

**AN ANALYSIS OF 230 CASES OF OPEN FRACTURE OF THE
LONG BONES TREATED BY OPERATIVE METHODS.**

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JUST because so much can often be done to save a limb of an individual who has sustained an injury that in itself is serious, but which is liable to undergo still more serious complications unless great care is exercised in its management, open fractures of the long bones form an extremely important type of injury, and one that possesses a surgical interest little short of that associated with any other form of traumatism.

There are few cases which afford a better test of aseptic methods; where everything goes well, nothing can be more satisfactory; though it must be admitted that, even where asepsis is absolutely maintained, the union of a fractured bone is often delayed considerably beyond what one looks upon as the average time in the case of a closed (simple) fracture. But when asepsis is not obtained, cellulitis, central medullitis of the bone, etc., leading to general infection in one case, or to necrosis of bone fragments in another, is the result; and the patient may only recover after an amputation of the injured limb.

The difficulty regarding asepsis is not only met with in those cases due to direct violence in which infective material is so frequently carried into the wound immediately; in those fractures also which are "open" in consequence of a fragment being driven through the soft parts from within, it is a quite common occurrence to find that the end of the penetrating bone is thoroughly well ingrained with dirt from the outside; and these cases, in fact, require treatment every bit as careful as do the direct injury fractures.

I have thought it might be worth while to publish some details regarding the results obtained in the treatment of those cases of open fracture of the long bones that have come under my care at the Glasgow Royal Infirmary. My plan of procedure, from the time when I first had an opportunity of dealing with these injuries, has been to operate in some manner upon every case of open fracture; and I find that there have been admitted to my wards, in all, 230 patients who sustained open fractures of the long bones, and received treatment for these injuries. I have, however, excluded those cases in which the general state of the patient on admission was so serious that death took place before any real treatment could be directed to the injury of the limb; and all cases of open fracture of the bones of the hands and feet have also been excluded.

Of the 230 cases under my care, 207 were males and 23 were females, a proportion of 9 to 1.

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Table I.—THE AGE OF THE PATIENTS AFFECTED, TAKING THEM BY DECADES.

AGE	NUMBER OF PATIENTS
0-10 years ..	11
11-20 " ..	38
21-30 " ..	52
31-40 " ..	47
41-50 " ..	43
51-60 " ..	24
61-70 " ..	13
71-80 " ..	1
Not noted ..	1
Total ..	230

In 168 cases the injury was caused by direct, and in 61 by indirect, violence, while in 1 case this question could not be determined. The nature of the direct violence is indicated by the table below.

Table II.—CAUSES OF INJURY DUE TO DIRECT VIOLENCE.

NATURE OF INJURY	NUMBER OF CASES	IMMEDIATE AMPUTATIONS	SECONDARY AMPUTATIONS
Railway	35	30 (including 12 avulsions)	3
Tramcar	5	5 (" " ")	0
Pit hutch	7	3	1
Fall of stone in pit ..	22	4	0
Lorry, cart, etc. ..	22	5	1
Crush	43	6	3
Machinery	17	11 (including 4 avulsions)	4
Direct blow	9	0	0
Dynamite explosion ..	4	1	0
Bullet wound	1	0	0
Fall on arm	3	0	0
.. ..	168	65 (including 18 avulsions)	12

Table III.—SITE OF FRACTURE AND NUMBER OF IMMEDIATE AMPUTATIONS.

SITE OF FRACTURE	NUMBER OF CASES	IMMEDIATE AMPUTATIONS
Upper arm	39	20 = 51·2 per cent
Forearm	31	9 = 29 " "
Femur	21	4 = 19 " "
Leg	139	33 = 23·7 " "
Total	230	66 = 28·7 per cent

This list brings out the lamentable damage inflicted in the cases of open fracture of the upper extremity, no less than 29 immediate amputations being

required in 70 cases (= 41·4 per cent); it also shows, as one would expect, the great preponderance of the fractures of the leg-bones.

This list further shows that 66 immediate amputations were necessary; all but one were cases of direct violence; and 18 of them were instances, either of complete avulsion of a limb, or of such separation of a limb that a segment was only attached to the main portion by a few strands of tissue or a tag of skin, when no other course of treatment was possible than to endeavour to get as good a stump for the patient as one could.

I have thought it right to include the cases of avulsion; for, although any attempt to save a limb under these circumstances is necessarily precluded, they complete my series of "immediate amputations" for injuries involving fracture of the long bones.

In the single case of immediate amputation on account of *indirect* violence, there was a fracture of the leg-bones, with extensive comminution, in a patient who was the subject of locomotor ataxia.

Of the remaining 65 patients who required immediate amputation, 30 had been injured by railway accidents, 5 by tramcars, and 11 by machinery; while all the cases of avulsion were due to one or other of these three agencies.

In a large number of the cases in which an immediate amputation was necessary, the state of the soft parts, rather than the degree of injury to the bone itself, was the factor which determined the amputation; although in the case of the railway and tramcar injuries, the bone was, as a rule, so smashed that no other line of treatment could be entertained. The injury inflicted by the wheel of a tramcar is very serious; it will be observed from *Table II* that all the five cases of direct injury by tramcar required immediate amputation.

Table IV.—SITE OF THE AMPUTATIONS.

SITE OF OPERATION	IMMEDIATE		SECONDARY	
	NUMBER	DIED	NUMBER	DIED
EXARTICULATIONS				
Hip	—	—	1	0
Knee	6	0	2	1
Shoulder	11	2	0	0
Elbow	1	0	0	0
AMPUTATIONS				
Interscapulo-thoracic ..	1	0	0	0
Humerus	11	2	3	1
Forearm	4	1	1	0
Femur	15	2	9	2
Leg	12	0	3	0
Total ..	61	7	19	4

Five cases of double amputation complete the total of 66 immediate amputations. These were as follows:—

One case, at the knee and through the femur (recovered).

One case, at shoulder and humerus (died; had fracture of the skull).

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Two cases, through femur and leg (1 died of shock).

One case, through both femora (died of sepsis, following gangrene of skin which had been stripped—*vide infra*).

Of the 66 patients who underwent an immediate amputation, 10 died, (15·1 per cent). Three of them died from shock, one being a case of double amputation. Four died from head injuries, three of whom certainly had a fracture of the skull (one of these three patients had a middle meningeal hæmorrhage, which was relieved by trephining; another had a double amputation, at the shoulder-joint and through the humerus); the fourth patient was also believed to have a fracture of the skull. One died from chronic Bright's disease. One patient had severe general bruising and scalp wounds. One patient, who required a double amputation (through both femora), developed gangrene of the skin, which had been stripped at the time of the accident off the posterior aspect of both limbs and off both buttocks. He died of sepsis following upon this gangrene.

There were, in all, 19 secondary amputations, with 4 deaths (21·05 per cent); but in only 14 of these had an attempt been made to preserve the limb. In the case of the remaining 5 patients, no endeavour was made to save the limb for the following reasons: In 3 cases the general state of the patient on admission to hospital was so serious that amputation, which was recognized as being the only possible means of treatment, could not be carried out; 1 patient refused to allow an amputation at first, but recognized later that it was unavoidable; 1 patient sustained an open fracture of a femur, from indirect violence, in a limb in which a resection of the knee-joint had been made twenty years previously; he came into hospital fourteen days after the accident, with well-established sepsis.

Four of these five patients recovered. The fifth patient died; one of his lower limbs had been jammed in a hoist, and became affected with acute spreading gangrene. The limb was amputated at the trochanters, as being his only chance, but it was unavailing.

There remain, then, from my series of 230 cases of open fracture of long bones, 159 patients for whom an attempt was made to save the limb.

The technique employed in all these cases has been on somewhat similar lines, but a more extended operation has been made in some cases than in others.

The original wound in the skin and subcutaneous tissue is excised, and the deep wound in the soft tissues opened up freely, so that all pockets are made thoroughly accessible. Muscle, fascia, and periosteum that is found ingrained with dirt is freely cut away, and any particles of dirt that are seen are picked out with forceps. The bone is thoroughly examined; if necessary, the fractured ends of the main fragments are turned completely out of the wound, and the extremity or surface that shows dirt ingrained is chiselled off. Small fragments of bone that are separated from periosteum are generally removed, but if attached to periosteum every effort is made to preserve them. Large fragments, however, are always preserved, whether attached to or separated from the periosteum; if these are soiled, the infected surfaces are removed, and those fragments that are loose are kept in saline solution until the wound is

ready for their re-implantation. It is specially important to preserve and re-implant these large fragments when they represent the "third fragment" of a "flexion" or a "spiral" fracture; for if they are not preserved, two pointed, and often narrow, ends of bone are left to come into proximity, and a pseudarthrosis may result; or if union does eventually take place, it will probably occur with considerable shortening.

I believe that in every case in which an extensive interference on these lines has been carried out, I have employed some form of "fixation" of the bone fragments; the "fixation" being effected in some instances by wiring the main fragments, in others by the use of "plates," and in others, generally in the case of a small fragment (e.g. a portion of an articular surface) which has been fractured off, by the use of a screw, to fix the small to the large segment of the bone. By the term "fixed," or "fixation," I refer to one or other of these three methods.

In a certain number of the cases—which, for reasons to be given later, I have decided to include in a separate category—the surgical interference has not been of quite such an extended character as in the former class. The original wound in the skin, however, is always excised, and the deep wound opened up; but, beyond picking or cutting out dirt particles introduced from without, as little interference with the soft parts is made as possible; ingrained bone is always chiselled off, but no "fixation" of the bone has been employed.

It is the writer's strong conviction that every effort should be made to close the wound in all cases of open fracture that are operated upon. This can often—generally, in fact—be done at once without any tension being put upon the parts around; but if there be evidence of tension, lateral incisions are made to give sufficient relaxation to the skin and subcutaneous tissues; and these incisions are always made in cases where there is considerable undermining of the skin, as so often occurs in the patients injured by direct violence.

But unless one feels very confident regarding the aëpsis of the wound, it is far better to leave it open than to suture it. This means delay in the healing, but no harm will result provided any bone or fascia or tendon that is exposed is kept moist (for if these tissues are allowed to become *dry*, necrosis to some extent is sure to follow). Leaving the wound open in these cases does not in any way preclude the employment of a fixing agent; under such circumstances the plates, screws, etc., hold the bone fragments in position until the soft parts around contract and consolidate; and once this has taken place, the plates can be removed without fear of any displacement occurring.

In my practice plaster cases have rarely been employed during the early stages; for "windows" are always required, and they frequently seem to induce œdema of the tissues in the neighbourhood of the wound; and this has often appeared to me to be a cause of delay in the healing process.

The two methods of procedure which I employ do not in reality differ widely from one another. To some extent they correspond to the two broad types of treatment employed by Continental surgeons in dealing with open fractures, and which are spoken of abroad under the terms "debridement" and "conservativ." As I understand these terms, the first is applied to a process which aims at the most complete and thorough mechanical cleansing of the entire wound, though fixation of the bone fragments appears to be

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employed but rarely. While, in the second method, beyond cleansing the external wound and the skin around it, and picking out particles of dirt, as little interference with the wound as possible is indulged in. The writer's "cleansing" process is a more extended one than the "conservative" method; for in all cases the bone is thoroughly examined, and, if need be, "cleaned" by chiselling off all portions that show dirt ingrained in them. It is just possible that this procedure might come under the term "debridement"; but in the cases in which "fixation" has been employed, the manipulation is so much more extended that it appears reasonable to keep the two methods distinct, and to write of "fixing" one class and "cleaning" the other.

Comparing the results obtained in the series of cases which form the subject of this paper, there were 112 patients whose fractures were treated by the more extensive operation of "fixation," and 47 patients treated by the "cleaning" process without fixation.

1. CASES TREATED BY FIXATION.

Of the 112 cases in this class, 9 patients died from the following causes: one of pneumonia; three of cardiac failure; two suffered from chronic Bright's disease; two had severe brain injuries (one of these certainly had a fracture of the skull); one after a secondary amputation (*vide infra*).

Secondary amputation of the limb was required in 7 patients for the following reasons: three because of extensive necrosis of soft parts (skin and subcutaneous tissue mainly) in the neighbourhood of the wound; four because of general sepsis of the wound.

One patient, whose limb was amputated on account of necrosis of skin, etc., died; he was admitted with an open dislocation of an elbow-joint and fracture of the forearm bones, shaft of the ulna and head of the radius. The ulna was "fixed," and the upper extremity of the radius was removed; but the skin of the whole forearm became gangrenous. It was an error of judgment on my part to endeavour to save the limb; it should have been amputated on admission.

The other 6 cases of amputation did well; and the 97 patients whose limbs were saved all recovered with good union of the fractured bones.

2. CASES TREATED BY CLEANING.

There were 47 patients treated by this method, of whom 4 died: one of sudden cardiac failure; one of shock (the patient had an open fracture of one femur and a closed fracture of the other); two patients died after secondary amputation (*vide infra*).

Secondary amputations of the injured limbs were required in 7 of these patients: in four cases, owing to sepsis of the wound; and in three, owing to necrosis of skin, etc.; probably these three ought to have had an immediate amputation on admission. Two of these seven patients died of the effects of sepsis. The others recovered.

It is somewhat remarkable that in each of the two classes of patients, seven should have required secondary amputation; and that this should have been necessary in three patients in each class owing to necrosis of the skin and subcutaneous tissue.

This stripping of the skin and subcutaneous tissue by the violence causing the injury is one of the most important factors to be considered in dealing with such cases, and it is often a matter of very great difficulty to judge how the skin, separated off from the underlying fascia, will react. Where the stripping is extensive, it may in itself constitute the chief, if not the sole, reason for an immediate amputation; for it will almost certainly necrose, and this necrosis will frequently be the forerunner of sepsis. And necrosis of stripped skin will of course be more certain to follow in a wound which has not been made aseptic than in one which is aseptic.

When, in one of these accident cases, one endeavours to preserve a limb from which the skin has been stripped for some distance, the chances of the vitality of the skin being maintained will be increased if incisions are made to permit drainage taking place of any blood, etc., that may be effused beneath it. If small areas of skin along the margins of the wounds necrose, this may only act as a delay in the healing process, without preventing ultimate success as far as the preservation of a useful limb is concerned; whereas, if the entire area of stripped skin should necrose, it may necessitate a secondary amputation.

Taking the whole series of 159 patients for whom an effort was made to preserve the limb, it will be seen that secondary amputations were necessary in 14 cases (8·8 per cent); with 3 deaths (21·3 per cent). Comparing the amputations resulting from the two methods of treatment, there were 7 secondary amputations in the 112 fixation cases (6·25 per cent), and 7 in the 47 cleaned cases (14·8 per cent).

With regard to the cases that were treated primarily with the object of preserving the limb, if possible, and looking at them from the point of view of the effects of direct and indirect violence as influencing the result—and this is an aspect of the question which, in consequence of the varying degree of injury to the soft tissues of the part, is one of extreme importance—we find that there were 100 patients whose injuries were the result of *direct violence*; and that 72 of these were treated by the fixation method, with 6 secondary amputations (8·3 per cent), four of them being necessary on account of necrosis of soft parts and two for sepsis; while 28 patients were treated by the cleaning process, with 3 amputations (10·7 per cent), two being for necrosis of tissues and one for sepsis.

Of 58 patients with fractures due to *indirect violence*, there were 40 who were treated by fixation, with 1 amputation, for sepsis (2·5 per cent); and 18 treated by cleaning, with 4 amputations (22·2 per cent), all being on account of sepsis.

In the case of the remaining patient (bringing up the total to 159), whose fracture was cleaned, it could not be determined whether the injury was due to direct or indirect violence.

It will be noticed that the patient had been injured by direct violence in every case in which a secondary amputation was required on account of necrosis of the soft parts.

There was no instance of tetanus in the whole series of cases; at one time antitetanic serum was injected whenever there was a specially dirty wound; but it has not been employed as a routine practice.

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The length of time required for the treatment of these patients in hospital has often been very considerable. Excluding the amputation cases, I find that those patients whose limbs were saved were in hospital, on an average, for a period of 62·7 days ; the longest period of residence being 200 days.

The question may arise whether it is worth while continuing treatment in these cases over such a period of time, and whether it would not have been better for the patient to have had the limb amputated. An open fracture of a bone in the close neighbourhood of a joint will sometimes lead to some degree of limitation of movement of that joint ; in part owing to effusion, which, however, can usually be readily got rid of ; but more frequently, perhaps, it is due to the difficulty found in exercising the joint during the process of union of the bone. My own opinion is that, even in the case of a lower extremity (and it is these fractures that require the long residence in hospital), when union results with a knee-joint partly limited in its range of movement, a working-man is better off with a limb in that condition than with an artificial one. At the present day, a man who has lost one lower limb has a very poor chance of obtaining employment again. I have made it a custom to enquire of all these people, some time after they have left hospital, as to their own feelings in this matter ; and only one patient—who had sustained a severe open fracture of one femur, and whose limb was saved, but with decided limitation of flexion at the knee-joint, and whose stay in hospital amounted to 125 days—thinks now that he might have been better off had the limb been amputated ; all the others have expressed their satisfaction that their limbs were preserved, in spite of the time required to do so, and in spite of any limitation in movement of joints that has resulted.

In my book, *Fractures and their Treatment*, when discussing the operative treatment of fractures in general, I wrote, *inter alia*, “ I fix most of the open fractures that I have to treat,” and to this practice several of my reviewers took objection ; but I have not seen any reason for departing from it, and I consider that the results obtained are quite satisfactory. The figures quoted show that the majority of my cases have been treated by the fixation methods. I believe that these methods give better results than the cleaning process does ; the fragments of the fractured bone are brought into as accurate position as is possible ; and, because of the free opening up of the wound that is necessary to enable the manipulations to be carried out, I believe a more perfect asepsis is obtained. It will be seen from the figures that have been given that, in the series treated by fixation, secondary amputation was required in 2·6 per cent of the cases on account of sepsis of the wound ; whereas, in the series treated by cleaning, it was necessary in 10·8 per cent of the cases for the same reason.