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THE TREATMENT OF OPEN FRACTURES*

BY

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The principles governing the treatment of open fractures hold good whether the fractures are caused by trauma common in civilian life or by the high-explosive missiles of modern warfare. Certainly war adds many more difficulties to the surgical problems presented by such fractures, as witness the extent of the problem, the severity of the injuries, the delay in bringing in the wounded—adding exposure, dehydration, and loss of blood to accentuate the shock of a painful injury—difficulties of transport and hospital facilities, and finally the especial prevalence of infection, particularly of tetanus and anaerobic infection. That the problem is immense only places it in line with the other problems this country is now facing.

Organization

The first essential to proper treatment is to place an effective organization to deal with each stage and to co-ordinate the entire period of treatment. The great increase of road accidents in recent years presented a similar problem for solution. The British Medical Association report of 1936 and the findings of the Interdepartmental Committee on Fractures formulated four guiding principles necessary for treatment. They were: (1) segregation; (2) unity of control; (3) careful after-care; (4) rehabilitation centres. The creation of a similar organization now both for civilian patients under the Emergency Medical Service and for the war-wounded would seem the first essential. There is nothing new in the problem, and it was solved successfully during the Great War. Robert Jones realized the need, and was able to produce an organization which dealt satisfactorily with the great numbers of severe fractures which came back from France to this country. He insisted on segregation, and, backed by the Advisory Council, he overcame all opposition and formed the orthopaedic centres, where, for the first time, segregation, unity of control, after-care, and rehabilitation were practised. With an organization which controlled in the end some 36,000 beds the fracture problem was solved. All that is needed is to recapture this organization, re-form these centres, and concentrate the patients and the skilled personnel. It is easily possible. It needs only the good will and foresight of those who control the Medical Services of the Fighting Forces and the Civil Medical Service to give us again what we had in 1918. It is interesting to recall Robert Jones's (1925) own words:

"The Great War afforded the most convincing proof of the mishandling of complicated, and even of simple, fractures.

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In the early period these cases arrived home with appalling deformities. Excessive shortening and malunion were the rule. . . . Men with no experience in this branch of work did the best they could, while men who understood how to treat fractures found the conditions such that it was impossible to obtain satisfactory results. They deplored the fact that . . . continuity of treatment was impossible. Fractures of the femur serve as a notable example. . . . In 1916 the mortality from these [open] fractures amounted to 80 per cent., a large proportion of the deaths occurring on the way to or at the casualty clearing stations. Later, when the Thomas splint was applied almost exclusively, and as near the firing line as possible, we have it on the authority of Sir Henry Gray that the mortality in 1918 was reduced to 20 per cent. This is an astounding and inspiring fact, and led Colonel Crile of the United States Army to say that the Thomas splint did more to prevent death from shock than any other single measure.

"The next great advance in the treatment of fractures at the front occurred when we were able to secure the segregation of cases. The country owes a great debt of gratitude to Major Maurice Sinclair. . . . His femurs came over with scarcely any shortening and with excellent alignment. The problems of segregation and of team work had been overcome, with very admirable results. In England, however, we were not in a position to segregate these fractures when they arrived. . . . Splints were removed too soon and often changed unnecessarily, and the good work abroad was thus sadly interfered with. . . . After a time permission to segregate the fractures was granted. . . . Let me emphasize again that the success in the treatment of fractures during the later phases of the war was due to expert supervision, simplicity of apparatus, team work, segregation, and appropriate after-care. These are the lessons the war taught us; are we going to apply them, and improve upon them, or are we to revert to the bad old way?"

In the recent evacuation of fracture cases from the London area we have, in fact, immediately returned to "the bad old way." Fractures from one segregated centre have been dissipated all over the South Coast. Continuity of treatment could have been maintained by their evacuation to a prearranged centre. Skilled personnel are available, and indeed very willing for work. In the present days the many details of necessary organizations to maintain the continuity of treatment could be worked out quietly between the evacuating hospitals (now casualty clearing stations) and their base hospitals.

First-aid Treatment

MECHANICAL TREATMENT FOR QUICK TRANSPORT

The method employed must be both efficient and simple; it must allow easy and painless access to the wound and protect the limb from harm during transport, and the splints must be easily carried by the stretcher party. For these reasons only two splints are advocated: for the arm the swivel ringed Thomas, and for the leg the Thomas knee splint. The method of application of these splints needs no explanation here. There is only one other splint

required to complete the stock of first-aid splints. It is a rather cumbersome piece of apparatus, but it should be available at the casualty clearing stations; it is a modification of the Thomas hip splint known as "Jones's abduction frame," and is used for high fractures of the femoral shaft and hip regions. One simple modification of this splint allows free access to gluteal and pelvic wounds—most difficult regions to treat adequately without the frame. The patient, who lies on this splint, can be lifted and moved without pain, without disturbing the fracture, and the dressing can be changed without interfering with the mechanism of fixation. With these three splints traction is easily applied and maintained, and need not be relaxed for any purpose during the period of transport.

While treatment can be satisfactorily maintained on the Thomas knee splint and the abduction frame, it should be stressed that the Thomas arm splint is essentially a transport splint, and its prolonged use will give rise to permanent stiffness of the elbow, wrist, and fingers.

TREATMENT OF SHOCK

Shock is present in varying degrees in all patients with open fractures, and in its initial stage is undoubtedly due to the pain of the injury. The first-aid treatment of shock is to immobilize the fracture by an efficient splint so that the patient can be moved without further aggravating the pain and increasing the shock. To this purpose the application of the Thomas splint and fixed traction will be undertaken with great gentleness and under the injection of 1/3 grain of morphine for an adult. In those patients in whom exposure, dehydration, and loss of blood have added to the shocked state the first step again is application of the Thomas splint under morphine followed by the administration of hot fluid by the mouth, the application of heat, and, if possible, a period of rest.

WOUND DRESSING

Here our aims are twofold—to cover the wound and so prevent further infection, and to conserve the vital quality of the damaged tissues. A dressing of a non-irritating modern antiseptic such as 1 in 2,000 eufflavine is adequate to both these aims. The use of strong irritating antiseptics such as iodine defeats the last aim, and consequently these substances are to be avoided.

TREATMENT BY SERA AND DRUGS

The main defence against infection of the wound is by early radical débridement. However, the prophylactic injection of tetanus antitoxin and anti-gas-gangrene serum should be made at the first available opportunity. Recent advances in drug therapy have given us sulphanilamide and its derivatives. These drugs are of the greatest value when once infection is established, but their prophylactic value against infection has yet to be proved.

Surgical Treatment of Wound

This stage of treatment should be carried out as soon as possible after receipt of the injury. Early efficient surgical treatment of open fractures is the only means by which we can prevent infection and so legislate to shorten the period of treatment and save the function of the injured limb. Hospitals for such treatment must be as near as possible to the "danger areas." The stages of surgical treatment of open fractures may be summarized as follows:

1. The preliminary treatment of shock up to the stage at which the administration of an anaesthetic is a safe procedure—this stage should be short and should rarely exceed one hour.

2. The prevention of infection by direct surgery at the earliest moment and certainly within eight hours of the injury. This includes the excision of all dead and dying tissues, ingrained dirt, and debris—the vital quality of the tissues left after débridement rather than the use of any antiseptic being the safeguard against infection.

3. The gentle reduction of the fracture. From this stage onwards the reduction is held either by the extension pieces of an orthopaedic table or by a distraction apparatus.

4. The immediate closure of all wounds treated within eight hours of receipt of the injury, either by suture or by skin graft if a skin defect is present. Wounds treated after this period are left open.

5. The application of a soft protective-pressure dressing to the area of soft-tissue damage in order to prevent oedema and death of the tissues from failure of return of fluids from the area of soft-tissue injury.

6. The final immobilization of the fracture in its reduced position. The principle hereafter to be followed is *rest*, complete and absolute. If the limb is placed in plaster-of-Paris this rest is assured—even the most inquisitive cannot remove a dressing placed under plaster! Plaster-of-Paris is used whenever it can effectively hold the reduction, incorporating, if necessary, transfixion pins through the proximal and distal fragments placed at some distance from the site of fracture. For some fractures splints are necessary—for example, in fractures of the shoulder-joint and some fractures of the shaft of the humerus the shoulder abduction splint has its place. For the pelvis, hip, and some high fractures of the femoral shaft the Jones abduction frame is indicated, while for the femoral shaft the Thomas knee splint is the splint of choice. All these splints allow the application of fixed traction, and without this additional aid it is not possible to hold the reduction of some fractures. But the governing principle should be retained—the wound dressings should be left undisturbed. I believe that it is upon the principle of rest that the success of the Winnett-Orr plaster is founded.

7. Complete rest of the injured limb for at least five weeks. The temperature and pulse rate may be somewhat raised during the early stages of this period, but if the general condition of the patient is satisfactory the plaster or dressings should not be removed. If the x-ray picture of the reduction is unsatisfactory it should be remembered that further manipulations undertaken before soft-tissue repair has occurred will most surely inflict additional damage to the limb. Such manipulations should be postponed until soft-tissue repair is sound enough to withstand this additional trauma.

Preparation of Limb for Operation

The undressing of the limb and the removal of the first-aid splint are parts of the surgical procedure, for in every way we must guard against inflicting additional injury. The open wounds are sometimes large and multiple; consequently it is not always possible to shave and wash the limb without further contaminating the wounds. It is safer to cover the limb with a sterile roll of gauze soaked in a suitable antiseptic or in spirit, the areas of the wounds alone being left uncovered. This technique allows us to cleanse the skin in the neighbourhood of the wounds, carry out the débridement, reduce the fracture, and close the wounds by suture, skin graft, or dressing before proceeding to the cleansing of the unaffected areas of the skin prior to the application of the plaster cast or appropriate splint. During the whole of these procedures it is essential that the limb be lifted clear of the table, and for this purpose the traction appliances of an orthopaedic table or a screw traction apparatus of the Böhler type are indispensable.

Anaesthesia

Shock is primarily caused by the pain of these injuries: to relieve the pain is to treat shock. There is no better anaesthetic agent for this purpose than brachial plexus

block by 25 c.cm. of 2 per cent. novocain for the upper extremity and low spinal anaesthesia for the lower extremity, and for patients seen early there is no reason to delay treatment. When the picture of shock has been accentuated by delay, exposure, dehydration, and loss of blood, with a consequent fall of blood pressure to 90 mm. Hg or below, there should be a period of delay to treat such shock adequately followed by anaesthesia by gas-and-oxygen with ether. Spinal anaesthesia in such patients is definitely dangerous.

Débridement

This is another lesson of the last war: "The large-scale experiment of 1914-18 established the failure, relative but none the less unmistakable, of antiseptics. It showed that what determined the fate of a wound was, above all, the vital quality of the tissues exposed to infection" (Leriche, 1939).

In those wounds seen before infection has supervened it is our task to make quite sure of the "vital quality" of the tissues remaining after the débridement. This means an excision of all dead and dying tissues and the removal of all foreign matter from the wound. The main force of trauma in the civilian type of open fracture is inflicted on the skin fat and muscles, and the quantitative sacrifice of non-vital tissues will be in that order. In the injuries caused by the high-explosive missiles of war the skin injury is frequently small and the muscle injury great. In both types the surgical exposure must be adequate to explore the extent of the damage, and the excision of dead tissues must be radical. Fortunately osseous tissue has remarkable powers of recovery; it may be smashed into multiple pieces, but if given a chance it will live. Débridement of bone should never be more than a shaving of periosteum or osseous tissue. Large lengths of bone should never be removed; indeed, it is wiser to amputate than to remove large lengths of the femoral or tibial shaft.

Buried sutures should seldom be left in the wounds after débridement, nor are they necessary. Muscles are damaged almost exclusively in their fleshy bellies where suture cannot hope to repair the damage. Few blood vessels require ligature. With the exception of division of the musculo-spiral nerve in open fractures of the middle third of the shaft of the humerus, nerves are seldom divided in the civilian type of injury. I understand that in war the sciatic nerve is often divided in gunshot wounds of the thigh associated with fractures of the femur. If a divided nerve is encountered in the débridement it should be sutured by the minimum number of stitches of the finest thread or catgut after the fracture is reduced. Such approximation of the nerve ends will save a very tedious exploration at a later date.

Value of Skin Grafts

All skin flaps raised from their connective-tissue beds by the violence of injury must be carefully examined and their vitality proved by demonstrating bleeding vessels from their edges. The débridement of such flaps must be continued until this demonstration has proved satisfactory. In the extremities such excision of skin will invariably leave a defect, for under no circumstance must skin be approximated in open fractures under tension. Often patients have lost areas of skin by the violence of the injury. If such skin defects are allowed to heal by the normal processes of tissue repair, not only is the healing extremely slow, but if the wound is a large one it is associated with permanent deformity in the underlying muscles, with associated loss of function to neighbouring

joints. Furthermore, the final scar, particularly if the healing has occurred under plaster-of-Paris, is of tissue-paper texture and a source of subsequent trouble; indeed, many such scars have to be excised and treated by skin grafting at a later date before sound healing has been attained.

For several years I have grafted these skin defects, and I am satisfied with the results. By skin grafting no time is allowed for fibrous-tissue changes to take place in the underlying muscles, and as a consequence the normal elasticity of the muscle is retained. The grafted area has a particularly healthy appearance; fat is often laid down under the graft, and the area stands up to normal trauma very well.

I have followed two methods of grafting: (1) immediately following the original débridement; (2) at the first change of plaster—that is, three to five weeks after the date of injury. Both methods have given excellent results. The second will be the method of choice during war, when speed is an important factor in treatment at the casualty clearing stations. The graft used is the split skin or Thiersch graft, which can be cut with a razor to quite large dimensions after practice. It must be accurately placed on the donor area and held in position by a firm pressure dressing; then it must be left undisturbed for at least a period of five days, when it will have "taken." The dressing may be kept in position for a much longer period, and can be left under plaster and the usual routine treatment for the fracture followed.

In the "delayed" grafting, the appearance of the granulating surface of the wound and the general condition of the patient are the indications whether or not the graft will be successful. If the granulations are healthy and the general condition satisfactory the graft will live. After a limb has been in plaster for a few weeks it may smell very offensively; if the wound when cleaned presents its usual healthy appearance it should be skin-grafted.

Treatment of Infected Open Fractures

In war many patients will receive their first treatment when the wound is obviously infected. The wounds in such cases should be explored and all foreign matter lying free in such wounds should be removed and adequate drainage established. The fracture should be reduced and held in the reduced position. Although I am a strong advocate of the Winnett-Orr method of treatment for such fractures, this method should be under the continuous supervision of the surgeon undertaking the treatment. Complications I have experienced have included severe secondary haemorrhage under the plaster and the development of gas gangrene under the plaster. Accordingly I believe that it is safer to transport such cases to the base hospitals in the Thomas splint and to allow the surgeon at the base full control of the Winnett-Orr method of treatment.

Open Fractures associated with Other Serious Injuries

Sometimes in civilian practice, undoubtedly more frequently in war surgery, the problem of serious abdominal injury is associated with that of open fractures of the extremities. Under one anaesthesia the immediate treatment must be completed. First the extent and nature of the more serious injury must be explored and treated before it is possible to legislate on the line of treatment to be followed for the fractured extremity. The treatment of the abdominal injury may so take charge of the situation that all that is possible for the open fracture is the application of an appropriate splint. With an ideal organiza-

tion such problems are the sphere of a surgical team, and although I remain a firm advocate of segregation of fracture patients I believe that in the "danger zones" the segregation should only be one department of a general hospital containing personnel capable of dealing efficiently with any emergency.

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THE INTRA-UTERINE DEVELOPMENT OF RESPIRATORY EFFORT*

BY

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The attempt to explore a subject so well worn as the regulation of respiration by approaching it from a new angle is admittedly a daring one; but a fresh approach seems to be the only excuse sufficient to justify the effort. In the present introduction, therefore, I shall put before you some glimmerings on the matter, as a crude attempt made to build it up from the developmental standpoint: developmental not in the philogenic but in the ontogenetic sense—that is, by studying the phenomenon as it gradually unfolds in the life of the mammalian foetus to see what sort of picture we obtain. Study of the regulation of breathing demands an understanding of the phenomenon of respiration, and as that appears to be bound up with the essence of movement itself you must bear with me if I start at the very beginning.

Stage I: The Initiation of Movement

The first neuro-muscular movements observable in the sheep foetus appear on the thirty-fourth day of foetal life—not quite a quarter of the way through pregnancy, which in the sheep is normally about 147 days. The foetus is perhaps the size of the thumb-nail, but it is large enough to admit of the appropriate stimulation of the sensory fields which correspond to the endings of individual nerves. The very first movement to take place is obtained from stimulation of the area just over the lip and under the eye: this corresponds to the position to which the maxillary branch of the trigeminal nerve has grown. The movement obtained is a slight lateral one of the head, and appears to be asymmetrical because the stimulus is asymmetrical: in the next few days the nerve grows down to the snout, at which time stimulation of that organ (involving the nerves from both sides) produces asymmetrical throwing back of the head.

It is interesting at the very outset that a nerve so intimately connected with respiration as the maxillary branch of the trigeminal should be the first to evoke movement.

Stage II: The Earliest Rhythmic Movement

Within the next week, or even the next three or four days, the capacity of the foetus for movement has advanced in quite a number of ways, of which four may be singled out: (1) the sensory area, stimulation of which can evoke movement, becomes much enlarged; (2) the adequate stimulus alters in nature; (3) the extent of the response becomes greater; (4) the response becomes rhythmic. To consider these in a little more detail:

1. Not to go further than the trigeminal nerve, the maxillary branch has now come to innervate a much greater area by, say, the fortieth day than was the case on the thirty-fourth. Moreover, the supra-orbital branch of the ophthalmic division has come into play. Thus, from considerable areas around the snout and eyes stimulation by a glass rod or a faradic current will evoke a response.

2. The repercussion of the enlargement of the sensory field means that a much less intense stimulus if applied to the enlarged area will evoke a response. Thus a drop of saline falling in the eye from no more than a centimetre will initiate movement; or, *in utero*, a current set up by the injection of warm saline into the sac, if it impinges on the face, will have a like effect.

3. As the days pass, more and more muscles become involved in the response. Starting with a simple movement of the neck muscles, it comes to involve the longitudinal muscles of the back; later those of the limbs and tail, as well as those of the throat and trunk: by the forty-second day the diaphragm is formed, and it too is involved.

4. The response has become rhythmic. No movement is sustained for any length of time, but the whole response lasts perhaps a half to three-quarters of a minute, in that it consists of a rhythmic series of individual spasms. Each spasm involves, as indicated above, a great part of the whole musculature of the living foetus. The conditions which determine its periodicity have not been defined.

This perhaps is the place for a word about the phenomenon spoken of as "spontaneous movement." Most users of this phrase, ourselves included, have safeguarded themselves by saying that it means no more from their pen than an admission of inability to ascribe any definite form of stimulus to the movements. The phenomenon is evident enough, and is that in first opening the uterus the foetus as seen in the sac is undergoing rhythmic movements similar to those described above. In view of what has just been said about the ability of currents in the amniotic fluid and slight changes of pressure to produce foetal rhythms, we are sceptical as to the spontaneous nature of these rhythms, using the word "spontaneous" in the sense of something which starts in the central nervous system without the interference of stimuli from an afferent field.

Stage III: The Individuation of the Generalized Rhythm into Somatic Movement and Respiratory Movement

If the rhythm be set up by stimulation of the snout with a glass rod at about forty days the following may be seen. The first, or the first and second, of the individual mass movements which constitute the rhythm differ from the succeeding movements as follows. The extensor element is more pronounced. The head is thrown back—a composite movement which consists of an extensor and a flexor component; in the subsequent movements the extensor component drops out and the head nods forward. During the seventh week of foetal life the two sorts of movements diverge in type, till at the forty-ninth day the initial somatic movement is a long-drawn-out spasm, while the tendency of the subsequent rhythm is for all the muscular movements to be shed except those of the diaphragm, the thorax, and the throat. Here, then, is the essence of the neuro-muscular mechanism of respiration. It consists of three components: the sensory stimulus, the immediate somatic response, and the subsequent respiratory response. I am fortunate to have Professor Adrian as my chairman: neither in his presence nor in his absence would I make any attempt to say by what chain of events in the central nervous system a foetus can start with a hit on the nose or rump and end with an effort to get up, followed by the movement of a breathless attack; I know he would not allow

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