An Address

ON

SOME OF THE PRINCIPLES AND PROBLEMS RELATED TO THE TREATMENT OF GUNSHOT FRACTURES.

DELIVERED AT THE QUEEN ALEXANDRA MILITARY HOSPITAL,
GROSVENOR ROAD, LONDON, ON MAY 26TH, 1916.

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IN CHARGE OF A SURGICAL DIVISION); HUNTERIAN
PROFESSOR 1914.

INTRODUCTION.

AFTER nearly two years of military surgery, during the whole of which time I have been especially interested in gunshot fractures, the feelings which are uppermost in my mind are those of interest and hope in regard to a difficult problem, rather than complacent satisfaction about a fully accomplished task.

For many years the vexed questions of fracture treatment have absorbed my attention, and in order to satisfy myself about fundamental principles I had for some time been carrying on experimental work concurrently with clinical practice.

Now for nearly a year I have been placed in the fortunate position of having the control of hundreds of fracture cases in a large general hospital, and by the courtesy of the authorities and of my colleagues I have been able to see much of the work done at other large hospitals in the East. During the greater part of this time I was entrusted with the founding and administration of a central splint factory which brought me into very close touch with a great number of medical officers, and the various conditions under which military surgical work has to be undertaken.

In many ways our conditions of work were ideal for progress in knowledge; we had many men and many minds constantly in intercourse with one another, and we had a large workshop or factory on the premises of the hospital, freely open to all military medical officers, so that the treatment of cases and the manufacture of apparatus went on side by side, the latter being conditioned by the former.

I venture to think that this simple, efficacious, and economical plan might well be adopted in this country, so that in every city where there are military hospitals there should be one or more workshops where all fracture apparatus can be made according to the requirements of the staff, so that every encouragement should be given in the way of the trying of new ideas.

Because, after all, the treatment of severe gunshot wounds under modern conditions is a new problem, and it must be met by new devices. Not that gunshot fractures are a new thing, but since the last great European war we have attained fresh ideals of aseptic surgery, and we have a fresh standard set us by x-ray photography. We realize at once that limbs can be saved which in 1870 would have been amputated; and as we can see shattered bones at every stage in the progress of the case, we cannot allow gross malunion to occur without an attempt not only to save the limb, but to preserve its form and function.

It would be unjust to suggest that the attitude of the authorities is opposed to research and advancement in the Army Medical Corps. The generous provision of pathological laboratories gives ample evidence that they wish to advance knowledge even in its more theoretical and less utilitarian aspects. But it is not sufficiently realized how in matters of everyday surgical practice—for example, the treatment of fractures—there is scope also for research and advance.

These introductory remarks are offered as explanation or apology (if apology is needed) for introducing to you so many new types of splints and other fracture appliances. Every pattern has been worked out according to the demands of experience, but I am fully conscious of the fact that finality has not yet been reached, and that

in every direction improvements are possible both in construction and still more in application.

I do not propose to weary you with any detailed description of these various splints, as this has recently appeared elsewhere, and as I would prefer to demonstrate the apparatus individually to any who are specially interested. But I would propose to discuss certain fundamental principles which seem to me to underlie the whole subject, and to devote special attention to what we may regard as problems not yet wholly solved.

THE PROBLEMS OF WOUND TREATMENT.

It has been well said that every severe case of gunshot fracture presents two stages: in the first there is a wound complicated by a fracture, and in the second there is a fracture complicated by a wound. Whilst it is of cardinal importance to observe that at no stage can either wound or fracture be neglected, it is nevertheless true that the infected wound does claim first attention, and that until it has been restored to a healthy and healing condition it is useless to complete the restitution of the bone form. From the earliest possible moment and until bone union is firm the limb must be immobilized and placed in such a position that the wound can be frequently dressed without moving it, or at any rate without changing the relative position of the bone fragments. The object of this, in the first place, is to prevent pain and further injury to the soft parts by the ragged fragments of bone. When bone healing takes place the immobilization is necessary to secure proper form and union.

Having secured, then, immobilization of the limb, we have to consider very briefly the main points to be observed in the treatment of the wound.

In the early period—that is, within forty-eight hours of the injury—the ideal to be followed would be that every wound, except the clean through-and-through bullet wound, should be disinfected by excision and the removal of foreign bodies. At a period of a week or ten days after the injury disinfection of wounds seems hopeless, and a selective method must be adopted, leaving those alone in which infection is quiescent and opening up those only in which it is active. It is easy to state this principle, but it is a matter of some difficulty to carry it out correctly. There is no doubt that a ragged shell wound with a retained missile must be opened up early and freely, and equally that clean perforating wounds should be left alone; but there is a large class intermediate between these which gives trouble and anxiety. There has been a bullet wound, the missile is retained and lies some distance from its point of entry. To open up the whole wound track would involve a very large incision and the exposure of fragments of bone to fresh infection.

A great many such cases do very well without any incision, but sometimes disaster may attend upon temporization. I give two examples of the latter:

One was a man with a small bullet wound in front of the thigh, four inches above the knee, a comminuted fracture of the femur, and retention of the bullet which lay behind the fracture in the middle of the thigh. For a fortnight he seemed to be doing well, except for an irregular temperature. Then a swelling occurred in the thigh, and this on incision proved to be a large very foul abscess, caused by the *Staphylococcus aureus*. Subsequently he had a secondary hæmorrhage, and died of septicaemia in spite of amputation.

The other had had a shell wound through the middle of the thigh, and the fragment of shell had been already removed, but the wound of entry was ragged and unhealthy. A drainage tube was inserted into the latter, but in spite of this the whole thigh became infected, and had to be opened posteriorly by incision, which extended from the knee to the buttock. I am glad to say that he eventually made a good recovery, but it would clearly have been much better to have opened up the unhealthy wound at first.

The only safe rule to pursue would seem to be to open up all cases in which there is any doubt. An irregular temperature, local tenderness, a rising leucocyte count, and an infection by the streptococcus, *B. pyocyaneus*, coliform or gas-producing bacteria, are all facts which require immediate operation.

As to the method of operation, it can only be said that nothing is really satisfactory except laying open the whole track of the wound down to the bone, and doing so in such a manner as to leave it widely gaping, so as to be independent of tubes or wicks for drainage. In the thigh the ideal situation for drainage is between the vastus externus

and the biceps, and by a partial transverse incision of both these muscles a wound is formed which by its position and its tendency to be kept open by muscular contraction is self-draining. As to the manner of dressing, it seems to me that loose gauze packing, with the addition, it may be, of salt bags or tablets, is best, and of tubes for irrigation where these may be necessary. As far as possible, deep pockets should be opened up so as to form shallow saucers, but this is not always possible, especially on the inner side of the thigh or in any situation where lie the great vessels or nerves. If a deep pocket has to be left, very special care must be taken in drainage. If a tube only is left, then a troublesome sinus results, whereas gauze packing to keep the cavity open is painful and difficult. A great help in this case may be found in the use of a special plugging instrument which I believe was invented many years ago for packing the uterus. It consists of a metal tube and a stylet terminating in a Y-shaped fork, and can easily be improvised. The tube is inserted at the bottom of the cavity to be packed and the ribbon gauze is pushed in by the stylet, the shape of the point always advancing the gauze as it is moved up and down in the tube.

I express no opinion about the relative advantages of various antiseptic or lymphagogic medicaments because most of my experience has been in the treatment of cases ten days after injury, at which time disinfectant treatment is almost hopeless. At this stage it seems to me that mechanical drainage and lavage must be the all-important elements of treatment by which the tissues can disinfect themselves.

The Question of Amputation.

The natural inclination of every modern surgeon at the beginning of the present campaign must have been to save every wounded limb, and never to amputate until forced to do so by the threat of death either of the wounded patient or his wounded member. But, laudable as is this inclination, it may be carried too far, and I would direct this criticism against the practice of the only surgeon with whose methods I am really intimate—namely, myself. On looking back over the surgical experience of the last two years nothing gives me more regret than the thought of how, in attempting to save shattered limbs, lives have been lost which might have been saved by timely amputation.

I believe that this regret will not be vain, because, in looking over my notes, it is not difficult to put forward certain rules for future guidance which will make mistakes fewer in the future. First, then, as to the facts. I exclude cases which have been so desperate in the extent of the wound and the degree of infection that death would probably have taken place in any case, whether amputation had been done or not. Of the remainder, when death resulted from gunshot fractures, which might have been prevented by timely amputation, all my cases fall under two anatomical and four pathological categories. Anatomically they have been injuries of the femur and the humerus; pathologically they have been (1) concurrent infection of the knee-joint; (2) secondary haemorrhage; (3) severely infected wounds of the thigh which could not be fully laid open; (4) loss of a large part of the femur associated with severe infection.

The fallacy which leads to disaster in all these cases in my experience has been the idea that it was safe to delay in the hope of saving the limb, reserving the idea of amputation, then death occurs before this can be done, or soon afterwards. Apparently this factor—that is, the danger of delay—is far greater in the case of septic fractures above the elbow and knee than those below; at any rate, I cannot recall any case of the latter in which amputation was postponed too late to save life.

It is not necessary to say anything further about the first two categories in the above list, but some qualifying remarks are called for about the others.

Sometimes a case is seen with a very septic lacerated wound going right through the thigh, so that the marvel is that the great vessels have not been severed. It may be impossible to open up such a wound without almost cutting the leg off.

For example, such a case came under my care in August, 1915. The wound was foul and sloughing, and passed from before backwards through the thigh at the junction of the middle and lower thirds. The femur was much comminuted. The patient was very ill, suffering from septic absorption and

dysentery. Under an anaesthetic the wound was cleaned as much as possible, and as one could pass four fingers right through the thigh, drainage was very free. Continuous irrigation was carried out, but he died four days later.

In such a case the wound could only have been laid open, by cutting right through all the muscles on the inner aspect of the thigh, which would have left the limb attached only by the soft tissues on the outer side of the leg. Such a procedure would really have been the first stage of an amputation, and if rapid improvement had not followed, then the complete removal could have been effected after a few days.

I think that this should be our rule in such desperate cases, to open up the wound at all costs by a transverse incision, and to amputate later if necessary. This gets over the difficulty and danger of a high amputation performed in a condition of sepsis and collapse. By doing it in two stages, as it were, both the shock and the sepsis are diminished, and there is a faint hope that when the first stage has been done and all the infected tissue excised, recovery may occur. The last category which I have mentioned is that in which a great part of the femur has been lost, either by the original gunshot or by subsequent operations. We have to consider various circumstances before deciding whether to retain the limb or not. If four, six, or more inches of the bone are lost; if the ends of the retained bone are septic, or devitalized—that is, appear to be bare in the wound—and if there are manifest signs of septic absorption, then surely it is better to remove the limb without delay, otherwise the future of such a case promises nothing better than a leg six inches shorter than its fellow, with a flail-like thigh, unless bone-grafting can be done. On the other hand, if any considerable loss of bone has been accompanied by rapid healing of the wounds, and the patient has retained his general health and vigour, it is always worth waiting for a future bone graft.

The Treatment of Foreign Bodies.

On this subject I would only point out two types of mistake which are often made. They represent the opposite extremes of practice. The commonest is the quite unnecessary seeking for inoffensive bullets, simply because these may be shown by an x-ray plate. In relation to a fracture, it is far better not to perform any operation which necessitates extensive opening up of the tissues simply to remove a bullet unless there is clear evidence that the latter is keeping up septic infection. In other words, the removal of a bullet should only be undertaken as a part of the cleaning of an infected wound, and not merely on account of the presence of a foreign body.

The other mistake is of a much more serious kind. It is the postponement of the removal of shell fragments until these can be located by the x rays. If I had not seen so many instances of this, it might be regarded as unlikely of occurrence. A man has a small, obviously infected wound caused by a shell fragment, with no exit. He is sent from the clearing station to ship, and thence to a general hospital for localization of the foreign body. By the time that this is done the most acute, and often fatal, sepsis has been set up. In such cases it is usually only necessary to enlarge the entry wound and insert the finger in order to find the shell fragment, with its fatal accompaniment of septic cloth taken in on its transit.

I have before me a piece of shell an inch and a half square and a third of an inch thick which I removed from a man's buttock seven days after his wound. He died from infection by a colon bacillus. I have seen a man who had travelled for six days with the time fuse of a shell in his shoulder-joint; he died of tetanus a few days after its removal.

The x rays should be our servant and not our master in the treatment of gunshot wounds. Septic shell wounds ought to be opened up without a moment's delay, and if metal fragments are present as an important element in causing the sepsis, they are easily traced.

On the other hand, because the x ray shows us a bullet, we ought not to open up the tissues of a fractured limb unless for the primary draining of a septic wound.

The Treatment of the Bone Fragments.

When in the early stages of the case the wound is opened up in order to provide drainage, or to remove

infected foreign bodies, there are encountered the shattered fragments of the bone, both main pieces of the shaft and many separate pieces. These ought to be treated with the greatest care, and never removed unless there is clear evidence of loss of vitality. Every bone fragment is a potential source of new bone growth. It has been proved both experimentally and clinically that comminuted fractures unite more quickly and more firmly than those in which there are only two fragments. But, on the other hand, a bone fragment is only a source of new bone when it is possessed of a vascular supply. If, therefore, a fragment of bone lies quite loose from all soft parts in a septic wound it is better to remove it. But generally it cannot be demonstrated that a splinter of bone is quite separated from its bed, and then it certainly ought to be left.

These remarks apply only to fragments of the shaft of the long bones. In the case of the articular ends of the bones the matter is quite different. In the shaft our ultimate aim is to restore strength, but near the joints the aim should be mobility, and if the joint is affected the bone fragments must be freely removed. Especially is this the case in the shoulder, elbow, wrist, and ankle. In the knee the problem is more complicated because both strength and mobility are necessary, and it is outside the scope of the present article to discuss this most difficult subject.

But to return to the question of a shattered shaft. If it is important to preserve the small fragments in their vascular bed, much more is it essential to take care of the main pieces of the shaft. Very often a free exposure of the fracture is made, one or other ends will appear to be bare—that is, denuded of its periosteum and soft tissues. But on this account such bare bone should not be cut off as if it was dead. It has its own vascular supply, which can be demonstrated by boring a hole into the bare bone, and noting how quickly this will bleed.

This leads to a most important point. In the early stages of treatment I would strongly urge that the less that is done to the broken shaft of the bone and its fragments the better. But later on, when the wound has been freely opened and is granulating healthily, pieces of bare bone may be seen in its depths. This is very frequent in wounds of the tibia, because of the superficial position of the bone. But it also occurs with any long bone if the overlying wound has been opened sufficiently freely. In such conditions, directly infection is over the repair may be greatly hastened by a simple procedure, which I have often carried out both for the femur and the tibia without an anaesthetic. The bare piece of bone is drilled by a $\frac{1}{8}$ -inch twist drill in a multiplying brace. Each hole is continued until it begins to bleed. Then within a day or two it will be noticed that each such drill hole is the seat of a small button of granulation, and before very long the whole bare area of bone will be replaced by bone granulation tissue or pro-callus.

THE RELATION BETWEEN TREATMENT OF THE WOUND AND TREATMENT OF THE FRACTURE.

When I began my work with gunshot fractures I was greatly impressed with the idea that the treatment of the wound and that of the fracture ought always to go on side by side and at the same time, but I am now inclined to modify this to some extent—in the case, that is to say, of fractures associated with very extensive and severely infected wounds. In these cases my present feeling is that the only treatment required for the fracture is that of immobilization with just sufficient extension to secure this until the wound has become healthy. If angulation of the fractured bone occurs in such a way as to bring the fragments close to the surface of the wound, this ought to be maintained or even increased. It greatly shortens the cleaning of the wound and facilitates the drilling of any bare bone that may be present. When nothing but granulation tissue can be seen in the wound, then, and not till then, will the process of bone repair have reached a stage when the relations of the fragments to one another is of any moment.

Two other facts favour this suggestion, and one militates against it. These will now be considered.

First, there is advantage in delaying full extension of the limb during the existence of infection and inflammation in the soft tissues. This is because extension involves tension, and the less tension there is in the tissues, the

easier the drainage and the better the natural resistance of the soft parts against inflammation.

Then, again, it must be admitted that full and adequate extension can only be applied to a limb for a limited time—possibly six or eight weeks. Now, it is quite clear that if we have only a period of eight weeks during which full and adequate extension can be kept up, this ought to be applied at that period when union of the bone is taking place.

In some cases the cleaning up of the wound occupies several weeks, and extension during this time is almost wasted, and then has to be relaxed long before the bone union is firm.

Against this policy of delaying full extension it may be urged that in the period of delay there must occur great contraction of the muscles and fibrous tissue, which will make it much more difficult to restore the position of the bones than if this restoration had been undertaken in the first place. This is a very weighty argument, and it can only be set aside by two considerations: First, that it is not proposed to delay full extension after cleaning of the deep wound has taken place, and during the period of acute inflammation very little fibrous tissue will be laid down; and the second is that by means of steady weight traction applied generally by means of a transfixion pin we have so efficient a means of extension that there need be no fear that it will be inadequate even if delayed, provided, of course, that it is not delayed after bone union has begun.

The Problem of Secondary Displacement.

If a broken bone is allowed to unite with a certain amount of angulation and overlapping or lateral displacement, this union will be by a bridge of callus, and for a very long period after its formation this callus is very feebly ossified, as can be demonstrated by the very unsubstantial shadow produced by the *x* rays. At any time during this period, the bone so united, if subjected to much muscular traction or to the body weight, will bend, and the original displacement will become much more pronounced.

This secondary displacement is common only in the case of the femur, because it is in the thigh only that the forces necessary for its production are present. But in this bone the possibility of secondary displacement is a matter of very great importance, which is not sufficiently recognized. Its importance lies in the fact that any restitution of form in a broken femur which is short of perfect at the time will become a source of serious deformity later on. One often hears and reads of cases of fractured femur so put up that there is less than 1 in. shortening. In the great majority of such, this shortening is not due to an actual loss of bone, but to the fact that the overlapping of the fragments has never been wholly reduced. One can predict with some certainty in such cases that this initial error will later on be greatly increased by further overlapping and by angulation. In other words, if we are content with any method which begins by allowing an inch shortening, we must be prepared to find that the final result is gross malunion, with several inches of error. This applies specially to septic fractures, for although I am aware that ultimately sepsis which has been overcome will produce an excess of callus, yet unfortunately in its early stages this callus is weak and readily yields to displacing forces.

The practical deduction from this consideration of secondary displacement of the fractured femur is that when we undertake its primary reduction we must do so as fully and accurately as possible, knowing that the final result is always likely to be less perfect than the initial.

The Principle of Axial Extension.

It is so generally admitted by all authorities that extension in the long axis of the limb is the fundamental principle in the treatment of septic gunshot fractures that it is not necessary to consider the arguments for this practice. Apart from operative fixation, indeed, it is the only principle which has been seriously advocated for the reduction of fractures which show initial displacement. The only diversity of opinion is as to the method by which extension should be applied and maintained.

In order to put the matter as simply as possible, and to avoid obscuring the issue by details, it may be stated that

there are two main views. According to the one which dominated practice long ago, before *x* rays were known, it was only necessary to pull the limb down to its full length and hold it there by a splint or retentive apparatus until union was complete. According to the other, which, although practised before radiography was invented, nevertheless owes its present position chiefly to the demonstration of its results by the *x* rays, reduction ought to be by the constant but gradual action of a weight or spring acting on the axis of the limb, and this extension force should continue its action until union is firm.

The first method is that of manual extension, followed by a retentive apparatus, and the second is that of constant extension, the joints of the limbs being left free for movements. In order to narrow down the present discussion, it is only necessary to consider the Thomas's knee splint as an example of the first, and the weight extension of the leg, slung in a cradle, of the second in the treatment of a fracture of the femur.

Thomas's Knee Splint.

The limb is passed through the padded metal ring, which takes its purchase upon the tuber ischii. The leg, to which adhesive plaster is attached, is pulled upon and the extension bands are tied to the bottom of the splint.

By this means, which can often be applied without an anaesthetic, it is claimed that the displaced femur is put into correct position and kept there until union takes place. This, indeed, is nothing more nor less than the claim of the surgeon of the old days, before radiography, that he could by a single manipulation "set the fracture" and by a simple apparatus keep it there until union has occurred.

If I doubt whether, when used for a gunshot fracture of the femur in an adult, the Thomas's splint makes good this claim, it is on three grounds. The first will only appeal to those who have been accustomed to operative treatment of fractures. But I would ask such to recall the common experience of even a recent simple fracture of the femur exposed under full surgical anaesthesia. Is it the case that by a single act of traction from the foot the bone readily falls into good position? Quite the reverse. It is usually a most difficult and strenuous task to replace the bone in full length and alignment even when guided by the hand and eye. Is it likely, then, that the same manipulation can effect this result so easily when the bone lies buried and inaccessible in the soft parts?

My second reason for doubt is that, though I have recently seen a fair number of cases treated by this splint, I have never yet seen one in which gross displacement had been corrected by it. On the other hand, in the great majority this displacement was unreduced.

My third reason is that those who commend its use either do not give any statement as to the length of bone attained by it, or else make use of such expressions as: "In the presence of free suppuration, half to one inch shortening may be regarded as the average."²

A further reason for thinking that satisfactory restitution of form does not always result from the use of the splint is to be found in the fact that so many have added to it some device by which a more efficient extension may be obtained. For example, Wallace and Mayberry have added a screw winch at the lower end by which the limb can be further extended. And Major Hull depicts in his book on *Military Surgery* (Fig. 9, p. 65) an arrangement by which an elastic band ties the lower end of the splint to a pole fixed below the bed, so that the fixed extension of the original splint may be supplemented by a constant elastic traction. (This is, of course, to adopt the principle of a Hodgen's splint.)

If there is reason to doubt whether the original traction on the leg accurately "sets" the broken femur, still more is it open to question whether such a correct position can be maintained for the six, eight, or twelve weeks occupied in firm union of the bone. It only needs a little slipping of the adhesive plaster, a little stretching of the adhesive bands, a little giving on the part of the soft tissues over the tuber ischii, to allow the powerful thigh muscles still further to drag the bone fragments out of position.

And when used for a gunshot fracture with a large wound, the leg has to be raised every day for purpose of dressing, and this movement alters the relative position of the femur to the tuber ischii, and therefore modifies the extension every time. That a hard ring round the thigh is

an uncomfortable device for a tender and inflamed leg would seem obvious, and it is very difficult to keep it from becoming soiled either by faeces or by wound discharges. If it is once soiled it cannot be replaced without taking off the splint, and this, too, must gravely imperil the position of the fractured bone. In this connexion, too, it may be noted that in spite of general assertions to the contrary, the discomfort of the thigh-ring is acknowledged by the advocates of the Thomas's splint, for in the same illustration to which I have just referred in Major Hull's book occurs the significant statement: "This elastic traction also relieves the patient of the pressure of the ring on his groin."

Continuous Extension.

It has always been recognized that it is the pull of the muscles which is mainly responsible for the element of displacement of a fracture which is most difficult to reduce. That this muscular tension is constant and elastic in its action, and not merely reflex or voluntary, is proved beyond all doubt by the difficulty in overcoming it when the patient is under full anaesthesia and the bones exposed in the course of an operation. Now, how is it possible to overcome this elastic tension of the muscles except by a constant traction in the axis of the bones?

If a constant weight extension (of 15 to 20 lb.) be efficiently applied to a recent fractured femur, so as to really pull upon the lower fragment, it will be found that within forty-eight hours the resistance of the muscles has been overcome and the bone has been restored to its full length or a little over. This is not a matter about which any doubt can exist after it has been put to a practical test. On a recent occasion I was able to demonstrate it to a number of medical officers. I showed them every case of fractured femur then in the hospital, numbering 36, and in every single case the bone presented the full length or from half to three-quarters of an inch increase. I do not suggest that this means that every case made a perfect recovery—as a matter of fact, some died and some had to submit to amputation—but nevertheless it served as a convincing demonstration that the system of continuous weight extension really and infallibly produced full reduction of the displaced bone; and, further, it can also be demonstrated that the reduction thus effected can be comfortably and fully maintained for three months.

The details of this method I need not go into, as I have so recently described them elsewhere.³ There is no difference in principle between the system which I am advocating and that of Hodgen, Bardenheuer, Codivilla, Steinman, and of the Balkan splint. It is merely a matter of practical detail. For example, the cleverest splint for a fractured femur ever invented is that of Hodgen, but inasmuch as it involves a system of accurate balancing and of unstable equilibrium, it is difficult in practice to carry out well, especially when there is a large wound which requires frequent dressing. The wire cradle splints which I have designed are perfectly simple, and being self-contained can be perfectly adapted for transport.

Now, what is said against this method of constant extension? It is alleged that when a weight is tied to the end of a leg every movement of the patient alters the tension, which becomes in this way not constant but intermittent. But this is certainly not the case if the limb is properly slung and the weight made to act by a cord which runs properly over a pulley. However the patient moves the weight moves too, so that if he pulls himself up the weight is pulled up, always keeping just so much tension on the muscles, neither more nor less. Counter-extension is made not only by the body weight, but by a broad padded flannel bandage round the sound thigh, tied to the head of the bed. This has the advantage not only of preventing the patient being pulled down the bed, but also of keeping the pelvis tilted up on the sound side, so as to secure abduction of the fractured femur—a matter of cardinal importance when the fracture is in the upper part of the bone.

The whole point of difference between the two systems of manual reduction with a fixation apparatus and constant extension lies in the possibility of overcoming muscle tension by a constant pull and the impossibility of doing this adequately by a single momentary act, and what applies to the initial reduction of the fracture applies with tenfold force to the maintenance during the long period of four to twelve weeks occupied by the consolidation of

the bone. It has also been said that the constant extension involves constant pain. This is not the case. If the full weight be properly applied under an anaesthetic, then it is usual for one dose of morphine to be given to the patient, and after twenty-four hours he is perfectly comfortable, apart from symptoms associated with his wound.

Other points of importance in the weight extension system are, first, that the limb is from the very outset kept with all the joints semiflexed, and this in itself is of great advantage because being the position of physiological rest it secures that no group of muscles is placed at maximum tension. And, second, all the joints, hip, knee, and ankle, being left free from bandage or strapping can be kept exercised throughout the treatment so that when the femur has united the joints of the limb are supple, and the muscles well nourished.

Transfixion.

It will be noted that in the above discussion I do not refer to transfixion as a cardinal element in the extension method advocated. In my opinion it is not essential in the early stages of fracture treatment, though it is more reliable than any other method in certain situations. These are in the majority of fractures of the femur and in a few of the fractures of the lower leg bones. That extension by adhesive plaster alone is capable of reducing and retaining every kind of fracture has been long ago demonstrated by Bardenheuer and his pupils; but the method to be always successful needs considerable skill and experience; it often involves the use of very heavy weights, which cause considerable pain, and the main axial tension often needs supplementing by various lateral pulls, which complicate the method.

These drawbacks chiefly affect the problem of the fractured femur, and therefore for the moment I will confine my remarks to that bone. If, instead of indirectly pulling on the bone by plaster attached to the skin, direct traction is made on a pin driven through the distal fragment, all the above objections are overcome. That is to say, a comparatively small weight (12 to 15 lb.) will suffice to correct displacement fully, and there is seldom any need of subsidiary lateral traction. The method is shown by experience not only to be much more precise in its results, but it is less painful to the patient and it is likely to cause less soreness of the skin. Further, it allows greater freedom for massage of the limb and exercise of the joints. If it is carefully performed and not applied until active infection is over, it involves so little risk of further sepsis as to make its use free from objection. But in many cases it is much better to use both the adhesive plaster and the transfixion alternately rather than be content with one method only. The reason for this is, that it often happens that a long period is required before the bone union is firm. Thus, when severe initial infection occurs, it is better, for reasons above given, to begin with light plaster extension, just enough to secure fixation and alignment of the bone without attempting fully to correct the shortening. Then, when the wound is quite clean, transfixion is applied and the bone held by it for six weeks at full length, beginning by slight over-extension and then allowing the bone to drop back into accurate apposition. This is done by using 15 lb. for ten days and 10 lb. for the rest of the time (provided the limb is in a position of semiflexed joints). After the transfixion has been removed, the union may still be weak and the plaster extension can be reapplied for a further period.

One of the most important variations in the application of transfixion which ought to be made under certain circumstances is the placing of the pin not in the distal fragment of the broken bone but in the bone beyond the next joint. That is to say, in the head of the tibia for fractures low down in the femur or in the os calcis for those near the ankle joint. I have used this method much more frequently lately, and have been very pleased with its results. Whenever either the line of fracture, a haematoma, or a wound lies within a handbreadth of the lower end of the bone, it is much better to transfix below the joint. The objection that this site of transfixion will tend to immobilize the joint and to stretch the ligaments is more than counterbalanced by the freedom from septic infection of the pin-track, and the fact that by pulling apart the joint surfaces, stiffness in the articulation is avoided. Transfixion of the tibia at the level of the

tubercle perforates nothing except skin, connective tissue, and bone, and there is therefore much less tendency to the formation of a septic sore in the soft parts than when a muscular region is perforated. Thus, if six weeks should be regarded as the maximum time for a pin to be left in the condyles of the femur it may remain for eight weeks in the tibia.

It is not necessary actually to transfix the bone in order to get mechanical fixation to it. The same result may be obtained by the use of a horseshoe screw clamp in which a screw is driven into the bone $\frac{1}{4}$ -inch on either side.⁴ I do not use this as a routine because it is a little more complicated and expensive, and because I do not regard the perforation of the bone itself as involving any risk. But it is very useful in one type of case, namely, in a T-shaped fracture into the joint either in the knee or elbow, with fracture of the femur or humerus. In such an injury the clamp presses together the separated condyles, and at the same time affords a fixed point on which traction can be made.

As regards the use of the double transfixion apparatus which I have described elsewhere, I think that its usefulness is very limited in gunshot fractures. If the simple distal transfixion or the screw clamp be first applied and traction adequately made whilst the limb is properly slung in a semiflexed position, it will be found that there is seldom any call for anything further. The chief value of the appliance is in order fully to correct overlapping of the fragments as the first stage of operative fixation.

OPEN OPERATIONS FOR THE FIXATION OF GUNSHOT FRACTURES.

I see no reason to retract anything which I have already published as to the dangers of operations performed upon gunshot fractures in their early acute stage of infection. Any open operation must mean large incisions and multiple drillings of the bone. That they have been followed by wide necrosis requiring amputation has been demonstrated. And thus far no one has brought forward any consecutive series of cases proving the contrary.

If infection is absent, or when it has been cured, the matter stands just where it did for the closed fractures of civil life. But I am bound to say that the experience of the last two years has very strongly convinced me that a careful study and practice of accurately applied extension methods leaves very little scope for open operations.

Unfortunately in the present war there will always remain one large class of case which will require open operations—namely, ununited and malunited fractures of old standing. This is such an important subject that I cannot treat it adequately in this place, but I should like to put one or two observations before you.

The first relates to the restoration of form and length as the first stage of every operation. In an old malunited fracture this may be a matter of immense difficulty, but it can be overcome by appropriate means. These consist in first breaking down the malunion, by an open operation if necessary, and then by applying transfixion and extension, using 25 lb. in the case of a femur, and keeping the limb slung up in a wire cradle. All that I have said above about the immense superiority of a gradual constant traction over a violent momentary one applies here with tenfold force. A malunited femur of three months' standing will require perhaps 200 lb. to restore it by a sudden act to full length, even after the callus has been cut through. This is due to the dense mass of fibrous tissue and the contraction of muscles and fascia. It involves great risk of rupture of the soft tissues and even of the great vessels. But the same thing can be done by 25 lb. by the steady pull of a weight acting on a transfixion pin for one week. Then when the skiagram shows that the overlapping is reduced, an open operation can be performed without undue labour or anxiety.

It will often facilitate this operation if, as its first act, the double transfixion apparatus is applied by placing a pin through the proximal fragment. In this way good hold is secured of both fragments, and by suitable rotation or the extension of one or other lateral screws, the fragments can be accurately moved into any position desired.

The next point is also of great importance. It relates to the necessity of refreshing the bone ends. It is not at all satisfactory merely to cut off the sclerosed terminations,

If only a thin shell of bone is removed, the tissue left behind is often dense and avascular. If a free excision of bone be done this involves shortening the limb. But as Wildey⁵ has shown, a much better way is to drill a number of holes into each bone end, or I would suggest parallel saw cuts, in the long axis of the bone, penetrating for half or three-quarters of an inch until freely bleeding vascular tissue is reached. By this means the active osteogenetic layers of the bone are opened up and rapid formation of fresh callus is secured. This restoration of the active osteogenesis of the bones may well be done at the first stage of the operation before transfixion and extension, and it will then be found in many cases that no further operation will be required.

My next point relates to the use of wire. Since plates have become the fashion wire has fallen into disrepute. Nevertheless, if it is used properly it is often a much better and more efficient means of suture than any other. Stout soft iron wire is, I think, the best material, and when it has been placed round the bones, or better still through them, it should be tightened by means of a special instrument which will prevent any slackness or kinking. The type of fracture in which wiring is much better than plating is the very oblique, that is, when the length of the fracture is three times the breadth of the bone.

My last word in regard to this subject relates to the use of plates. Whether used in a recent or an old case, the plate is nothing more nor less than an internal splint the design of which is to hold the bone in good position until natural repair has taken place. In an old fracture repair will be slow and the natural forces which make for displacement are especially strong. Therefore a long plate applied by a series of "wood-threaded screws" which hold only by a frictional grip is likely to become displaced before it has fulfilled its functions. The use of converging screws of "metal-threaded screws" tapped into the bone, or of opposite bolted plates will give a much more secure and enduring fixation.

If, however, only the ordinary plates and screws are at hand, it will greatly add to the prospects of success if the original transfixion pin be retained and a weight of 10 lb. be left for a further five weeks after operation, maintaining the bone in alignment and thus relieving the screws of the tension which otherwise will probably tear them out before union has taken place.

Bone Grafting.

The most interesting chapter in the repair of fractures is that which deals with their union by means of living bone grafts. This, too, is a subject on which I can merely touch in the briefest manner. It may be taken for granted that there is conclusive experimental and clinical evidence in favour of the use of autogenous grafts, and therefore it need not detain us to inquire as to the relative advantages of these over homogeneous or heterogeneous grafts, and much less about the rôle of dead or decalcified bone.

The theory of autogenous bone grafting is by no means settled, but that a freshly taken piece of bone will, when laid into a suitable bed, become united to it and form a living part of the skeleton is beyond all doubt, and the relative importance of osteo-conduction or osteogenesis is of no great practical consequence. But there are several points of practical technique which I am convinced are of paramount importance, but are not sufficiently recognized by surgeons.

First, as to the capacity of the graft. It has, I think, been proved that a graft can grow without any periosteal covering, but, on the other hand, if it has periosteum on one surface it will grow better and more surely. In other words, periosteum is not essential for vitality, but it will afford a ready means of interchange between the vessels of the graft and its bed. Another point which is quite certain is that a living piece of bone will not act as a centre of new bone growth if it is implanted anywhere in the tissues, and that if it lies loosely movable it will remain indolent and inactive.

Just as in plant grafting, so with bone—the graft must be firmly implanted in an active tissue of like structure and firmly held there, otherwise neither union or growth will occur.

The non-recognition of this fact has led to a long series of disappointing results in intra-medullary bone-grafting for fractures. A piece of bone is taken, and loosely placed in the medullary cavity of two bone fragments of the fracture without firm adequate fixation. The result is a constant movement of the broken bone, and a failure of the transplant to take root. When we bear in mind the structure of bone, and how its active elements of osteogenesis are encased in minute canals, it is easy to understand that it is necessary for the graft to be brought into firm contact with its bed for new blood vessels to pass over from one structure to the other. We do not know whether there is any essential difference in the capacity of different bones—for example, the tibia, the fibula, or a rib—to act as a rapidly growing graft, but at present the tibial crest is all the fashion.

Secondly, as to the desirable characters of the bed. If a graft is to have the best chance of taking firmly and quickly it must be fixed to its bed over a wide area, and this area should be richly vascular. In the case of bridging a gap in a bone both these conditions are obtained by cutting a longitudinal slice or sector from each of the fragments to be united. Before fitting the graft on to the surface prepared for it the latter should be scored transversely by a fine saw, so as to provide furrows between the bed and its graft in which pro-callus can at once collect. But though the bony bed is the all-important one, the soft tissues should not be neglected. Scar tissue should be clipped away, and after the graft is fixed by its two ends the tissues round it should be snugly drawn together by catgut so as to avoid any dead spaces. If the periosteum has been preserved on the graft, it will adhere and become vascularized quickly from the soft tissue surrounding it, and this is its chief advantage.

Thirdly, as to suture or fixation of the graft. Recent workers in this subject, of whom the most eminent is Albee of New York, have discarded all metal fixation agents and use only animal ligatures. I venture to think that this may be carried too far; if followed rigidly it will greatly limit the possibilities of bone grafting in the restoration of bones from which a segment has been lost. In the humerus or the femur, for example, if we are to make good the gap, the bone graft, if only tied in place by kangaroo tendon or catgut, will be allowed a degree of mobility which will be very prejudicial to union.

On the other hand, if wire sutures, metal bolts, or even, though rarely, long plates, be used to fix the fracture and the graft, efficient immobility will be secured, and I have never found that these metal structures have given any trouble.

When Albee wants to use a small bone nail he makes it then and there from the patient's shin bone with a lathe. But this greatly complicates the matter and puts it out of the range of practical surgery. One might as well give up catgut and always make sutures or ligatures out of strands of the patient's own fascia. Ivory pegs hold firmly and are ultimately absorbed, and they will prove to be of great use in fixing a bone graft.

CONCLUSION.

In conclusion, if I have spoken to any purpose I have convinced you that the subject of the treatment of gunshot fractures is one in which there still remains many unsolved problems, and I would that I could say this in such a place and in such a manner as to secure further interest in the matter. In all truth it is important enough, for there are tens of thousands of our men, and before the war is over there will be hundreds of thousands, with broken bones.

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THE medical department of the University of Pennsylvania, the Jefferson Medical College and the Medico-Chirurgical College of Philadelphia, have been amalgamated. By their union they form the largest school of medicine in the United States. The total enrolment for the three schools in 1914-15 was 1,126, and the total number of graduates in 1915 was 284.