THE INITIAL SURGERY OF LIMB INJURIES.

BY

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From ancient Egypt comes the earliest account of the treatment of wounds on the Edwin Smith Papyrus which was written in about 3000 B.C. It is a handbook on the treatment of wounds and bruises and was discovered in a tomb of Thebes in 1862. The writer recommends applying fresh flesh kept in place by a bandage for the first day and afterwards dressings of fat and honey. It also contains evidence to show that fractures were treated with splints and that surgical instruments were used at this time.

Hippocrates, living in the fifth century B.C., is the first person to have used antiseptics, for in one of his works he described how he applied tars to wounds.

Celsus, who lived from 25 B.C. to A.D. 50, described a type of wound excision. In his “De Re Medica” he stated: “Now a wound when of long standing should be cut with a scalpel, its margins excised, and incisions made at the same time into any livid areas surrounding the margins.” His teaching did not last long for in the second century A.D. Galen thought that all gunshot wounds were poisoned and advocated that they should be treated by pouring in boiling oil, or by cautery, both the most painful procedures. Without question, this treatment was methodically carried out for the next 1,200 years until the time of Ambroise Paré.

Paré served thirty years in the French Army. His first taste of active service was in the attack on Turin by Francis I in 1537. There were so many casualties in Turin that Paré’s supply of oil was quickly exhausted, and he was only able to treat a few of the cases as Galen had advised. To the others, he was forced to apply “a digestive of eggs, oil of roses, and turpentine.” The following day he was surprised to find that those who had been dressed with the “digestive” had little pain and their wounds were not inflamed, while those who had had boiling oil applied were “feverish,” with great pain and swelling of their wounds.” He decided that gunshot wounds were not poisoned and

1A thesis-submitted for the M.D. of Cambridge University.
"then I resolved never more to burn thus cruelly poor men with gunshot wounds." "Je le parisait; Dieu le guatat," as it is written in Old French "I dressed him and God healed him," was Paré's favourite expression which occurs many times in his descriptions. In his account of the wounded at St. Quentin he described how he found that the ligature was often better than the cautery for controlling haemorrhage in amputations.

About the same time a German surgeon, Wilhelm Fabry of Hilden, near Dusseldorf, acquired much experience during the Thirty Years' War. He introduced the tourniquet and proved the importance of amputating through healthy tissue in cases of gangrene.

Baron Larrey was chief surgeon to Napoleon's army. He recognized the importance of operating soon on battle casualties. He introduced his "ambulances volantes" which were light two-wheeled vehicles drawn by two horses. They could be rushed up to the front line where no heavy ambulance could be taken, so making it possible to collect and deal with the wounded quickly. At this time amputation was the rule for compound fractures and severe injuries. Larrey advised prompt amputation by the guillotine method as soon as it had been decided that the limb could not be saved. At the battle of Borodino he performed 200 amputations.

A contemporary of Larrey was Auguste Nélaton. He invented a porcelain-tipped probe to locate bullets, the porcelain being marked when it touched the leaden bullet. It is interesting that the first person whose wound was probed with this instrument was Garibaldi.

George James Guthrie was Wellington's surgeon and earned the title of "The British Larrey." In 1815 he published his monograph on "Gunshot Wounds." Like Larrey he advised that when amputation was essential it should be performed as soon as possible after injury and certainly within twenty-four hours. His rule appears to have been "When in doubt, amputate," and in his hand this carried a mortality of 50 per cent.

In 1832 Sir George Ballingall published his "Outlines of Military Surgery" which gave a clear picture of the subject before the time of Lister. The usual dressing for wounds was a cold water compress. In gunshot wounds, and especially if they involved a joint, Ballingall had "a very high opinion of the beneficial effects of large and repeated leeching" and he advised that a large supply of leeches should be available in military hospitals. Hospital gangrene, that severe anaerobic wound infection, was very common and in Ballingall's opinion was best treated by the cautery.

He wrote concerning fractures: "The practice of swinging or suspending fractured legs in a sort of cradle, as I have seen in many continental hospitals, might well be extended. It would greatly add to the comfort of the soldier compelled to travel with a broken leg." He also described a method of treating compound fractures which had recently been rediscovered and named "the closed plaster" method. He mentioned, first, how Larrey in Egypt treated compound fractures with cushions or compresses of straw which were left undisturbed until cure was complete. Then he described how "a small boy was brought to my tent in India, having sustained a compound fracture of the leg.
I was preparing to amputate the leg when the parents came and carried him away to a potter who enveloped the limb in clay and finally cured the patient."

The antiseptic method was introduced by Lister in March, 1865, in the case of a compound fracture of the leg. At first he used crude carbolic acid and various forms of putty or plaster "containing carbolic acid." To minimize the irritant action on the skin he used a "protective" such as tinfoil or oiled silk. Later he insisted that everything which touched the wound whether dressings, instruments or fingers should be treated with the antiseptic. In 1867 he published his first results in the *Lancet* under the title "On a New Method of Treating Compound Fractures." He described 11 cases, 9 recovered with life and limb, 1 died, and one had to have the limb amputated.

The introduction of antiseptics and anaesthetics together with the early treatment afforded by the "Field Hospitals" which were started in the South African war prevented the wholesale practice of amputation. Sir George Makins related his surgical experiences in South Africa and his book is "mainly a clinical study of the nature and effects of injuries produced by bullets of small calibre."

However, during the First World War new weapons were used and injuries from shellfire were more dreadful than those caused by bullets. The surgeons had little more than the records of the South African War to guide them and were bewildered by the appalling sepsis with which they were confronted in Flanders. By painfully acquired experience they learned that it was necessary to lay wounds widely open, to remove all foreign material that was readily accessible and to incise deep fascia as a decompressive measure. By 1916 such men as Henry Gray, Rutherford Morison and Carrel were performing secondary sutures. Then came the researches of Shaw Dunn and others showing that gas gangrene was a specific infection of devitalized muscle, and on this basis surgeons began deliberately to remove all dead muscle. Later the importance of the time factor was appreciated and surgical organization was directed towards getting the patient to the surgeon within eight hours.

Surgery was at its height in 1917—when the war was static and lines of evacuation were short (some patients were in London within twelve hours of wounding). By this time delayed and even primary sutures were being performed. There were no sulphonamides and no penicillin—surgeons relied on such antiseptics as hypochlorous acid (Dakin), iodoform (BIPP of Rutherford Morison), permanganate of potash and salicylic acid, while other-agents such as salt bags (Gray), soap solution (Haycraft), hypertonic glucose (Beckwith Whitehouse) were all tried. Gray insisted on splintage and drainage, and all came to realize that cases must be held until the stitches had been removed. Once the war changed to one of movement, as it did in 1918, results were less good, largely because the time factor could no longer be respected.

Stammers writing in the *Lancet* in 1945 drew attention to the influence of terrain on the treatment of wounds. He stated that: "During the present war until May, 1940, casualties in France were few and were being treated according to the technique of 1917, the small numbers made any set organization for delayed suture unnecessary."
"Then came the experience of three years in the desert where evacuation lines were of unheard-of length and the time lag made delayed suture generally impossible.

"It was realized that wounds did not become so foully septic and that gas gangrene was not so common as on the soil of Flanders, and a technique of trimming and of fascial incision for decompression became the one of choice; the old 'excision' was condemned as mutilating. The influence of climate and terrain is very significant here. Compare the soldier wounded in France —wearing a dozen thicknesses of clothing soaked in rain, boots and gaitered trousers impregnated with the liquid mud of a highly cultivated country—with the soldier wounded in the desert, stripped to the waist or wearing only a thin open shirt and shorts exposed to the sun and fighting in the barren sand. It is these factors far more than the sulphanilamides that led to the good behaviour of wounds and that made a less radical operation sufficient to prevent the spreading cellulitis and pocketing of pus later to be seen in Italy."

In North Africa, a cultivated country like France, surgeons adopted an "excision" rather than a "trimming" technique.

In Sicily, surgeons from the desert and North Africa met and there were many differences of opinion regarding treatment. But in Italy wounds did behave differently from those in the desert, and it was not long before all surgeons became more radical.

Debenham had shown how conservative the surgeons in the desert had been. Writing of his experiences there he said that "Extensive operations for flesh wounds have been unnecessary and meddlesome. Wide excision has not been found necessary and a trim is adequate, usually combined with incision of the skin and deep fascia at each end of the wound to assist drainage. Long incisions are only necessary to relieve tension under the deep fascia due to a haematoma."

Working in an entirely different country, Stammers then related how the wounded were treated in Italy. "At the commencement of the offensive in May, 1944, and almost for the first time since 1939, conditions were ideal for delayed suture to be adopted as a routine.

(1) Forward surgeons had learned the best way of treating wounds in Italy.
(2) They had adequate supplies of penicillin.
(3) There was a narrow front with short lines of evacuation along good roads.
(4) Base hospitals were within three hours of the advanced surgical centres.
(5) Base surgeons were fully alive to the advantages of delayed suture and organized accordingly.

"The results have been most encouraging and it is no exaggeration to say that several thousand men have been returned to duty much earlier than they would have been without delayed suture."

He stresses the following points:
(1) Stitches and ambulance journeys are incompatible.
(2) All soft tissue wounds are best splinted for the journey. When muscle
is involved splinting is essential and it should include the joint below the injury.

(3) For major muscle wounds three-day course of penicillin is given. 15,000 units three-hourly intramuscularly or by glucose saline drip.

"Leave flaps of amputation stumps open—even two guiding stitches are likely to result in accumulation of clot which in turn is a source of sepsis.

"Finally after operation the wounds should not be inspected until the patient has reached the theatre of the hospital at which suture is to be performed. In the absence of pain or toxæmia any exposure of the wound at staging posts is meddlesome and will certainly lead to superimposed infection."

Except for the administration of penicillin intravenously I agree with all these observations; but I found that when penicillin was given intravenously it soon produced thrombosis of the vein.

In 1944 Donald, writing of his experience with the Eighth Army, stated that: "Immediate wound suture had no place in these campaigns, except for head and abdominal wounds. Even delayed primary and secondary suture were seldom possible, so long were the communication lines."

In fractures of the lower limb the various modifications of the Tobruk plaster all afforded satisfactory immobilization. Patients with thoracobrachial plasters for immobilizing fractures of the humerus travelled less comfortably.

Amputation was performed to conserve as much tissue as possible. "The exception to conservation is the compound fracture of the tarsus. All but the mildest of such cases require foot amputation sooner or later" and Donald believed that this was better done at once.

As early as 1942 Trueta detailed a "five-point programme" for the treatment of wounds. They were:

(1) Prompt surgical treatment. The risk of serious post-traumatic infection is directly proportional to the time between the receipt of the wound and the surgical operation. Ether is the safest anaesthetic, spinal anaesthesia should never be used in a shocked patient. The amount of anaesthetic given should be the minimum required to enable the surgeon to carry out his task.

(2) Cleansing of the wound. He advocated soap and water followed by iodine to the skin.

(3) Excision of the wound. Without proper excision the wound should not be enclosed in plaster.

"To ensure proper excision the wound must first be enlarged. In wounds caused by high explosives the extent of damage in deeper tissues, particularly the muscles, is often enormously greater than that in the skin and superficial layers, and consequently unless the traumatic opening in the skin is considerably enlarged by incision, excision of the deeper tissues is very difficult and must generally be incomplete.

(4) Provision of drainage—where a deep and narrow cavity remains at the bottom of the wound, counter-drainage must be provided by the insertion of a piece of corrugated rubber through an opening into its most dependent part.
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(5) Immobilization in plaster of Paris cast—this should be applied direct to the skin except over bony prominences.

"Good plaster of Paris is highly absorbent and facilitates the rapid absorption of discharge from the wound."

Few of the accounts I have read on the treatment of war wounds mention the type of anesthetic. I agree that ether is the safest to use in the hands of a not very experienced anæsthetist, but I believe that the anæsthetic is every bit as important as the surgery and in order to obtain good results the best anæsthetists must be sent forward.

I do not agree with Trueta about applying plaster of Paris directly to the skin. This may be all right if the patient is not going to be evacuated and can be watched. But this is seldom feasible during battle, and under these circumstances all plasters must be padded and split, otherwise they are going to give trouble. Twice have I seen gangrenous limbs caused by an unsplit plaster.

In 1943 Professor Yudkin recommended "adequate excision of muscle so as to produce a funnel-shaped aperture for drainage." In late compound fractures of the femoral shaft which are infected he recommended:—

(1) Incision and approach to the site of the fracture from the lateral aspect of the thigh through the vastus lateralis muscle.

(2) Funnel-like excision of this muscle with the apex at the site of the fracture.

(3) Suturing if necessary of the skin edges to the deep fascia.

"The object of suturing skin edges to deep fascia is to prevent premature closing of the wound cavity with consequent pocketing. The skin edges are sutured to suitable deep fascia or often to muscle by means of two or three catgut sutures on each side of the wound cavity. The elastic pull of the skin then tends to retract the deep muscle layer and thus prevents occlusion of the cavity deep in the limb. This suturing should not be undertaken until the wound has been amply treated with sulphanilamide powder. It is essential to prevent any infection under the skin flaps, and this is also guarded against by the use of catgut which will absorb rapidly and enable the skin edges to retract later. This usually occurs in seven to twelve days, during which time the success of the operation is being decided. This procedure seems to lessen the depth of the wound and the depression of the scar afterwards."

I do not agree with this procedure at all. I can think of nothing worse than suturing all the layers of the wound together and so preventing any blood or serum between the layers getting out into the wound. I only quote this suggestion to condemn the method.

Trueta published a second paper on "War Surgery of the Extremities" in 1944. "The first essential is an examination of the patient as a whole, rather than his wounds, in order to assess his condition, and if necessary to commence resuscitation measures immediately.

"First the skin and the wounds are cleansed with soap and water. The use of a small nail brush is essential in removing dirt from the skin and tissues."

He condemned the bold excision recommended by Russian surgeons as
harmful and unnecessary. They were treating wounds as they were cancer, excising widely through healthy tissue and in fact performing a "cancer excision."

"Instead of undertaking the excision of 'contaminated' but otherwise healthy tissue we must concentrate on removing disorganized and devitalized tissues whose blood supply has been impaired."

He did not like the thoracobrachial plaster method, of immobilizing fractures of humerus to the side of the chest, and thought that the arm should be immobilized abducted in a shoulder spica. "The arm of a man in a well-made shoulder spica should require no more space laterally than the thigh of a man in a comfortable sitting position.

"I strongly urge that all wounds and fractures of the upper half of the thigh be immobilized in a well-fitting spica and that the use of the Tobruk plaster be restricted to injuries of the knee and lower third of the femur."

He stressed the importance of elevating the limb after enclosing it in plaster to prevent œdema, and stated that this should be carried out with every limb injury even if it were just a hand.

He condemned the meddlesome surgeons on the line of evacuation who changed plasters for no apparent reason en route. "The first change of plaster should be carried out at base hospitals where the delayed primary sutures are being done."

Truelta recommended the application of a hip spica in certain injuries. I think it is a dangerous thing to apply, and should not be used. Patients in hip spicas travel badly, suffering considerable discomfort en route, and usually have enormous plaster sores when the spica is removed. This is probably due to the fact that it has not been put on properly but during evacuation a hip spica produces sores more quickly than anything else, and so it was condemned. A modification of the Tobruk plaster which I used for high compound fractures of the femur, compound hip-joints or when the buttock was involved, I shall describe at the end of the thesis. It fixed as well as a hip spica, but was not so cumbersome.

Max Page drew attention to the frequent misuse of the word débridement which was appearing in the surgical literature at this time.

"The word 'débridement' used in a surgical sense appears first in French literature in the time of Ambroise Paré, and it was regularly employed by Larrey in his case records from the Napoleonic campaigns. Its significance was consistent with its derivation, viz. to release tension in the tissues by incision; the removal of any foreign body which came to hand was included in the process.

"The word continues to have this meaning in French surgical circles, though it is true that towards the end of the war 1914-18 when early wound excision was introduced as a primary measure, the word 'débridement' was at times used to denote that procedure."

He then suggested that the word "débridement" should be abandoned and recommended that the terms "wound excision" or "wound revision" should be used in its place to describe the initial surgery of a wound.
Mitchiner, reviewing the results of four years of war surgery in 1944, wrote: "The main difference between wounds of this and the last war is that most of the present casualties have large lacerated wounds whereas in the last war a large number of the wounds were from bullets."

He condemned the practice of primary suture, and regarded it as a dangerous procedure.

"In through-and-through joint wounds expectant treatment is often justifiable but this should be accompanied always by immobilization of the limb and extension applied to keep the bony surfaces of the joint separate.

"In those cases in which damage to the great vessels of a limb accompanies severe compound fractures with extensive laceration of muscles it is still best to amputate promptly if the patient's life is to be saved and this applies especially if, in addition, joints have been laid open into the wounds."

He believed that "Syme's amputation has been abandoned more at the behest of the instrument maker than at the discretion of surgeons."

He recalled many Syme's amputations performed in the last war which enabled the patient not only to continue in the Army but also to walk many miles without undue fatigue.

I worked with the Canadian Corps on two occasions in Italy. They asked me to perform a Syme's amputation whenever possible and they preferred it to any other type of below-knee amputation. The reason was that they said they could make a better prosthesis for a Syme's than we could in England; whereas we could produce a better below-knee prosthesis than they could in Canada.

Limb injuries appear to be far more common than injuries to the trunk, probably because many trunk injuries are fatal and do not leave the battle-field. I have only the details of the cases I treated during the Italian campaign—a total of 1,558 cases of which 1,307 were limb injuries. Some of these were of a trivial nature so that if properly treated the men could return to their units within a few weeks.

It was very difficult to obtain a complete picture of each case and to learn the appearance of their wounds at the various ports of call in the line of evacuation. Our only connecting links with the base were the consulting surgeons and the follow-up cards which unfortunately were rarely returned. But our consultants paid us frequent visits, watched us at work, made suggestions how we should modify our technique, and told us about the cases they had seen in the base hospitals which had either done well or badly. The prognosis of each case depended upon the initial surgery, and as limb injuries are so common I propose to describe how I believe a forward surgeon should deal with them. This is my reason for choosing the subject for my thesis.

It would take a very long time to describe in detail the initial treatment of each particular limb injury which may occur in warfare. I have attempted to write about only the main principles and have described the initial treatment of wounds involving muscle, blood-vessels, bone and joints as well as a very brief plan of how to deal with important injuries such as buttock wounds and
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when to perform a primary amputation. These remarks are based on experience gained from treating over 2,000 cases while I was working with a forward surgical team.

Looking back to the time when I first had to deal with war injuries I am now convinced that our treatment was not good. Patients arrived in the theatre insufficiently resuscitated, often had a bad anaesthetic, and I did not excise their wounds properly. It took us a little time to realize all the mistakes we were making, and then we began to form a plan of treatment for all injuries, and our results improved.

I think that I was inclined to rely on sulphanilamide powder rather than surgery in order to produce a clean wound. One of the best lessons I had was when my consulting surgeon told me to do approximately one hundred cases without using any bacteriostatic drug. I can remember thinking to myself at the time that I had to rely on excision alone to produce an aseptic wound, and it certainly made me more careful over my technique.

It often took me longer to excise a large wound than it did to operate on a penetrating abdominal injury. For instance, the largest wound I saw was caused by a hand grenade exploding in the trouser pocket. It had been given to the patient by his platoon serjeant—without the pin. It blew off nearly all his right gluteal muscles, the greater trochanter of his femur, extended halfway down his thigh and up into his loin. It also amputated his right forearm. This wound took me about two hours to excise, longer than I usually spent over a severe abdominal injury.

**Geographic Factor.**

It was also necessary to vary the amount of excision with the local conditions of the country in which the campaign was being fought. In the desert, wounds were relatively clean and required little excision, whereas in Italy and France, where we were fighting over cultivated soil, a much wider excision was necessary in order to produce a clean wound, and in particular to prevent anaerobic infection.

**X-rays and Localization of Foreign Bodies.**

A word about X-rays. They are a help in all injuries, but are not essential, and in fact during a battle it is a great mistake to try to X-ray any other than the most deserving cases. I saw this once attempted at a Casualty Clearing Station where I was attached with my surgical team. There was a queue of wounded waiting to be X-rayed and another queue waiting for their films to be developed before they came into the theatre. Finally many of them were operated on before their films had been developed, so X-raying them had been a complete waste of time. As a rough guide all head, neck, chest, abdominal and joint injuries should be X-rayed. With limb injuries the value of radiology is to show the number and position of the foreign bodies rather than the bony injury; for at the first operation the removal of foreign material is of greater importance than the reduction of the bony deformity which does not matter so much.
When dealing with penetrating wounds of joints it is absolutely necessary to obtain antero-posterior and lateral films before attempting removal of the foreign body. In the knee-joint on two occasions I can remember going through the popliteal fossa to remove a foreign body which was lying behind one femoral condyle. The entry wound in each case was on the anterior aspect of the joint, so that without an X-ray I should not have found the foreign body.

But the importance of X-rays diminishes with the severity of the injury. I found that when dealing with very ill patients, taking films distressed them and it was difficult to obtain good films, so that they were rarely of advantage when they were produced.

**Preparation for Operation.**

After being resuscitated and if necessary X-rayed the wounded man was admitted into the operating theatre. I used to examine his field medical card and question him about his injuries, for occasionally he would tell me about one which had not been entered on his card.

Then I inspected his injury, and if it were a limb, felt for arterial pulsation distal to it. I compared the temperature with the opposite limb and tested for nerve lesions. If he had just an entry wound I would ask him where he was having pain. With this question he sometimes pointed to where the foreign body was lying. In any case I inspected the other side of the limb myself for foreign bodies frequently came to rest under the skin.

The removal of the dressing often required an anaesthetic. A gauze pad soaked in aqueous acriflavine solution was placed over the wound while the surrounding skin was shaved and cleaned. It took two orderlies to clean a limb properly. One held the limb while the other washed and shaved; and they were told to use plenty of soap and hot water for this purpose.

The pad was removed from the wound; the skin painted with flavine in spirit and towels were put round.

**Multiple Injuries.**

As a general rule and with very few exceptions I explored all wounds. But each case must be judged individually, and when I was dealing with multiple injuries I used to operate on the most important ones first, and took a chance with the others, doing only what was essential—such as splitting the deep fascia—rather than subjecting the patient to a long operation. I dealt with the most important wounds in the correct sequence so that the patient was moved as little as possible during the operation, because all movements worsened his general condition and lessened the time I could spend operating.

The time spent over the operation was an important factor, for the patient would stand a certain amount and no more. I had to decide what to do during this period and then stop, otherwise the length of the operation alone might have killed him.

If after excising one or two wounds his general condition deteriorated considerably and there were other wounds still requiring attention—I stopped
operating, tipped up the table so that his head was lowered, covered him with blankets, gave him blood and oxygen and left him for half an hour or so, while I dealt with another case on my second operating table. After this time, he usually recovered sufficiently for me to carry on; but now I had to work fast, for every minute counted.

**THE EXCISION.**

I commenced excision of a limb wound by enlarging it a little in the long axis: then by applying tissue forceps to evert the skin edges I excised the track through the subcutaneous fat liberally, for it always contained a considerable amount of dirt. I left the skin alone except to remove small tags which were obviously devitalized. I opened up the deep fascia in the long axis of the limb. It was the amount of damage deep to the deep fascia which determined how long the incisions had to be made. They must be made long enough, and should always reach to the full extent of the skin incision. I never hesitated to open up the full length of the calf or thigh if I considered it was necessary. When I was dealing with the fascia lata of the thigh, transverse incisions were required as well in order to decompress the muscle adequately. But I avoided transverse skin incisions round a limb. If the track crossed from lateral to medial aspect, I followed it from the lateral aspect as far as possible, then made a counter incision on the medial side and continued the pursuit from here. It is as well to remember that in the leg there is a deep compartment of muscles, which require decompression, when dealing with wounds in this situation. Twice have I seen necrosis of these muscles when the deep transverse fascia of the leg has not been incised.

I avoided incision over bone where the resulting scar had a chance to become adherent and painful. If there were several wounds on one side of a limb with considerable underlying muscle damage, I joined the wounds together even though the resulting incision was rather "S" shaped. It enabled me to open up the deep fascia more fully than if I had attempted to excise each wound separately.

Very small tracks involving only muscle I followed as far as possible, but would not conduct a long search for a small foreign body which in all probability would not give any trouble. I followed the track by vision rather than palpation excising damaged fascia and all muscle which would not contract or bleed.

I think the most difficult wounds to deal with were those caused by blast where large lumps of earth had been blown into the tissues. They were full of nooks and crannies containing dirt, and each one had to be opened and excised. When dealing with dirty wounds I irrigated gently with aqueous flavine solution which washed away most of the dirt—although care had to be taken not to push it more deeply into the tissues.

A good light was essential, preferably a spotlight. After removing the foreign body I carefully inspected the bed in which it was lying, for nearly always pieces of clothing were taken in as well. Sometimes the track did not
ILLUSTRATIONS.

EXCISION OF A WOUND.

Fig. 1.—Cleaning and shaving the limb.

Fig. 2.—The wound has been excised down to deep fascia.
**Excision of a Wound.**

Fig. 3.—After excision and adequate decompression. Compare size now with fig. 1.

Fig. 4.—The type of plaster used for a compound fracture of radius and ulna. Cramer’s wire to prevent pressure on the fingers.
end here but led to another foreign body lying more deeply. The Bosch were keen on laying mines one on top of another, so that our Sappers having removed the first might miss the ones underneath. In a similar way, very occasionally, their pieces of metal entered our men—one following another through the same entry wound. It is important to look for a second foreign body in the bed from where the first has been removed, even though there is only one entry wound.

Thus the track must be followed by vision from entry wound to foreign body, and it was rarely possible to say where it would lead. I remember one man coming into the theatre with what appeared to be small entry and exit wounds of the buttock. They eventually proved to be two entry wounds which led down through the back of the thigh from where pieces of clothing were removed. One foreign body was found in the popliteal fossa and the other in the soleus muscle. It required dissection of most of the structures on the back of the thigh in order to follow these tracks properly. The removal of foreign bodies became more important as our methods of treatment improved. When delayed primary suture was performed as a routine on the fourth to seventh day it became necessary to search for more foreign bodies and so minimize the possibility of infection later.

The size of the entry wound was often misleading and bore no relationship to the amount of underlying muscle damage or to the size of the foreign body. It was impossible to assess the amount of muscle damage from the external appearance of the wound, I think it depended upon the size, shape and velocity of the missile and whether it was rotating. The elasticity of the skin must have been responsible for the fact that I have on several occasions removed a foreign body of twice the diameter of the entry wound through which it has passed.

**Drainage of Wounds.**

My aim was to produce as aseptic a wound as possible, to allow room for the muscle to swell and to provide adequate drainage. Serum and blood oozed from the surface of the wound during the subsequent two or three days depending upon how successful I had been in producing hæmostasis. I tied off all bleeding points with thread, for I found it faster to work with than catgut and as far as I know it did not give rise to any trouble subsequently. Divided tendons or nerves I left completely alone. The well-excised wound should allow any small collection of fluid to drain out of it while the patient is lying on his back. This is most difficult to obtain on the anterior aspect of the thigh: for when the limb is elevated blood and serum collect in the upper part of the wound from where it is impossible to drain. I usually made a counter incision on either the medial or lateral side of the thigh, whichever was nearer to the track, and opened up the deeper part of the wound through this incision. How long this kept open I do not know. I considered putting a rubber drain through in certain cases, but never did this, because I was not sure when the dressing would be changed, and was anxious that the rubber drain did not stay in too long.
WOUNDS OF THE BUTTOCK.

Most buttock wounds require an X-ray examination of the abdomen, rectal examination and collection of a specimen of urine. I often opened up the track completely for through-and-through wounds of the buttock when this did not entail dividing thick muscle. I think this was a wise procedure, because the amount of muscular damage to the glutei, lying between small entry and exit wounds, surprised me; and this is impossible to excise without opening the whole track. Dirt and clothing hide themselves away between the coarse muscle fibres and cannot be seen without an adequate exposure. It also enabled me to see injuries to the superior and inferior gluteal vessels which are not uncommon, for torn arteries may be pulsating but not bleeding at the time of excision.

I never had cause to perform a colostomy for wounds near the anal margin, but evacuated such a case to a centre, where delayed primary suture could be performed as soon as possible. While excising a buttock wound I sometimes found the track going through the iliac bone. If I had previously decided that it was probably not a penetrating abdominal injury, I obtained access to the pelvis through an oblique incision about two inches medial to the anterior-superior iliac spine. This is an extraperitoneal approach and few muscle fibres need to be divided, but it enabled me to follow the track after it had entered the pelvis—giving me an excellent view of the contents, and of the internal iliac vessels if they required ligation. On two occasions I can remember following the tracks through the iliac bones and finding large foreign bodies lying by the side of the rectum, retroperitoneally. The rectal wall was a little bruised but everywhere intact. I removed the coccyx in both cases in order to drain the bed in which the foreign body had been lying. Both did well and healed within six weeks. The pelvic tissues very easily become infected and I think coccygectomy should be considered in such cases if this provides drainage for the wound track.

INJURIES TO BLOOD-VESSELS.

My opinion regarding the treatment of arterial injuries changed after I had heard Lt.-Col. Brown read his paper at the Rome Surgical Congress which he called "A Plea for Conservatism in the Primary Treatment of Wounds of the Main Arteries of the Limbs." Until this time, a suspected arterial injury I considered an indication for immediate surgery. I did not ligate the vein as well unless it was injured. But after tying the femoral, popliteal or posterior tibial artery I would split the calf fascia on the postero-medial aspect along its full length. After ligating the brachial artery I usually split the deep fascia on the volar aspect of the forearm, although I do not think it is so important as the calf.

When muscle is deprived of its blood supply it swells, and if it has no room in which to swell, it dies. It is for this reason that it is so important to open up the deep fascia widely in arterial injuries. Gauze dressing is placed on the wound and a posterior plaster slab applied for support. The limb is kept at about six inches below the rest of the body and as cool as possible. It has
lost its blood supply until the collateral vessels open up, which they usually do during the first forty-eight hours if the limb is going to live; and so in order to survive, its metabolism must be lowered—which can only be achieved by keeping it cool.

I ligated the femoral artery on five occasions in Hunter's canal. Only one of these developed gangrene and in this particular case I did not split the calf fascia because at this time I had not realized its importance. Four days after the first operation I had to perform a below-knee amputation; the skin in the flaps looked viable, but after dissecting away all the dead muscle I found that I was left with only the medial head of gastrocnemius. I thought that this was sufficient to make a stump but unfortunately the skin sloughed further and he had to have a thigh amputation at the base hospital. The case was interesting because I heard from other surgeons that in their experience the medial head of gastrocnemius is the last to become gangrenous in ischaemia of the calf. It appears to have a better blood supply than the other calf muscles. I think it was a forlorn hope trying a below-knee amputation with this case, and I should have saved the patient another operation if I had performed a thigh amputation at first.

I had three popliteal arterial injuries. One I repaired with silk and he did very well. The other two I ligated and split the calf fascia, but one of these developed gangrene necessitating a thigh amputation. The second got away with his leg, but what he was like eventually when walking about, I do not know.

Thus before the Rome Surgical Congress my practice was to operate on all suspected arterial injuries and either ligate or very rarely repair them. But I do not think that this was the soundest treatment. I now believe that a small wound involving the artery to a limb which is not bleeding externally and in which the swelling is not increasing should be left alone and watched: so that if possible the patient can be evacuated to a vascular centre where the traumatic haematoma can be dealt with, and this gives a better chance of preserving the limb.

**Compound Fractures.**

I was taught to remove all loose pieces of bone and bone denuded of periosteum. But I am sure this is not always necessary and is, in fact, bad treatment when dealing with the long bones of the limb: for eventually any deficiency here has got to be filled up with a graft and bone chips. I think it is better when dealing with long bones to leave all loose pieces of bone in order that they have a chance to revascularize and act as grafts: aided by penicillin most of them did, and healed without becoming infected.

After excising the patella the extensor muscles to the knee-joint are lengthened relatively, so that full extension can never be performed. I only excised the patella if it was severely comminuted. When it was fractured along one of its lateral borders I excised the loose fragments and left the main part of the bone alone.

Good drainage is essential in fractures of the femoral shaft. There is always a fair amount of oozing which cannot be stopped and this must have a channel
in order to drain away, otherwise it becomes infected. An incision down to the site of the fracture along the postero-lateral aspect of the limb is often not sufficient. I used to make transverse incisions and cut away healthy muscle in order to make quite certain that this posterior drainage channel remained widely open when the limb was in plaster.

**Compound Joint Injuries.**

Approximately 2 per cent of the injuries I treated involved the knee-joint. I will describe their treatment as an example of how to deal with a joint injury:

Antero-posterior and lateral films must be taken to localize the foreign body. Minute through-and-through wounds required only aspiration of the haemarthrosis and introduction of 50,000 units penicillin. Severer injuries, where there was considerable loss of articular cartilage and destruction of the joint, required amputation. All other wounds I excised. I used to open up the joint fairly widely in order to have a good look inside, removed the foreign body, and loose bits of cartilage or bone, then washed away blood with saline. I closed the synovial membrane, then stitched up the fibrous capsule, but left the remainder of the wound open. I injected 50,000 units of penicillin into the joint, applied dressings and a Tobruk plaster. The joint usually required a second aspiration and injection of more penicillin about the third day. In order that the joint could be inspected easily I used to cut a window in the plaster over it and fasten the loose piece of plaster in position with a bandage.

The types of knee injury which became infected were those associated with T or Y shaped fractures of the femur or tibia, i.e. where the track had passed through the femoral or tibial condyles (and taken dirt with it). It is not easy to clean a track through cancellous bone, and following up my cases at the base I found that it was this type of injury which was most likely to go wrong. I think when there is comminution of the tibial or femoral condyles you have to consider primary amputation, depending upon the amount of damage to the articular cartilage and how much dirt has been taken in.

Compound fractures of the os calcis and other tarsal bones often require primary amputation. It is impossible to excise them properly and I usually had to resort to nibbling away bits of bone and irrigation if I decided to leave the foot.

**The Hand.**

Injuries of the hand require the minimum amount of surgery and only enough need be done to produce a clean wound. Protruding sharp ends of metacarpals or phalanges should be trimmed so that they are smooth and easily covered with skin. It is as well to remember that the thumb is the most important digit and as much of it as possible must be preserved. I never sutured divided tendons or put in any skin sutures. A difficult skin flap of the hand I tried to hold in position by the dressings alone.
The Initial Surgery of Limb Injuries

Amputations.

During December, 1944, 46 traumatic amputations of the lower limb were admitted to a British Casualty Clearing Station. They had been caused by the box telemine and they all had similar injuries. In each case the foot had been forcibly dorsiflexed and dislocated forwards through the ankle-joint. Often the foot was missing or might still be attached with some of the extensor tendons. The muscles were torn from the tibial and fibular shafts and pushed up near the knee-joint. Sometimes the anterior tibial vessels were torn high up in the calf as they pass through the intermuscular septum.

Fat embolism following telemine injuries was rare—I only saw one case in about a hundred such injuries. Whereas during the Gothic line battle when we were dealing chiefly with antitank mine injuries, fat embolism appeared to be fairly common. Out of twelve traumatic amputations caused by antitank mines three developed fat embolism clinically. One of these three died and the diagnosis confirmed at post-mortem, the other two survived.

Apart from traumatic amputations the two main indications for performing a primary amputation are to save the patient's life and to remove a useless limb.

When a patient is admitted to the theatre with only limb injuries—a clue to the possibility that he may require amputation is a message from the field transfusion officer stating that he has not responded well to resuscitation. With limb injuries, after haemorrhage has been controlled, this failure of response may be due either to gross trauma pulpung muscle or to gas gangrene.

If in spite of resuscitation he were going downhill I would put on a tourniquet just above the wound excluding the damaged tissues from the rest of the body. After this procedure such a case improved sufficiently to amputate proximal to the tourniquet, and after the operation when I examined the limb there was always a great deal of muscle damage or evidence of anaerobic infection.

Unless it is unavoidable I would never amputate an arm at the first operation. The main deciding factor is the amount of damage to the brachial plexus. Even if there had been extensive damage to an arm I tried to patch it up, and give it a chance, for it could always be amputated later.

The patient may stand you fixing up his arm, but if he has a leg injury as well he may not stand a second lengthy excision. The loss of a leg does not matter so much. I usually left leg injuries to the last, so that if his general condition had been exhausted while I had been dealing with an associated abdominal, chest or arm injury, I could either amputate or excise the leg wound, whichever produced the less trauma. A through-knee amputation is the quickest and least traumatic one to perform.

Primary Suture.

Certain wounds are suitable for primary suture, but it is only advisable to attempt this during a quiet period. The patient must be held for ten to fourteen days and the stitches removed before he is evacuated. It is a great mistake to fill all available beds with sutured wounds and then be told to prepare to receive casualties. It should be a general rule not to evacuate any
casualties with the stitches still in position—they travel badly. The ideal case
to perform primary suture is a recent tangential wound involving skin, sub-
cutaneous tissue, deep fascia and muscle. After excision care must be taken
over haemostasis, then penicillin powder is applied, the skin edges trimmed
and brought together with interrupted sutures. No attempt should be made
to suture muscle or deep fascia. The limb is splinted with a plaster slab and
parental penicillin given intramuscularly 15,000 units three-hourly for five days.
After ten days the sutures are removed and dry dressing applied, movements
are commenced and the patient can then be evacuated if necessary.
I did not attempt primary suture when there was a compound fracture and
do not think it should be considered if there is a retained foreign body.

**Dressing and Fixation.**

Finally about the dressing and fixation of limb injuries. After the wound
had been excised I applied penicillin powder commencing in the deepest part
first—muscles and tendons had to be retracted to ensure that the powder reached
all over the wound. Then I put on either one layer of vaseline gauze followed
by dry gauze or dry gauze alone. These must never be allowed to encircle the
limb and if there are wounds on each side care must be taken to leave gaps
between the gauze dressings. Wool can then be wrapped round from a roll
followed by a plaster cast. Nothing under the plaster must encircle the limb
other than cotton-wool. I have had to amputate at least two limbs for gangrene
due to ischaemia by gauze being wrapped around the limb under a plaster cast.
Every facility must be given for the limb to swell and all plaster casts should
be split after being applied.

The two best weapons for fixation are plaster of Paris and the Thomas’
splint. The only time I used Cramer’s wire was in the form of an arch over
the hand or foot to prevent the pressure of blankets.

For muscle wounds of the forearm I applied either a thin plaster cast or
plaster slab which fixed the wrist in the position of strength. But when the
forearm bones are fractured an above-elbow plaster should be used for im-
obilization.

When dealing with muscle wounds of the arm or shoulder, I bandaged the
arm to the chest with two flannelette bandages followed by a few plaster
bandages to keep them in position. I used this also if the scapula was fractured.
But with fractures of the humerus or when the shoulder-joint was involved, I
applied a thoracobrachial plaster with the arm to the side (in order to facilitate
evacuation). If there was a radial nerve palsy—with the wrist in dorsiflexion—
I carried the plaster to the proximal interphalangeal joints on the palmar aspect
of the hand. Full movements of the interphalangeal joints must be allowed,
for these are extended by the lumbricals and interossei, the extensor digitorum
communis acting mainly on the metacarpophalangeal joints.

Muscle wounds of the leg, injuries to the foot and fractures of the fibula I
immobilized in a below-knee plaster cast. When the tibia was fractured the
plaster was carried above the knee and slung on a Thomas’ splint. Muscle
wounds of the thigh I supported on a Thomas' splint, but always applied a Tobruk plaster for fractures of the femur and knee-joint injuries.

If a thigh injury was associated with a large buttock wound, I cut off the ring from a Thomas' splint and attached the lateral bars to a plaster shell for the patient to sit in. The limb rested on the remains of the Thomas' splint and both buttocks fitted into the plaster shell which was fixed around the pelvis with a many-tail binder.

I used this method several times on cases which it appeared would require a hip spica for proper immobilization. It was more easily applied and provided as good fixation. Patients travelled well in this appliance—better than they did in a hip spica.

Except for the fingers and toes which should be left as free as possible, I tried to over-immobilize an injured limb rather than to leave it with little support. Stretcher bearers will respect a leg in a Thomas' splint and treat the patient gently, whereas a thigh wound dressed with a bandage and covered with blankets may be handled roughly and then will arrive back in a swollen and oedematous condition.

For very trivial wounds requiring no immobilization I applied plaster of Paris bandages over the ordinary woven bandages in order to keep them in position. I found that dressings slipped easily during evacuation and it is important to guard against this occurring.

Lastly I always marked the time, details of the wound and operation on the plaster so that whoever received the case at the next port of call could easily find out what had been done when he inspected the limb and the plaster.

**Analysis of Cases (Treated During the Italian Campaign and on Pantelleria).**

<table>
<thead>
<tr>
<th>Category</th>
<th>Total</th>
<th>Deaths</th>
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</thead>
<tbody>
<tr>
<td>Head injuries</td>
<td>18</td>
<td>0</td>
</tr>
<tr>
<td>Facio-maxillary</td>
<td>6</td>
<td>0</td>
</tr>
<tr>
<td>Chest</td>
<td>49</td>
<td>5</td>
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<tr>
<td>Abdomen</td>
<td>61</td>
<td>17</td>
</tr>
<tr>
<td>Abdomino-thoracic</td>
<td>30</td>
<td>13</td>
</tr>
<tr>
<td>Amputations</td>
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<td>5</td>
</tr>
<tr>
<td>Fractures</td>
<td>305</td>
<td>3</td>
</tr>
<tr>
<td>Joints</td>
<td>69</td>
<td>0</td>
</tr>
<tr>
<td>Burns</td>
<td>87</td>
<td>2</td>
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<tr>
<td>Soft tissue wounds</td>
<td>342</td>
<td>7</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>1,558</td>
<td>52</td>
</tr>
</tbody>
</table>

**Amputations:**

7 Above Elbow—1 death.

5 for traumatic amputation—1 died of multiple injuries elsewhere.

1 for severely comminuted radius and ulna.

1 for gas gangrene.

2 Below Elbow.

1 compound radius and ulna.

1 gangrene of forearm muscles.
29 Above Knee—3 deaths.
   6 for traumatic amputation—1 died of fat embolism.
   8 for gas gangrene—1 died.
   7 comminuted femur involving knee-joint—1 died of multiple injuries.
   6 comminuted femur.
   2 severely comminuted tibia and fibula.
41 Below Knee—No deaths.
   20 traumatic amputations.
   7 comminution of tarsal bones.
   12 comminution of tibia and fibula.
   2 gas gangrene.
12 Amputations of fingers and toes.
   6 cases of Bilateral Leg Amputations—No deaths.
      1st, above-knee, bilateral, for gas gangrene.
      2nd, above-knee, bilateral, for severe muscle and bone damage.
      3rd, below-knee, bilateral, for severe mine injury.
      4th, above-knee one side, below-knee other, for traumatic amputation and severe bone damage.
      5th and 6th bilateral above-knee for gas gangrene.
7 Deaths from Soft Tissue Wounds were due to:
   1st, external iliac vessels ligated, whole of lower-limb ischaemic. Patient died four days later—could probably have been saved by a through-hip amputation, for he must have been absorbing toxins from the limb the whole time. He had no other injury and certainly appeared to die from a severe toxaemia.
   2nd, subclavian vessels ligated—a German Prisoner of War, died soon after operation and probably was not transfused sufficiently.
   3rd and 4th died of anuria, both had considerable muscle damage.
   5th and 6th died of blast injury to lungs.
   7th vomited during induction of anaesthetic and died before operation—an elderly Italian civilian.

All these cases were operated on under field conditions sometimes just within, sometimes just out of, shell range. Post-mortem examinations could not always be performed, due either to pressure of work or to the difficulties under which we were working.

Most limb injuries were evacuated immediately they came around from the anaesthetic and only the very severe ones were held. So it is difficult to give an accurate picture of every case and the ultimate result. This may account for the fact that the mortality was so low. Total number of limb injuries treated during the Italian campaign was 1,394, out of which 17 are known to have died.

I only know of one of my cases developing gas gangrene when he reached the base hospital, there may have been more but I was never told of any others.

During this war the transfusion service developed and played an enormous part. I purposely have not mentioned anything about the treatment of wound shock or "cold hypotension" as some people prefer to call it, because it is really another subject and one which is not yet fully understood. However, given adequate resuscitation worse and still worse injuries came to the theatre fit for operation. I remember one transfusion officer saying at the end of the Italian campaign that he thought he could keep any severe limb injury alive as long as they did not develop anuria or fat embolism later. I do not think that the forward surgery in this war was very different from the forward surgery...
performed towards the end of the first world war. In this war it was the transfusion officers and probably improved anaesthesia which lowered the mortality and allowed more severe injuries to be dealt with.

REFERENCES.


