Reconstructive Surgery in Peace

based on

Orthopaedic Surgery in War.

By

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Montreal, Canada

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Foreword.

The author of this timely series, A. Mackenzie Forbes, M.D., C.M., is a Fellow of the American College of Surgeons; a member of the American Orthopaedic Society; lecturer in orthopaedic surgery, McGill University, Montreal; orthopaedic surgeon, Montreal General Hospital, and surgeon, Children's Memorial Hospital, Montreal.

Dr. Forbes is a lieutenant-colonel in the Canadian Army Medical Corps. He went to France with the First Canadian Contingent, serving in Number One Canadian General Hospital, Canadian Expeditionary Force Overseas, for sixteen months, when he was recalled by the Canadian Government for work in Canada.

Being early on the ground, and in touch with the work through the entire war, especially with the important reconstruction work being done in Canada, Dr. Forbes, is, as few surgeons in the United States are, in position to speak from a wide range of experience. His message in this series is earnestly commended to the serious attention of the American medical profession.
—Editor.

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Introduction

A REPORT of an address made by the Director of Orthopaedics in the service of the Government of the United States has recently been published. He says: "About 75 or 80 per cent. of those who came back from the front proved to be cases which needed some kind of surgical repair, the bringing back to a condition of efficiency, which came under the head of orthopaedic surgery.

"Sir Alfred Keogh says that if it were not for the repair work England would have six hundred thousand cripples, and that is enough to wreck an army.

"The plan made by the Surgeon General of the United States Army is that the orthopaedic surgeon shall take charge of the cases which are to be orthopaedic as near to the time of the injury as possible and that care should be maintained throughout until the man was sent back home or was returned to the line."*

In the discussion which followed, the question naturally arose. "What are orthopedic surgeons, and who is qualified to do orthopedic surgery?" Orthopedic surgery is simply reconstructive surgery and other things being equal, those most capable of reconstructing the injured framework of the human body are those who have devoted the most time to the study of reconstruction. Now there are many American so-called general surgeons whose fame has been earned not by their devotion to the problems of abdominal or cerebral surgery, but by their labors in the field of reconstructive surgery. It is need-

* *American Journal Orthopaedic Surgery*, December, 1917.

less to say that the more thoroughly the problems of reconstruction have occupied these surgeons, the more likely they are to be efficient in the care of the wounded.

Surgical Reconstruction.

No one would suggest that none but declared orthopaedic surgeons are capable of undertaking this reconstructive work, but the hypothesis that the more reconstructive work done, the more efficient the surgeon, naturally draws attention to the training along these lines of the American orthopaedic surgeon, and suggests his place of usefulness in the field of reconstruction.

To some it may be a matter of surprise that I should claim so great a breadth for orthopaedic surgery, but to those who are conversant with the works of such surgeons as Sir Robert Jones, of Liverpool; Whitman, of New York, and the late Gwilym Davis, of Philadelphia, my claims will not come as a surprise. Again, the very word orthopaedic is derived from the two Greek words, *orthos* and *pais*, which translated literally would mean a straight child. Thus the business of orthopaedic surgeons is to make straight people by combating deformity either threatened or existing and, practically, orthopaedic surgery may be defined as "the surgery of the framework of the human body," in contradistinction to abdominal surgery, genito-urinary surgery, cranial surgery, thoracic surgery or the surgery of any other special part.

The Scope of Orthopaedic Surgery.

Both the British and the Canadian Army medical corps have defined the scope of orthopedic surgery as applied to their respective armies. As this paper is to be devoted to the treatment of the lesions and wounds of soldiers, I shall accept their classification as the basis on which this branch of surgery will be briefly discussed.

I will then ask the reader to consider the following lesions: (1) The result of gun-shot wounds and other violent injuries to joints, such as fractures into and about joints, fracture-dislocations, infec-

tions, etc.; (2) disabilities of the feet; (3) malunited and ununited fractures; (4) injuries to ligaments, muscles and tendons; (5) cases requiring tendon transplantation or other measures for irreparable destruction of nerves; (6) nerve injuries complicated by fractures or stiffness of joints; (7) certain complicated gun-shot injuries to joints; (8) cases requiring surgical appliances.

As I have neither the time nor the inclination to fully describe all subjects which have been studied by orthopedic surgeons, may I ask the indulgence of my readers if I discuss principally some points taken from a mass of material collected in the preparation of three addresses on this subject delivered by me within the past year and a half, which material has been revised as far as possible to the present date.* Much that might be said will be left unsaid, but it is my sincere hope that something of what I have to say may prove of service in helping our wounded, and that although I am at present deprived of the honor of individual service I may yet be of some assistance in this way.

Infections.

Because of his training in the treatment of pathological conditions and deformities of the bony framework of the human body, the orthopedic surgeon may be usefully employed in any position from and including a casualty clearing station to a base hospital in England or America.

In dealing with wounds in hospitals in France our first aim is to save the soldier's life and the second is to save the part affected, the two greatest dangers to both being infection and secondary haemorrhage.

Amputations are recommended usually only when they are necessary to save lives threatened by infec-

* Addresses delivered at:
(1) The Annual Meeting, Nova Scotia Medical Society, June, 1917.
(2) The Annual Meeting, Medical Society of the State of Vermont, October, 1917.
(3) The Annual Meeting, Lake Keuka Medical and Surgical Association, July, 1918.

tion. In the majority of such cases it is unsafe to perform the ordinary classical operations.†

The saving of limbs in which there are compound fractures with coincident infections demands not only the employment of the most modern methods but the most careful immobilization by appliances of such character that it is possible not only to dress the wounds, but, if necessary, to syringe or irrigate the infected channels. For such, in many patients in my service, plaster of Paris has been used. This dressing, when properly applied, is most satisfactory, especially if it be fenestrated, for drainage, lavage and dressings. The windows for such purposes, cut in a plaster cast, are carefully swabbed with melted paraffin before each dressing. This is applied over absorbent cotton and it fills the interstices between the plaster and skin as well as between the layers of plaster. Of course, there are many objections to the use of plaster of Paris, especially near the front line. These have been epitomized by Major L. W. MacNutt, who was associated with me in army medical work in France.‡

Primary and Delayed Primary Suture.

Baer, the associate professor of clinical orthopaedic surgery of Johns Hopkins, Baltimore, has drawn our attention to the all-important subject of primary and delayed primary suture in the treatment of war fractures. (*American Journal of Orthopaedic Surgery*, August, 1918). He says.

"The treatment of fractures from battle casualties is for the most part the treatment of soft-part wounds, plus the added difficulties which the injuries to bony tissue involve.

"To understand, therefore, the treatment of frac-

†See Amputations and Amputation Stumps.

‡Objections to Plaster in Casualty Clearing Stations.

"(1) Rush during a 'stew.'

"(2) Necessity for rapid evacuation

"(3) Liability to gas infection, which makes many large fenestrations necessary.

"(4) Likelihood of surgeons at the base being unwilling to assume responsibility for prolonged stay, without seeing the condition of entire limb. Pressure points as well as infection."

"(5) Difficulty in careful observation of cases during transit from C. C. S. to Base."

tures, one must thoroughly appreciate the changes which have been made in the treatment of wounds of the soft parts.

"All battle casualties are to be considered as infected.

"It is necessary to remove all projectiles, clothing, devitalized tissue, as early as possible, at least before the twelfth hour after injury.

"These wounds can then be considered as aseptic in character and a primary suture made, thus converting compound fractures into simple fractures, and appropriate treatment for these simple fractures thereupon instituted.

"What a marvelous and astounding change is this in the application of surgical principles since that fatal day in August, 1914. One cannot but stand in awe and wonder at the results which have been achieved, as he compares the present with the past: pus, with a clean lineal scar; continued pain caused by the packing of gauze and constant irrigation, with the peace of being left alone; the long and often painful processes in the restoration to function, with function restored almost voluntarily and swiftly; weeks and months of treatment, with recovery in a comparatively short time.

"How have these things come about? By the formation of a trust, a trust composed of the surgeon, the bacteriologist and the radiologist, all working harmoniously and constantly together.

X-Ray.

"Every battle casualty is radiographed immediately on its entrance to the hospital, and, generally, while en route to the operating room. A definite description of the fracture is given, and, if a projectile is present, its exact location is made, generally by means of fluoroscopy. These localizations are generally indicated on the surface by two markings, and the distance and direction from each marking is stated.

Bacteriology.

"The bacteriologist determines for us the type of organism present in the wound. Ninety per cent. of all these wounds are found to be infected by one

or more organisms. Here we have both aerobes and anaerobes; the types most commonly found are the staphylococcus, the streptococcus, the pneumococcus, the colon group and the organisms producing gas gangrene. We have learned from these bacteriological studies just what course we may pursue in our operative treatment; just what conditions will prevent a successful primary closure; when it will be necessary to immediately open a wound ordinarily closed; what the indications are for a secondary closure and how soon it may be done (Carrel).

Primary Sutures.

"Primary suture is the method of selection, when this can be done. Experience has shown that primary suture may be successfully performed in 80 to 95 per cent. of the cases.

Technique of Primary Suture.

"Disinfection of skin, with iodine, soap, water and a scrubbing, or other methods. Removal of skin edges together with the tract made by the projectile. Removal of all projectiles and of all devitalized tissue. The performance of complete hemostasis. The accurate approximation of skin edge without tension.

"The time to operate is generally regarded as being within the first twelve hours.

"It has been said that 10 per cent. of battle casualties, even when they have arrived at the hospital within the first twelve hours, cannot be primarily closed, and mainly for the following reasons: Cases where the shock is so great that the patients cannot stand the operation within the first twelve hours; deep wounds, where the complete excision of all devitalized tissue is uncertain or impossible; wounds, where no X-ray being present, the projectile cannot be extracted; wounds where the loss of substance is so great that complete closure is impossible, etc. It has been shown that about 5 to 10 per cent. of the primary sutures are not successful, and this is due mainly to streptococcus.

"In an evacuation hospital, all wounds which are received within the proper time after injury, and

which are applicable to primary suture, are closed by this method. At the same time, cultures of the wounds are taken. The wounds that must be opened immediately on the bacteriological report are those primarily infected with the virulent types of streptococci.

"The virulent streptococci, generally by themselves, and always when associated with other organisms, such as streptococcus, enterococcus, the gas gangrene group, etc., demand immediate opening of the primary suture.

Delayed Primary Suture.

"The delayed primary suture is the method of wound closure which has been adopted in all those cases where primary suture would have been done except for circumstances, generally of military character, which made it inadvisable. The technique of delayed primary suture is exactly that of primary suture, except that the skin is not closed, and a dry, sterile dressing is placed over the wound. The skin edge is brought together from three to eleven days later.

"The hospital at the front can generally keep, in times of stress, only 20 per cent. of its beds *permanently* filled. All primary sutures should be kept at the place of operation for at least ten days, so that the wound may be watched and not subjected to the traumatism of transportation. Therefore, where cases must be removed immediately, within six or seven hours after operation, delayed primary suture takes the place of primary suture.

"This method of procedure has been found eminently successful. The delayed primary sutures are sent to the rear within six or seven hours after the initial operation, and are closed preferably on the second, third, or fourth day.

Fractures.

"The particular object of this paper is to bring before you the necessity for the early treatment of bone injuries, by primary or delayed primary suture, for this is the keynote to the successful handling of war fractures. *To change an infected compound*

fracture into an aseptic, simple fracture at the outset is to do away with the greatest difficulties which are found in the treatment of war fractures.—(The Editor.)

"In the statistics given by Lemetre, in a series of 421 compound fractures of all bones (a list of which were added in the paper), among which there are 51 compound fractures of the humerus and 26 compound fractures of the femur, the most difficult of all war wounds to treat and the ones which have formerly given the highest mortality, there is a complete cure with a simple fracture of 91 per cent. and, if we add the partial failures, which do not affect the treatment of the fractures, we have 97 per cent. of cures—better than that for soft-part wounds.

"All compound fractures must be operated upon by the technique of primary or delayed primary suture, within eight or ten hours of the casuality. Thus the problem is one of the treatment of the simple fracture.

"The transportation of the wounded must be accomplished with this end in view. Hospitals of sufficient size must be located in the zone of the advance, near enough to make this transportation possible.

"Each hospital must be sufficiently staffed with surgeons of sufficient skill, with a bacteriologist and radiologist, in constant consultation for the proper carrying out of this technique."

If British and American army surgeons can equal or even approximate the results published by our French Allies, then indeed shall we be able to say with Baer, "What a marvelous and astounding change is this in the application of surgical principles since that fatal day in August, 1914. One cannot but stand in awe and wonder at the results which have been achieved."*

* The surgical principles involved in the "primary and delayed primary suture" of the wound to the soft parts in a compound fracture have a broader application. Major L. W. MacNutt, who has had a considerable practical experience in a casualty clearing station at "the front," says, in speaking of the closure of wounded joints:

"The question of drainage of a joint is open to discussion. Personally I doubt if it should ever be necessary, except, perhaps, in late cases. I did between fifty and sixty joints at a C. C. S. and did not drain any except one hip-joint."

Violent Injuries to Joints.

Fractures in and about Joints, Infections, etc.

In the hospitals at the base, with care and the passage of time, infection has not the same terrors as at the front, but new problems present themselves, not so much in the field of preventive surgery as in the field of reconstructive surgery. Studying this latter field will necessitate first the study of lesions of the larger joints.

CHAPTER I

Major Injuries About the Hip

SOME of the most serious injuries seen in the war are those about the hip-joint, not only because of the possibility of future impairment of the joint, but because of the great mortality associated with such.

My friend and late associate in army medical work in France, Major L. W. MacNutt, speaking of these wounds seen in a Casualty Clearing Station, says that the majority of hip-joint wounds with fracture do not reach a C. C. S. Those who do are extremely liable to a gas infection. When cases reach a C. C. S. within a few hours there is a reasonable chance of saving the limb; but these cases usually arrive late, minimizing chances of both life and limb. It is difficult to completely excise a wound about the hip-joint, and unless this can be done success will be rare by irrigation and drainage.

On the lines of communication and at Base Hospitals conditions are somewhat different.

In early injuries the problem is to save life and limb. The hope of saving the latter must not allow of persistence in conservative treatment when life is threatened.

The cleaning of such wounds must not be neglected. In the early days of the war many surgeons were inclined to remove too many bony fragments in their endeavor to secure drainage. This must be guarded against.

Immobilization.

The difficulties of immobilization in injuries about the hip in warfare are very great. This difficulty is especially apparent if there be a compound fracture which is, unfortunately, usually the case. The abduction frame described by Sir Robert Jones is often used and in early cases is superior to all forms of treatment, with one notable exception, *viz.*, a plaster of Paris spica.†

I still maintain that in spite of the objections raised by Major MacNutt, if it were possible to have a Hawley table or even a simple form of sacral support in each Casualty Clearing Station, and to put patients suffering from such lesion into a plaster spica immediately after the wound had been cleaned and drained, and if it were possible to maintain these patients in such immobilization under constant and skilled supervision many lives and limbs would be saved.

The objections against the use of plaster in a Casualty Clearing Station have been epitomized by Major MacNutt, as quoted in the "Introduction."

Other splints may be more suitable, if at a later date such treatment as that of Carrell and Dakin is indicated, but we do not sufficiently appreciate the benefits derivable from treatment in plaster of Paris.

Immobilization is as necessary for the safety of the patient as is relief from infection. The most difficult form of treatment is often, in this fracture, the most satisfactory; thus the fenestrated plaster of Paris spica is recommended. Such a plaster cast, if carefully applied, and if it reaches from the nipple to the toes of the injured side will assure perfect rest and ample opportunity for cleansing the wound by irrigation or the syringe. In such plaster splint the bed-pan may be used and the patient transported any distance in comparative comfort. Plaster of Paris will help to save both life and limb, but it must be properly applied by one who is willing to

†Denis W. Crile has suggested a modification of the Thomas Hip Splint for this class of patients. Whether it will prove to be simple enough, and easily adjustable enough for use at the front, time only will tell. (See *British Medical Journal*, April. 1918.)

remove it (if there is any suggestion that some untoward change or affection is taking place underneath the plaster), thus sacrificing much labor.

Transporting the Patient.

Major MacNutt recommends the following as the simplest method for the transportation of a patient suffering from a fracture of the upper part of the femur:

The patient is placed in a Jones abduction frame with a sliding foot piece. His broken extremity is placed in the attitude of rest, *viz.*, a position of rotation only slightly external to the mid-point between internal and external rotation. It is unnecessary in most patients to remove the boot, either a spike may be driven through the heel or a figure-of-eight bandage may be applied fore and aft over the boot and fixed for extension and immobilization to the end of the splint. The patient will travel almost any distance in comfort when so treated.

The following is another rapid method of fixation, and one especially suited for the transportation of those suffering from fracture of the middle and lower thirds of the femur: The Thomas splint is bent about one inch above knee, so that when bottom of ring and tip rest on floor, the upper bars (ring to knee) lie parallel with the floor. A supporting flannel bandage should be placed above upper end of lower fragment (fixation). One of main objects in this method is to restore the femoral arch or crown. The splint tip may then be fixed to foot of bed, elevated about 12 inches, and extension accomplished by gravity. When this is employed with the usual fixation at the site of fracture, extension, and a supporting hammock of flannel bandage placed beneath the femoral fragment, its upper part will act as a splint to the fractured femur, and its lower part as a pedestal for the splint proper, to assure the maintenance of a proper relationship between the thigh and the splint.

Position of Election.

The position of election in the hip is of importance, as it is in all other joints which are injured

and liable to become ankylosed.

In lesions in which ankylosis can be expected, and indeed in all lesions except typical fractures of the neck, the limb should be fixed in a position of slight abduction to guard against threatened adduction without either flexion or extension because, whilst the tendency is to see flexion, this in slight degree is not disadvantageous. The foot placed mid-way between external and internal rotation should be supported in plaster.

In this, experience has made me differ with Sir Robert Jones, who says ankylosis should be encouraged, in a position of very slight abduction, with thigh extended, and very slight outward rotation.

Simple Fracture of the Neck of the Femur.

Forbes (*Am. Jr. Orth. Surg.*, 1909): In studying disabilities about the hip the subject of fracture must first engage our attention. Compound and infected fractures rarely admit of classical treatment and are dealt with elsewhere in this chapter, but in order to attempt to complete a study of war lesions where suppurating wounds, although predominating, are not alone, simple fractures must be considered.

I think that it is generally conceded now that non-union which was in the past the end result of the majority of so-called intra-capsular, or medial fractures, was due in the past to imperfect re-position of the fractured ends.

The principal causes of deformity at the seat of fracture were: (1) external rotation of the distal fragment, with a protrusion forward of its broken extremity (caused by the external rotation of the leg); (2) an indrawing of the upper extremity of the femur caused by a spasm of the rotators; also (3) elevation of the distal or femoral fragment.

The anatomical principles for the opposing of the two fragments were first demonstrated by an American, Professor T. J. Maxwell.* His method and that of Whitman, of New York, which is known as the abduction method, are the two best methods for

*Ruth, *Therapeutic Gazette*, 1907; Ochsner, *Annals of Surgery*, 1904.

the treatment of such fractures. In war surgery the latter is the most practical method. I will, therefore, describe it briefly.

Abduction Treatment of Fracture of the Neck of the Femur.†

In complete fractures of the neck of the femur the affected limb is usually shortened, somewhat flexed, rotated outwards and often slightly abducted, thus the outer fragment is turned forward, displaced upwards and usually lies on a lower plane than the head.

As one has no control over the inner fragment, contact can be secured only by adjusting the outer fragment to it. This is accomplished as follows:

"The patient having been anesthetized is placed upon the back, the shoulders and head supported by a box of sufficient size, about seven inches in height, the pelvis resting on a sacral support, provided preferably with a perineal bar for fixation of the trunk, both extended limbs being held by assistants. That on the sound side is then abducted to the normal limit to demonstrate the normal range and to fix the pelvis. That on the injured side is then under traction slowly abducted and rotated inward, the surgeon supporting the joint with his hands and pressing the trochanter gently downward. The limitation of abduction, caused by contact of the deformed neck of the upper border of the acetabulum, is recognized, but it is easily overcome. When the limit of normal abduction is reached it may be inferred that the proper relation between the neck and the shaft of the femur has been restored. The limb in this attitude of complete extension, abduction and slight inward rotation is then securely fixed by a long plaster spica. It may be noted that this method of reducing the deformity by abduction followed by the immediate application of support hardly corresponds to what

†References: Royal Whitman, of New York;
(1) *Annals of Surgery*, 1900;
(2) *Medical Record*, 1904;
(3) *Lancet*, 1913;
(4) *Surgery, Gynecology and Obstetrics*, 1916;
(5) *Annals of Surgery*, 1916;
(6) *Boston Medical and Surgical Journal*, 1916-1917.

is known as the 'breaking up of an impaction.' Far from endangering union it should favor it by actually apposing the fractured surface.

"If the fracture is complete the same treatment is adopted with the following modification: The patient lying in the position described, the disabled member is first flexed to disengage folds of capsule that may have fallen between the fragments. It is then extended and rotated inward to the normal attitude, and under traction and counter-traction the shortening is completely overcome, as demonstrated by measurement. The sound limb is then abducted to the limit to demonstrate the normal individual range and to fix the pelvis. The limb on the injured side is then slowly abducted by the assistant while the surgeon supporting the joint pushes the thigh upward from beneath to force the two fragments against the anterior part of the capsule. When the limit of abduction has been reached the capsule will be tense, thus directing the fragments, now in a horizontal plane and end to end, toward one another and finally forcing the contact. If the fracture is near the head, the outer fragment may be inserted beneath the acetabular rim. If at the base, the trochanter under ordinary conditions will be apposed to the side of the pelvis, thus preventing upward displacement. Furthermore, the muscles whose contraction favors deformity, will be completely relaxed, or so changed in direction that displacement from this source is impossible. The fracture is as if it were locked by internal splinting and it is only necessary to hold the limb in the attitude of complete abduction and complete hyper-extension by a plaster spica. This, being an independent splint, permits frequent changes of attitude, even turning the patient to the ventral attitude to rest the back.

"In the treatment of elderly subjects it is well to raise the head of the bed from one to two feet to lessen the danger of hypostatic congestion of the lungs and to increase the blood supply at the seat of injury. Repair is very slow and weight must not be borne for many months. In the after-treat-

ment the support of a modified hip splint is desirable, and functional recovery will be hastened by massage and by appropriate active and passive exercises of which by far the most important is to draw the limb at intervals to the complete limit of abduction.

"One often encounters cases in which the disability from fracture of the neck of the femur persists even though union has taken place. This is due in great part to adduction, which is induced primarily by depression of the neck of the femur and by fixation of the limb in the line of the body, as in conventional treatment. That part of the deformity due to muscular retraction may be overcome by force under anesthesia. The limb is then fixed for a time in the degree of abduction that the deformity permits. If, as is often the case, the fracture has failed to unite and the open operation is impracticable, the upper extremity of the femur may be forced forward beneath the antero-superior spine and the limb may be fixed in an attitude of abduction and extension by a short spica, as originally suggested by Lorenz. (Whitman, *Orthopaedic Surgery*, Fifth edition.)

The Operative Treatment of Fracture of the Neck of the Femur.

Probably the first published case of open operation for simple fracture of the femoral neck was that of the late Gwilym G. Davis in the *Annals of Surgery* of 1905. There, screwing the fragments together was advocated in *recent* fractures. Da Costa is on record as having advocated fixation in *recent* fractures, about the same time. In 1908, before the American Orthopaedic Association, Davis advocated freshening the edges through an anterior wound in cases of ununited fractures (Davis, personal communication).

Operations, however, for ununited fractures had frequently been performed much earlier than this. Gillette published a case in 1898 where he united head to neck by means of an ivory peg. Sayre had previously employed a gimlet for the same purpose. Whitman and many other orthopaedic surgeons have

made practice of similar or nearly similar proceedings. In 1915 Albee first suggested the bone graft peg in the treatment of fracture of the neck of the femur. (*Annals of Surgery*, July, 1915.)

The Operative Treatment of Recent and Ununited Fracture of the Neck of the Femur.

Albee, of New York, has recently published an article on this subject.* In this he stated that it is his "uniform practice to insert the bone graft peg in every operable case in which the fragments are loose or unimpacted."

As a reason for this practice he quotes the British Fracture Committee as having stated that good results have hitherto been obtained in only 23 to 28 per cent. of all fractures of the neck of the femur, under all forms of treatment; but to my mind this unanalyzed statement is not sufficient to justify such radical procedure as operation. If Whitman's results showed only 28 per cent. of serviceable union in cases in which no operation had been performed I would willingly agree to Albee's suggestions. I would willingly agree that treatment by all non-operative methods was a failure, but Whitman has done much better than is suggested in the above figures. Under these circumstances should it be our "uniform practice" to insert the bone graft peg in every operable case in which the fragments are loose or unimpacted? Would it not be better judgment for surgeons to improve their non-operative technique in the treatment of this fracture instead of adopting the system of performing an unnecessary operation in many cases which under suitable non-operative treatment in skilled hands yields, as Whitman claims, good results?

At the same time there are some patients in whom operative treatment, in recent cases, may be indicated. Again, there are many cases of ununited fracture of the femoral neck which demand open operation. For these cases, then, it will be well to study Albee's technique which, at least theoretically,

*American Journal of Orthopaedic Surgery, August, 1918.

is the most perfect available, and which under the skilled hands of Albee has yielded excellent results.

The Operation.

The operation is performed on a Hawley table or in war surgery some modification of it may be used. Albee reaches the point of fracture by an incision beginning at the anterior superior iliac spine, curving downwards to terminate at a point three to five inches below at the inner border of the sartorius. This muscle and the rectus are retracted outwards. The ilio-psoas is retracted inwards. The fracture is exposed. All foreign matter is removed from between the opposing fragments. These latter are freshened by means of a curette. Good apposition is now assured by traction and abduction, combined with manual pressure, through the incision.

A second incision is now made over and just below the great trochanter, which is thus exposed. With a gimlet the proper direction for the motor saw is determined by trial. Albee accentuates the fact that the drill should exactly follow the double inclination of the femoral neck, *i. e.,* upward and forward. When the gimlet is withdrawn the half-inch motor drill is carefully inserted and pushed through the distal fragment until the burr end of the drill appears between the fragments. By reading the depth to which the drill has been inserted and comparing this with the distance already calculated as necessary by means of a skiagram, and now confirmed by observation, the surgeon can decide on the distance to which it will be wise to insert the graft into the capital fragment. The drill is now disengaged from the motor and left *in situ,* thus, in the meantime, preventing any possible displacement of the fragments.

A sufficient portion of the crest of the shin is now excised. The cross section of this should be large enough to be shaped into a peg for insertion into the drill hole now completed. The dowel-cutter for the preparation of this peg should be of at least three-eighths inch in diameter.

The graft having been secured from the tibia and converted into a peg, this should be sharpened for insertion into the canal prepared in the femoral neck.

Because the drill used in the femoral neck and the dowel-cutter used for preparation of the peg are complementary, the peg should fit into the canal prepared for it as accurately as does a ground glass stopper into a bottle. The peg or graft is driven home.

Before closing the anterior wound fragments from the incised tibia are placed between the opposing fragments of the femoral neck and maintained or stabilised there by gentle impaction on the great trochanter.

This extremity is then secured in a long plaster of Paris spica extending from the toes to the axilla. This spica should maintain the extremity in such position as was found to be most favorable at the time of operation.

Weight-bearing should not be allowed inside of six months.

In closing this description it is well to point out that Albee sometimes advises removal of the femoral head, in cases of old ununited fracture where the fracture has occurred near the head and where there is considerable rarefaction and disintegration of it. Here he inserts the great trochanter into the acetabulum, as was done by Sir Robert Jones and is described in the article under the heading of "Pseudo-Arthrosis of the Hip." *

All the procedures described are of real value in dealing with ununited fractures about the hip, and further, as it has been said, there may be some cases of recent fracture where similar operative treatment is indicated.

Malunion.

Stiffness of the hip associated with limitation of abduction and extension, often accompanied by osteoarthritic changes in the hip joint, is frequently the sequel of malunion in this region. It is because

*British *Medical Journal*, 1908.

of this the position of election as chosen by Sir Robert Jones is a position of slight abduction, extension and external rotation. (*British Medical Journal*, 1916.)

Flail-Joint.

The hip is the only joint where a flail-joint is to be preferred to an ankylosis purchased by the risks attending operative procedures. With suitable support a flail-hip can be made a useful joint.

There are certain operations, such as that of Albee, which aim at causing an ankylosis of this joint. In my opinion they can be useful only in selected cases because while a flail-like condition of the hip is not disadvantageous, fixation of the hip certainly causes great discomfort.

Excision of the Hip.

This was considered at one time to be a most dangerous and unsatisfactory operative procedure. It was considered primarily so because of the danger of shock at the time of the operation, and secondarily so because of the possibility of the neck of the femur slipping over the acetabular ridge after the removal of the femoral head, causing both lack of stability and pain on weight-bearing.

I think that the possibilities of shock at the time of the operative procedures have been to a great extent eliminated by more modern procedures.

In 1913 I reported an operation which could be performed both rapidly, efficiently and without shock.

The skin incisions which are used are those recommended by Brackett, of Boston. They extend (a) from the anterior superior spine posteriorly to the superior extremity of the great trochanter; (b) downwards over the great trochanter and femur for three inches; (c) from the junction of (a) and (b), in a direction posteriorly, for two or three inches.

These flaps having been reflected, the great trochanter is exposed. It is then removed by means of a chisel by an incision directed upward, the muscles attached to it being left *in situ*, as was done by Sir Robert Jones in his operation for arthroplasty

some years ago. (*Vide Brit. Med. Jl.*, Feb., 1908.) This exposes the neck of the femur. The head is then brought into view by rapidly and strongly retracting the adjacent muscles. The capsule is opened. Into this opening is inserted a spoon-shaped instrument described as an evulsor in the original description of this procedure, and when these are not available a raspatory or other blunt instrument will do almost as well. By insinuating this around the femoral head the capsule is not only easily detached but the head of the bone can be rapidly pried out of the acetabulum.

The head is then easily removed by means of a Gigli chain saw or chisel, care being taken to preserve as much of the neck as possible. The neck is then returned into the acetabular cavity. The capsule and deeper tissues are then united to as great an extent as possible about it. The great trochanter is pegged to the femur in its original position. The wound is closed without drainage and the extremity encased in plaster of Paris in a position of as great abduction as possible.

In my estimation the dangers of the femoral neck slipping upwards on weight-bearing are to a great extent eliminated by the last procedures suggested. Albee, some years ago, suggested a procedure to immobilize the hip by an excision of a part of both femoral head and acetabulum. I am inclined to think that movement, even if limited movement, may be secured by the procedure I have described; and as Albee's procedure does nothing but immobilize, it is questionable whether it is to be considered in war surgery except in cases where stability, and especially stability for the relief of pain, are to be desired. In Albee's operation the length of time necessitated for the carrying out of the technique will often militate against its usefulness, whereas an excision as described, if combined with the insertion of a cap or cowl of pig's bladder, as described by Baer, of Baltimore, to cover the cut surfaces of the femoral neck, may often prove satisfactory.

Sir Robert Jones' Pseudo-Arthrosis of the Hip.*

This writer has been accustomed to exsect the head of the femur to assure a new hip joint in osteo-arthritis, a condition very similar in its deforming influences to malunited fracture.

His operation consists in removing a slice of the great trochanter, chiseling through the neck and screwing the separated portion of the trochanter to the proximal end of the neck in order to avoid union of the fragments.

A longitudinal incision is made about six inches in length with the upper border of the trochanter as its centre.

An incision is made across the base of the trochanter just below the insertion of the gluteal muscles.

A slice of the trochanter from this point to its junction with the neck above is sawn or separated by a very wide osteotome and retracted upwards. The capsule is now opened and the head separated from the neck with an osteotome or saw.

Extension is next put on the femur and the trochanter with its muscles attached is screwed on to the head of the femur, which remains in the acetabulum.

Deep and superficial sutures complete the operation.

* *British Medical Journal*, 1908.

CHAPTER II.

The Knee.

Compound Fractures Implicating, and Injuries Penetrating Into, the Knee-Joint.

IN DEALING WITH injuries to the knee-joint it must be realized that they present one of the most serious problems of surgery. If this joint is penetrated by infective material, and especially if, added to this, there is an injury to either of the great bones forming the joint, life is endangered. Treatment of such wounds demands therefore the greatest care. Whilst endeavoring to save the joint, we should always bear in mind the fact that it may be easier to save the limb than the life. Many serious injuries to the knee-joint are followed by limitation of movement, if not by ankylosis, which latter causes the greatest inconvenience. Until recently it was well to consider whether it was worth while attempting to save a leg in which ankylosis at the knee was the best we could hope for, if this attempt was to be made at the risk of the patient's life. This was especially so because we knew that amputation about the lower third of the femur allows of the use of an artificial limb with a knee-joint, and that this limb is often superior to a natural limb with an ankylosed knee.

Improvement in Results.

Fortunately, however, our methods have changed during the past eighteen months to two years. The following has been reported in a personal communication by Major L. W. MacNutt; it is of such great importance in showing the trend of modern war surgery and the improvement in results over the early war methods that I will quote it almost verbatim:

"In a series of thirty-eight knee joints treated at a casualty clearing station, which included

penetrating and perforating wounds with and without fracture, I always excised all badly damaged tissue, removed all small and detached dirty bone fragments, and cleansed and replaced others. I removed the foreign body when present. Thoroughly irrigated with hot saline; then dried out the cavity with gauze swabs which had been wrung out of ether. Closed the wound completely in layers, and applied a dry dressing.

"In all cases, where possible, the fracture when intra-capsular was made extra-capsular by suture of the synovial membrane below the fracture. In two cases the supra-patellar bursa had to be brought down to form a new synovial membrane for the joint.

"The limb was put up in a bent Thomas splint, using extension by strips of gauze attached with ordinary glue* and tied to the lower end of the splint. Used in this way it will keep the lower joint surfaces apart and the action of gravity, as well, assists extension. In several very severe fractures the foot of the bed was elevated to produce more extension.

"In this series of thirty-eight patients two required amputation through the lower third of the thigh; one of them died of "Bipp" poisoning. All the others healed by primary union, except a few where owing to the loss of large areas of skin and subcutaneous tissue it was impossible to close them. These healed primarily with granulations over the

* "I think extension is better obtained by strips of gauze fastened by glue than by adhesive.

"The limb should be well washed, not shaved, and rubbed with alcohol, dry. The glue is applied, best with the hand, against the grain of the hairs and gauze applied and lightly bandaged. This will never slip and is very easily removed by pulling in the opposite direction to the hairs. It will not leave the leg "shaved" as does adhesive. It is not painful and does not take away pieces of skin." (MacNutt).

FORMULA.

Common Glue	aa		Sinclair
Water	50	parts	
Thymol or Menthol	½	part	
Glycerine	2	parts	
Calcium Chloride	2	parts	

bared area. Two or possibly three would require skin grafting later. All these patients were kept three weeks before they were evacuated to other hospitals. In severe and badly infected, as well as in late cases I took the extra precaution of injecting two to four c.c. of a 2 per cent. solution of formaline and glycerine, though it was always thought that cases in which this severe treatment was not necessary would eventually have more useful knees. All cases were treated by evaporating lead lotion. This was used for only twenty-four to forty-eight hours. No drainage tubes were used, although in a few cases a drain of three to four strands of silk worm gut were inserted between the skin sutures for twenty-four hours. At times when short of Thomas splints we had to use back and side splints, thus losing most of the possible extension. This resulted in lessened joint movement. Passive movement was begun at the end of two weeks."

Incision for Examination of Knee

In opening a knee-joint many incisions have been employed, usually one to surround the wound.

An incision which gives an excellent view of the interior of the joint is vertical or slightly convex outwards. The patella is sawn through vertically and its margins spread apart. The periosteum is incised to one side of the saw cut for a valve closure. (MacNutt.)

Danger of Suppuration

The danger of suppuration in the knee seems to lie mainly in two things: First, the difficulty of drainage, and, secondly, the liability of the infection to spread into the synovial pouches and about the intermuscular septa both in the thigh and in the leg. From a mechanical point of view, then, the head of the bed should be elevated in all such cases in order to minimize the possibility of the spreading of the infection of the thigh by gravity, which often means the loss of our means of retreat by amputation through the lower third of the femur in patients in whom our conservative position of watchful waiting has become plainly untenable.

Although the results from the closed method of treatment given by Major MacNutt, and experienced by other surgeons, are most gratifying, the time has not yet come when we can forget our knowledge of drainage.

*Drainage.**

Because of the anatomical conformation of the joint, surrounded as it is by muscle and tendon, and formed by the close apposition of two of the largest bony surfaces of the human frame, drainage depends on the position in which bony apposition is least marked, and gravity counts most. (Notes on War Surgery, *British Medical Journal*, 1915-16.)

The great subcrureus bursa is well known, and where the joint is drained it is never overlooked, but this is not the case with the complicated pouches at the back of the joint.

The knee-joint is divided into two main pouches behind by a septum projecting forward from its posterior wall and formed in order from behind by the posterior ligament, the crucial ligaments and the ligamentum mucosum. Each of these pouches receives the posterior protuberant extremity of the corresponding condyle in extension. These pouches terminate above and behind the condyles in sacs, which are beneath the corresponding head of the gastrocnemius. The outer pouch also sends a synovial prolongation along the popliteus tendon. The usual method of draining the knee-joint by a tube passed below the patella and another passing up into the subscrureus bursa leaves these two posterior pouches untouched. The leg in such cases is kept extended on a splint, which closes the way to the front of the joint by a coaptation of the bony surfaces.

When these pouches rupture from distention with pus, their anatomical position directs the pus up the thigh, between the hamstrings and the great adductor, and down the calf between the gastrocnemius and the deep muscles.

* (Barnard, *The Practitioner*, 1901).

It is clear, then, that each of these pouches must be drained by a posterior incision placed as far back as possible.

On the inner side, the knee being fully extended, the protuberant extremity of the condyle is cut down upon, and a pair of stout forceps is pushed under the head of the gastrocnemius and withdrawn open. A tube is then inserted. This incision will be found to be between the sartorius and gracilis tendons and usually just behind the internal saphenous nerve.

In a similar way the outer condyle is cut upon. The incision here passes between the biceps tendon and the gastrocnemius and just behind the external popliteal nerve. It is important, therefore, in both cases to be economical in the use of the knife, and, after the skin has been incised, to use director and forceps to open the joint. Anatomical guides are useless in practice, because of the inflammatory swelling: one knows that the pouch surrounds the prominent condyle, which can easily be felt, and one cuts down until the cartilage of the condyle is reached. A drainage tube should be passed across the front of the joint beneath the patella, and another directed up into the subcrureus bursa from either the inner or the outer side. The discharge from the anterior tubes rapidly diminishes, and the wounds heal some time before the two posterior incisions cease to discharge and close. This is proof in itself that the drainage is practically as well as theoretically correct.

Some surgeons recommend that a probe or director should be passed back from the anterior incisions, and that this should be cut on in the popliteal space and a tube passed through. It is only suggested that this should be done on one side. Until the knee-joint is disorganized and its ligaments softened and lengthened, this is an impossible procedure. Not even a probe will pass between the bony surfaces when the knee is extended, and a tube, if it could be introduced, would be crushed and flattened.

Result of Treatment

Infections of the knee in the great majority of cases were, under pre-war methods, followed by ankyloses and this in the majority of patients was in flexion. Flexion in case of ankylosis is of advantage. I am perfectly aware that my great teacher, Sir Robert Jones, considers that the position of election—the position to be preferred in ankylosis—is one of full extension, but experience, both in civil and military practice, has proven the reverse to my satisfaction. Soldiers are continually presenting themselves for pensions because of ankylosis of the knee, and those with ankylosis in the extended position always complain most bitterly.

When teaching my students at McGill University, I frequently relate the story of the English surgeon who, having excised most successfully a curate's knee happened to meet his patient in a tram-car about a year later. The surgeon was struck with the easy position in which the curate sat with knees flexed and in evident comfort. Excusing himself for his curiosity, the surgeon asked: "Are you not the Rev. Mr. —— whose knee I excised last year? If so why, then, so perfect a result? I see you sitting here as though your knee had never been diseased and never submitted to opertaion." The curate replied to the great surgeon, "I owe you an apology. I got so tired of people tripping over my foot, that I went to a surgeon and persuaded him to amputate above the knee, and to day you see me wearing in comfort an artificial leg." Here was a patient who found an ankylosed and extended knee so annoying that he sacrificed his leg to get relief.

That well-known orthopædic surgeon, Colonel E. G. Brackett, who is now Director of Orthopædic Surgery in the United States Army, wrote me a personal communication in May, 1916, on this subject. He said: "I have been putting up the knees at an angle of 35 degrees, this being the average angle of election, and is apparently the most convenient mean angle for both walking and sitting."

Further, he said, "I have recently seen a man who had an ankylosed knee at 42 degrees from an old tumor albus of childhood. This man tells me he has taken no odds from any man in his work, and he has even been a hod-carrier."*

I firmly believe that a position of moderate flexion is the position of election, and holding such belief am accustomed to put this doctrine into practice with results that have proved satisfactory to my patients.

The reader's attention is urged on this point, because not many months have elapsed since I heard a surgeon—a so-called general surgeon—who considered himself an authority in cranial surgery, in abdominal surgery, in thoracic surgery, and in reconstructive (orthopædic) surgery, recommending the excision of a moderately flexed knee in order to get extension. In surprise I asked the reason, and was informed that this was recommended to insure stability. Surely, if an excision is done it is done in the expectation of getting bony union, and surely if bony union is secured even stability in flexion can be assured. Is it possible that when a surgeon feels it necessary to place an excised knee in extension to assure stability he is acknowledging his doubt as to his technique being sufficient to assure bony union in flexion?

Flail-Joint

It is generally conceded that flail-joints are more or less useless except in the case of the hip. The knee as a flail-joint is useless. Flail-joints should be stabilitzed. To do this excision must be practiced.

Excision

This subject must bring to the mind of all Canadians the work of the late Professor Fenwick of McGill University. Excision was an operation largely practiced by him as a cure for tuberculosis of this joint.† He really brought the technique of

* This is important when calculating a disability in the general labour market.

† "Excision of the Knee Joint," by George Egeworth Fenwick, 1883.

this operation to so great a state of perfection that seemingly nothing further can be suggested to improve on his procedure. He secured union and stability by adopting a curved incision through both femur and tibia, and by the close apposition which he assured through the perfection of the mortise made by such form of incision.

For us who are war surgeons the simplest procedure is to be desired. To our minds good union will secure stability. Good function of the limb will ever be the greatly-to-be-desired goal.

The operation which I perform to stabilize the knee for tuberculosis is very simple.

A horseshoe incision is made through the skin and deep tissue to the bones. The base of this is well above the patella and its apex, mid-way between the patella and the tibial tubercle. This flap which includes the patella is turned up. The articular surfaces are removed by a small coping or fret saw. Such is purchasable for not more than fifteen cents. The raw surfaces are apposed in flexion and maintained there by pegs or nails. The knee is secured in plaster-of-Paris for at least two months.

The operation which I advise in war surgery when the foregoing procedure is not applicable because of an ankylosis due to destruction of the joint is done through a similar incision. A linear osteotomy is performed through the junction of the tibia with the femur. The incision, by its direction through the bone, is calculated to secure both union, through accurate apposition, and flexion at the site of the joint, now destroyed. When the bony surfaces are accurately apposed they are so secured by either bone-pegs or ordinary wire-nails, as advocated, I think, by Sir Harold Stiles, of Edinburgh.

Fortunately for our wounded soldiers, a successful excision should assure a useful limb.

Derangements

These in times of war and in times of peace are perhaps more frequently seen in the soldier than

in any other class. In peace and in war the soldier, in the course both of his duties and his pleasures, is subject to many physical injuries which in more sedentary occupations and pursuits are rare.

The most common injury of the soldier's knee is sprain or rupture of the internal lateral ligament. The second most common is dislocation of the internal semi-lunar cartilage.

Dislocation of a Semi-lunar Cartilage

In considering the subject of dislocation of a semi-lunar cartilage the words of Colonel Clarence L. Starr are worthy of note. He says: "Sixty per cent. of cases returned from the front line with a diagnosis of slipped or dislocated semilunar cartilage were wrongly diagnosed"; also,

"For diagnosis of slipped cartilage the history is not enough, as on more than one occasion it was the writer's experience to find a perfect history of symptoms of slipping of the cartilage which had been obtained by one patient from another. It was our plan to 'try out' suspicious cases of loose cartilages in the gymnasium, and if no locking took place and no synovitis followed the patients were transferred to their reserve battalion." (*American Journal of Orthopaedic Surgery*, July, 1918.)

The Advisability of Operating

The advisability of operating on a seasoned soldier who becomes unfit by reason of a recurring dislocation of a cartilage is open to debate. Is it possible by operation to secure his services in the front line, or will operation improve only his potentialities for service on the lines of communication and his chance in the general labor market when he is returned to civil life?

Operation undoubtedly will do the latter. Will it do more? Whitman says: "In cases in which the inconvenience is at all serious . . . removal of the cartilage is indicated, . . . in my experience there is no operation more uniformly successful than this, or in the confirmed cases more directly indicated, since a loose cartilage is of no functional

value but is a dangerous incumbrance." (*Medical Record,* July, 1916.)

Sir Robert Jones says: "I *strongly urge* operation in those cases where a recurrent displacement is at times followed by acute symptoms. I advise it in all recurrent cases where a strenuous athletic life is a means of livelihood or a physical necessity."

"I think operation absolutely imperative in the case of men who work or stand in dangerous places." (*Clinical Journal,* 1906; *Annals of Surgery,* 1909.) And he says: "Is operative treatment invariably successful? In the great majority of cases a perfect recovery may be predicted: in a certain small percentage of cases the symptoms recur."

Let us then consider our original questions, and add, can recruits whose history is marred by a recurrent dislocation be made fit for service in the front line, and can the services of the seasoned soldier be assured by operation? Certainly Sir Robert Jones and Whitman seem to have answered this question in the affirmative, but I feel sure that many medical boards are refusing candidates for the front line daily because of such a history of recurrent dislocation. I have already published my general protest on the subject of the refusal of men because they were not without blemish. They (the military authorities) have often refused to accept for repair those who were easily reparable. (*American Journal Orthopaedic Surgery,* July, 1918.)

Those who do not feel that operation is justifiable, either to make the recruit fit for service or to assure the continued service of the seasoned soldier, may rightly say that there was a strong impression in the early years of the war that while such operation might be advisable in civil practice, experience had not demonstrated its advisability in military practice. With this statement I am inclined to agree, but, whilst the care of the wounded in this war has been carried out remarkably well

and the various army medical corps have been most fortunate in securing the services of many of the world's greatest surgeons, it cannot be denied that the military medical authorities have not always succeeded in placing the right man in the right place: In my opinion any discredit therefore which this operation may have earned during the war cannot be considered as militating against its usefulness as demonstrated by such surgeons as Jones and Whitman. Indeed, the former has drawn particular attention to the fact that often "the so-called recurrence is due to an overlooked accessory factor." (*Annals of Surgery,* 1909.) In order to confirm my statements, I may again quote Major MacNutt who says, "I have seen many men at the front who had previously had a cartilage removed, but very few complained of. or could show evidence of, any present disabilty."

Causes of Dislocation

Before considering the subject of operative procedures, it may be wise to consider why indirect injuries, and especially twists, are followed by rupture of the internal ligament and damage of the semi-lunar cartilage. Sir Robert Jones says:

"If we remember the anatomical fact that the internal semi-lunar cartilage is closely connected 'round its convex margin with the deepest layers of the internal ligament and with the capsule of the knee-joint, we will understand why a severe twist of the knee with the leg abducted may rupture the ligament and drag the semi-lunar cartilage with it, straining or tearing the attachments of the anterior horn. At this stage the inner side of the knee-joint is, so to speak, opened out, and everything depends upon what happens when it closes again, as soon as the distorting force ceases to act.

"If the cartilage is caught in displacement between the bones the knee 'locks' in the manner familiar to us all. The cartilage may be split, fractured transversely, rolled up or completely torn from its attachments. A perusal of the literature of the subject, indeed, shows that every conceivable

injury to the semi-lunar cartilage may take place, and such cases have often been fully described. Sometimes the cartilage slips back into position without being crushed or caught between the bones, there is then no locking of the joint, but, in every respect, the etiology of the lesion is the same with the exception of the actual injury to the cartilage, and the patient generally states that he felt something 'slip' or 'click' in the knee, but could quite easily straighten it immediately after the accident. The history suggests the usual cartilage injury of text-books but without locking: the knee becomes distended with fluid, and the patient refers his pain to the inner side. The physical signs are tenderness on pressure over the internal lateral ligament, and a specially tender spot to the inner side of the ligamentum patellæ just above the border of the tibia, a symptom always strongly suggestive of an injury about the attachment of anterior end of the semi-lunar cartilage." (*British Medical Journal*, 1916.)

Operation

Before entering into a description of operative procedures, let me warn the reader that in the past the knee-joint has been considered the most sacred cavity of the human body. Greater precautions should be taken in operating on this joint than operating on any joint or cavity. It has been thought that even the peritoneal cavity can of itself combat sepsis much more effectively than can the knee-joint.* The most careful asepsis and technique is necessary to prevent infection by swabbing: bleeding is controlled by means of the tourniquet. Sir Robert Jones covers the knee with gauze soaked in 1 to 1,000 biniodide of mercury and makes his incision through this. He fixes the cut edges to the wound.

The knee to be operated on is placed in the flexed position. It is flexed to a right angle and allowed

* During the past eighteen months or two years it has become usual to open a wounded knee-joint, to remove all foreign material, to clean out the joint and then *to close it*. The results have been excellent, thus suggesting that the knee joint has great powers of resistance.

to hang over the table. The incision is short and curved. Its convexity points slightly forward. It should extend from a point above and one inch to the inner side of the lower angle of the patella to half an inch below the tibial tubercle.

The cartilage may be found in any position. In most instances it is evident. If hidden from view, retract the capsule. The cartilage should be manipulated by means of a sharp hook, although all manipulations should be of the gentlest nature. Sir Robert Jones says that it is only necessary to remove the loose portion of the cartilage, be it a frayed border, a circumferential tear or a detached anterior border. Dr. Whitman, on the other hand, recommends that the entire cartilage be removed. He feels that in doing this he removes a possible cause for further trouble.

My practice is usually similar to that of Whitman, who detaches the anterior or free half by a slight pull with the forceps and does the same with the posterior half by means of scissors. Jones recommends that after removal of the cartilage the operator should seek fringes or other sources of future trouble. The wound is sutured with thin catgut in as many layers as possible. The skin is sutured with horse hair or thin silk wormgut and the incision dressed and firmly bound with a roller bandage. After a light plaster bandage is applied with the knee in slight flexion, the tourniquet is removed. The plaster splint is retained for about two weeks. The knee is then strapped with zinc oxide adhesive plaster to guard against strain. The patient is instructed to cultivate an elastic gait in walking. The soles of his boot are thickened on the inner side. Whitman says "in cases of a favorable type cure is practically complete in a few weeks." (*Medical Record*, 1916.)

Tibial Spine

Sir Robert Jones (*Brit. Medical Journal*, 1916) says: When discussing derangements of the knee, fracture of the tibial spine must be considered. In this accident the knee is subject to violent torsion,

such as may produce a dislocation or a rupture of the crucial ligaments. The displaced fragment of bone may be lodged in the front part of the knee-joint and so prevent its full extension. Diagnosis is verified by X-ray examination.

Robert Jones states that the most constant symptom is a somewhat rigid block to full extension, usually accompanied by pain behind the patella.

Treatment

If the knee can be fully extended it should be fixed in this position for a long period to allow of union. If it cannot be extended even by careful manipulations it is best to excise the displaced bone and to fix the knee in extension.

Rupture of the Crucial Ligaments

In severe accidents to the knee-joint in which there has not been a complete dislocation and yet there is abnormal mobility, this lesion may be suspected.

A diagnosis is made by considering the mechanism of the crucial ligaments with the injury in question.

Sir Robert Jones draws attention to the facts that:

(1) The anterior crucial ligament is tense when the knee is fully extended and prevents the tibia from being displaced forward on the femur.

(2) The posterior crucial ligament is tense in complete flexion, and prevents the tibia from being displaced backwards on the femur.

(3) Both ligaments check inward rotation.

Abnormal mobility indicates elongation or rupture of the corresponding ligament, but prolonged distension of the joint with fluid may cause elongation of ligaments, simulating rupture.

Treatment:—Rest with the knee in the extended position and so fixed by plaster or splint.

Fractures About the Knee Joint

First, *fractures of the patella.*

Fracture of the patella is an injury of common occurrence and of great importance. The fracture

may be either transverse, longitudinal or star-shaped.

Indirect violence is responsible for fourteen times as many fractures of the patella as direct violence.

Whilst direct violence can conceivably produce a transverse fracture, practically it does not. When fracture is due to direct violence the fragments do not tend to separate, as the lateral expansions, or ligaments, are not necessarily torn. This, in war surgery, is a most important point. In fracture of the patella the amount of separation of the fragments depends entirely on the extent of tearing of the lateral expansions of the quadriceps tendon.

The *position of the fragments* in transverse fracture, according to Sir James Earle, in "The Chirurgical Works of Mr. Potts," 1808, is this: "By the action of the united tendons of the extensores muscles of the leg, the superior fragment is pulled upwards and separated from the inferior, but the latter remains nearly, if not absolutely, where it was before the accident; there is nothing to act upon it, and therefore it cannot, nor does it, move."

According to Cheyne and Burghard, "the upper fragment tends to become more and more drawn up until there may be a gap of several inches between the two fragments. The most important point of all is that the periosteum is not torn across on a level with the line of fracture; the periosteal rent is usually below this line, with the result that a piece of periosteum projects for half an inch or more beyond the lower edge of the upper fragment and curls 'round and lies over the fractured surface. Hence when the two fragments are approximated, this layer of periosteum is interposed between them and this is an essential reason why union by bone does not occur except after operation. Another point to remember is, that the lower fragment is usually tilted forward and therefore when the upper fragment is brought into contact, the cartilaginous surfaces do not lie in the same plane."

The Degree of Separation

According to Scudder ("The Treatment of Fractures," Eighth Edn.), the degree of separation depends upon the amount of distention of the joint and upon the extent of the tearing of the lateral aponeurosis of the knee, permitting muscular contraction and retraction.

Symptoms

The ordinary symptoms are pain in the knee and immediate disability. The diagnosis in injuries about the knee-joint is often rendered obscure by great swelling, but the utter inability of the patient to raise the heel from the bed is a very suspicious sign that the patella is fractured. Inability to extend the knee is suggestive of either fracture of the patella, rupture of the patellary ligament, rupture of the quadriceps tendon or separation of the tibial tubercle.

Relief of Distention

Distention of the joint may be so great that the method of relief is indicated. Aspiration may be tried. Aspiration followed by firm compression by bandage often suffices to relieve the effused fluid. John O'Connor, as far back as 1896, recommended operation, stating that if blood is present an incision should immediately be made into the synovial sac, but aspiration should suffice unless much thick bloody fluid or clot is present, in which case incision with closure will assure a useful joint. I wish to accentuate this point because there seems to be some prejudice against such incision. In confirmation of this statement I can cite a case where a consulting surgeon in France disallowed such form of arthrotomy. The patient has now a stiff knee.

Golding Bird, not many years later, in speaking of the removal of extravasated blood by massage, as recommended by Sir William Bennet, stated: "This end is more expeditiously given by free incision."

Treatment of Simple Fractures

In simple fractures treatment is an easier matter than in compound fractures. Operative treatment

is necessary if the fragments are widely separated, but separation depends, as already stated, on the extent of the laceration of the lateral expansions of the quadriceps tendon. Longitudinal and stellate fractures are rarely accompanied by much laceration of the lateral expansions and rarely by much separation. On the other hand, transverse fractures are often accompanied by great separation and thus non-operative means of treatment will often fail to get either juxtaposition or bony union.

Barnard has expressed the view that the cases suitable for operation are the indirect fractures, in which the fragments are separated for more than half an inch, the lateral patellary ligaments are torn: crepitus cannot be obtained in rubbing the fragments together, because a fringe of aponeurosis intervenes, and the joint is distended with blood. This further separates and tilts the fragments. Yet it must never be forgotten, he says, that even in such cases skillful non-operative treatment will, in the majority of cases, give an almost perfect result. I feel that the operation should be performed on those in whom perfect function of the leg is necessary.

In considering the advisability of operative treatment, it is to be remembered that operative treatment consumes less time in convalescence and an excellent result is achieved, but operation exposes to danger. The working-man who wants to get to work should, if conditions are favorable, have his patella sutured, for he will go to work quicker and have a better knee-joint than by any other method of treatment. So should a soldier when his country is in the midst of a great war be treated by operation; but to perform this operation every condition must be good, asepsis must be perfect, the acute symptoms must have passed away, the tissues must have had time to recover from their trauma, the patient must be fairly young and one should be certain that the necessary apposition of fragments would be impossible by other means.

Operation

I always expose the fracture by means of a horse-shoe incision with its base upwards and its apex lying over the middle of the patellary ligament. In this flap is included all the tissues, to muscle and periosteum. The fracture is now examined and the cut edges cleaned and apposed. Often it will be found that suture of the torn lateral expansions of the quadriceps tendon is all that is necessary to maintain this apposition. Often it is wisest to include in the line of sutures the periosteum also. Rarely is it necessary to actually unite bone to bone; rarely is it of consequence whether soft sutures of wire be employed, some preferring one and some the other. Closure of the wound without drainage and immobilization of the joint in the extended position terminate the procedure, but the sooner passive movement is employed after the operation the sooner does the patient get about.

Massage

Sir William Bennett has pointed out that the final result depends on the amount of mobility finally retained by the upper fragment of the patella. He says: "The first object, then, in a case of fracture of the patella, whether wiring has been practiced or not, is to prevent, by constant manipulation, any adhesions forming around the upper fragment and fixing it to the femur."

Scudder says: "After suture of the patella, massage and gentle passive movement should be begun at the end of two weeks. At the end of three weeks the patient may go about with the knee protected by a light, stiff dressing. After about six weeks or two months, a flannel bandage and a cane will be all the protection needed to the knee. At the end of three months the knee should be almost functionally perfect." On the other hand, Scudder says: "In non-operative cases the knee should be fixed for four weeks and treated with necessary massage. At the fourth or sixth week one should employ a removable retaining apparatus, use passive motion and allow the patient

to get about with crutches. At the eighth week the patient may discard his crutches, use a cane, and limited daily active motion may be permitted as well as the removal of all support. In non-operative cases the union is usually fibrous, although it may be bony."

Sir William Bennett puts down three months as an average time for cure by splints with massage . . . a vast improvement on purely splint treatment, but which, other things being equal, does not compare favorably with the result of operation, where a patient is up in two or three weeks and by four or five weeks is walking and working safely and well. The knee being kept in a splint only till the first restlessness of the operation has subsided, never suffers from the stiffness which the treatment by splints for even one month causes.

My opinion, stated briefly, is that, while it is apparently true that operative treatment is followed by more rapid function than treatment by expectant methods, it is unwise to allow unrestrained and violent exertion after operative treatment before one is sure that the fragments have become united by organized tissue.

Compound Fractures of the Patella

In the surgery of war this is a more common injury than simple fracture, although the latter is not uncommon. It is also a very serious injury, because in it one of the largest synovial cavities of the body is exposed to infection.

Treatment of Compound Fractures

According to Scudder, it is safest and wisest in these injuries to lay open the knee-joint and to clean it out. The skin wound should be closed and the knee-joint immobilized. Unless this can be done the prognosis in regard to function is very bad. In any case the surgeon is warned not only of the dangers of infection of the knee-joint but of the difficulties of treating the same, and the grave prognosis for limb and even life in this injury. (See MacNutt: "The Treatment of Infected Joints by Closure.")

CHAPTER III.

The Ankle.

THE MOST IMPORTANT injuries about the ankle in war are compound fractures. In Major MacNutt's experience the treatment of this lesion has given a very unsatisfactory joint both for early and late results.

In his personal communication to me he says: "In three or four cases it was necessary to remove the head or even the whole astragalus. I have no later reports on these, but a few such came before me for board in London last spring with an ankylosed ankle. A poor substitute! It is open to question whether such a member is worth saving. When at the I. O. D. E. Hospital, London, an officer was admitted (Major R.). He had been shot through the left ankle in the South African war. The astragalus was removed; a stiff ankle resulted. This caused him a great deal of inconvenience and three years later he had the foot amputated and an artificial foot applied. Since then he has danced, played tennis, golf, mounted his horse in the usual way and he led his battalion in the advance on Courcelette. (Somme, 1916.)

"I think the artificial foot was more serviceable to him than a stiff ankle. At any rate, he was perfectly satisfied with the exchange."

From my personal experience I would say that an astragalectomy in compound fractures involving the joint, especially the astragalus, is clearly indicated.

Compound Fractures About the Ankle (Potts)

A compound Pott's fracture is a most serious injury. In it, of course, the most careful cleansing is necessary before reduction is undertaken. The possibility of being able to assure efficient drainage must be studied.

Treatment depends on two considerations: first, the extent of the laceration of the soft parts; secondly, the amount of injury to the bone. If the laceration is so great that the foot is useless, in alarming sepsis and (in civil practice) old age, amputation is indicated. If, however, it is at all possible to save the foot, posture and even pegging of the fragments may be considered in conjunction with sufficient drainage, making use of the Dakin treatment, and other methods available.

Pott's Fracture (Simple)

The important features of this injury are fracture of the lower end of the fibula and rupture of the tibio-fibular ligament permitting a dislocation of the foot both outward and backward. These injuries may be associated with fracture of the internal malleolus or with tearing of the internal ligament. The place of fracture of the fibula is usually about an inch to an inch and a half above the base of the malleolus.

Sir William Bennett has drawn attention to the resulting elongation of the heel as being characteristic of this fracture. This, of course, is due to the dislocation of the foot backward at the ankle-joint. The dislocation backward and outward must be reduced and the broken ends re-apposed if treatment is to assure good function. The satisfactory setting of the fracture, or fractures is impossible without a full reduction of both dislocations. The relief of pain and the reduction of the dislocations as well as the setting of these fractures depend upon the overcoming of muscular tension. This fact, so essential to successful treatment and to future function was demonstrated in Pott's original monograph published in 1808: "All this trouble, pain, difficulty and inconvenience are occasioned by putting and keeping the limb in such position as necessarily puts the muscles into action. . . This occasions the difficulty in reduction, and the difficulty in keeping it reduced; this distorts the foot, and by pulling it outward and upward makes that deformity which always accompanies such accident;

but if the position of the limb be changed, if by laying it on its outside, with the knee moderately bent the muscles forming the calf of the leg and those which pass behind the fibula and under the os calcis are all put into a state of relaxation and non-resistance all this difficulty and trouble do in general vanish immediately; the foot may easily be placed right, the joint reduced, and by maintaining the same disposition of the limb, everything will in general succeed very happily." (Sir James Earle, 1808.) It is for this reason that Sir William Bennett says that the treatment is obviously in semi-flexion.

Treatment

Effective treatment of Pott's fracture is of the greatest importance. Lack of this results in such deformity that the patient is hardly able to walk at all. Successful treatment depends on three things:

(1) Posture to relax the muscles in spasm.

(2) The reduction of both dislocations.

(3) The apposition of fractured bones.

In treating a Pott's fracture guard against both backward displacement of the foot and outward deflection of the external malleolus and the foot. To do these things it is necessary to get muscular relaxation by posture or by anæsthesia. To maintain reduction it is wisest to continue treatment in such posture as assures muscular relaxation, with all that that means in the relief of pain and in the patient's comfort.

At the time of "setting" a Pott's fracture, when the muscles are sufficiently relaxed, the knee is flexed and the upper part of the leg is fixed by an assistant, while the surgeon grasping the foot with one hand and the leg with the other, manipulates the foot into position.

When the surgeon is satisfied that the bones forming the joint are in good position, and that nothing interferes with the normal functions of the joint, the limb may be fixed with the foot

firmly inverted. If the foot is not sufficiently inverted the fracture of the fibula may not be sufficiently reduced. Sir Robert Jones inverts the foot to the position used by Whitman, of New York, in his treatment of rigid chronically sprained foot, and maintains the foot in this position.

In my opinion, plaster-of-Paster is best suited to so maintain the foot. A cast of this can easily be converted into internal and external splints by incising vertically its anterior and posterior borders. This, indeed, is a very necessary procedure because treatment by massage is as essential as reduction and fixation.

All the essential features of further treatment Sir William Bennett considers can well be assured by the use of Neville's splint.

My friend, Dr. H. L. Prince, of Rochester, feels that Stevenson's dressing is safer and as secure as my favourite plaster-of-Paris.

Treatment of the Deformities Resulting From Pott's Fracture

In war, deformities may often follow the treatment of even a so-called simple Pott's fracture, because of the great difficulties of attendance confronting the surgeon, hence deformity is much more likely to follow compound infected fractures about the ankle. Often, then, we are called upon to discuss procedures for the amelioration of such deformities. Here each case should be considered separately. Sir Robert Jones has suggested that in certain patients vertical skin incisions over the lower ends of both fibula and tibia may be made. Through these incisions wedges may be cut from these bones. He mentions that instead of performing the complete operation at one time it is wiser to be content with incomplete incisions through both fibula and tibia, *viz.*, four-fifths through the fibula and three-fourths through the tibia; then sew up, but do not attempt to re-fracture before ten days. Feiss has reported an interesting case operated on for this deformity.

Fixation at the Ankle

After various nerve injuries, after certain injuries to muscle, and after some injuries to the bones forming the ankle-joint, operative procedures directed towards stabilizng the foot must be considered. These stabilizing operations will be considered under the two headings, arthrodesis and astragalectomy.

All irreparable injuries to the nerve supply of muscles essential to stability, suggest either tendon transplantation or fixation at the ankle. After great destruction of muscle whose function it is to control the foot, transplantation or fixation may be indicated. After some bone injuries, such as grave fractures of the astragalus, excision of that bone may be indicated.

Of course, after many of these injuries stability at the ankle may be assured by the fashioning of a suitable brace, but the relief from a brace is only temporary.

I remember having seen a Canadian officer who had lost his anterior tibio-fibular group of muscles. They had been literally obliterated by a piece of shell. When the wound healed provision had to be made for the marked foot-drop which followed. This soldier returned from England wearing a brace, but is he to use this for the rest of his life? The surgeon asks instinctively will it be possible by tendon transplantation to assure stabilty for such an ankle? Will it be possible, or will it be advisable to try some plastic bone repair?

Arthrodesis of the Ankle Joint

This is a favourite operation for stabilizing at the ankle in cases of flail-joint, but experience has shown that while it prevents foot-drop and flexion, and extension at the ankle, it often proves to be inadequate in guarding against varus or valgus; because in patients in whom some operation is necessary for the purpose of making a stable ankle-joint, the ligaments maintaining apposition between the astragalus and the os calcis are so lax that

a sub-astragaloid arthrodesis* as described by the late Dr. Gwilym G. Davis, of Philadelphia, is often indicated to prevent abnormal lateralization of the foot. For this reason, then, an astragalectomy as described by Doctor Whitman, of New York, is often preferred in American clinics. (*N. Y. Med. Record*, 1914.)

Operation

An incision of about three inches in length is made with its centre over the ankle-joint and its alignment placed to the outer side of the extensor longus digitorum and the peroneus tertius. This incision cuts through the skin and deep tissues to the bone. In making it care must be taken to keep to the outer side of the tendons mentioned, as otherwise the anterior tibial nerve is endangered. The joint is opened, the tissues are retracted, and the

*Sub-Astragaloid Arthrodesis, as Practiced by Dr. Gwilym G. Davis, of Philadelphia (Letter of May, 1918):—

(1) Make a half-inch incision below and just in front of the external malleolus, over the articulation between the calcaneum and astragalus. Gouge away the articulating surfaces of the calcaneum and the astragalus in a direction backward and inward.

(2) A second incision half an inch long about three-quarters of an inch below and slightly in front of the internal malleolus (over the articulation between the sustentaculum tali and the astragalus, and running anterior to the scaphoid). Destroy the astragalo-scaphoid joint anteriorly, then turn the gouge posteriorly and destroy the joint between the sustentaculum tali and the astragalus. Connect this second incision with incision number one. Dig up and destroy the whole sub-astragaloid joint; then, when you think you have done too much, go all over it again and be sure you have destroyed the joint. Leave all chips between the bones.

(3) Place the foot in plaster (with a board on the sole of the foot). Maintain in this position for, say, eight weeks. After the operation the foot should be kept elevated. The cast should be split down the front to allow for swelling.

(4) When the plaster is removed use a boot with a pad of hard felt under the arch and, if there is any tendency to varus or valgus, put a wedge in the edge of the sole and heel to hold the foot in proper position. If the position is not as good as desired use a side-iron to hold the foot, as is desired.

It is to be noticed that it is a wise precaution to renew the first plaster at some time between the end of the third and eighth week, in order to assure that the original position is satisfactory. The splint or raised shoe, as described, can be worn for three or four months until we have a satisfactory correction.

cartilaginous surfaces of the astragalus, tibia and fibula are removed. The astragalus is then mortised into the receptacle between the malleoli, which has been prepared for it. The incision is closed by deep and superficial sutures. The wound is dressed and the foot and leg placed in plaster-of-Paris or in a splint, after assurance has been made that the foot has been carefully apposed to, and is at right angles to, the leg.

In performing this operation a tourniquet is employed. In addition to the above technique, I often assure fixation of the bony surfaces, now denuded of cartilage, by uniting the foot to the leg by means of an ordinary long wire nail driven through the plantar cutaneous surface, of the heel, through the os calcis and into the tibia. This is allowed to remain *in situ* as long as it is not loosened by local osteo-porosis. This condition usually makes it possible to withdraw this nail without pain to the patient in from ten days to three weeks. The fact that such a peg becomes easily extractable in such time is an object-lesson demonstrating the inutility of depending on Lane's plates for more than the temporary fixation of fractures. Further, it demonstrates the inadvisability of using a method which causes necrosis, when osteogenesis is desired.

Lastly, the operator's attention is drawn to the conservative rule that fixation for six or eight weeks is desirable when bony union is sought—not fixation to the exclusion of massage and careful friction, but fixation which assures immobility.

Astragalectomy

Astragalectomy is an operation often performed on this continent and especially by Whitman, of New York, whose technique is, in my opinion, to be preferred to that of all others. (*American Jour. Med. Sciences,* 1901; *Medical Record,* 1914.)

In war surgery this operation has a very distinct place. In wounds of and about the ankle, with extensive compound fracture of the astraglus, this procedure is more particularly indicated; but it is

also indicated in certain cases of paralysis causing calcaneous [club-foot in which the heel alone touches the ground, the instep being drawn up toward the shin] and again in some cases where moderate fixation is desired.

A brief description of a typical astragalectomy will be now given in order that this operation may be included in the armamentarium of the war-surgeon, although a careful study of Whitman's articles on this subject is suggested to those surgeons whose work is at the base.

In performing a typical astragalectomy, an incision is made through the skin and deep tissues from a point behind and about one and one-half inches above the external malleolus downward and forward to the extensor tendons of the toes on the dorsal aspect of the foot on the outer part of the head of the astragalus. This is of a semilunar character and has its convexity downwards. Through this the peronei are exposed and divided or displaced backward. The astragalus is then exposed and as far as possible detached from the surrounding tissues. The foot is then inverted to an extreme degree, after which the astragalus is pried out by blunt dissection. The whole foot is then displaced backward* until the scaphoid is opposed to the anterior surface of the tibia. The incised tissues are then united by deep and superficial sutures and the foot and leg encased in plaster-of-Paris. A tourniquet is employed during this operation and it is removed only after the plaster cast is completed. It is advisable to elevate the foot and leg when the patient has been returned to his bed.*

*Dr. Whitman in a personal communication says:

"I would emphasize the prime importance of backward displacement to re-adjust the weight-bearing and to limit dorsal flexion in cases of paralysis of calf, and to assure stability and symmetry. Backward displacement is essential in all cases. If for fracture, the displacement should not be so extreme as to prevent dorsal flexion; but ordinarily, if for paralysis, the tibia should override the scaphoid."

CHAPTER IV.

The Shoulder.

ONE OF the most frequently injured joints in trench warfare is the shoulder.

Fractures of the Upper End of the Humerus

In war surgery, where nearly all fractures are of the compound variety, treatment of those about the shoulder-joint is most difficult because of the necessity of dressing the wound, which in the majority of cases is infected.

In Field Ambulances and other places where none but temporary dressings and fixations are possible, perhaps the simplest method of treatment is by the use of an axillary pad, with a bandage applied for the purpose of fixing the arm to the patient's trunk.

At Casualty Clearing Stations, when at all possible, completely excise the wounds and get the fragments into position. In badly infected cases, or when excision is not possible, a modified Thomas knee splint, or the wooden triangle, as later described in this chapter, may be used. Major MacNutt reports three cases suffering from fracture of the humeral head or glenoid, where he opened and cleaned out the joint, and closed immediately, just as has been recommended in the knee joint. It is no doubt a daring procedure, but the result in each of his cases was good and there is no reason why such treatment should not be the routine in certain classes of wounds, as it is absolutely in accord with the most modern surgical teaching.

In Base Hospitals

In studying the position of the fragments in a fracture about the shoulder-joint it is noticed that the upper fragment is pulled upward by the combined pull of the muscles inserted into the great

tuberosity, *viz.*, the supra-spinatus, the infra-spinatus and the teres minor. It is also *pulled forward* by the subscapularis muscle. In this upward and forward position it is fixed by the counter-impingement of the acromial process against the great tuberosity. Thus in fractures, when attempting to adjust the lower fragment in alignment with the position which the capital fragment takes by unopposed muscular pull, the lower fragment must be abducted to a line with the shoulder. It must also be rotated inward and be carried forward (Albee, *Medical Record*, 4th May, 1912.)

The Triangular Splint

In base hospitals a Thomas knee splint with extension by adhesive plaster (see Extension) makes a very fair method of treatment. Better, perhaps, in some cases is the triangular wooden splint described by me in the *British Medical Journal* ("Notes on War Surgery, *Brit. Med. Jour.*, 1915-1916): "In these fractures we have sometimes employed a triangular splint which can be fashioned in wood by a carpenter in fifteen minutes. One side of this triangle runs from the apex of the axilla to the great trochanter of the femur of the same side; the second side of the triangle supports the patient's extended arm in a position at right angles to the body; the third simply unites the other two sides of the triangle. Any degree of traction can be used with this splint by the use of adhesive plaster ("stickers") if the supporting arm of the triangular splint has been made long enough. Most wounds can be dressed without disturbing the splint. The position of the third or uniting side of the triangular splint can be changed easily, thus allowing of adduction of the patient's arm when this assures better reposition of the fragments."

It is to be noted that this splint can be made to hold the arm in a forward as well as an abducted position by a simple re-arrangement of the angle of union of the upright and (arm) supporting limbs of the triangle.

This splint in its present form does not compare with plaster-of-Paris, because it does not provide so easily for the necessary internal rotation and forward position of the humerus, and because when applied to the under surface of the arm it does not impinge so accurately against, and thus control, the upper end of the lower fragment which tends to drop into the floor of the axilla because of gravity. In employing it then, the axillary fossa must be filled with absorbent cotton.

There is no reason why a plaster-of-Paris spica cannot be used for the treatment of these compound fractures about the shoulder-joint, as it can be fenestrated for the dressing of the wound and such window protected by melted paraffin, applied as a paint, in the manner already described. (Notes on War Surgery, *Brit. Med. Journal*, 1916.) Further, with such plaster-of-Paris dressing the lower fragment cannot only be held in abduction in a line with the joint, but it may be carried forward and controlled in internal rotation and in apposition with the upper fragment.

Operative Treatment of a Fracture of the Shoulder

In studying the possibility of being able to "set" an old fracture, or reduce a deformity already existing, by an open operation, it is necessary in war surgery to bear in mind the possibility of relighting an infection and if not endangering life certainly causing irreparable injury.

The incision for the operative treatment of a fracture about the shoulder-joint should be U-shaped with its apex about one and one-half inches above the insertion of the deltoid muscles. This should penetrate the skin, fascia, and deltoid. These should be turned up *en masse*. By employing this method of incision the circumflex nerve is not endangered.

This joint can now be examined, and if the head of the humerus has been fractured, apposition of the ends may be secured and best maintained by some absorbable material, such as kangaroo tendon or chromicized catgut.

The soft parts can now be replaced and the wound closed, either with or without drainage. The extremity should then be immobilized by a plaster-of-Paris spica in the position already detailed in our description of the anatomy of the shoulder.

Malunion

If moderate malunion occurs after treatment of fracture of the humerus, near the shoulder-joint, impairment of the power of abduction usually results. This emphasizes the importance of abduction in primary treatment. If malunion is recent and remediable by operative procedures, perhaps the safest route is that just described. If the deformity is great and bony union secure, an osteotomy may alone give chance of success.

Ankylosis

There are certain injuries to the shoulder-joint, caused by gunshot and other wounds, which must inevitably end in bony ankylosis; hence proper posture in the treatment of injuries about this joint is of importance not only for the "setting" of fractures but also when ankylosis is to be feared. In such a case it is essential to have the arm placed in such a position that it will be of greatest use to the patient when the shoulder-joint is functionless. This is of special importance, because excision, as an operation, is not to be recommended in lesions of the shoulder-joint, since a flail-joint here is often functionally useless. It is fortunate that the best position for union is approximately the best position for function after ankylosis.

Position of Election

With an arm ankylosed in abduction to about 50 degrees with the elbow slightly in front of the coronal plane of the body, the hand can easily be brought to the mouth by bending the elbow. In the same position of ankylosis the arm can be raised by scapular movements. This, then, is the position of election in such conditions. Flail-arms should be ankylosed in this position. Joints which have been allowed to ankylose in faulty positions

may require high osteotomy of the humerus for correction and for the purpose of bringing them into this, the position of all others to be preferred.

Excision

In military surgery of recent lesions about the shoulder-joint, it may be necessary to excise the head of the humerus, but for lesions which are not recent this operation is almost never necessary or advisable, because, as has been pointed out, ankylosis at this joint is to be preferred to a flail-joint. Further, much of the stiffness due to ankylosis is compensated for by the supplementary mobility of the scapula. Indeed, a shoulder-joint ankylosed in the position of election is, as a rule, to be preferred to a shoulder-joint in which there is usually serious interference with voluntary motion. Let us consider the amount of motion which is gained after the operation of excision.

The arm cannot usually be abducted and elevated beyond the horizontal line; often it lies close to the chest. Even if the deltoid retains its power elevation is impossible, because of the loss of the fulcrum-like action of the head of the humerus. The power of rotation also is lost by the division of the muscular insertions into the two tubercles.

It is seen then that in war surgery, no matter how great the injury to the shoulder-joint may be, an excision must be undertaken only after mature consideration. This war has proven practically what has been already demonstrated theoretically, that no matter how shattered a bone may be the fragments are often capable of living, and that if any operative effort is to be made it should be in the way of apposing fragments and not of excising them. (See Operative Treatment, Fractured Shoulder, page 55).

In the majority of cases, then, it is wiser to assure a useful arm by maintaining it in the position of election already described, even if ankylosis at the shoulder should follow healing, than to excise the head of the humerus, which can rarely be expected to be followed by a good result.

Arthrodesis of the Shoulder Joint

Certain injuries to the shoulder are followed by a flail-joint. This is not as useful as a joint ankylosed in the position of election. Hence it is wise to be prepared to operate in order to secure ankylosis, in cases where it has been necessary to excise the head of the humerus and in cases where a flail-joint has resulted from injury.

Function of the arm does not depend on the scapulo-humeral joint alone. The clavicular joint and the mobility of the scapula also enter into the functional abilities of the arm. Motion absent in one or the other of these parts may be compensated to a very high degree by the others, provided there is sufficient stability present. The shoulder-joint proper may be obliterated and yet good motion of the arm assured by means of the scapulo-thoracic muscles, provided always there is definite union in good position between the scapula and the humerus. Such union is secured by the operation of arthrodesis.

The technique of the operation is not simple. All authors agree that the anterior incision through skin, deltoid and scapula gives the easiest access. Some think the deltoid should be freely loosened from its upper insertion, or from the acromion. After the joint is opened the cartilage is thoroughly removed from the head and socket and the surface of the bone roughened with the chisel. Several authorities emphasize also the importance of exposing and scraping the lower surface of the acromion. (Bucholz, *Am. Journal of Orth. Surgery*, June, 1918.) Fixation is difficult. Some wire the head to the glenoid. Others wire the head to the acromion as well. Bone-pegs also have been used. The reason for failure of this operation seems to have been in most cases insufficient fixation.

It has already been noted that a flail-joint at the shoulder is often functionally useless, yet the value of an arthrodesing operation has not been sufficiently appreciated. I remember, for instance, having heard of an officer who presented himself at a

medical board in London with his right arm hanging uselessly by his side. He had been wounded in the shoulder and the humeral head had been excised about that time. One of the members of the board advised an operation to ankylose the shoulder. The presiding officer recommended an elastic cap. This latter recommendation was adopted.

CHAPTER V.

The Elbow.

Fractures

IN FRACTURES about the elbow-joint, with the single exception of fracture of the olecranon process, the usual disability is limitation of flexion. In all simple fractures about the elbow-joint, not involving the olecranon, to replace the fragments the following routine may be practiced when the erect posture is possible:

(1) The patient sits on a chair facing the operator.

(2) The operator stands before the patient with his foot on the rung of the chair, the operator's leg being between the lower extremities of the patient.

(3) The operator places a thumb over the anterior surface of the radial head of the affected arm. With his other hand he pulls firmly on the wrist of the affected arm.

(4) The operator now makes firm pressure with the thumb on the radial head. He flexes (acute flexion) and supinates the forearm with his unemployed hand.

I think that all those who follow Sir Robert Jones are accustomed to begin treatment in this way, and to maintain the correction secured by binding the limb in this position by means of a bandage, fixing the wrist to the neck. In civil practice a leather collar and cuff are used for this

purpose. Further treatment consists in the maintenance of this position for at least three weeks, when the forearm is gradually dropped into a position of extension. This gradual release from acute flexion is done in from one to three weeks. The great advantage of this treatment is that the position tends to prevent the formation of callus on the anterior surface of the joint which subsequently may cause limitation of flexion.

Fracture of Olecranon

Of fractures about the elbow-joint this alone is best treated in extension. If there is much separation of the fragments operative fixation may be considered. On account of the frequency with which union by fibrous tissue takes place in cases of fracture of the olecranon, several writers have advocated primary wiring of the fragments in all cases. Good results have been obtained, but this treatment does not appear to have been adopted by many surgeons as a routine procedure. In most cases treated without operation the fibrous union is so firm that there is no interference with the usefulness of the arm. If, however, there be non-union, or if there be subsequent loss of power, secondary wiring is advisable; it has been followed by most excellent results. (Platt, *Practitioner*, 1901.)

Compound Fracture Above the Elbow

Although in simple fractures flexion is the position of choice, in compound infected fractures, as seen in present-day warfare, the position is often inadvisable; and, indeed, drainage is often more easily obtainable during treatment in full extension. A good way to secure such extension and immobilization is by the use of a small Thomas knee splint. This, used with extension by means of adhesive plaster,* forms a treatment the efficiency of which may be increased by the employment of a cuff made of plaster-of-Paris applied closely to the skin, and over the adhesive plaster,

*See foot-note, page 27, chapter on the Knee Formulae for Glue.

fenestrated for dressings at the seat of the wound in the manner already described.

Major MacNutt feels that drainage should rarely be necessary. He says: "The question of drainage of a joint is open to discussion. Personally I doubt if it should ever be necessary, except perhaps in late cases. I did between fifty and sixty joints at a C.C.S. and did not drain any except one hip-joint. This was a hopeless case of fracture (comp. comminuted), acetabulum, head and great tronchanter, with gas gangrene. Patient died."

In discussing the treatment of this fracture Major MacNutt says: "In fractures of the lower end of humerus (comminuted) involving the elbow joint, I have had very good results by putting the arm up in complete flexion, using a pad in he bend—no splint, and bandaging the wrist to the shoulder palm to shoulder."

In very severe fractures about and implicating the elbow-joint, it is sometimes safest to excise the whole joint, excision being generally considered a reasonably good operation. In my experience of discharged soldiers in whom this operation has been performed, before returning to Canada, the results would warrant its employment but rarely, because in the majority the flail-like joint resulting, even if well protected by the best "creation" of the instrument-maker, gives but rarely as useful an arm as is seen where the elbow has been ankylosed in the position of election. Further, an excision can always be performed at a later date, whereas it is much more difficult to cause fixation of a flail-like elbow when so desired.

In Major MacNutt's communication I notice these words: "I have not found it necessary or advisable to excise an elbow-joint, but have seen it done several times with a result which, to my mind, was not so useful as an ankylosed joint.

"On two occasions I saw a French surgeon excise the elbow, suturing a piece of the triceps in between humerus and radius and ulna (radial head removed).

He claimed that this would give a movable joint. I did not see the end-result."

The Position of Election

This must always be in the mind of those practicing war surgery. In the elbow it varies according to the patient's occupation. Usually a position of flexion to about 100 degrees is to be preferred, as here the patient can bring his hand to his mouth, brush his hair, and even button his clothes, as well as carry a pail, etc. If both elbows are to be fixed it is wise to secure the second joint at an angle of 80 degrees.

Supra-condyloid Fractures

These are the most common fractures about the lower end of the humerus. In them the forearm and elbow are carried upwards and backwards by the force of the accident, thus flexion is bound to be restricted or lost unless reduction is affected. For this anæsthesia is necessary. Reduction must include acute flexion with downward traction of the forearm. This is then supinated and flexed at the elbow. In this position it is maintained. In from one to three weeks massage and passive movements must be commenced.

Malunion may be followed by the condition known as cubitus varus, which is loss of the normal angle of the elbow-joint. In this condition the forearm instead of being directed slightly outwards in the extended position at the elbow, is directed more or less inwards. This may later require osteotomy for its correction. (Hoffman, *N. Y. Med. Journal*, 1902.)

Fracture of the Head of the Radius

The displacement is usually outwards and forwards. For simple fractures of the neck the treatment is full flexion of the elbow with the forearm supinated. When the head is dislocated as well as fractured, the simplest treatment is to remove it.

Excision

Excision, from a surgical point of view, is an operation which has much to recommend it, but

from the point of view of function this operation *is often disappointing. Motion is usually easily* assured—sometimes by excision alone, and sometimes by excision and arthroplasty.* Sufficient stability of an excised elbow, on the other hand, is often assured with difficulty. Some sort of splint is ordinarily required to control the joint. Excision, then, may be indicated in acute or recent serious and complicated injuries, but it is doubtful whether it should even be considered where ankylosis in good position already exists or is possible. Major MacNutt says: "I remember boarding an officer in London with his right elbow ankylosed at 135°. He could play tennis, paddle a canoe, swim, and play golf, etc. Could he do so with a flail-joint?"

There is not much to suggest regarding the technique of excision. The close proximity of the ulnar nerve to the bone will suggest caution in carrying out this procedure. The necessity for securing an ample separation of the cut bones in order to prevent further union must be borne in mind.

*Arthroplasty here has been done a variety of substances. Fascia, membrane, pig's bladder and muscle (triceps)—all have had their advocates.

CHAPTER VI.

The Wrist.

ALTHOUGH compound fractures about the wrist-joint have not in my experience, been very common in war surgery, they are of great importance because the synovial sheaths or membrane about the wrist-joint is so complicated that it is next to impossible to clean, drain or disinfect this joint; treatment here is hence often necessarily most radical. Such operative procedures as excision, which was, I think, first suggested to me by Sir George Makins, is often indicated to save life. Dearly bought experience with this injury in France impels me to say that excision must always be kept in mind when treating a patient suffering from an infection of this joint.

Excision

In infected wounds it may not be possible to perform a typical excision. Indeed, in war surgery the projectile has already performed the greatest part of the operation. Thus the army surgeon is asked to do two things: First, to save his patient's life by securing drainage; second, to so further complete the operation as is necessary to secure a useful joint.

In studying the procedure recommended for performing a typical excision, such, for instance, as that of Lord Lister as described by Mr. Jacobson (Jacobson, "The Operations of Surgery"), one is impressed with the fact that this is a most complicated operation. Fortunately, however, it does not seem to be necessary to follow in all things the technique suggested in this procedure. Doctor F. J. Shepherd, the late Dean of the Medical Faculty of McGill University, in a personal communication, says: "In excising the wrist, instead of too much dissection I used the bone forceps and clipped through the bones

to get movement, then took the pieces away. I do no stated operation." It seems to me that in war surgery where, as we have said, the joint is probably both infected and already, to a great extent, destroyed, the suggestion made by Doctor Shepherd will be found most valuable and the atypical procedures suggested by him will probably be of more value than the more complicated operation bearing Lord Lister's name.

Simple Injuries of the Wrist

Colles Fracture

This injury occurs at the lower end of the radius. Fractures within one and one-half inches from the wrist-joint should alone be included under this name.

Displacement:—In falls upon the palm the force is transmitted from the thenar eminence to the radius, and the bone breaks at its weakest part; at the same time the lower end of the radius is driven backwards and upwards, and is also somewhat rotated, so that the articular surface looks downwards, backwards and somewhat outwards instead of directly downwards. The fracture is usually, but not invariably, impacted. When impaction occurs, the upper fragment is driven into the lower, and it is not uncommon to find the latter considerably split up, the fracture often extending into the joint. The line of fracture is usually more or less transverse from side to side, but is oblique from below upwards and backwards. There is frequently rupture of the internal lateral ligament of the wrist-joint and in some cases the attachment of the triangular fibrocartilage to the ulna is also torn through. (Cheyne and Burghard.)

Cotton (*Annals of Surgery*, 1906) has expressed doubt as to the frequency of impaction.

Diagnosis

Besides the classical signs of fracture, the fact that the radius is driven upwards gives us an infallible sign. Normally the radial styloid process is a quarter of an inch below the ulnar process, but in cases of Colles' fracture it comes to lie at the

same or a higher level. This is called the *Signe de Langier*. The diagnosis of Colles' fracture is, however, usually easy, owing to the presence of the typical deformity. This deformity which simulates a silver-fork, when well marked, cannot be mistaken, but when it is of slight degree want of care has caused many to overlook this fracture; it is therefore advisable in injuries about the wrist to compare the levels of the styloid processes as a matter of routine. Separation of the lower epiphysis of the radius is an injury which should be carefully distinguished from Colles' fracture. Smith's fracture (reversed Colles') should be remembered, as also should dislocation.

Complications

There is frequently an accompanying lesion of the lower end of the ulna. The ulnar styloid process is frequently detached in these lesions. It is wise also to examine the upper extremity of this bone.

Treatment

Reduction of the displacement is the most important element of treatment. Usually this can be done by hand. Sir Robert Jones seizes the lower fragment of the radius and, using the knee as a fulcrum, draws the lower from the upper fragment and forcibly pronates. Whilst keeping the forearm fixed he endeavors to force the lower fragment in front of the upper fragment. (*Liverpool Medical and Chir. Journal,* 1885.)

In cases where difficulty is found in the manual reduction a Thomas wrench may be used, but if the method already described has failed it may be well to attempt reduction first by grasping the hand as in shaking, and flexing and lateralizing the hand towards the ulnar side.

As a general rule the deformity of Colles' fracture may be corrected up to the second or third month after the fracture.

Evidence of a persisting inflammation is the best guide by which to judge our ability to make such non-operative correction.

Mal-Union.

This often causes great functional disability. In such cases it may be wise to attempt correction by open operation.

Operation for Mal-union. (Lothrop's Technique.) The essentials for a successful result in operation for mal-union about the wrist are:

(1) An accurate understanding of the displacement, such as is gotten by clinical study and the study of a skiagram or series of skiagrams.

(2) Careful preparation of the skin of the forearm and hand. Here it may be suggested that it is wise to cover the patient's hand with a sterile rubber glove.

(3) The use of a tourniquet (a pneumatic tourniquet is probably best.) This should be applied over a folded towel, just below the elbow.

(4) The forearm should be placed at rest on a table and the hand should be held semi-pronated by an assistant.

When these preliminaries have been arranged an incision should be made on the external surface of the wrist about one and a half to two inches long. The centre of this should be over the fracture. A radial vein may be encountered which may be ligatured or drawn to one side. Expose the tendons of the extensor brevis pollicis and supinator longus muscles. Approach the line of fracture in *front* of and *behind* these tendons without disturbing them much. No other tendons need be encountered or at least much disturbed. Expose the fracture, using small periostial elevators. Keep close to the bone and expose the line of fracture for the full width of the radius, front and back, reaching nearly to the radio-ulnar articulation. This is done with retractors, pushing the soft parts away from the bone without opening any tendon sheaths. By means of a small bone drill, numerous perforations are made in the line of union so as almost to sever the lower fragment. The separation is then completed by means of small chisels. The retractors guard the

soft parts against injury. Gentle force is used so as to entirely free the lower fragment. It will be possible now to correct the backward and forward displacement. Sometimes the position is made more satisfactory if the projecting anterior border of the lower end of the upper fragment is removed with narrow-bladed rongeur forceps.

The prominent ulna is an unsightly deformity. A shortening of the ulna will permit of accurate apposition of the radial fragments and will probably avoid ulnar deformity. This shortening of the ulnar shaft is best done near to, but away from, the wrist-joint, and may be most easily done subperiostially with the Gigli saw through a short skin incision. It *may* or *may not* be wise to unite the divided ulna with absorbable sutures to maintain accurate apposition. The wounds are not drained. Obviously this complete operation upon radius and ulna is applicable only to selected cases of old deformity resulting from fracture.

The care of the wrist after operation is like the care of an ordinary, recent, uncomplicated fracture.

Fracture of the Scaphoid

Early cases are found to be the cause of pain and tenderness on the radial side of the wrist with swelling, spasm and loss of function. Immobilization is usually sufficient treatment in these.

Chronic cases complain of continued pain in hyper-extension and a weakened wrist. Tenderness, swelling and muscular spasm may be present.

If treatment of these cases by rest, massage and other tentative measures does not cure, removal of part or the whole of the scaphoid bone is indicated. Scudder feels that removal of the whole bone is likely to be followed by weakness of the wrist. In my experience this has not happened, but if cure can be effected by excising the smaller portion of the broken bone, as suggested, this alone should be done.

Operation

An incision is made on the dorsal surface of the wrist to the inner side of the tendon of the extensor

carpi radialis longior. The annular ligament is divided and the fracture exposed. Flexion and abduction at the wrist will best bring the scaphoid into view and it can be either wholly or partially excised by scissors and curette. Rest is then indicated.

Chapter VII

Injuries of The Foot.

Week Feet, or Chronic Strained Feet.

CHRONIC strained foot, so-called flat-foot, and depression of the posterior arch or pronatovalgus are here considered.

Soldiers are more prone to complain of disabilities of the feet (both real and imaginary) than of any other organic or functional lesion. Whitman states that it has been estimated that from 30 to 40 per cent. of those examined by the exemption boards during the year 1917 presented either potential or actual disability of this character. (*Medical Record,* July, 1918.)

Armies are fit or unfit, according to the condition of the feet of the rank and file.

A great divergence of opinion seems to exist as to what is a foot fit for service or a foot unfit for service. Looking back on the recruits and soldiers with whom I have come in contact since the outbreak of war, I am impressed with the idea that many men demonstrating so-called pathological conditions of the feet have been wrongly refused as unfit for service, and many presently unfit men have been accepted without duly safe-guarding the interests of the individual and the Nation.

Disease has been guarded against. Diseases have been conquered. Since the introduction of inoculation and other preventive measures typhoid is almost unknown in the army. In the Spanish-

American war out of 100,000 American troops 20,000 developed typhoid. In the Boer war there were 57,000 cases of typhoid, with 8,000 deaths. In the present war the death-rate from typhoid amongst *inoculated* British troops on the Western Front is lower than the death-rate amongst civilians in England.*

Syphilis has been controlled. A medical officer is said to have earned a much coveted decoration for distinguished service by saving for active military service twenty thousand men who were suffering from venereal diseases. Yet abnormalities, deformities and pathological conditions of the feet remain almost unstudied—and certainly unconquered. Such are the causes for the rejection of many recruits, otherwise eminently fit for service, and, conversely, such lesions are responsible for the immediate and unwatched employment of many recruits at present unfit, although, potentially fit for the arduous life of a soldier. These conditions are responsible for more discomfort, and even suffering, amongst our soldiers on active service, than any other remediable cause. These are responsible for the return to civil life of a great number of trained soldiers who are otherwise fit for active service. Abnormalities, deformities and pathological conditions of the feet remain a greater influence for evil amongst a people defending their sacred rights than many causes more dreaded, many causes more feared.

The seeming simplicity of these affections has given great confidence to recruiting officer and army medical officer. Are not many of the medical administrative officers more self-confident than studious? What have they done towards saving for the army recruits so afflicted? What comprehensive scheme have they devised which may be accepted as a reasonable guide in medically examining the feet of recruits? What preventive methods have they devised for the care of soldiers who have a tendency to weakness? What methods have they proposed

* William Boyd, *Canadian Medical Journal*, 1918.

for making fit those who are temporarily unfit because of these affections?

In the early days of the war many strong and enthusiastic Canadians were refused permission to serve in His Majesty's forces because they were suffering from so-called flat feet.

Lumber-jacks from New Brunswick and the North Country were refused because there were no apparent arches to their feet. How absurd! What is a normal or standard arch? Surely their abilities to perform the duties of such occupation ought to have been a sufficient recommendation, a sufficient guarantee of their future efficiency as soldiers.

There are races of men whose feet show no arches as described. The negro submitted to the standards of many of our medical examiners would be rejected without exception because of his normally low arch. The feet of many athletes appear to be archless. This appearance is due to muscular development and is a sign of strength and not of weakness. Yet many athletes, the lumber-jack and the negro, submitted to a medical examiner sufficiently hide-bound by army rule and rote, were declared unfit for active service, and lost to their Country and the great cause of civilization and democracy for which we were at war.

The recruit whose occupation was one of physical toil can be depended upon to stand even the forced marches of active service and the "pavé" of Flanders and northern France in spite of a so-called loss of arch. The clerk and the man of sedentary life who may have complained of his feet as he stood about day by day behind the counter or at office work will cease to complain as his general condition improves under the wholesome and athletic life in the army. This will be especially the case if such men are taught how to save their feet and how to use their feet. This will be the case if some common sense is applied to, and adequate supervision is exercised in, the choice of army boots and fitting the men with the same.

It is solely a question of organization, that one quality so rarely seen amongst us and the lack of which is responsible for nearly all our difficulties of the past four years.

In examining the feet of a recruit, various points must be taken into consideration:

First, is there persistent abduction of the foot? (Abduction from the mid-line of the leg.) In early cases this is a voluntary attitude. In advanced cases it has become a fixed deformity. Whitman says that if this attitude of abduction, when exaggerated to deformity, be analyzed, it will appear that the first and most noticeable change in contour is a lateral bulging in front of and below the internal malleolus. This is caused by inward and downward rotation of the astragalus. When normal feet are placed side by side with the heels and toes opposed, an interval persists between them, caused by the slight outward curve of their inner borders. The most important indication of the potential or actual weak foot is a bulging inward so that the two feet when placed side by side are in contact throughout their entire extent; or, if the bulging is more pronounced, it is impossible to oppose the heels and toes simultaneously. (*Med. Record*, July, 1918.)

Second, flexion of the foot as a whole. Is this limited by contraction of the tendo Achilles?* The ability to flex the foot is necessary in marching. On it depends the prehensile or grasping action of that machine.

Third, is there hyper-extension of all the toes with accompanying subluxation of the phalanges on the dorsal aspect of the metatarsal heads when attempts are made to flex the foot? Such condition is a fruitful source of trouble. When the recruit walks, the anterior arch is forcibly depressed at each step, thus the anterior arch soon

* Whitman says shortening of the tendo Achilles, except as a secondary result of long standing deformity, is rarely found in the clinic of the Hospital for the Ruptured and Crippled, the largest in the world.

gives way and an arthritis with pain, discomfort on lateral pressure, tenderness over the metatarsal heads, and callosities on the weight-bearing surfaces result.

Fourth, can the recruit invert his foot, *i. e.*, are the tibialus anticus and posticus functioning normally? This is a most important question, because these muscles support the keystone of the posterior arch, and on their strength depends to a great extent the marching ability of the soldier.*

Fifth, is the arch resilient? The recruit stands, and apparently he has little posterior arch; the recruit sits, and his arch returns to the so-called normal contour. This denotes an elasticity of muscle and ligament which means strength and normality. It is seen in feet whose function is good.

Sixth, is there tenderness over the scaphoid or over the attachments of the plantar ligament? Such usually denotes an inflammatory condition associated with chronic strain.

Seventh, are there signs of spurs, or so-called rheumatoid arthritis, be it general or a local traumatic arthritis due to abuse of the foot, perhaps by wearing improperly fitting or protecting boots or shoes?

Eighth, is the foot pliable, or is it held by muscular spasm, fibrous or bony change?

Chronically strained feet may be divided into two classes, the rigid and the non-rigid.

Rigid Chronically Strained (Weak) Feet.

In order to adopt a classification it may be said that rigid, chronically strained feet may be subdivided into four groups: one, those due to, or accompanied by, chronic and generalized muscular spasm; two, those in whom spasm of the peronei dominate; three, those in whom fixidity may be attributed to adhesions of a non-bony fibrous type; four, those in whom fixation is definitely due to bony changes.

* Dr. Whitman accentuates the fact that the tibialis posticus is the chief inverter of the foot.

Type One.

This includes those accompanied by generalized muscular spasm, and is the most common type. The symptoms of this class of cases are temporarily relieved, or minimized, by the induction of anæsthesia. In these we may well seek an explanation of the muscular spasm in an arthritis, because it is a well-known fact that muscular spasm is a symptom of such condition. Such arthritis may be due to chronic strain, to traumatism, or to a so-called rheumatoid condition, especially of the infectious type, thus gonorrhœa as a causative factor must be excluded.

Treatment.

Find the cause, if possible. Remove this cause. Then treat locally, first by rest and second by hyperæmia, such as caused by the use of dry heat.

In mild cases local rest can be assured by strapping with adhesive plaster after manipulation, as practised by Whitman of New York. These manipulations and strapping are calculated to perform an important office. They are to invert the foot and to restore the strained and falling arch to a position of rest approximating the normal. In this position the foot is maintained in an attitude and under conditons aiding a return to normality.

More severe cases must be treated by more severe measures. Manipulations may be difficult and rest in plaster-of-Paris for some weeks in the position described may be preferred to the rest assured by the use of adhesive plaster.

Prognosis.

The prognosis as regards return to a civil vocation is good. Some may be returned and made fit for military life.

Type Two.

This includes those cases which are due to, or are accompanied by, spasm of the peroneal muscles.

This is a type clearly described and apparently often seen by Sir Robert Jones, although rarely

seen or described by American writers. It is difficult to see why, in an inflammatory condition of a foot, there should be spasm of only the peroneal muscles, although it is quite conceivable that with generalized muscular spasm peroneal spasm may dominate. In this type the induction of anæsthesia may temporarily minimize or relieve the muscular spasm for the period of narcotism.

Treatment.

Here rest in the inverted position is again essential. Sir Robert Jones has described an operation which he frequently practices with success. A small incision is made over the peroneal tendons, just above the external malleolus. The tendons are exposed and a small portion of, say, three-quarters to one inch is excised from each. The foot is then placed in inversion.*

Prognosis:—Probably more favorable in every respect than that of the previous class.

Type Three—The Fibro-Adhesive Type

This type differs from the two preceding types in that in it there is definite organic change and the symptoms of it are not relieved by the induction of anesthesia. The bones of the affected foot are bound firmly by adhesions. It is usually held in a position of valgus. It is nearly always congested and tender in places, especially over the scaphoid bone. The patient complains of great pain on attempting to walk. He walks with his foot held in position of abduction. Attempts to invert the foot are accompanied by pain and often the audible breaking down of adhesions. This type is a more advanced type than either type number one or type number two. It may follow either of these types. It is often due to a definite so-called rheumatoid condition, especially of an infectious type (sometimes gonorrhœal),

Prognosis.—The prognosis for civil life is fair, but for military life it is bad.

* Whitman says that he does not approve of exsection of parts of the peronei. He says tenotomy is occasionally indicated.

Treatment.—Find a cause, if at all possible, and treat this cause. Attempts may be made to break down adhesions either manually or by means of a Thomas wrench, after which any correction secured may be confirmed by the use of plaster of Paris.

Fourth Type—The Bony Adhesive Type.

The deformity in this, as in the type immediately preceding, is not relieved or even improved by inducing anæsthesia. The affected foot is held firmly by bony changes. Pain and untoward symptoms are not so great as in the preceding type. This type often follows the more acute fibro-adhesive type. When organized bone is laid down the damage is done, and rest, wrenching or plaster can avail but little.

Prognosis.—The damage has been done. While the feet can be made reasonably comfortable for civil avocations they can never be used in a prehensile capacity so necessary in marching. In military life, therefore, the prognosis is bad.

Treatment.—Operative treatment has been recommended by American surgeons. Excision of the scaphoid is practiced by some. Certainly the results do not warrant its ordinary employment amongst soldiers.

Speaking generally, then, after studying the rigid forms of chronically strained feet, one is forced to conclude that in so far as military life is concerned the prognosis in nearly all is bad.

Non-Rigid Chronically Strained (Weak) Feet.

Non-rigid strained feet are those which give rise to dissension and error.

I have been perfectly candid in stating that in military life the prognosis in *rigid* forms of strained feet is generally *bad*. I shall be equally candid in stating that in the *non-rigid* forms the prognosis is *good* for military life. It is only a question of organization—that great lack in the life military. There is no reason why a place should not be found in the army for each and every recruit suffering from non-rigid strained feet.

The Canadians, confident of the speedy termination of the war, have in the past attempted to enlist only those who were without blemish. Have they not often refused to accept for repair those who were easily reparable? Have they not often accepted as fit the potentially unfit, without making any endeavor to preserve their fitness? But to the weight of evidence against accepting for service recruits demonstrating so-called flat feet of the non-rigid form, comes the confirming and damning evidence of those who have seen our soldiers suffering on forced marches over the pavé of Northern France and Flanders. But even this evidence, important though it may be, is insufficient to condemn as unfit those whose feet are only potentially a source of unfitness. It merely suggests that the potentially unfit have been neglected.

It draws us nearer to the knowledge that organization is just as necessary in the army as in civil life. It impresses on us the undeniable fact that although, when one's country is at war, there is a place for every man, that place must be chosen with some little common sense. Again we were impressed by the fact that if we wanted to win in this Great World's War we were obliged to conserve our energies only to use them prudently and with judgment.

The pertinent question arises, if we make use of recruits demonstrating non-rigid forms of weak feet is it possible that by service these feet may become rigid? The answer is plain and in the negative. According to experience, chronically strained feet presenting no symptoms, if conserved will not progress to rigidity. Further, if they present symptoms, such feet should be treated until the soldier is once again fit for active service in the front line.

"Marching Fracture"

Complaints—Painful foot or feet.

Examination—Swelling, may be extreme. Tenderness on light pressure along metatarsals.

X-Ray—Fracture of second, third or fourth and very rarely of fifth metatarsal. The fracture is always simple and treated as such.

Cause—Said to be long and tiring marches with badly fitting boots.

The chronic, non-rigid strained foot may show:

1. Abduction (from the mid-line of the body) with inward and downward rotation of the astragalus, causing a bulging on the inner side of the foot so that the two feet when placed side by side are in contact throughout their entire extent, or if the bulging is more pronounced it is impossible to oppose the heels and toes simultaneoulsy (Whitman, *Medical Record*, July, 1918).

2. A shortened tendo Achilles.

3. Eversion of the foot (pronation).

4. A flattening of the arch. This flattening may be seen only on weight-bearing, *i. e.*, the resiliency of the arch may not be lost.

5. A chronically strained (weak) foot may demonstrate hyper-extension of all the toes on attempting flexion of the foot, which symptom is at least a precursor of a depressed anterior arch with all that that means.

6. A strained foot may be tender on pressure over almost any part, but pathognomonic is tenderness over the scaphoid, or the attachments of the plantar ligament.

7. The ability to invert the foot may be decreased or lost.

Prognosis.

All recruits or soldiers suffering from these conditions can be made fit for active service by treatment suited to the acuteness of the condition. Whitman cites the case of several young men who were referred to him for "weak foot" and who on this account had failed to pass the physical examination at the Naval Academy, but had been granted the privilege of a second examination in three months. These were placed under treatment by him. He says: "This treatment was effectual and I was able to assure the authorities that such candidates, understanding the methods of self-protection, were, in my opinion, better risks than the majority of their classmates, in that they were assured against future disability by their knowledge of its causes and nature."

Treatment.

Acute conditions and exacerbations of symptoms in chronically strained (weak) feet demand rest—rest secured by means of adhesive plaster, or rest in plaster-of-Paris, as already described. Chronically strained non-rigid (weak) feet demand that the recruit or soldier should be given instruction in the subject of the use of the foot as a prehensile machine; instruction in the attitudes of rest on standing and sitting; instruction in the preservation of the normal arch.

Whitman says: "All recruits should be inspected; bad or predisposing attitudes should be corrected and exercises should be enforced. Pain in this class is caused by strain. After it has subsided the soldier should be treated so that future strain may be prevented."

He insists that faulty attitudes, such as outward rotation of the limbs, particularly abduction of the feet (the attitude of inactivity) must be guarded against. Voluntary inversion—resting the weight on the outer border of the feet—is the attitude that is the best safeguard against strain.

Straight walking must be insisted upon. Exercises for strengthening the calf and the abductor muscles of the feet are important and corrective measures. Straight walking such as is characteristic of the Indian gait. In-toeing is simply an exaggeration of this.

Soldiers who possess strained (weak) feet should be served with suitable boots which will permit of the exercise of the functions of the foot. They may require such devices for the maintenance or restoration of the posterior arch as were devised by Thomas and Jones, of Liverpool, or they may even require such instrument for the forcible correction of faulty attitude as was devised by Whitman, of New York.

It may be well to clearly state here that, in my opinion, the correcting instrument of Whitman, of New York, is incomparably better than all other methods of civil life, also for soldiers in barracks

and in hospitals; but in the front line, in trench-warfare, and the activities of service, the methods of Thomas and Jones are the more practical schemes to aid in the preservation of the normal relationship of the tarsal bones.

CHAPTER VIII.

Depression of the Anterior Arch and Anterior Metatarsalgia.

THIS AFFECTION is more rarely complained of than similar conditions of the posterior arch.

To understand it one must understand the anatomy of the anterior arch, formed as it is of all the matatarsal heads, bound together by transverse metatarsal ligaments and muscle as well as by prolongations from the plantar ligament. These metatarsal heads articulate with the five phalanges.

Two tendons are attached to each phalanx on both dorsal and plantar surfaces.

It will be seen, then, that associated with this anterior arch, and really forming part of it, are the metatarso-phalangeal joints, each of which is supplied by the external branch of the anterior tibial nerve, whose mother nerve supplies also the extensor communis muscle which is attached to the dorsal surface of the phalanges, as already noted.

Depression of the anterior arch may be due to local or to general causes. Because of the proximity of the articulations to the arch, a depression with the consequent trauma must soon be followed by an arthritis of the metatarso-phalangeal joints.

This arthritis gives rise to spasm of the muscles adjacent to or having a common nerve supply to these joints. The anterior tibial nerve supplies both common extensor muscle and metatarso-phalangeal joints, thus an arthritis of these joints is accompanied by spasm of that muscle.

Tonic spasm of the extensor muscle causes extension of the toes. If this lasts long enough, hyper-extension follows with a subsequent shortening of the extensor tendons. This results later in a subluxation of the toes on the dorsal surfaces of the metatarsal bones. Further extension of these dorsally subluxed toes causes an increasing depression of the heads of the metatarsal bones. This is the chief cause of pain in this affection.

Symptoms.

It will be seen, then, that an arthritis with pain, swelling and tenderness, which symptoms are characteristic of anterior metatarsalgia, follows depression of the metatarsal heads and that this arthritis is symptomatic of, indeed constitutes, what is known as anterior metatarsalgia. Now, besides these symptoms one can feel the depressed heads of the metatarsal bones impinging against the soft parts of the plantar surface. The depressed heads give rise to callosities in this region.

Two characteristic signs of anterior metatarsalgia are: first, tenderness on pressure on the metatarsophalangeal joints; and second, pain on lateral pressure and counter-pressure on the forepart of the foot.

Prognosis.—In civil life the prognosis is good and in military life, except in extreme cases, it should be good also.

Treatment.

In mild cases, rest with non-operative restoration of the arch is all that is required. The easiest method of securing rest is by the use of suitable boots with the addition of a leather bar tacked across the sole, just behind the metatarsal heads, which will serve to suspend these in the air and prevent trauma in walking. This has been called an anterior heel. The same purpose can be carried out by the use of a spoon-shaped steel arch support which terminates anteriorly in the same position and is so arched as to maintain the bones of the anterior arch in normal position. The arch may,

also, be maintained by means of strapping with adhesive plaster.

In more severe cases operative procedures may be considered. The description of the deformity and the order of its development suggest rational operative treatment. The deforming influences must be reversed. The depressed metatarsal heads must be elevated. The hyper-extended and subluxed toes must be flexed and the dislocated phalanges reduced. The sinking of the metatarsal heads must be overcome by fixation of the anterior arch. All these may be accomplished by transplantation of the common extensor tendons, when this muscle which was the deforming influence becomes a remedial agent.

This transplantation is performed through a semi-lunar incision across the dorsal surface of the metatarso-phalangeal joints. Each long extensor is isolated and detached from its phalangeal attachment. A hole is drilled through the neck of each metatarsal bone and the extensor tendon attached there by paraffined silk. The incision is then closed, first by deep catgut and then by silkworm or horse-hair suture. Further, it may be necessary to lengthen the tendo Achilles and the plantar fascia to secure adequate correction prior to completing the operation.

The success of this operation may be assured by completely flexing the toes at the time of operation and by maintaining this position after operation.

CHAPTER IX.

Claw Foot.

FOR THE PURPOSE of this article, so-called claw-foot may be considered an exaggeration of anterior metatarsalgia. Its etiology is uncertain. Local causes may be responsible for it, or it may be due to certain general conditions, as for instance, diseases of the nervous system.

In claw-foot are seen, but to a much greater extent, all the symptoms shown or complained of in chronic anterior metatarsalgia with the addition of an increased posterior arch, a shortened plantar ligament and a contracted tendo Achilles. The foreshortening of the foot may be extreme. The foot may be fan-shaped, spreading out anteriorly and the metatarsal heads may not only impinge against the soft tissues, but also may be enlarged and deformed.

Prognosis.—The milder forms are amenable to operative treatment. The graver forms cannot be made fit for service by operative procedures.

Operation.

I perform the same operation on these cases as recommended in anterior metatarsalgia, except that, in addition, it is often necessary to lengthen the tendo-Achilles and always necessary to lengthen the plantar fascia. This may be done by multiple subcutaneous incisions. After performing this operation the toes must be dislocated downward. When this has been done, in many cases it will prove impossible to bring the edges of the incision in the skin into apposition. In such cases a semi-lunar incision is made on the dorsal and cutaneous surface of the foot. This permits the original wound to be united but leaves a large bare area at the site of the last incision which may be skin-grafted at the time of operation.

In some cases it has been necessary to perform wedge-shaped osteotomies through the dorsal surfaces of the metatarsal bones in order to change the bearing surfaces of the metatarsal heads. Sometimes it may be necessary to excise the heads of some or all of the metatarsal bones. Sir Robert Jones (*British Med. Jour.*, 1916) has devised a series of procedures to deal with the various phases of claw-foot, but one cannot help feeling that conditions demanding such serious measures can hardly be so remedied as to make the soldier fit for military service.

CHAPTER X.

Hammer-Toe.

AT THE ONSET of this war it was the custom of many so-called general surgeons to amputate all hammer-toes which were causing disabilities. This had not been the custom of orthopædic surgeons for some years, because the amputation was found to weaken the anterior arch, and in addition the space left between the adjacent toes was found to permit of a deforming adduction which interfered considerably with the function of these. It was then that a partial amputation, leaving only the proximal third or half of that phalanx was suggested. This preserved the anterior arch, but only to some extent guarded against the adduction already spoken of. I think it was Goldthwait, of Boston, who at that time suggested than an excision of the flexed joint be performed, and Merrill, of Philadelphia, recommended that the flexor tendon should be transplanted into the neck of the proximal deforming bone.

Hammer-toe is a deformity of doubtful origin. It may be congenital and it may be acquired. The fact that in the majority of cases it is found in the second toe and often in the second toe of both feet suggests its congenital origin.

It is due to a flexion of the first and second phalanges at their interphalangeal joint. This flexion is accompanied by contraction of the tendons and ligaments.

Prognosis.—By modern operative procedure this deformity can be relieved without injury to the function of the foot and the patient can be made into a physically fit soldier if he is otherwise normal.

Treatment.—The simplest form of operation is to expose the head of the proximal phalanx through a dorsal incision and to excise it. If a sufficient portion of the shaft be excised with the head, the contracted tendons will cease to exert a deforming influence and the toe can be straightened out and maintained in correction.

CHAPTER XI.

Hallux Valgus.

HALLUX VALGUS or bunion is due to trauma and usually to the trauma of an ill-fitting boot or shoe. In it the great toe is, as a rule, adducted towards the mid-line of the foot. The metatarso-phalangeal joint would seem on inspection to be enlarged. Examination of the bones entering into the joint may demonstrate an outgrowth of bone, the result of a traumatic arthritis or osteitis about the head of the metatarsal bone, but in many cases as, Painter points out, this is not seen.*

"One needs to study the gross anatomy of these cases both in the beginning and well-advanced types. To palpation and inspection there does not seem to be any gross osseous thickening over the head of the FIRST metartarsal even in cases where there is marked deformity.

"The X-ray examination does not reveal any appreciable thickening of the metatarsal or phalanges.

* C. F. Painter, *Boston Medical and Surgical Journal*, 1916

Except where there have been some osteo-arthritic changes in the bone due to a diathesis, I have seldom observed any enlargement of the metatarsal heads. The conspicuous change which one notes in these specimens is an atrophy and oftentimes an erosion of the inner articulating surface of the metatarsal. It is this surface that is not apposed to the corresponding articular surface on the phalanx and this lack of apposition results in the alterations of the bearing surfaces above mentioned.

"These facts, I think, pretty conclusively show that hallux valgus is not an exostosis of the metatarsal head or its articulating phalanx. If it is not this then it is merely a lateral deviation of the great toe at the outset, accompanied by stretching of the inner capsular attachments and later on by structural alterations of the articulating surfaces no longer in use, dependent upon lack of function."

Prognosis.—By operative procedures alone can this affection be cured in soldiers. Operation followed by eight weeks' rest should make a soldier fit for duty. In civil life much less time is ordinarily set aside for convalescence, but as operative procedures consist in an arthrotomy with excision of the metatarsal head it is wisest, in the case of a soldier whom we desire to make fit for service, to assure perfect relief of deformity by allowing for a sufficient period of rest after operation.

Operation.*

An incision of from 2½ to 3 inches is made through the skin only from the interphalangeal joint of the great toe proximally. This is made to the inside of the long extensor tendon. A second incision is now made through the skin incision parallel and to the inner side of this tendon, cutting down now to the periosteum. The metatarso-phalangeal joint is exposed. With a blunt dissector and scissors, the metatarsal head is then delivered through the incised skin on the dorsal surface of the foot. A Gigli saw is then slipped around the neck of the bone, which is sawn through,

* Forbes, *Medical Council*, 1913.

and removed by an incision running obliquely backward and inward. The sharp edges of the sawn bone are smoothed or nipped away. The operation is completed by closing the wound and carefully dressing the foot. The more time and care taken in closing the wound the better for the patient. Up to this step only four to five minutes have been consumed. The closure of the wound is done by subcutaneous sutures of fine catgut. The skin is united by many single strands of horse hair. The dressing is calculated to hold the great toe in a position pointing inwards with its cartilaginous base apposed to the cut end of the first metatarsal bone. No endeavor is made to remove either redundant skin or an enlarged bursa. Nature will look after these.

CHAPTER XII.

Hallux Rigidus.

THIS IS NOT a common deformity. It is related to hallux valgus. In it there is loss of the power of hyper-extension following an arthritis of the metatarso-phalangeal joint of the great toe. This arthritis is usually due to traumatism. C. F. Painter, in *The Boston Medical and Surgical Journal,* May, 1916, says: "Inasmuch as hallux rigidus is caused by an hypertrophy of the bone on the dorsum of the distal end of the first metatarsal, it would seem that under the conditions present when the seam of a shoe presses continuously against this point while the foot is in action, and the 'break' in the shoe, which necessarily comes opposite the point of flexure of the foot, will increase this pressure, the factors needful to produce such an hypertrophy as that which characterizes hallux rigidus are all present."

Sometimes a skiagram will reveal a definite cause for the block causing inability to extend the toe. At other times there is no definite block or organic

cause for this inability to hyper-extend, further than a definite arthritis.

Because extension (dorsal flexion) of the great toe is essential to the prehensile function of the foot, a patient suffering from hallus rigidus is unfit for active service.

Prognosis.—Patients suffering from this lesion can easily be made fit for active service by properly applied treatment.

Treatment.—In mild cases give rest to the joint by using the anterior heel suggested in the previous chapter. This combined with massage will often relieve the condition. In graver cases treatment as suggested for hallux valgus is recommended.

CHAPTER XIII.

Malunited and Ununited Fractures.

THIS GROUP affords ample scope for all our mechanical skill, while providing a host of cases which are at once the most interesting and the most satisfactory from the standpoint of results.

Malunited fractures invariably present difficult surgical problems. The constant presence of infection in gunshot wounds of the bones, and the difficulty in applying the ordinary principles of treatment in the early months following the injury, have led to the most lamentable results. Experience has taught that it is unwise to undertake operative procedures on the bones until many months have elapsed after the last signs of infection have disappeared.

Unsuspected infection lurks about the ends of damaged bones for a long time after the wound has healed, and extensive operative work is very apt to end disastrously from the lighting up of old infections. Six months appears to be the minimum time which should elapse between the healing of

the primary wound and the reparative bone operation.

In considering the question of malunion, appearances must not be considered as detrimental to function.

Sir William Bennet, about sixteen years ago, undertook an investigation of this subject and summed up his deductions in these words:

"What I decidedly mean to say is, that the mere fact that the bones of a broken limb do not unite symmetrically and quite in the straight line, is not of necessity, in itself, any reason why disability should occur, or why the wage-earning power of the individual should be diminished."

The words of Sir William Bennett are strong words, yet there remains a certain proportion of patients in whom osteotomies and bone fixation will be found necessary, hence this latter subject may well be considered here.

Ununited Fractures.

Perhaps of all conservative methods available for the treatment of ununited fractures, the one spoken of by that most ingenious of old-time orthopedic surgeons, Thomas, of Liverpool, as "damming and jamming" is the most efficient. All of us know something of Bier's system of treatment by congestion. Bier followed Thomas who, for years before Bier was even born, surgically, if not actually, treated ununited fractures successfully by producing congestion by what he called "damming."

Conservative treatment has not been superseded by the methods of Lane, Albee and others. These treatments should only be considered in special cases and where conservative methods have failed.

Lane's methods, if not revolutionizing the treatment of fractures, by those most familiar with the surgery of bone, can, at least, be said to be a most valued addition to surgical technique; but there are certain disadvantages about their use, not only because all open operative procedures may be under certain conditions subject to criticism, but also

because the presence of a metal plate instead of stimulating osteo-genesis retards it.

Let me reiterate: metal plates and screws retard osteo-genesis; they cause porosis and, further, their presence will never, can never aid union of bones long ununited, where there has been a distinct pathological change in the ends of the fractured bones, which change usually consists of a degeneration of bone cells with a coincident increase in calcium salts—an area of eburnation.

How can we expect, in the treatment of ununited fractures, to see bones, no matter how well joined by means of Lane's plates, showing signs of osteogenesis if, as is often the case, the ends are capped with an area of sclerosis sometimes extending for one and one-half inches? Thus, often, it is not splinting alone which is required but the furnishing of a bone-growing and osteo-conductive element in contact with the healthy bone beyond the eburnated area. It is for these cases, especially where an autogenous osteo-genesis cannot be depended upon, that the bone inlay or graft consisting of the three elements, periosteum, endosteum and marrow popularized by the orthopædic surgeon, Albee, is recommended.

That bone, instead of metal, is now available, not only to splint difficult and uncontrollable fractures, but also to stimulate osteo-genesis in ununited fractures, is most fortunate at the present moment, when thousands of soldiers are returning to our hospitals with injuries to the bones, which urgently call for radical operative procedures before they can be fitted to return to useful civilian life.

Gallie's Researches.

For the past four to five years a Canadian, a member of the American Orthopædic Association, I speak of Gallie, of Toronto, has been experimenting on the transplantation of bone, and I am proud to say has produced an experimental work which not only has clarified our past knowledge of this subject but has added information of the utmost value and importance to our knowledge of osteo-genesis

at a time when all information is sought with avidity for the benefit of those who have suffered bone lesions in our Great Cause.

The results of these experiments were reported by him at the meeting of the Canadian Medical Society held in 1917. As he has been kind enough to furnish me with a copy of his report, which I hope will be published in the *Canadian Medical Association Journal*, I can, fortunately, quote verbatim many of his conclusions.

Albee's work had stimulated all of us, but what was the history of the transplanted bone which in spine and extremity became, apparently, fused with its host?

Gallie's studies were undertaken for the express purpose of learning the history of implanted bone.

In the experiments made by Gallie it has been observed that both bone graft and osseous host are necessary for the formation of new bone. If, for instance, an autogenous graft be placed in a canal prepared for the reception of the same in a selected living bone, or host, various interesting phenomena are noted.

First, nearly all the cells in the interior of the graft, be they bone or be they of other living tissue, which are not bathed in the lymph exuded from the host coagulate and die.

Second, on the surface of the graft and in the open mouths of the Haversian canals are many osteoblasts which are in a position to absorb nutriment from the lymph exuding from the osseous host. These osteoblasts so nourished are capable of living and proliferating. At the end of ten or more days, the osteoblasts on the periosteal and endosteal surfaces of the graft having so proliferated, new bone formation can be plainly seen on these surfaces.

Third, in addition to forming new bone about, and on, the surface of the graft, these proliferating osteoblasts proceed to attack the dead bone of the graft and rapidly produce excavations, about the edges, which are at first filled with proliferating

cells and later by new bone laid down by these cells upon the walls of these excavations.

Fourth, whilst these changes are occurring on the surface, a re-establishment of the circulation has been taking place as the result of new blood-vessels penetrated into the mouths of the Haversian canals. This penetrating proceeds with extraordinary rapidity and in small porous transplants is complete in approximately two weeks.

Fifth, osteoblasts spread (with these blood-vessels) from the surface into the Haversian canals; thus at the end of three weeks from the time of transplantation, the same changes which have been described as occurring on the surface are also taking place within the substance of the bone.

Here, now, we have the immigrant osteoblasts, nourished by means of the newly formed blood-vessels and increasing by proliferation, attacking the dead bone in the interior of the graft, rapidly producing excavations, and at the same time laying down new bone to take its place. At first this phenomenon occurs only near the surface of the bone. Later this absorption of dead bone with the formation of new bone spreads deeply into the transplant until the whole graft is permeated by new blood-vessels and osteoblasts rapidly forming new bone.

Gallie tells us that the rapidity with which these changes occur depend on three factors: (1) inversely as to the size of the graft; (2) inversely as to its density; and (3) directly as to the abundance of the supply of osteoblasts which survive on the surface of the graft.

It has been demonstrated that the absorption of the dead bone of the graft and the formation of new bone in the graft is necessarily slow in very thick grafts, owing to the distance the new vessels and osteoblasts have to permeate. Indeed many months may elapse in such cases before replacement can occur. The density of the graft is important also. Replacement is necessarily slow in hard dense bone, such as the crest of the tibia,

while it is rapid in open cancellous bone, such as a rib.

It has also been demonstrated that if a graft is cut in such a way that the endosteal and periosteal surfaces are undisturbed and exposed to a good supply of lymph, the changes described occur with certainty and rapidity, whereas, if the periosteal and endosteal surfaces are removed very little osteogenesis takes place from the graft itself owing to the scarcity of osteoblasts.

A series of experiments were undertaken to prove the importance of the living graft as an osteogenetic factor. Devitalized bone was grafted into a living osseous host. Here all the changes described were slow and uncertain. A further experiment was undertaken with heterogenous bone. Here, as in devitalized bone, replacement must depend on osteoblasts from the host alone.

A second series of experiments were undertaken to prove the importance of the host. Gallie transplanted a graft into muscle instead of into bone. Here, if any attempt at osteo-genesis occurred it was small and ineffectual, the graft indeed disappearing in time by absorption.

Corollary.

(1) Gallie's experiments are in agreement with those of MacEwen. They indicate that the periosteum is only a lining membrane and that the great majority of osteoblasts cling to the bone when the periosteum is removed.

(2) It is seen that the autogenous graft itself has a most important function to perform in osteogenesis, and that of the graft the most important parts in this function are the periosteal and endosteal surfaces.

(3) It is necessary to appreciate that the osseous host, as well as the autogenous graft, has a distinct place in the osteogenetic function.

Practical Deductions.

The important lessons to be deduced by practical surgeons from the results of these experiments are:

(A) Both the graft and the host have their distinctive places in osteo-genesis and are of equal practical importance.

(B) The periosteal and endosteal surfaces are the essential parts in the bone-forming function of the graft and in reconstructive surgery of bone are the necessary parts of the graft.

(C) Living and autogenous bone is necessary for the formation of bone because both devitalized and heterogenous bone slowly absorb and disappear under the action of the body fluids and giant cells. According to this, when gaps in long bones are to be filled, the autogenous graft only should be employed, as here we have a condition in which contact for the graft can be secured only at the extremities; consequently the replacement of the central portion of the transplant must depend on living osteoblasts on the surface of the graft itself.

Again, in the treatment of non-union in fractures, the autogenous graft is essential, because here we are dealing with fragments of bone in which osteoblastic activity is at a minimum.

(D) Grafts should be cut in such a manner that the largest possible "osteoblast-bearing" area is exposed. Gallie says that when the tibia is used the graft should be cut from the face of the bone and not from the crest. I often employ the outer surface of the tibia. The width of the graft should be greater than its thickness.

(E) The choice of the site from which the graft is cut is of importance. If strength of the graft is not essential a rib is better than a portion of the tibia, in that a rib which has been so incised as to expose a large endosteal surface to a supply of lymph, is, because of the large number of osteoblasts on this surface, more capable of causing osteo-genesis than is a long bone. At the same time, in operations undertaken for such lesions as ununited fracture, it may be necessary to secure a graft which is strong enough to assure the stability of the ends of the broken bone; but as Gallie points out, this may be surrounded with a number of

small strips which will assure the formation of marked callus.

(F) Heterogenous and devitalized bone have a distinct place in bone surgery. Although they are not to be used where the host cannot be expected to sufficiently stimulate osteo-genesis, as in ununited fractures, they are to be preferred in all such positions where metal plates have been used in the past.

The advantages of these heterogenous grafts are obvious. No foreign material which is apt to get loose or produce irritation is introduced; the plate can be made in any shape; and no secondary operation is necessary, either for securing the graft in case of using an autogenous graft or for the removal of the splint in the case of the use of a metal plate. Gallie has recovered specimens which show the union of plate and pin to underlying bone, with the later laying down of new bone on the surface of the plate and the replacement of dead, by living, bone. At the end of six or eight months all signs of the heterogenous graft had disappeared. What can be better in all such cases where Lane's plates would have previously been selected!

CHAPTER XIV.

Injuries of Nerves.

MANY of the wounded, returning to the Base, are suffering from nerve injuries which were originally complicated by fractures and which now may be accompanied with stiffness of joints.

The most important work performed by Canadians on this class of injuries from the beginning of the war until 1917 was that done at Ramsgate. Since then there have been many important communications. Major Alwyn Smith, an orthopædic surgeon of Winnipeg, presented at the meeting of the Canadian Medical Association held in 1917, a report of fifty cases operated on in the Ramsgate Canadian Military Hospital. As his deductions from these include many of the most important points in the practical surgery of peripheral nerves, I will incorporate some of them in this chapter, holding myself responsible principally for the editing of these. In my self-appointed task, as editor and compiler, I will endeavor, however, to add any suggestions of interest which have been published since Major Alwyn Smith's report became available.

In discussing the operative treatment of nerve injuries, it must be agreed that certain fundamental principles be recognized before any organization or surgeon can be prepared to give efficient treatment. Injuries to nerves may be direct or indirect. Cone, (*Am. Jr. Orthopaedic Surgery*, August, 1918) points out that symptoms are not necessarily due to a direct tear of the nerve; injury of bone and soft parts with consequent scar-formation is frequently responsible for complete or partial paralysis.

Cases of peripheral nerve lesions require uninterrupted treatment for a considerable length of time. If a surgeon is not able to study his case before operation and to assure himself that operative treat-

ment will be followed by efficient after-treatment, he is not justified in attempting any secondary operation for the repair of a non-functioning peripheral nerve.

If an institution is not prepared to furnish for the weeks and months following operation that efficient after-treatment of a patient necessary to assure that all possible functional regeneration and histological repair has occurred, such institution cannot honestly undertake the treatment of such patient; but, on the other hand, should complete arrangements for the treatment of the patient in a suitable hospital.

A military policy which permits soldiers to wander from hospital to hospital, convalescent home to hospital, convalescent home or barracks, is not, in my judgment, fair to the wounded soldier, the country, the medical profession or even the military organization which the country rightly holds responsible for the care of its sons who through the exigencies of a cruel war have had to become soldiers, and for whose care the people will some day rightly demand an account.

In cases of nerve repair surgery must run hand in hand with massage, electrical and postural treatment. These forms of treatment must be carried out with continuity of purpose. It is unfair to permit of surgical intervention without assuring that this is to be followed by approved after-treatment. Good results cannot be obtained by any policy which permits surgical procedures on one continent being followed by convalescent treatment on another continent, in institutions where those in charge can have no real knowledge of the past procedures undertaken in any given case—where lack of continuity characterizes the whole history of the patient's treatment.

It is generally accepted that the sooner damaged nerves are repaired the better are the patient's chances of a favorable result, but, at the same time, operative procedures must be preceded by careful study of the case, and are only indicated

when all chance of secondary infection or the setting up of a latent infection are past.

In my experience of wounds in war the kind of projectile inflicting the wound makes a very important difference. Bullet wounds are less likely to be infected than shell wounds. Bullets are less likely to carry before them infected material which may on any disturbance of the local circulation, be it through secondary operation or otherwise, set up an infection which may, at least, seriously interfere with the results of surgical intervention and possibly endanger even limb or life.

In nerve injuries it has been found that cases due to bullet wounds which have healed rapidly, may be operated on with safety within three weeks from the time the wound is healed. This, at least, was the experience of the Canadian Hospital at Ramsgate. On the other hand, it has been observed that wounds due to shrapnel or high explosive require a longer period of time, more especially if there has been bone involvement or the presence of fine metallic bodies. In these it may be advisable to wait at least three months after the healing of the wounds.

The average time of operation in these cases undertaken by Major Alwyn Smith, at Ramsgate, was five and a half months. The majority of such cases seen by him were shell wounds in patients transferred from other hospitals.

Electrical Reactions.

The conclusions arrived at by Colonel Clarence L. Starr, whose experience included several hundred such cases treated at the Granville Canadian Special Hospital, are these: Cases of definite nerve lesions, examined, the voluntary motor loss carefully noted, as soon as they reach the hospital, are carefully noted, the sensory changes, epicritic and protopathic, and loss of joint sense, worked out; the electrical reactions tested and their reaction to the Jones condenser recorded.

Daily massage and galvanism to the affected group of muscles are prescribed, and examination

repeated at intervals of ten days. If, after a series of such examinations no improvement is noted, and the galvanic response, as indicated by the Jones condenser, is weaker, the lesions are considered complete and exploration is advised.

If there is no sepsis, in cases of bullet wounds two weeks after healing is complete, and in cases of shrapnel or shell wounds with prolonged suppuration, two months after healing is complete, operation is undertaken.

The earlier conclusions of Major Alwyn Smith, who really initiated this work in the Canadian War Hospitals, are here cited:

When a patient with a suspected loss of continuity in a peripheral nerve is presented for examination in an institution fitted for the treatment of such lesions, systematic examinations by faradism and galvanism are prescribed and on the response to the latter usually depends the diagnosis. Stress is laid on the sluggish response to galvanism and to the increased amount of current required to produce it.

Cases showing prompt response to galvanism in some muscles and sluggish response in others supplied by the suspected nerve should be watched for improvement, or otherwise, as a partial lesion may be suspected to exist. Should no improvement occur after six weeks of treatment by electricity and massage, operative procedures should be considered.

In Major Alwyn Smith's cases all lesions which were demonstrated to be complete at the time of operation had displayed loss of irritability and a sluggish response to galvanism before operation. All such cases failed to respond to faradism and the sensory disturbances were anatomically constant.

Whilst a patient is being treated by electricity and massage for a nerve injury, or whilst a patient is being treated by these means before or after operation, the paralyzed muscles must not be allowed to become stretched. They must be guarded by orthopædic appliance or contractures will oc-

cur; and, further, the rule must be made to correct all contractures at or about joints distal to the lesion before undertaking any operative procedures on non-functioning peripheral nerves.

When undertaking an operative procedure on a nerve the operator must begin with the firm determination to secure end-to-end suture, if continuity be lost by a localized area of otherwise irreparable destruction.

When there is marked scar-tissue formation it is advisable to make the incision above and below the scar and to pick up the nerve at the upper and lower levels. At these levels it may be dissected as it passes through the surrounding fibrous tissue. When this has been done a critical examination as to the functional viability of the nerve should be made.

During this examination and during all further dissection the nerve should be held by means of soft sterile tapes.

When a nerve has been isolated by dissection through an area of scar-tissue it should be examined with a faradic current above and below the injury if there is no visible loss of continuity, and below only if such loss of continuity is apparent.

In the majority of cases the surgeon will be interested to note that in complete lesions there is no response to electricity although the electrode may be applied below the lesion. It has been noted that the lower end degenerates in a few days.

When the examination by electricity has been completed, the suspected nerve must be examined by eye and by finger, for although often there is no visible loss of anatomical continuity there is a loss of histological continuity. Often a definite nerve bulb is discovered on ocular examination.

"When a complete severance of the nerve has occurred, one finds a mass of fibrous tissue between the ends adherent to them. As a rule, the ends are bulbed like the ends of nerves in amputation stumps. These were formerly considered fibrous neurofibromata, but can no longer be classed as fibrous

masses. There is more of nerve than fibrous tissue in most of them.

"The fibrous scar between the nerve ends contains young nerves in the great majority of cases. I have found young and adult nerves in the excised pieces in 90 per cent. of cases. This scar is usually wavy, cellular, vascular connective tissue."—(CONE.)

Sometimes the nerve may appear normal to the eye but by palpation a fibrous "block" may be recognizable. Should the faradic current have failed to pierce this "block" it is advisable to divide the nerve at its hardest point and to treat it in the manner about to be described for the union of a divided nerve.*

When a nerve has been divided by projectile or incision it will be found that the cut extremities have degenerated and that they are composed of fibrous tissue and not of nerve tissue. It is useless to unite areas of fibrous tissue which will separate the axones of the injured peripheral nerve. Such procedure would simply result in a "block" in the functional and histological continuity of the nerve.

These areas of fibrous tissue must be excised before nerve tissue can be united to nerve tissue. The best procedure for such excision is to steady the fibrous extremity of the nerve under examination by means of mouse-tooth forceps, whilst a series of incomplete cross sections are made in the substance of the nerve, at a distance of one-eighth inch, beginning at the extremity and carried up or down until healthy nerve tissue is encountered (and the ends bleed slightly).—HADLEY WILLIAMS.

These incisions are made with a sharp scalpel almost, but not completely through, the circumference of the nerve. When healthy nerve tissue is recognized by the protrusion of the bundles of nerve

*Sir Harold Stiles says: "If on stimulating the thickened or bulbous nerve, it is found that the muscular response is fairly good, it is often advisable to incise the involved portion longitudinally in one or two places; if on the other hand, the faradic response is feeble, an exsection should be done to expose nerve fibres free from all scar or neuromatous tissue." (Amer. Jr. Orth. Surgery, June, 1918.)

"tendrils" the last-made incision is converted into a complete section of the nerve.

The amount of loss of nerve tissue should now be gauged and the area to be bridged demonstrated.

"Whenever end-to-end suture can be obtained by any means, nothing should be left undone to bring it about."

Shortage can be overcome in four ways:

(1) By flexion of an intermediate joint, which is applicable to loss of nerve continuity in the lower and upper extremities.

2) By free dissection above and below, which is also applicable to loss of continuity in both upper and lower extremities.

(3) By transplation of the nerve-path to a straight line. This is applicable to the musculo-spinal nerve of the upper extremity.

(4) By dislocation of the nerve. This is applicable to the ulnar nerve at the elbow joint.—ALWYN SMITH.*

When the severed ends of a peripheral nerve are ready for suture a temporary stitch of fine catgut is placed through the nerve ends by means of a fine non-cutting needle at a distance of about half an inch from each extremity. This stitch will give temporary fixation to the cut ends. This will facilitate the permanent suturing, which is done with the finest white sewing silk on the finest domestic needle. (No. 9 Calyx self-threading needle is advised by Major Alwyn Smith.)

Sir Harold Stiles employs the finest linen thread, *viz.*, the No. 160, supplied by Messrs. Turnbull & Wilson, Edinburgh.

The divided ends are then united by a continuous suture carried only through the nerve-sheath. It is important to assure that the cut extremities of the sheath are everted to avoid ingrowth of fibrous tissue. The stay-suture is now removed.

*Lt.-Col. Hadley Williams (Can. Med. Jour., Aug. 1918) reports a case where he, 17 years ago, removed a portion of the humerus in order to permit the severed ends of the musculo-spiral nerve being brought together.

The newly sutured nerve is now either covered with a layer of fascia lata or buried in muscle. Major Alwyn Smith seems to prefer the former. This procedure is carried out by excising a sufficient portion from the thigh, wrapping its inner or muscle surface about and in contact with the nerve, converting it into a complete tube by chromic catgut sutures and anchoring it to the surrounding tissues.

Doctor Peet, a surgeon of Toronto, most interested in orthopædic surgery, has advised the burial of the repaired nerve in an adjacent muscle. The writer has never had an opportunity of carrying out this suggestion, but theoretically it seems to be well worthy of trial.*

The last cardinal principle in the surgical treatment of nerve lesions is to assure that prolonged after-treatment is carried out. This must be given in suitable institutions. As Major Alwyn Smith has pointed out, then, and only then, will the surgical treatment of nerve cases become truly adequate.

We have considered the surgical principles involved in the suture of nerves. Unfortunately space does not permit of a discussion of the operative procedures suggested for the suture of individual nerves. These have been fully dealt with by the Scottish orthopædic surgeon, Sir Harold J. Stiles, and all practicing the surgery of the peripheral nerves are advised to study his work.* (*Am. Jour. Orthopaedic Surgery*, June, 1918.)

When an injury involves one of the nerves of the forearm it may be necessary to combine the suturing of the nerve with a transplantation of one or more of the adjacent tendons.

Colonel Clarence L. Starr (*A. M. Jour. Ortho. Surg.*, July, 1918; *Ibid*, July, 1918) draws our attention to tendon transplantation for irreparable

*Sir Harold Stiles writes: "After suture the nerve should not be ensheathed either with s .cia, facia lata, or cargile membrane, as these materials only serve to promote the formation of cicatricial tissue. The best bed for the nerve is one consisting of fatty cellular tissue or healthy muscle." (Amer. Jour. Orth. Surgery, June, 1918.)

nerve lesions in these words: "The success attending the transplanting of tendons in irreparable nerve lesions is little short of marvelous. In musculo-spiral damage, it is particularly useful and results are almost as satisfactory as complete nerve recovery. In this case the pronator radii teres is inserted into the two primary radial extensors, the palmaris longus into the extensors of the thumb, and the flexor carpi radialis into the common extensor. The result, after proper training, is a complete voluntary extension of wrist, fingers, and thumb."

CHAPTER XV.

Amputations and Amputation Stumps.

THE LAST SUBJECT which should be discussed in a paper dealing with orthopædic surgery in war is what we have learned regarding amputations and artificial limbs. We have learned a great deal. Operations which were considered with great favor in the piping times of peace have not stood the test of war. Experience in war surgery has so well demonstrated the inadequacy of peace-time methods that a memorandum, which suggests the hand of Sir Robert Jones, was published on this subject by the Crown in March, 1916. Much that was published in that memorandum is quoted here, my only authority being that I, by so doing, am simply propagating knowledge which has been collected to help the subjects of the King and his Allies.*

At the same time the subject matter of this memorandum has been elaborated and critically revised by a study of the important work of Mr. Muirhead Little, published in the *American Journal of Orthopaedic Surgery* of April, 1918. From this I have quoted at length, and thus desire to

*Messrs. Harrison, Lons, London, March, 1916.

acknowledge my indebtedness to this surgeon for his valuable contributions to this subject.

General Consideration.

It is a general rule that an amputation stump should be made as long as possible; but the longest stump is not always the most useful to the patient, or the best for the fitting of an artificial limb.

If the bone cannot be well covered eventually, it is better to re-amputate than to allow the flaps to become drawn in, adherent and distorted in the process of cicatrization.

Surgeons and all makers of artificial limbs are agreed in the conclusion that, except in the cases of the hip and the shoulder, where there is no choice, exarticulations do not provide satisfactory stumps for the following reasons:

(1) The articular end of the bone is always more bulky than the shaft; consequently the resulting stump is more or less bulbous immediately after the operation, and becomes still more so as time goes on and the soft parts shrink. It is very difficult, if not impossible, to fit such a stump properly with a rigid socket such as is generally to be preferred. Another objection is that the artificial limb must be wider than the natural one at the end of the stump, and consequently is unsightly.

(2) The joint of the artificial limb cannot be fitted on a corresponding level to the sound limb unless it is placed on the sides of the end of the stump, making the artificial limb still wider than its fellow and increasing its asymmetry.

(3) Large flaps are needed to cover the bone end, and these are often difficult to obtain in such a situation, and are likely to be of low vitality and prone to slough. In this war sepsis has been and is so widespread that osteoplastic amputations, which were becoming usual in civil life before the war, are generally out of the question. There must be very few cases in which the surgeon is sure enough of his asepsis to venture on this procedure.

(4) No doubt the best end-bearing stumps are those in which the section has been made through

cancellous bone, but the fact that the section is through the compact bone and medullary cavity of the diaphysis, has proved no bar to the use of an end-bearing pad. Of course, scars over the end of the bone are not well adapted to bearing pressure, although some of them may do so.

(5) An anterior scar is also objectionable, because in all amputations of the lower extremity considerable pressure has to be borne by the front of the lower end of the stump in the action of lifting or swinging forward the artificial limb. A posterior scar is, therefore, to be preferred in all amputations of the leg and thigh.

(6) In the upper extremity end-scars not adherent are preferable, for here end-pressure does not occur, and leverage is all-important. It is very rarely that outgrowths of new bone, forming spurs, or osteophytes, are of any practical importance. They are very seldom large except in the thigh, and then they are usually found at the inner side of the end of the bone, where they are not exposed to much pressure and give no trouble.

(7) The guillotine amputation,* or amputation without flaps, was originally intended to be a temporary measure, to be followed later by re-amputation and the provision of a proper covering for the end of the bone, but a certain number of these cases have come to us in which the wound has been allowed to heal without any secondary amputation, and with the protruding end of bone covered by nothing but adherent fibrous tissue. In the upper extremity, such scars seldom give trouble, but in the lower extremity, when the soft parts are dragged up by the flexion of the bucket, the nutrition of the scar is interfered with, and it is very apt to break down and ulcerate.—(MURRHEAD LITTLE.)

In other cases a secondary amputation has been followed by adherence of the edges of the flaps to

*During my last year in France, I never did the ordinary Guillotine amputation, always preferring a modified Cuff operation—in which, though Cuff is not so long as recommended, still the bone may be sawn fully two and one-half inches above skin incision. Skin retracting to about bone level—Later traction on skin will cover bone end.

one another, but a broad band of scar tissue adherent to the bone intervenes between the edges of the skin flaps. If the flaps are voluminous they will be infolded, and their edges are separated from one another, thus forming what may be called a bifid stump.

Although there is no drag upon such a scar when an artificial limb is worn, the soft parts are apt to be pressed together, and a troublesome form of eczema often appears on the contiguous surfaces. This condition is due to the secondary amputation having been performed while the tissues were still in too septic a condition for primary union. These premature attempts to produce a sound stump lead to repeated re-amputations, of which some unfortunate patients have suffered as many as seven in the same limb.

Special Amputations.

Upper Arm.

The best amputation is circular, or by short equal flaps, at the lowest possible level. Some shoulder joint movement can be preserved with a stump only two inches in length (measured from the anterior axillary fold), but a shorter stump is for all practical purposes a shoulder amputation. Special care should be taken to prevent (by passive movement) adduction contracture at the shoulder joint.—(Crown Memorandum.)

After amputations through the shoulder joint or through the neck of the humerus (from a prosthetic point of view they are the same), a leather cap or an artificial arm can be fitted over almost any scar, but as the leverage pressure comes mostly on the side of the chest, it is advisable not to leave an adherent scar in this situation. Amputations through the upper third of the humerus offer a very short stump for the attachment of an artificial limb. The muscles of the shoulder, especially the pectoralis major, the latissimus dorsi, and the teres

major, are attached so low down on the shaft as to form insuperable obstacles to the attachment of a socket, but if the attachments of these muscles are severed and the arm kept fully abducted during the subsequent process of healing, a very valuable addition to the available length of the stump can be secured. It is often necessary in such an operation to slide up a flap of skin from the chest wall in order to cover in the axillary wound. Recent experience has shown that after such an operation there still remains ample power of adduction for all practical purposes. In arm amputations length of stump is of the greatest importance, and as the strains which the stump has to bear are mostly lateral pressure from leverage, the condition of the skin over the end of the bone is of much less importance. It is better to save half an inch in length rather than sacrifice it in order to cover the end of the bone with skin, for the artificial appliance does not exert direct end-pressure upon the soft parts such as gives trouble in the lower extremity.—(MUIRHEAD LITTLE.)

Through the Elbow-Joint.

This offers no advantages over amputation immediately above the joint, and the stump is more difficult to fit with an artificial elbow-joint.—(Crown Memorandum.)

Forearm.

The best amputation in this region is at the junction of the middle and lower thirds. Above this point, it is particularly desirable to secure as long a stump as possible. In short forearm stumps, *i. e.*, two or three inches below the elbow, difficulty is experienced, not only from loss of leverage, but from the tendency of the short stump to slip out of the socket of the artificial limb during *active* movements of the elbow.—(Crown Memorandum.)

The muscles on the flexor surface of the forearm and of the upper arm occupy so much space as to hinder effective flexion of an artificial limb. The tendon of the biceps, when this muscle is contracted in flexion, tends to push forward the forearm bucket,

so that a short stump here is apt to slip out of the bucket on flexion. As the muscular action of the biceps is most important, one cannot follow the precedent of the pectoralis major and detach its insertion. Some advantage, however, may be gained by removing the fleshy bellies of the flexor muscles, which are no longer of any use. The most useful stumps of the forearm are those following amputation about the junction of the middle and lower thirds. Lower down than these the parts are often badly nourished and the skin adherent and cyanotic. In all amputations in the forearm care should be taken to prevent firm adhesions between the two bones, and to preserve the two movements of pronation and supination, which can be made useful in a suitable artificial arm.—(MUIRHEAD LITTLE.)

Amputation by short equal antero-posterior flaps is the best. Pressure from the artificial limb occurs only on the circumference of the stump, so that a terminal scar is desirable.—(Crown Memorandum.)

Through the Wrist-Joint.

Amputation through the wrist-joint, though not so objectionable as some other exarticulations, gives a particularly unsightly artifical arm, owing to its extra length. After amputations through the metacarpus, a useful appliance can be fitted, which, by utilizing the flexion movements of the wrist, enables a good grasp to be effected by means of a movable thumb and fixed fingers. It is hardly necessary to say that in amputations lower than this anything that can be saved is worth having, for, even if only a little finger is left, it can be made extremely useful by means of a fixed stump to which it can be opposed. No attempt is made to make such a stump resemble the natural parts in appearance, but in addition to this working appliance, ornamental fingers and a glove can be supplied.—(MUIRHEAD LITTLE.)

Lower Extremity.

Thigh.

When this war began, the case of a man who had suffered exarticulation at the hip-joint was a pitiable one. It is true that some sort of artificial appliance could be and was supplied, but the appliances then available were all of very limited use. Since then, however, experience in the fitting of what is called a "tilting-table" has resulted in such improvements that at the present moment the patient with amputation through the hip-joint is better off than one who has six inches of the femur remaining. This appliance, which is very inappropriately named, consists of a leather socket moulded round one-half of the pelvis, in which the patient sits, and on to which, by means of steel supports, an artificial limb is attached. In locomotion there is no movement corresponding to the hip-joint, but a joint is provided to enable the patient to sit down, with a spring lock for walking. Owing to these improvements, therefore, it appears to the writer that exarticulation at the hip or amputation through the neck of the femur, should be much more often performed than it has been up to the present time. The risk of the operation, if it is performed in steps, need be no greater than that of amputation in the upper third of the thigh. By amputating through the neck of the bone, the difficulties of the operation are diminished, and just as good a stump results as after exarticulation. In an average British soldier, whose height is five feet, six inches, the length of the femur is less than 18 inches, measured from the tip of the great trochanter to the level of the articular surface of the tibia; consequently, the upper third of the bone is only six inches long. Such short stumps are often flexed and abducted, and it is extremely difficult to correct this flexion. Moreover, the stump is not long enough to enable the patient effectively to control the artificial limb. The middle third of the thigh has been the site of nearly half the amputations of the lower extremity treated at Roehampton. The

longer the stump available the better, and end-bearing, that is to say, the support of part of the body weight on the end of the stump, is of great value to the patient. The scar should always, if possible, be situated well away from this surface. A posterior scar is the most favorable. Leverage action of the stump on the leg causes pressure on the front of the bone, and especially near the end of the stump. At the same time it should be remembered that the femur in a thigh stump lies much nearer the outer than the inner side, and the former aspect of the stump has to sustain a considerable amount of pressure against the bucket. External scars are for this reason objectionable and to be avoided. It is preferable to attach the cut muscles or their tendinous expansions to the periosteum at the end of the bone. If the adductor muscles are left free to retract they form a troublesome lump at the inner side of the upper third of the thigh, which hinders satisfactory fitting of the socket. Although these muscles, thus rendered useless by the loss of their points of insertion, will atrophy in time, the process may occupy a year or two. The most favorable positon for an amputation of the thigh from the prosthetic point of view, is the lower third, just above the condyles. If possible, a long hooded flap should be made, giving a posterior scar. The resulting stump should have a good bearing surface. The skin in this region is thick and bears pressure well, and the length of the lever gives good control of the stump. If, as rarely happens, asepsis can be counted on, a Stokes-Gritti operation gives excellent stumps, and is to be recommended provided the patella is securely fixed to the end of the bone.—(MUIRHEAD LITTLE.)

Through the Knee-Joint or Condyles of the Femur.

Amputations through the knee-joint are seldom satisfactory. Even when the scar is well placed, the skin is often adherent and the end of the stump will not bear much pressure. The objections to exarticulation in generaly apply here.—(MUIRHEAD LITTLE.)

*Gritti's Trans-condyloid and Stokes Supra-condyloid Amputations.**

These two operations are often confused. Between them there is this all-important difference: in Gritti's, the section of the femur is made *through* the condyles; in Stokes', at least one-half inch *above* them. In other words, the one operation is *trans-*, the other *supra-condyloid.*

On this point great stress has been laid, and very rightly by Sir W. Stokes, and a comparison of the two operations will convince every one that he *is* correct. If the section of the femur be made through the condyles, the sawn patella will not fit down into place. It will either be drawn up altogether on to the front of the femur, or else will project forwards, somewhat like the half-open lid of a box, at an angle to the board-sawn surface, which is also too large for it to cover, and across and off which it is liable to be shifted by the contraction of the quadriceps, if it has been found possible to get it into place. To effect this, an amount of force will be required which is almost certain to result in bruising of the cut periosteum on the edge of the femur, and consequent necrosis. If, on the other hand, the saw is made to pass a full inch above the condyles, the patella will fall readily into place; it will cover more completely the now smaller surface of the femur, and will remain easily *in situ* here.

Operation.

A tourniquet having been applied, the limb brought over the edge of the table and supported, and the opposite one secured out of the way, the surgeon standing to the right of the limb, with his left index and thumb marking the base of the flap, makes an incision commencing (on the left side) an inch above and rather behind the external condyle, carried vertically downwards to a point opposite to the tibial tubercle, then broadly curved across the leg and carried upwards to a point opposite to that from which it started. This flap having been

*Jacobson.

dissected upwards, together with the patella (after section of the ligamentum patellæ), a posterior flap is cut nearly as long as the anterior. This may be effected in one of two ways, either by the surgeon looking over and then stooping a little (the limb being now raised), next drawing the knife from without inwards across the popliteal space, thus marking out and then dissecting up a skin flap, or by transfixing and cutting the flap from within outwards. Of the two I prefer the first: the latter is the speedier, but less suited to bulky limbs. The flaps being retracted, the soft parts are cut through with a circular sweep a full inch above the articular surface of the femur, the bone is then sawn through here, and the limb removed.

The posterior surface of the patella is next removed with a metacarpal or small butcher's saw. This last step is the only difficult one in the operation, owing to the mobility of the bone; it will be facilitated by an assistant with both his hands everting and projecting the under surface of the anterior flap, so as to make the patella stand out from it.

The vessels—popliteal, one or two articular, and the anastomotic—having been secured, drainage is provided, and the flaps are brought together with numerous points of suture, save at the angles.

The difficulties of fixing the patella have been made apparent to me by a recent case where I excised the knee for tuberculosis. During the operation both the anterior surface of the femur and the tibia were prepared for the reception of the patella which on its part was denuded of cartilage and nailed to its receptacle. The nail became loose by local osteo-porosis before the bones became united by bone and the patella became so tilted that its edge caused a pressure necrosis of the skin covering it.

Leg.

In the memorandum referred to, the authors state that the best amputation through the leg is situated about four inches below the level of the knee-joint, because here it is often possible for the patient to

bear weight directly on the end of the stump, in which case he walks without perceptible limp. At a lower level in the leg (excluding Syme's amputation) it is not often possible to obtain a weight-bearing stump, and the bucket of the artificial limb takes its bearing from the circumference of the leg just below the knee. We are of the opinion that the better functional result of the higher amputation would justify its performance even when a lower site is available. Amputation by an anterior "hooded flap" gives a good stump with the scar behind. A terminal scar should be avoided if possible. (Crown Memorandum.)

On the other hand, Muirhead Little states: A much extended experience, however, has convinced the writer that an amputation at or below the middle of the leg gives a far better result. The additional leverage secured by the longer stump is of such practical value as to outweigh the advantage of the large bearing-surface of the upper third of the leg. The amputation at a point about four inches below the knee-joint corresponds to the amputation at the site of election which was so much favored by the older surgeons; but this amputation was designed to produce a suitable stump for a kneeling leg. Nowadays, the kneeling leg is a last resort in cases where it is impossible to fit a lower leg socket. The gait of a patient with a short leg stump, who is wearing a below-knee leg, is very much better than that of a patient with a kneeling leg.

With a long stump below the knee, it is sometimes possible after the patient has had some practice in walking, to dispense with the side steels and thigh corset. This is obviously of great advantage to the patient, but a stump longer than eight or nine inches is often ill nourished at the end, and the area of bone-end is so small as to offer a poor surface for end-bearing. An artificial limb for amputation in the lower third of the leg is unsightly, owing to the necessary thickness of the socket. It ought not to be necessary, but it unfortunately is

so, to warn surgeons against the practice of sawing through the fibula at too low a level. In the majority of leg amputations which have come under the writer's notice, the fibula has been left too long. This bone bears pressure badly, and should be divided at a level one-quarter to half an inch above that of the section of the tibia.

Experience has shown that below the junction of the middle and lower thirds of the leg, Syme's amputation gives the best stump. If the metatarsus cannot be saved, it is not worth while to preserve a part or all of the tarsus. Chopart's amputation gives a stump which has a good weight-bearing surface, but owing to the preponderating strength of the calf muscles, it sooner or later acquires an equinus deformity, and this tilting results in the scar being pressed against the ground and giving pain. It is impossible to restore the "spring" of the foot by attaching any appliance to the front of the stump, without sacrificing the freedom of the ankle movement.

Foot.

By far the best amputation in the region of the foot is Syme's amputation. Experience demonstrates that no other amputation gives such uniformly good results. Whenever Syme's amputation is feasible, no other amputation (excepting removal of toes) should be performed in the region of the foot. (Crown Memorandum.)

Muirhead Little says: "Very bulky Symes' stumps are to be avoided. The best result is to be obtained by dividing the bones well above the malleoli instead of at the usual level. The section should be made at right angles to the general axis of the whole leg, below the knee."

Amputation Stumps.

The chief requirements of a good stump are:

(1) A good covering for the bone.
(2) Sound healing.
(3) Consolidation.
(4) Painlessness.
(5) Freedom of movement.

Some of the foregoing points must be taken seriatim:

(1) A good covering for the bone. Muirhead Little in critically examining this dictum says:

"This implies that the skin should not be adherent to the bone; that the scar should not be exposed to pressure, and that the blood-supply should be adequate, always remembering that a stump which may do very well by itself is sometimes unfitted to stand the friction and pressure of the socket of an artificial limb.

"In this connection, it is worth remarking that there may be even too much mobility of the soft parts. This occurs when, instead of fixing muscular aponeuroses to the bone-end, the surgeon has sutured the flexor and extensor masses of muscles to each other across the end of the bone, and healing has taken place without adhesion between these aponeuroses and the bone. In such a case if the patient attempts to move the stump, the first effect is movement of the scar to and fro across the end. When a limb is fitted and walking is attempted, a good deal of power is wasted in this movement, and friction between the skin and the limb socket is liable to produce abrasions, etc."

(2) Consolidation. After amputation the stump remains swollen and somewhat tender for a considerable time. Consolidation of the soft parts continues for several months, and if a bucket limb is applied prematurely, it soon becomes loose and ill-fitting from shrinkage of the stump. As a general rule four months should elapse from the date of amputation before any attempt is made to fit an artificial limb. Consolidation may be hastened and the condition of the stump much improved by firm bandaging during this time. (Crown's Memorandum.)

When a stump is sufficiently consolidated to bear weight without either pain or injury, the soldier should be fitted with a "Reducing Test Leg," which is fixed to the stump by a similar basket to that which will be employed with the artificial limb

which eventually is to be supplied to him. This, of course, is lighter, simpler and cheaper than a finished artificial leg. It is all that is necessary for locomotion and the pursuance of a great many useful occupations. It serves a very distinct rôle in the period of readjustment of the tissues after amputation of a thigh or leg and fills a place in the functional education of one who is destined to wear an artificial limb. It should, in my opinion, be employed in almost all patients before measurements are taken for a finished artificial leg. If its advantages had been recognized before, much money would have been saved the community.

(3) Freedom of movement in the joint above amputation. Needless to say, any considerable diminution of the normal range of movement in the joint just above the site of amputation is a drawback. This is particularly objectionable in the lower extremity and especially at the hip, where it is the cause of much discomfort and difficulty in locomotion if an artificial limb is fitted without previous correction of the deformity. Unfortunately, this deformity is extremely common in cases of amputation of the thigh. It is, no doubt, due partly to the fact that the attention of the surgeon is too much occupied with the treament of the serious general condition of most of these patients to consider what may seem to him a trivial detail. Its presence is often not suspected, as it is marked by a compensatory lordosis, and general surgeons are frequently unfamiliar with the proper method of estimating hip contraction by means of hyperflexion of the sound limb. Its production is fostered by the custom of supporting the stump on a pillow, for the greater comfort of the patient. This is sometimes unavoidable, but much trouble might be prevented by daily passive extension of the hip as soon as wound conditions allow of it. (Muirhead Little.)

Limitation of abduction at the shoulder-joint, flexion at the hip and flexion at the knee are the commonest deformities due to muscular contraction

about the joint. These deformities are not always apparent on superficial examination, but, if a methodical search be made, can be demonstrated.

Flexion at the hip can be demonstrated by what is called Thomas flexion.*

As already stated, kneeling stumps are extremely undesirable at the present day; and, therefore, all stumps below the knee should be kept straight in extension and not allowed to become flexed. This applies in principle to all stumps.

Contractures must be prevented by suitable treatment.

Imperfect Stumps.

The following are the most common conditions which prevent or delay the fitting of an artificial limb:

(1) *Sinuses.*—In our experience a persistent sinus is almost invariably due to a necrosis of bone in the end of the stump. Such a condition requires free incision (preferably excision of the sinus track) and removal of the sequestrum before permanent healing will occur. When a sinus is present in a stump more than two months after amputation, a skiagram should be taken (after injecting with Beck's paste if necessary), and a radical operation carried out without further delay. A skiagram will usually show the presence of a sequestrum. A few sinuses are due to non-encapsulated and irritating silk ligatures.

(2) *Painful stumps.*

Pain may be localized or diffuse.

(a) *Localized pain* on pressure is nearly always due to the presence of a bulbous nerve-end near the end of the stump. Sometimes the nerve-end is not bulbous, but spread out and adherent to the bone or to the scar. (Crown Memorandum.) At

* Thomas Flexion.—Flexion of the thigh is often disguised by tilting forwards of the pelvis made possible by lumbar lordosis. If we do away with this tilting of the pelvis, which reposition may be done by flexing the normal thigh, and thus reduce the lumbar lordosis (or straighten the lumbar spine), the thigh under question will be fixed into the position of flexion deformity which has been disguised.

the time of operation these can generally be guarded against by carefully searching for all nerve-ends and cutting them as short as possible.

Muirhead Little says: "The acute tenderness of a painful bulbous nerve is probably due to septic neuritis, for some bulbous nerve-ends in amputation stumps are not painful and give no trouble. As a rule, removal of the bulb, when followed by aseptic healing, does away with the symptoms, but in some cases the newly-formed bulb, in its turn, becomes hypersensitive. In these cases it is probable that active neuritis is still present. Prolonged physiological rest, without the aid of any appliance, will often cure these recurrent cases. In a few, however, the trouble is of central origin. Not only the main nerve trunks, but also the branches of cutaneous nerves may be involved."

Painful nerve-ends are not always evident to the patient until the artificial limb is worn, when the pressure of the bucket may give rise to intolerable pain. They should, therefore, be sought for by the surgeon, and, if present, removed before the artificial limb is fitted.

(b) *Diffuse tenderness* (except in recent stumps) is usually due to periostitis or necrosis. The latter condition, of course, requires operation.

(c) *Pain*, either localized or diffuse, is sometimes due to the presence of sharp bony spicules projecting from the end of the bone. These osteophytic outgrowths are commonest in stumps about the middle of the thigh, and they may need to be removed before an artificial limb can be worn.

Unsound Scars.

Unsound scars, other than those associated with sinuses, are seen more especially in cases in which large areas have been allowed to heal by granulation. A large scar adherent to the end of the bone, though undesirable, does not as a rule prevent the wearing of an artificial limb, but sometimes there

In Amputations—especially of thigh—the bulbous nerve end can be to a great extent avoided by cutting the sheath at least one-half inch longer than fibrils and ligaturing it over end of nerve stump.

is persistent or recurrent ulceration, and reamputation is necessary. In fleshy stumps the drag of the soft parts may cause pain or ulceration of the scar. (Crown Memorandum.)

Acknowledgments.

In closing this series of articles on orthopaedic surgery in war, I wish to express my thanks to those who have helped in the preparation of them. I have tried to give due credit to those whose works I have quoted. I want especially to thank those who have helped me through personal communications.

I want to thank Dr. Francis J. Shepherd, late dean of the Medical Faculty of McGill University, for his suggestion regarding excision of the wrist. I have often wished that I had had an opportunity of submitting for his revision all the subjects which have been discussed in these papers in order that we might have profited by his long experience and surgical judgment.

I owe a great deal to Dr. Royal Whitman, who personally, examined my articles on Weak Feet, Astragalectomy and Simple Fractures of the Head of the Femur.

I cannot sufficiently express my gratitude to Major MacNutt for his communications which have often added an element of personal interest to these papers, which interest has, in my opinion, greatly increased their value.

My thanks are due, also, to Lieutenant-Colonel Brackett and others who have added to the information which I have been able to put before the reader.