies and slight splintering of the joint surfaces, the foreign bodies and bone splinters which enter the articulation and might interfere with its function should be removed, together with all lacerated and contaminated tissue. The synovia should be closed if possible and the soft parts treated according to indications.

(d) If there is a loss of substance on one side of the bearing surface (the trochlear, for example), resection is indicated if lateral deviation is probable.

(e) If most of the joint is smashed, one must decide between complete resection in the hope of getting a movable joint, and simple drainage or partial resection with ankylosis in view. The nature of the operation will depend upon the extent of comminution.

CASES IN WHICH INFECTION IS ESTABLISHED.—Arthrotomy in generally the best operation for all cases except those in which there is extensive comminution at the ends of the bones, when resection should be performed. Resection is the best and quickest method of terminating infection, but if it means extensive removal of bone (for fractures may extend halfway up the humerus or down the forearm and it is difficult to draw a limiting line) it is better for the patient to suffer a long course of suppuration and retain a stiffened arm than to have a flail forearm.

When enlargement of the wounds does not afford sufficient drainage, the typical incision for arthrotomy should be made along the outer border of the olecranon. This will drain the entire articulation and, together with enlargement of the original wounds, should suffice. On account of the superficiality of the elbow no tubes are necessary.

Resection:

The Ollier incision is best, as it gives access and good drainage, and the ends of the bones are not so apt to project through the wound during the after treatment as with the letter H incision. The incision passes downward, from the commencement of the external epicondylar ridge, along its posterior border, to its tip, then obliquely downward and inward to the middle of the base of the olecranon process, and straight downward along the posterior border of the ulna. The operation must be entirely sub-periosteal, even to conserving the periosteum of the minutest fragments. For the humerus the section of the bones should pass through the epicondyles, but it may sometimes be necessary to go a little higher; for the ulna, just so as to remove the articular surface of the coronoid process; for the radius, through the neck. Hemi-resections do not succeed. All the cartilage must be removed from all the bones. The head of the radius must be removed, or supination will be lost. The wound is merely filled very lightly with sterile gauze, which should not be removed until the eighth or ninth day.

Amputation:

Amputation should never be performed for injuries to the elbow if the pulse is present at the wrist, even if more than one of the nerves is divided.

Mechanical treatment:

All wounds of the elbow do better by suspension than by any other form of treatment. The joint, although at rest, moves slightly, and if there is any chance whatever of escaping ankylosis this chance will be preserved. For injuries not requiring resection the forearm and arm are suspended as for fractures of the lower end of the humerus, but no traction is used. When infection is present a slight separation of the joint surfaces is desirable and the arm should be hung by the forearm alone (Fig. 38). If greater separation of the joint surfaces is required, the suspending pulley is shifted nearer to the foot of the bed, thus increasing traction. As infection subsides the pulley is moved toward the head of the bed until the desired amount of flexion at the elbow is obtained, and the weight of the upper arm is also suspended, so that the patient may

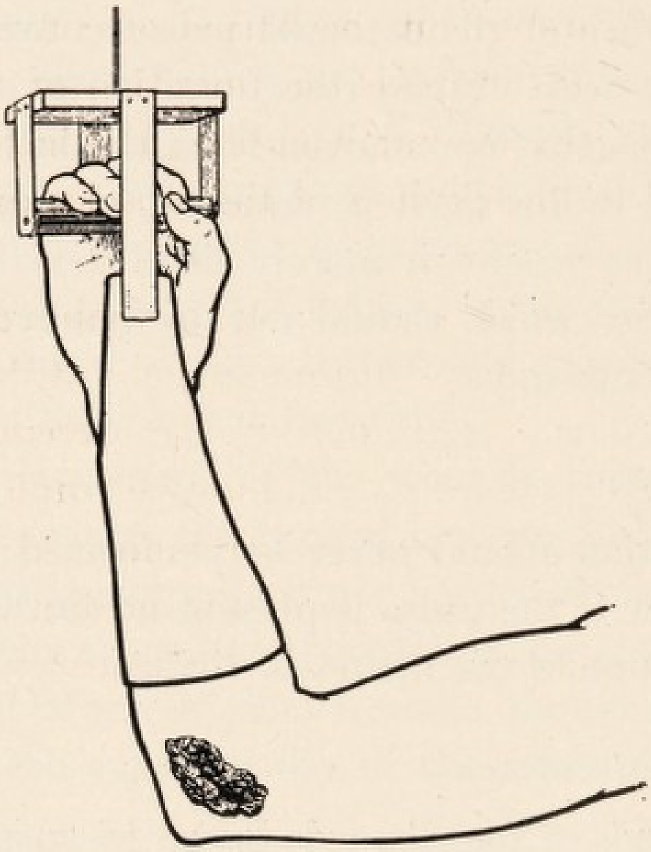

Fig. 38.—Method of treating infected wounds of the elbow joint by suspension. Note that the upper arm is not supported.

make attempts at motion and thereby possibly prevent ankylosis.

In complete resections entire restoration of the joint is the goal aimed at. In order to avoid stretching the muscles and separating the ends of the bones, the limb should be slung as for fracture of the humerus (Fig. 16), but without any traction. There will be enough unconscious motion for the first week, but after that time the forearm should be flexed and extended a little more each day, preferably by the patient himself and never so as to cause lasting pain. Active motion must be encouraged throughout the period of convalescence for two reasons: to improve the nutrition of the muscles, and to mold the new articulation; the latter being accomplished by the pulling of the muscles on the periosteum.

If suspension is not available, a double gutter splint with hinged side pieces forming a joint at the elbow may be used. The hinges permit the necessary motion. Non-articulated splints should not be employed.

A thorough course of sun treatment is particularly valuable to these cases, both for healing the wounds and for preserving the tone of the muscles.

WRIST

Wounds and fractures are seldom confined to the carpus alone, and usually either the inferior radio-ulnar articulation or the metacarpus is also involved. It is consequently necessary to consider all the articulations as one as far as treatment is concerned.

Gun-shot injuries in the region of the wrist, although not, as a rule, dangerous to life, are particularly serious in regard to loss of function, especially if the wounds become infected. The tendons about the wrist are frequently lacerated or divided; and if infection occurs they become irreparably embedded in cicatricial tissue when not destroyed in the infective process. It is therefore imperative that all injuries likely to become infected be operated upon at the earliest possible moment to remove not only foreign bodies but also pieces of bone which, if infection should ensue, would give rise to protracted suppuration. As the wrist is seldom covered by clothing, pieces of fabric are seldom entrained into it by projectiles, but fragments of shell or grenade, however minute, are apt to cause infection which sometimes develops in a peculiarly slow and insidious way.

Transport:

Flat splints should never be used for injuries of the wrist and hand. An efficient splint for transport may be made of the wire ladder splinting furnished by the Red Cross.

Operative treatment:

As a movable wrist is out of the question once suppuration is established, resection is indicated in all cases of fracture of the carpus except those showing bullet wounds with punctate orifices. The resection should not be typical, as for tuberculosis, but should generally be confined to the fractured bones with due regard to the lateral deformities which may ensue. The semilunar and scaphoid should not be removed and the cuneiform left, for instance, as a crippling distortion would result. When the extremity of the radius has been destroyed or removed the head of the ulna should be resected. In general, the trapezium and trapezoid on one side and the unciform on the other should be preserved.

If the wound and fracture involve the metacarpus and the carpus (particularly if the tendons of the corresponding finger are affected, as, for example, the os magnum, the third metacarpal and tendons of the middle finger) a good operation is to amputate the middle finger and split the hand right down to the carpus, removing all the fractured bones. The halves of the hand can be at once reunited if the wound is clean, or sutured secondarily if it is infected.

For extensive resections of the carpus the incisions for approach are two: an external incision which follows the radial border of the extensor indicis, commencing at the level of the line joining the styloid processes and extending to the middle of the second metacarpal; and an internal incision which commences just above the styloid process of the ulna and passes down well to the inner side of the extensor minimi digiti to 2 cm. (1 in.) above the lower end of the fifth metacarpal. The tendons should be carefully retracted after dividing the posterior annular ligament.

If the lower ends of the radius or ulna are resected the periosteum should be preserved with the greatest care in order to obtain restitution of the extremities of the bones. As for the carpals themselves, bony restitution is not so important, for a cicatricial wrist is to be desired; but the sub-periosteal method should be used in order to avoid injury to the overlying tissues.

Mechanical treatment:

After extensive resection the hand has to be immobilized in a position of dorsal flexion until repair is established, in order to avoid the tendency to displacement toward a position of palmar flexion due to the greater strength of the flexor muscles. This should be done by means of a molded plaster splint (Figs. 39 and 40). By using this splint the thumb as well as the palm is well supported and the fingers can be moved.

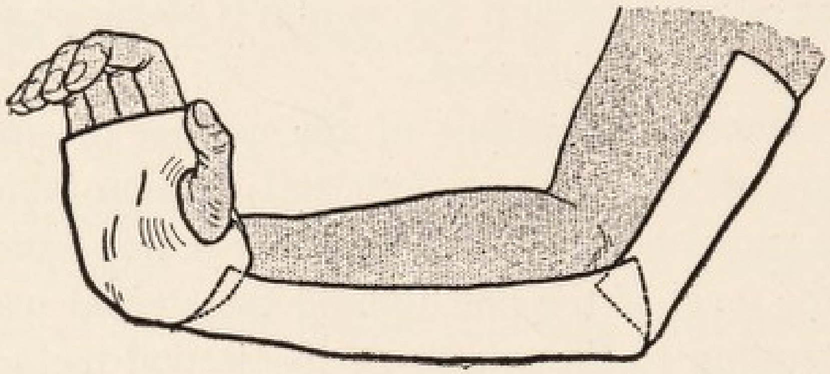

Fig. 39.—Molded plaster splint for immobilization of the wrist. (By the courtesy of M. le Médecin-Major R. Leriche).

When wet dressings have to be employed, as in infected cases, the original plaster splint should be carefully removed at the first dressing and another applied. If the first is in good condition it should be thoroughly dried and then impregnated with melted paraffin; it can subsequently be used for a long time without becoming softened by the dressing solutions. As an alternative, if sheets of gutta-percha can be had, they may be heated in hot water and the splint molded out of them.

For later treatment, when absolute fixation is not necessary, one of the cock-up splints may be used to advantage.

After extensive resections passive and active motion should be limited to the fingers until repair is well advanced. After limited resections passive and active motions of both wrist and fingers should be commenced at the end of a week.

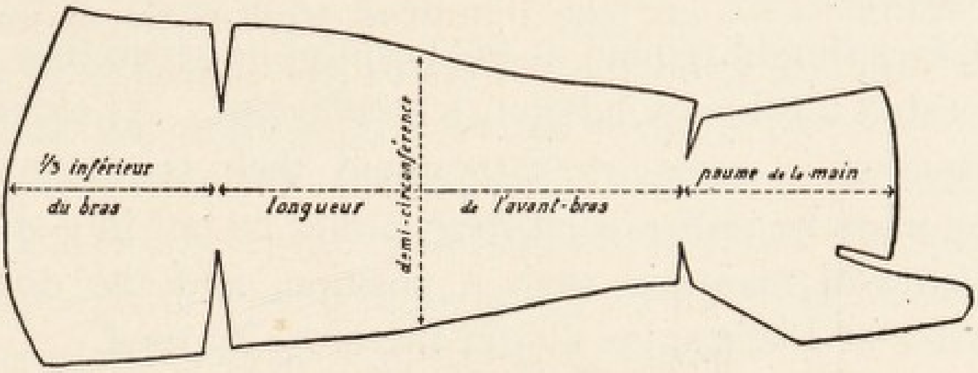

Fig. 40.—Method of cutting thicknesses of crinoline to make molded plaster splint for wrist. (By the courtesy of M. le Médecin-Major R. Leriche).

HIP

On account of its depth in a mass of heavy muscles, its close relation to the cavity of the pelvis and the organs contained therein, and the great danger of anaërobic infection, gun-shot injuries of the hip joint are extremely serious. It is probable that only exceptional cases reach the surgeon, the greater number being killed immediately or dying of hemorrhage and shock. Of those who do live to reach the surgeon, many succumb from complicating injuries to the intestine or bladder, and others from rapid development of infection due to the favorable field for the growth of anaërobes afforded by the lacerated muscles.

In no class of cases is early operation more imperatively demanded to save life, yet more often prevented on account of shock.

Transport:

Fractures of the hip joint are transported in the same manner as fractures of the upper part of the shaft of the femur.[1]

Cases should remain at the hospital in which they are operated until consolidation is established. As extreme abduction is necessary throughout their treatment, if they must be transported they should be put in a splint which will maintain such a position, and the double plaster of Paris spica should therefore be used.

Operative treatment:

Bullet wounds with punctate orifices should not be operated upon, but such cases must not be evacuated until all danger of infection is past.

All other wounds should receive operative treatment as soon as the patient's condition permits. The nature of the operation will depend upon the character of the injury and whether infection is already established or not.

Operations Before Evident Infection.—For wounds of the joint without bone injury, or those merely complicated by grooving of the bone or embedding of projectiles therein, the treatment should be as for any other joint wound. Primary suture should not be attempted, however, the wound being left open for delayed primary or secondary suture.

[1]Pages 73-79.

If there is extensive comminution of the head and neck of the femur, even if it extends down the shaft, complete sub-periosteal resection of all the fragments should be made on account of the great danger, if infection should supervene, of continued and perhaps fatal suppuration amidst them. The cartilage of the acetabulum should be removed in nearly all cases, because, as there is no hope of regaining an articulation, firm ankylosis is the result to be sought for, and also because suppuration, if it should occur, is prolonged by the presence of the cartilage. When the os innominatum has been pierced by the missile, the bone fragments and projectile should be removed, even if an ischio-rectal or an abdominal incision has to be made.

For resections and extensive operations on the joint, the approach from in front should be selected as easier and causing less traumatism to the muscles. The posterior route would at first sight seem preferable because it affords dependent drainage, but it destroys the attachment of the muscles to the trochanter and digital fossa (which will be the most important muscles in preventing dislocation of the femur on the dorsum ilia during after-treatment). It is therefore better not to enlarge existing posterior wounds except in so far as is necessary to trim and clean them. The best incision is one which commences at the antero-inferior spine of the ilium and passes outward and downward toward the great trochanter, following in general the direction of the neck of the femur. This incision is deepened between the rectus femoris mesally and the tensor fascia femoris laterally. The capsule of the joint is split longitudinally and then cut away transversely at its attachment to the acetabulum. If the neck has not been fractured it can be cut with a large bone-cutting forceps or by a gigli saw, and the head removed.

Drainage, if the original wound does not open posteriorly, should be made by a stab wound at the border of the gluteus maximus. Two small drainage tubes should be inserted, but only as far as the cavity left by the removal of the bone. The anterior wound should be left open for delayed primary or secondary suture.

Operations During Evident Infection.—The same remarks apply as for non-infected cases except that the indications for resection are more pronounced. Injuries to the bones likely to prolong infection, such as fissured fractures, should be treated by typical resection. If the bone injury is slight resection may be postponed as perhaps unnecessary. In such cases the capsule should be fully opened; drainage tubes must never be passed through it, however, but should go just to its level.

Mechanical treatment:

In cases where there is no complete fracture the limb should be suspended in flexion of the hip and knee and in moderate abduction and traction. This is most easily accomplished by means of a Hodgen's splint and the Hennequin method of making traction (Fig. 33). Such a position is best for drainage and is the most convenient for patient and attendants. A traction pull of five or six kilos should be sufficient.

In cases of fracture by rifle ball which have not been operated upon, and in cases of resection, a position of extreme abduction is indicated, in the first to prevent coxa vara, and in the second to keep the end of the femur in the cavity of the acetabulum and to compensate for shortening. In non-resected cases a certain amount of flexion at the hip is permissible, but not in resected cases. The non-resections need strong traction, but the resections should have only slight traction. The limb should therefore be suspended on a straight splint (the straightened Hodgen's is usually the most convenient), and only slightly elevated from the bed; a traction pull of from 16 to 18 kilos to commence with being applied for the non-resected cases and of from 4 to 5 kilos for the resected cases. To maintain abduction the sound limb must also be suspended in marked abduction.

In the resected cases, as soon as the danger of infection is past and the wounds are healing, it is advisable to put on a double plaster of Paris spica; this need not be carried below the knees.

Amputation:

As disarticulation at the hip joint is an exceedingly shocking operation, and more so than resection, the latter is sometimes preferable as a primary operation, even when the injury to the bones is so extensive as to make restoration of the function of the limb questionable.

There are also cases in which the pelvis, as well as the hip, is infected, and in which a disarticulation would not benefit the pelvic condition. For these, resection and drainage would seem the lesser risk. In most infected cases of severe and extensive injury to the soft parts and femur, however, amputation at the hip is advisable.

KNEE

Wounds of the knee have aroused more interest and controversy than those of any other articulation. No other joint demonstrates so vividly the course of normal repair or infection, and it is generally accepted as the type as regards the results of different treatments. In the early months of the war nearly all wounds of the knee became infected, and in a very large proportion amputation was performed. The usual treatment for an infected knee was to insert through and through drains into multiple incisions, and suppuration continued until the cartilage disappeared, after which the bones could become covered with granulations and repair gradually took place. The patient, during this long period, was subjected to all the dangers of severe sepsis, and finally emerged (if he did emerge) without the limb or with a stiff knee, and his viscera shattered by amyloid degeneration. It was soon discovered that resection, by removing the cartilage and affording free drainage of all the recesses of the joint, hastened resolution and repair. The greatest improvement in treatment (and, in fact, a milestone in the treatment of all joints) was the discovery that by a proper surgical (i. e., operative) cleaning of the wounds the joint cavity could be closed with even more impurity than wounds of soft parts, and that infection could be eliminated in the great majority of cases. More recently, observations in a number of cases of suppurating knees in the service of the author have tended to prove that in such cases simple incisions, sufficient to open the recesses of the joint but without the use of drains, lead to rapid decline of the infection and repair without destruction of the joint.

Anatomically the joint is complicated. Besides the main bursa extending upward under the quadriceps extensor muscle, there are a variable number of bursae in the popliteal space in relation with the popliteus and gastrocnemius muscles, which may or may not be involved in an infection of the joint. Usually they escape until the joint becomes more or less disorganized. If they become infected they are apt to cause abscesses which dissect their way into the calf unless opened at an early date. The popliteal nerves and vessels lie directly behind the joint, and incisions to open the popliteal bursae must be made by careful dissection. If drainage tubes are used in these cases there is great danger of secondary hemorrhage from pressure ulceration.

Transport:

All injuries of the knee should be transported from the field in a Thomas splint with traction. A well padded, posterior board or wire ladder splint should be used in addition, to support the joint. For late transportation, the Thomas splint is good for ordinary cases; for cases which have been resected a plaster of Paris splint, extending from the foot to the waist, should be employed.

Operative treatment:

Operative treatment varies greatly with the extent of injury to the joint, and also with the absence or presence of infection. The normal knee, in everyday life, is more subject to accident than any other joint; in other words, it is inherently weak. It is important, therefore, that the treatment should be directed toward preserving strength and avoiding any sacrifice of ligaments or tendons. On the other hand, if part of the bone, sufficient to destroy the bearing surface of the joint, has been lost, it is impossible to restore it; and in order to obtain a strong and useful limb it is advisable to resect, as an ankylosed knee is better than a weak and deformed one and one subject to recurring accidents.

As the type of operation to be performed depends chiefly upon the anatomical lesions, the cases will be grouped accordingly, and not by the absence or presence of infection, the only exception being perforating bullet fractures and wounds with punctate orifices which should not be operated.

(a) *Wounds entering the articulation, with or without lodged projectiles, but without injury to the bones.* These should be pared and excised as usual, the foreign bodies removed, the synovia sutured if the operation takes place at an early date, and the superficial wound closed by primary or delayed primary suture. If the projectile has passed across the joint, the latter should be opened at the opposite side so as to provide sufficient access to not only extract the projectile but to inspect the cavity and remove all contaminated tissue. If obviously infected the wounds should merely be left open, and if the joint has been distended with pus incisions should be made at each side of the thigh into the upper part of the quadriceps bursa and each side of the patella tendon. No tubes should be used.

(b) *Lodged projectiles in the epiphyses but not entering the joint.* These should be removed and the tract carefully excised. If the joint is full of blood it should be opened and washed out with normal saline. Unless it is infected the opening into it should be sutured. The original wound should be left for delayed primary suture. If the joint is infected secondarily from a projectile lodged in an epiphysis it is usually best, on account of the infection being established in the bone, to resect the joint.

(c) *Fractures involving only a small portion of the bony surfaces and not endangering the future relations of the bones.* In early cases, before infection, the loose fragments should be removed and the joint closed. If the joint is infected and the wounds of the bone cannot be isolated from the joint and drained directly to the exterior, it is wiser to resect.

(d) *Fractures with loss of substance destroying the bearing of the joint* (one condyle of the femur, for instance, or one tuberosity of the tibia). These should be resected whether infected or not.

(e) *Comminution of the joint.* These cases should be resected or amputated.

(f) *Fractures with extensive fragmentation.* These usually demand amputation.

(g) *Cases in which simple drainage has been made without causing the infection to subside and with* *marked signs of general sepsis persisting.* These are best treated by resection or amputation, depending upon the strength of the patient. If there is doubt it is advisable to amputate.

Technique of resection:

The resection should always be as conservative as possible, and just enough bone removed to obtain a good surface for apposition. In cases without fracture the cartilage can be removed from the posterior aspect of the condyles after taking the saw cut. The patella should usually be excised. The saw cut should be made so that when the sawed surfaces are in apposition the knee will be flexed to about 10°. It is not necessary to excise the synovia; the cartilage is the structure that retards and restricts repair. In clean cases the bones should be fixed in apposition with nails, and the wound closed. Resections in infected cases should be left open, and the ends of the bones kept separated by traction until the infection disappears.

Delayed or fibrous union occurs sometimes after resections of infected joints and necessitates a secondary resection. This should not be done until the wound has been healed for a sufficient time to eliminate the danger of post-operative infection. As these secondary resections, and other late resections for demority, do not always unite well it is very good practice to put in an inlay graft. If this is done failure will seldom occur.

There are some things which should not be done in operations on the knee. The patella ligament should never be divided unless during resection, for the knee in most instances will have to be resected later; if sufficient access is unattainable by means of curved lateral incisions, the patella and its tendon and ligament may be split longitudinally. Extended experience has proved that the method of treating infected knees wide open in flexion is undesirable. It is bad practice to drain through the popliteal space; it is much better to resect.

Mechanical treatment:

All cases, with the exception of non-infected resections, are best treated by suspension in a Hodgen's or Thomas splint bent to 165° at the knee, and just enough traction to steady the limb—a weight of 3 to 4 kilos is sufficient. It is, however, impossible to immobilize a limb sufficiently after resection of the knee by suspension without a firm support behind the thigh and leg to prevent displacement and angulation. This can be accomplished by means of a molded plaster splint extending from the gluteal fold to the foot. The splint should be removed when hard and dried, and paraffined as has already been described in dealing with the wrist. A gutta-percha splint is equally suitable. With this rigid support suspension in a Hodgen's splint has given excellent results. Resections for infection should be treated with enough traction to keep the ends of the bones apart until the infection disappears, when they should be allowed to approximate. Non-infected resections, and those in which infection has subsided, should be immobilized as absolutely as possible in order to promote firm union. For this purpose a plaster of

Paris splint extending from the foot to above the hip joint should be used.

ANKLE

The calcaneo-astragalar articulation will be studied in this group, because no definite separation can be made between fractures of the two articulations.

In considering the treatment of injuries of this region, and also those of the anterior tarsus and metatarsus, two main points must be kept in view: firstly (orthopedic), the conservation of the function of the foot; secondly, the peculiarities of the course taken by infection. The orthopedic question is dealt with in the description of the operations for each region.

Infections of the short bones are apt to take a slow and insidious but persistent course, the infective osteitis gradually extending and involving the articulations and adjacent bones. Unless treated vigorously by removing enough of the bone or bones to afford free drainage, suppuration is apt to persist for months and may, from absorption of bone, destroy the usefulness of the foot or necessitate amputation. The surgeon will consequently do well to anticipate this irregular destruction by a resection on orthopedic principles which will arrest the infection and provide a useful foot. Moreover, particularly in wounds of the anterior tarsus, infections are apt to take a very violent course, involving the sole of the foot and ascending the tendon sheaths—so much so that wounds of the foot are not only exceedingly dangerous to the member but to life itself. This explains what might otherwise seem extraordinarily radical operations for wounds of this region.

Transport:

The Cabot posterior wire splint should be used for transport from the field. For late transport some form of plaster of Paris splint is desirable.

Operative treatment:

As the ankle joint, on account of the tight mortise formed by the malleoli, is very difficult to drain, it is often better to remove the astragalus than to await a prolonged and problematic recovery by simple drainage, all the more so because the orthopedic result after removal of the astragalus is excellent. On the other hand, it is extremely important to preserve the malleoli and the mortise between them, as well as the os calcis which should never be removed in toto. In infected fractures of the malleoli above or of the os calcis below, therefore, the astragalus, when it is necessary to obtain drainage, should be sacrificed, even if little injured, in order to preserve the other bones. In primary operations for wounds or projectiles lodged in the astragalus, if it is found, in curetting out the bone, that the posterior part of the body has to be removed to such an extent as to destroy its form and bearing power, the whole bone should be excised. On the other hand, partial resections of the head give good orthopedic results.

Most fractures of the astragalus should be treated by total excision, even if caused by rifle balls and presumably uninfected.

In wounds and fractures of the os calcis resections should be as limited as possible, and the tuberosity and plantar surface should never be removed. The gap caused by removal of the astragalus gives sufficient room to treat more conservatively fractures of the malleoli above and of the os calcis below.

The incisions for excision of the astragalus are made on both sides of the foot. The outer and more important begins from 5 to 6 cm. (2 to 2½ in.) above the extremity of the external malleolus and passes downward along the anterior border of the fibula, curving gently forward in the direction of the interval between the fourth and fifth toes to end at the cuboid. It is deepened to the outer side of the peroneus tertius and anteriorly to the peroneus brevis. From its center a short straight incision is carried backward and downward to the tip of the external malleolus; this exposes the inferior tibio-fibular, the tibio-astragalar and the astragalo-navicular articulations. The internal incision, about 6 cm. (2½ in.) long, curves along the front of the internal malleolus to its tip; from the center of this incision another is carried forward and slightly downward to the navicula, but does not cross the tibialis anticus. This opens the tibio-astragalar and the astragalo-navicular articulations and only divides the extreme anterior fibers of the internal lateral ligament. The astragalus should be removed sub-periosteally with the sharp periosteal elevator, carefully avoiding any injury to the over-lying soft parts. The gaping wound should be very lightly filled with gauze from each side. No through and through drainage should be used.

For exposure of the os calcis the incision is made on the outer side of the foot in the shape of the letter L, the vertical portion being at the anterior border of the tendo-Achillis and the horizontal parallel with the sole at the junction of the thin skin with the thick skin of the sole. This affords plenty of room for all operations upon the calcis, particularly in conjunction with the original wounds.

Mechanical treatment:

For simple drainage of the ankle, and for all atypical operations, suspension in a Hodgen's splint with a slight traction by means of Sinclair's skate (Fig. 31 D) is by far the best treatment.

The after-treatment of resections of the astragalus by suspension is more difficult, on account of the tendency to displacement of the foot, but it is advisable to use suspension and traction in infected cases until the infection is arrested. For clean cases of resection the best method is to employ a plaster of Paris splint reaching from the toes to the knee. This, of course, has to be removed at every dressing, but in clean cases the dressings are so infrequent that this is no great inconvenience. Increased comfort will be afforded to the patient if the limb in the splint be suspended.

Old fistulæ of the astragalus and vicious union of the ankle and foot are best treated by astragalectomy. The position of the foot must be carefully watched after excision of the astragalus. At first the foot hangs loosely, but as repair takes place it gradually becomes drawn up against the tibia and fibula. If the splint is not properly applied the foot may be displaced too far forward or backward and become useless; there is also a tendency to inward rotation, which must be met and corrected. A firm cicatricial union should be sought for rather than a new articulation; early movements are not indicated, therefore, nor should the patient attempt to walk until cicatrization is complete, i. e., three or four months on an average. Much attention must be given to the toes in order to prevent incurvation; they must be massaged daily and their active motion encouraged. When repair is sufficiently advanced to permit walking, a shoe with lateral steel braces extending up the leg should be fitted in order to prevent lateral deviation of the foot.

Tarsus and Metatarsus

As has already been stated in regard to the ankle and posterior tarsus, operations for fractures of this region should be performed at the earliest possible moment to avoid infection, with its deplorable consequences, not only to the articulations and tendons of the foot, but to life itself.

Transport:

As for fractures of the ankle.

Operative treatment:

The question as to amputation or resection in these cases is decided by the amount of destruction of the soft parts, tendons and skin. Even extensive injuries involving the greater part of the tarsus can be treated by resection with good orthopedic results if sufficient soft parts remain.

The nature of the resection will depend on the extent of injury transversely. For wounds and fractures of single bones, partial resection and ablation of all torn tissues and foreign bodies suffices as a rule, when it is done primarily and before infection is established. After infection has set in the affected bones should be entirely removed. When the bones are fractured transversely across the foot, resection of the entire anterior tarsus, with partial resection of what metatarsals may be injured, gives excellent results. Resections of the bones at one side of the foot are not so satisfactory on account of the tendency to lateral deviation, and they should not be performed unless at least half or more of the tarsus is preserved. For more extensive injuries it is best to resect the entire tarsus, removing the astragalus but always leaving the os calcis.

Injuries to the metatarsus, if severe, may be treated by resection combined with disarticulation of the corresponding toes.

For resection of the tarsus the incisions already described for the astragalus and os calcis, and the typical incisions for navicula, cuboid and cuneiforms advised by Ollier, are used in conjunction with the original wounds. The incisions for resection of the anterior tarsus are four in number: one passing along the inner border of the foot from the tubercle of the navicula to the articulation of the cuneiform with the first metatarsal; a second passing close to the outer border of the extensor hallucis, uncovering the navicula and passing between the internal and middle cuneiforms; a third passing between the extensor tendons of the fourth and fifth toes and opening the articulation between the external cuneiform and the cuboid; and a fourth passing along the superior border of the peroneus brevis and uncovering the cuboid. It is not necessary to remove the heads of the metatarsals or of the astragalus in resections of the anterior tarsals. The large cavity left by extensive resections should be gently filled with gauze, which, in the clean cases, should not be removed for eight or ten days.

When the wounds involve the sole, threatening infection of the tendon sheaths or already infected, a successful method of treatment has been to split the foot longitudinally, by a dorsal and plantar incision, the two joining in the commissure between the toes. The halves of the foot are then separated, and the bones resected if necessary; when infection is present the former are kept apart until it has subsided. These incisions, by laying open the dense tissues of the sole, have been very efficacious in limiting infection and have, at the same time, given satisfactory functional results. Such a longitudinal splitting in the sagittal planes is less destructive than another which has been recommended; namely, a splitting of the sole away from the bones by incisions along the border of the foot. These splitting procedures require a secondary operation for closure, unless the wound is so clean at the primary operation as to warrant its being done at that time.

Mechanical treatment:

Resections of the tarsus have to be immobilized for a long time to prevent deformity by cicatricial and muscular contraction. The posterior molded plaster splint is the best.

An orthopedic shoe should be worn and weight should not be put on the foot until sensitiveness has disappeared.

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