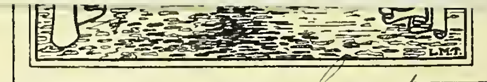
THE EARLY TREATMENT OF WAR WOUNDS

H.M.W. GRAY

OXFORD MEDICAL PUBLICATIONS

WAR SERIES



No........ Sept. 1919

14-5

Recommended by
Arthur H. Clark.

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PUBLISHED BY THE JOINT COMMITTEE OF
HENRY FROWDE AND HODDER AND STOUGHTON
AT THE OXFORD PRESS WAREHOUSE
FALCON SQUARE, LONDON, E.C.1

THE EARLY TREATMENT OF WAR WOUNDS

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LONDON

HENRY FROWDE HODDER & STOUGHTON

OXFORD UNIVERSITY PRESS WARWICK SQUARE, E.C.

1919

PRINTED IN GREAT BRITAIN
BY HAZELL, WATSON AND VINEY, LD.,
LONDON AND AYLESBURY.

FOREWORD

By Lt.-General T. H. J. C. Goodwin, C.B., C.M.G., etc., *Director-General of Army Medical Service*

The experience of our military authorities in the present war has been that, for long periods, it was not possible to carry out any "war of movement." Our armies were obliged—though not content—to hold their own against greatly superior odds.

As regards Military Surgery during the first two years of the war we were encountering unfamiliar conditions, acquiring new experiences, and dealing with wounds of a nature, and on a scale, hitherto undreamed of.

It was perhaps inevitable that advances should at first be somewhat slow. During the last year or two affairs appear to have progressed more rapidly and satisfactorily, and great improvements have been made in many directions. The early treatment of wounds, the prevention and treatment of shock and collapse, the operative procedures in all types of injury, and many other problems, have received close attention with the result that the advance in these and many other matters has been very marked.

Thousands of limbs and lives are now saved which, at the commencement of the war, would have been regarded as irretrievably lost.

Our views on many questions and problems have ehanged, are still ehanging, and no doubt will beeome still further advaneed in the future. It is very important that the present situation as regards advances in Military Surgery should be elearly and definitely set forward and published in eoneise form, in order that every surgeon throughout our various areas of war may beeome fully aequainted with the methods at present in vogue.

Under the conditions of life whieh now obtain, the Army surgeon has not sueh full opportunities for study as might be desired, and this small handbook by Colonel Gray, giving the valuable experienees of himself and other workers, should prove of immense assistanee.

T. H. Goodwin, D.G

September 9th, 1918.

PREFACE

For three and a half years I served as Consultant Surgeon in France. The first eighteen months were spent at the Base, the last two years with one of the Armies. The D.M.S. of that Army placed upon me the responsibility of ensuring "that the standard of surgical work in the Army should be as high as possible."

This book is a record of what was done by the surgical workers of that Army and a testimony to the efficiency of the administrators who facilitated that work. In it I have attempted to convey to medical men who have not yet had the good fortune to have been selected for duty at the Front either in France or elsewhere, some idea of the nature of the work to be done there and of the aspirations of the men who have tried to "make good" in carrying out that work.

It is hoped, also, that the book will be of assistance to those surgeons who, having had no experience of the early treatment of war wounds, may be called upon, possibly with little warning, to treat such wounds soon after their infliction.

There is little time in these busy days for reading long dissertations. Volumes have been written on the subject matter of almost every one of the chapters of this book, and more especially of those dealing with regional injuries, but it is believed that the brevity here displayed in treating these subjects will not diminish materially the usefulness of the book.

It can hardly be expected that all the recommendations made will pass unchallenged, but as they are the outcome of concentrated observation and thought by one who has had unusual opportunities, and of discussion and collaboration with numerous brilliant young surgeons possessed of fresh, active brains and equally dexterous hands, they ought to possess a value of their own. Most of the procedures adopted received general recognition and application, in some instances, however, only after considerable delay, which, in view of the clamant need for rapid developments, seemed to me regrettable.

This is a young man's war, in surgery as well as in purely military matters. The progress of events demands that younger men should have every chance in a sphere of action where mental and bodily activity count for so much.

The Third Army was professionally happy so far as the exigencies and limitations of war would allow. It was an Army where one man shared his knowledge with another, where collaboration and loyalty were combined, to the great benefit of the wounded man. The happiness, efficiency, and enterprise in that Army were due in very large measure to the Sahib at the head of its Medical Service, Sir J. Murray Irwin, K.C.M G , C B

It was a great privilege and honour to work with the medical officers of that Army. Their keenness and efficiency were inspiring, and their thoughtfulness and courtesy afforded a constant encouragement. Amongst them are many who did most excellent work in an unobtrusive way; though their qualities have not yet received adequate recognition, they are bound to make their mark. It would be invidious to name them here. To one and all I feel most grateful.

I am sure that no one will take umbrage when I make an exception and mention the name of Captain K. M. Walker, whose work in the forward areas has been of such a pioneer kind, so good, so unassuming, and so helpful to wounded men and to medical officers alike. He compiled, along with me, the small pamphlet on the work of advanced units, which was circulated in our Army and which is embodied in the first chapter of this book. He is mainly responsible for the chapter on Wound Shock.

All will unite with me in unstinted praise of the Nursing Sisters, who contribute so much to the success of the surgeons' work. Their untiring devotion to duty, in spite of frequent discomfort and danger, is a never-ending wonder. The orderlies, stretcher-bearers, and ambulance car drivers also cannot be forgotten. Among the theatre and ward orderlies are assistants as faithful, capable and willing as one could wish to have. The stretcher-bearer on the field is one of the heroic figures of the war.

Many of the chapters on operative work were written in their original form for a pamphlet on surgical treatment of war wounds which was circulated in the Third Army in the beginning of 1917. They were drawn up in collaboration with the surgical specialists of the casualty clearing stations in that Army. For this reason I have drawn to a considerable extent, in the chapters on general wound treatment and on treatment of fracture of the femur, from the contributions to that pamphlet by Major C. H. Upcott and Lt.-Col. R. C. Dun. The chapters on head and knee injuries were largely written at the Base in 1915. Most of the chapters, in a somewhat different form, have been published in the New York Medical Journal.

I have not written anything on abdominal wounds. It has always seemed to me that a surgeon who has mastered the technique of successful excision of an ulcerating cancer of the colon is capable of obtaining as good results as possible if he applies the same principles in the treatment of war wounds of the abdominal organs coupled with those used in combatting spreading peritonitis. To Major-General C. S. Wallace, C.B., is chiefly due the credit of having rescued such wounds from the application of the policy of *noli me tangere*. I recommend the paper by Colonel Owen Richards, D.S.O., published in the *British Medical Journal*, April 27th, 1918, on "The Selection of Abdominal Cases for Operation," to the attention of abdominal operators.

I have dealt only incidentally with the organisation of surgical work, and of the special arrangements which must be made before and during active fighting. These matters were the subject of numerous memoranda drawn up in my capacity of Consultant Surgeon with the Third Army. They were circulated officially from time to time in that Army, and will, I hope, prove to have some permanent value.

Medical officers who have not experienced the stress, anxiety, and limitations of work near the Front during severe fighting must read this book with open minds and sympathetic tolerance. The conditions of patients' wounds as well as their hold on life vary so enormously within short spaces of time that a man who has been literally snatched from death at a dressing station or casualty clearing station may seem to have but little wrong with him when he is safely tucked in bed in a Base hospital. Needless to say, the reverse side of the picture is only too frequently seen. Surgeons in advanced units can, even in quiet times, only *approach* the ideal which it is possible to attain in more permanent surroundings. It is essential to take a broad-minded view, and never to forget that there are more ways than one of applying the same principle. The particular method adopted by a medical officer at the Front in any given case must be determined by the conditions on the spot, the facilities at hand, the number of cases that come in, and the circumstances affecting evacuation. If the correct principle has been recognized and applied, to criticize the means because they do not conform to some particular technique would be to take a narrow view.

H. M. W. GRAY.

August 1918.

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"He who knows not, and knows not that he knows
not, is a fool; shun him.
"He who knows not, and knows that ho knows not,
can learn; teach him.
"He who knows, and knows not that he knows, is
asleep; awaken him.
"Ho who knows, and knows that he knows, is a
king; follow him."

Old Arab Saying.

THE EARLY TREATMENT OF WAR WOUNDS

CHAPTER I

SURGICAL TREATMENT OF WOUNDED MEN AT ADVANCED UNITS

It is beyond the power of words to convey anything but the feeblest impression of the conditions under which surgical work is carried on at a very advanced unit during a big "push." For the doctor fresh from a palatial, well-ordered hospital, who has hitherto had all things made easy in virtue of his training and surroundings, and who may be so confident of obtaining good results that he dreams of performing marvellous operations at the front, there will be much to learn and much to unlearn. The dimly lighted dugout dressing-station, the dust, the wet, the mud, the blood, the noise, the bustle, the numbers of wounded, the appalling wounds, the hopeless shock—will open his eyes, test his capacity and resource, and tend to break his heart as never before. Here is no brilliantly lighted and fully equipped theatre, here his patients do not come before him in spotless apparel, here he has not unlimited skilled assistance, here no aseptic ritual is possible, here he must be content with very simple things. And through it all he must keep cool, he must hurry, he must be thorough, he must be gentle and careful in every possible way. His is the responsibility to make or mar a man for life. Often his patients, shattered in nerve as well as in limb, can give but feeble response to his utmost efforts, so that a little slip in judgment, a little unnecessary exposure, a little lack of ordinary comfort even, or a little rough or unconsidered handling will tip the scale and send them to that death which their foes have desired.

What a necessity for each equipping himself as best he can so that he may give of his best to those who deserve it more than ever men did! In so far as we fail to accommodate ourselves to these unavoidable conditions or neglect opportunities of acquiring for ourselves or imparting to others the special knowledge which will help our wounded men, and fail to put that knowledge into practice, so far do we fail in duty to our country. These chapters set forth what the writer after a varied experience of nearly four years has found to be the best methods of treatment for the wounded man from a purely professional point of view. Administration is not dealt with, although any attempt to divorce administrative from professional work is full of danger to the success of our calling. If the administrator neglects the advice of his clinical brother his administration may result, during a big battle, in the loss of literally hundreds of lives and of limbs which would otherwise have been saved.

It is impossible to enter into details with regard to all procedures or types of injury. Some are described more fully than others for various reasons. One is impressed by the fact that the methods of treatment which are most successful are those which are simplest and follow the indications of Nature most closely. The medical officer who can land his patient at the next stage of the journey in best condition with the fewest contraptions serves his country best. Some measures described are so simple that, were they not so frequently neglected, it would appear almost superfluous to draw special attention to them. Principles of surgery remain the same, but the application of them is perforce adapted to local conditions. Original minds will always devise the means to the end in the greatly varying and new conditions which this war will continue to force upon them. At the field ambulance, at the casualty clearing station, at the hospital on the lines of communication in France, and at the base hospitals in England, the problems of surgery are widely different. Even the most skilful hospital surgeon of civil life must pass through an apprenticeship at any of these places before he becomes of the same value as his house surgeon of pre-war days who has qualified in war surgery. The experience of even a few weeks may produce a wonderful revision of the standard of values.

No work is done under such a variety of conditions as the work of the field ambulance and of the regimental medical officer. The circumstances in which a field ambulance finds itself, and the resources at its disposal, are so different under the conditions of ordinary trench warfare and of a big engagement, that it is impossible, as in the case of other units, to lay down hard and fast rules that are of more or less universal application. What is easily attained under ordinary conditions may be absolutely impossible during the heat of a battle, and methods of treatment, that are well within the reach of ambulances working in one portion of the line, may be entirely impracticable to those working under less favourable conditions. For this reason, objections may be raised that some of the methods of treatment laid down in the following pages are impossible at times of great pressure. This is, unfortunately, only too true, but it affords no argument against an attempt to reach the high-water mark of treatment under the most difficult conditions. At the same time, it must be remembered that in many cases what was once considered impossible to achieve in a field ambulance has now become common practice. The higher the ideal of treatment is set, the better will be the standard that is normally reached.

The Importance of Preventive Work.—As indicated, enormous difficulties beset advanced work, especially during severe fighting. The conditions of warfare demand, to put it bluntly, that wounded men shall be got out of the way so that supplies of reinforcements, ammunition, and food to the fighting line are not interfered with. But while the primary function of advanced medical units is to clear the wounded as rapidly as possible, yet the enormous importance of preventive work must constantly be kept in mind. The effects of treatment of the wounded man at the earliest stages are reflected in the whole course of his subsequent illness. The influence of efficient early treatment cannot be overestimated. The fate of a life or limb is often determined before the arrival of the wounded man at the casualty clearing station, and no subsequent surgical skill can undo an error that has previously been committed. The "results" of the casualty clearing station, to a great extent, reflect the good or the bad work of the forward units. Treatment begins when the patient is first seen, and not in the operating theatre. The prevention of early complications gives a man a good start in his struggle. Only the most necessary procedures can be carried out, but these must also be the best possible.

Intercommunication with units farther back will ensure the highest efficiency and improvement. Reports as to the condition in which patients arrive there should be furnished and treatment at the more advanced units should be amended, if necessary, according to the indications given.

The three great factors for evil which have to be combatted in these early stages are shock, hæmorrhage, and sepsis, which react on each other in marked fashion.

Shock.—The intense surgical shock from which some of the wounded suffer must be seen in order to be appreciated. Primary shock from the injury is aggravated by unavoidable early handling and by transport of the patient. This fact is brought home in a negative way by the observation that a man with a fractured femur who lies out for a day or two after being wounded, arrives at the casualty clearing station in better condition on the whole as regards pure shock than one who is picked up and transported without delay. A comparatively smooth railway journey has a deleterious effect. How much worse is the effect of transport down uneven trenches, over rough country, and along bumpy roads! A wounded man left lying out keeps his limb at rest and recovers from the first shock of the injury. Close attention must be paid to these indications because other considerations compel the immediate removal of the patient to a place where he can be operated upon to the best advantage Every effort must be made to prevent the summation of painful stimuli, which transport inevitably provides, from producing fresh shock or intensifying, beyond the patient's endurance, the shock already present. The most important elements in combatting the development of profound secondary shock are rest, both mental and physical, and warmth. Rest during the journey is procured by proper fixation and efficient support of the injured part and prevention of jarring bumps. Complete rest to the patient is out of the question at this stage and therefore the aid of sedatives has to be invoked, and should be used as early as possible in order to render him less sensitive. Morphine is very valuable, but its purely depressing effect on the vital centres and on metabolism, which are in these cases already too often at a low ebb, constitutes a disadvantage. Omnopon, or any similar extract of opium under a different name, is preferable, because this depressing effect is not manifest to anything like the same degree. Two-thirds of a grain of omnopon is equivalent in sedative action to about one-fourth to one-third of a grain of morphine. At this point one may say that much of the benefit of the sedative is lost if the patient is at once sent off on his journey. He should be detained, if possible, for fifteen minutes or more, until the injection has taken effect. Every dose of morphine or omnopon, and the time at which it is given, should be noted on the field medical card. It is only in special circumstances that precautions against shock, other than those mentioned, can be employed before the patient reaches the advanced dressing station. These other remedies will be described later. (*See* Chapter III.)

General anæsthetics should be used as little as possible. Chloroform and ether decrease the already unstable nervous control and predispose to shock. If such an anæsthetic is compulsory, patients should be retained, if possible, for several hours thereafter.

Acute Sepsis.—The sepsis most to be feared in very early stages is caused by gas forming bacilli.

Gas gangrene develops rapidly in parts which are deprived of circulating blood; witness the extraordinary rapidity with which the whole body becomes affected after death. Interference with the circulation is brought about in varying ways, each contributing to the loss of the normal supply of oxygen to the tissues. The most important should always be borne in mind. The wounds most likely to be attacked are those in which there has been considerable destruction of muscle tissue accompanied by interference with the blood supply. The specific bacilli develop most rapidly in lacerated muscle deprived of circulating oxygenated blood. Wounds of the buttock, of the thigh, and of the lower extremity generally, are particularly liable to gas infection owing to the anatomical arrangement of their vessels. Shock or severe hæmorrhage predisposes to the development of the infection owing to the slowing and enfeeblement of the circulation. On this account shocked cases frequently slide very rapidly into a condition of profound toxæmia. The patient is too often with the devil and in the deep sea. If the main vessel of the limb is injured the danger is still greater, because, owing to general enfeeblement, efficient collateral circulation is so delayed that before it is established the infection often obtains a firm hold. Pressure of blood-clot renders the walls of the wound anæmic, while inflammatory effusion, both liquid and gaseous, adds a steadily widening vicious circle. Prolonged use of a tourniquet has a disastrous effect.

The prompt recognition of early signs of gangrene in a wounded man, followed by his immediate evacuation to the casualty clearing station, accompanied by a warning note, may result in the saving of a life that must otherwise inevitably be lost. It must be remembered that the presence of gas in the tissues in sufficient amount to give rise to the phenomenon of crepitation is a late sign in gas gangrene. By the time that crepitation exists, gangrene is usually well established and the patient's life is endangered. An early and very suggestive sign is rapid, and somewhat inexplicable, increase in pain accompanied by marked swelling. The characteristic sweet and offensive odour is also present at an early period. On examining the wound it is found to be dirty, dark in colour, and on pressure gives forth dark, discoloured, evil-smelling blood, sometimes mixed with bubbles of gas. The skin around may already be bronzed and swollen. Frequent general signs are vomiting, thirst, a rise in the pulse rate and symptoms of intense toxæmia. Sometimes the cheeks are flushed to a dusky red, but as a rule the skin acquires early a pale lemon colour.

Hemorrhage.—One need not do more than draw attention to the fact that hæmorrhage predisposes to shock and will aggravate shock already present. On the other side, the only good thing that can be said of shock is that by enfeebling the circulation it may prevent so great a loss of blood as might otherwise occur. It should always be remembered that every ounce of blood is of the greatest importance to the wounded man. An extra ounce lost may be like the fatal straw on the back of the camel.

Shock in Slightly Wounded.—Such remarks apply to all severe wounds, but in a number of slight wounds the element of shock also becomes manifest, sometimes in a very great degree. It is remarkable also how in some patients shock suddenly develops, especially during transport, for no evident reason. It seems that their power of endurance suddenly breaks down. Such men are often of a highly strung nature, excitable and talkative while being dressed. They do not usually complain of pain, and there may be no hæmorrhage or other shock-producing factor present. It may be that a sufficient injection of sedative will prevent the onset of such shock.

General Treatment

The Condition of Wounded Men.—As already stated, the great majority of the severely wounded give evidence of the existence of some degree of shock or collapse, and attention to their general condition is as important as attention to their wounds. Shock is generally due to the combined action of several causes, amongst which the most common are: (1) hæmorrhage, (2) exposure to cold, wet, hunger, and fatigue, (3) pain and anxiety, (4) the presence of multiple injuries, (5) the injury of some important organ, as in lesions of the trunk and head. Next to the actual injury, the journey from the trenches to the casualty clearing station is the most potent factor in producing shock, and every effort must be made to render this journey as easy as possible for the wounded man. This can only be done by attention to innumerable details, which, considered separately, may seem insignificant, but taken collectively may make the difference between life and death to the patient. Viewed in this light, no attention that contributes to the wounded man's comfort during his journey is so trifling as not to merit care and consideration. The good work of an ambulance rests on attention to these details rather than on the performance of surgical operations.

As these points in general treatment are of such paramount importance, they will be considered under separate headings.

Care of the Wounded in Front of the R.A.P.—Regimental stretcher bearers should be instructed in the danger of wound shock and taught the urgency of preventing unnecessary loss of body heat during the carry back to the aid post.

To obviate this loss, they should be supplied with a certain number of waterproof sheet-blanket packets, each packet consisting of one blanket wrapped up in a ground sheet. These are strapped to the stretcher ready for use, and are returned with the R.S.B.s as soon as they have delivered the wounded man at the aid post. When the aid post is situated at some distance from the front line, these measures to prevent early exposure are doubly necessary. The occasional loss of a blanket will be amply compensated for by the saving of wounded men who would otherwise die from the effects of being carried on bare stretchers.

Regimental stretcher bearers should also be instructed in the gentle handling of patients and in the application of splints. Rough or unnecessary movement, as one of the most potent factors in precipitating shock, must be avoided.

In certain cases where the carry to the aid post is a long one, it may be possible to keep a small supply of splints at, for example, the company headquarters.

Warmth.—There is no measure which is of such vital importance to a seriously wounded man as the provision of warmth. The first complaint heard in a regimental aid post is almost always of cold, and throughout the wearisome journey to the casualty clearing station the same complaint is repeatedly voiced. Many stretcher cases arrive at the clearing station so cold that the pain of their wounds has been relegated to the background, and in severely shocked cases the surface temperature may have sunk to as low as 90°. During winter months the mortality from shock materially rises as the result of the increased cold. The necessity for mobilizing every means of warmth in the forward area is so great that no excuse is offered for dealing with the matter in detail.

Blankets.—The chief protection of the wounded man against cold during the first part of his journey lies in the liberal use of blankets. At no time is the loss of heat more rapid than during the first two hours after wounding, and every effort must be made to prevent exposure to cold at this period. Nothing is more striking than the deterioration in condition that takes place when a stretcher case has been sent on his journey without a blanket beneath him as well as one on top. There are difficulties attending the maintenance of a good supply of blankets in a regimental aid post, but, except in a big engagement and a rapid advance, these difficulties are not insuperable. Even in the latter event, if R.A.M.C. stretcher squads never make the return journey empty-handed, but carry up as many blankets as possible, some attempt may be made to cope with the exhaustion of the regimental aid post blanket supply. During quieter times the difficulties are much less, and it should be possible to maintain a sufficient reserve to allow of every stretcher case being provided with a minimum of two blankets. In cold weather and with shocked cases a third must be added.

Method of Folding Blankets.—In order that the practice may be universal and that the maximum advantage may be obtained from the blankets, the following routine should be adopted and adhered to.

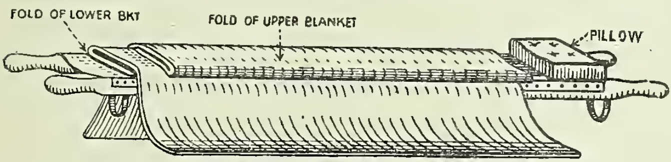


FIG. 1.

Immediately on the completion of the dressing and of the cutting away of blood-soaked clothing, the patient should be carefully lifted on to a clean and prepared stretcher. Two blankets are previously laid on the stretcher, each with a double fold corresponding with the width of the stretcher. The breadth of the blanket is used, as it is sufficient to reach from the foot of the stretcher to the position occupied by the pillow. Blanket beneath the pillow is wasted. If the breadth be not quite sufficient, the two blankets need not exactly coincide, but the upper one may be placed slightly higher on the stretcher than the lower. (*See* fig. 1.)

While awaiting use the free portions of the two blankets may be rolled up and laid on the stretcher. When required these free portions are opened out, the patient is lifted on to the two double folds, and the free portion of each blanket wrapped in turn round him. The wounded man by this arrangement has four thicknesses of blanket beneath him and two on top. If his jacket has been removed, or if he has an overcoat, it is laid as an extra covering over his feet. In rainy weather a mackintosh sheet

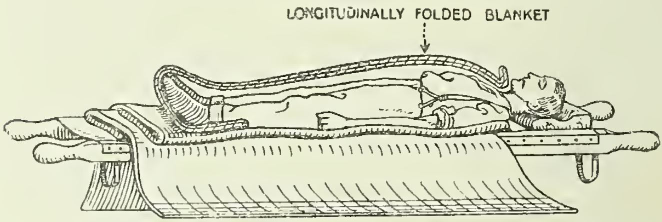


FIG. 2.

is added to protect him from further wet. On arrival at the advanced dressing station, or before leaving the aid post, if the supply permits, a third blanket is added. The portions of the blanket wrapped round him are undone and the third blanket, folded along its length, is placed over him. (*See* fig. 2.) The lower extremity of this is tucked well in beneath the man's feet and the two corners brought round and secured above the legs by a safety pin. After the addition of the third blanket the free portions of the other two are again wrapped round him. He has now four thicknesses of blanket above him as well as below.

This method of using blankets has three advantages. (1) By having a routine procedure, to be employed in every case, there is less likelihood of men being evacuated insufficiently protected against cold. (2) The maximum benefit is obtained by using blankets in this manner. (3) Blankets so adjusted do not work out of position in the way they do when other methods are employed.

When space permits the blankets may be thoroughly

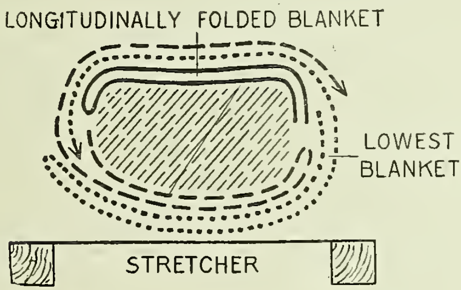


Fig. 3.

warmed before use by having the prepared stretcher placed over a stove, as suggested on page 20.

Every effort must be made to store blankets in as dry a spot as possible. This is especially important in the case of regimental aid posts. At every casualty clearing station arrangements must exist for the drying of blankets so that no wet one need ever be returned to a field ambulance. At the main dressing station of an ambulance an excellent drying room may be constructed by utilizing the heat of an incinerator. The incinerator is built into the end of a hut, the flue being carried along its middle

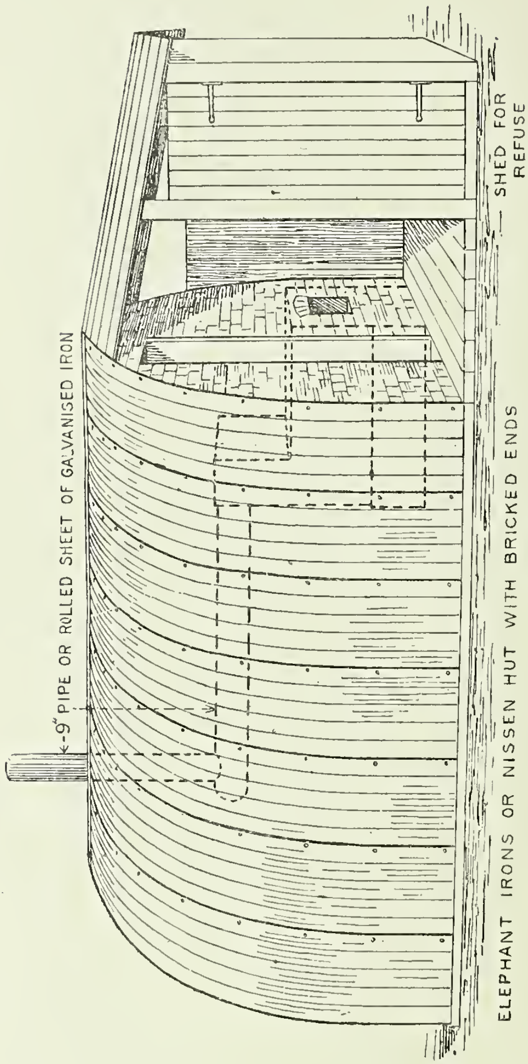


FIG. 4.

and out through the roof at the opposite end. If it is properly constructed, even fæcal material may be burnt in the incinerator without any smell being noticeable inside the hut. A drying room of this description is economical in fuel, effective, and of great value in overcoming one of the difficulties incidental to clearing the line in wet weather. It may be modified by addition of a tank for hot water and steam disinfector. (*See* fig. 4.)

Removal of Wet Clothing.—During bad weather wet clothing should be removed as early as possible and the wounded man put into a dry suit of pyjamas. Sometimes this may be done at an advanced dressing station, but often no arrangements for the change into dry clothes are to be found further forward than the main dressing station. The advantages of an early change are enormous, and every effort must be made to accomplish it as far forward as possible. It is impossible to get a wounded man warm while he is surrounded by a cold compress of wet clothing, and to get a man warm is as important an item in ambulance treatment as to dress his wounds.

In any case, during wet weather the boots and socks should be removed at the aid post, and the feet well rubbed. In cases of severe shock in fracture of the femur it is advisable to leave the boot on the injured limb. The handling entailed by removal of a wet boot and sock may seriously increase the shock.

Hot Water Bottles.—The ideal would be to send every severely wounded man down from the regimental aid post provided with hot water bottles. Unfortunately this ideal is sometimes difficult of attainment, not only because the supply of rubber bottles fails, but also because in many cases the means of obtaining hot water are very limited. During big engagements such a plan is obviously impossible, but during quiet times it is usually feasible.

2

When the supply of rubber bottles gives out, ordinary water bottles and empty wine or beer bottles may be pressed into the service. When there is difficulty in obtaining hot water, hot bricks, wrapped in sandbags, form the best substitute. The water bottles or bricks are placed between the layers of blankets so as to avoid the danger of burns. The perineum and the axillæ are the best regions to which to apply heat. Particular care must be taken to protect from burning in the case of unconscious or very collapsed patients, and in those suffering from paraplegia. Under wet clothing or bottle coverings scalding will occur especially easily.

There are very few advanced dressing stations which, during ordinary times, are not in a position to provide some form of artificial heat for the severely wounded passing through. It must be borne in mind that the employment of the light railway is becoming more and more common in the evacuation of the wounded, and that these light railway trucks are sometimes lacking in heating arrangements. A night journey in an unheated railway wagon is at all times an uncomfortable ordeal, and to the severely wounded man, insufficiently wrapped in blankets, and unprovided with hot water bottles, it is only too likely to be fatal.

Heating of Conveyances.—It is during the earlier parts of the journey towards the casualty clearing station, and while travelling in Decauville trucks and in barges, that hot water bottles are most needed, and it is unfortunate that this should just be the period when the greatest difficulty exists in providing them. Motor ambulances, with the exception of the Ford, are now heated by means of their exhaust, and this modification has undoubtedly resulted in the saving of many lives. In cold weather the production of heat from the exhaust may be accelerated by running the car for a time on the low gear. Although it is inadvisable to employ this method in the case of the Ford, a simple expedient will help to remedy the defect, and, as these cars often evacuate cases from a very forward position, will at the same time provide means of heat when other sources are unavailable. Let every Ford car carry two rubber bottles as a permanent equipment, to be filled when required from its own radiator. A convenient tap exists underneath, and the hot water removed may be replaced from the full petrol tin of water carried for that purpose. This expedient for obtaining hot water in case of urgent necessity, and when no other source exists, is not necessarily confined to the Ford.

The Heating of Dressing Stations.—As the heating arrangements of dressing rooms are usually very meagre, care must be taken to expose the wounded man as little as possible during dressing or when giving him an injection. Much can be done in protecting the patient from draughts from doors or faulty windows. When he is suffering from multiple wounds, only one portion of his body should be exposed at a time, and the dressing completed as rapidly as possible. It is an excellent plan to place a small oil stove midway between the two trestles upon which the stretcher rests. Whatever the temperature of the rest of the room may be, this arrangement will provide a current of warm air which rises from the stove, and diffuses round the stretcher at the time when the man, exposed for his dressing, is most susceptible to cold. By allowing the free ends of the two lower blankets to fall down on each side of the stretcher, a chamber of hot air is formed beneath it. This arrangement can easily be employed far forward, even in an aid post, where a Primus or Beatrice stove can be used as the source of heat. Two bricks are placed on the stove to prevent burning of the stretcher. These bricks, after cooling to a suitable temperature, can be covered with sandbags and placed between the layers of blanket and sent down with the wounded man, in lieu of hot water bottles.

The hot air may be made to circulate over the patient by means of the following simple device. The already warm folds of the blanket, hanging on each side, are placed over the man. One or two stretcher bars are fixed to the stretcher near the middle. A piece of Gooch splinting, four slats wide, is tied to the horizontal part of the suspension bar, so that the two outer slats of the Gooch fall on each side of it and the ends of the splint project equally. One " tie " in the middle is sufficient. A blanket, or blankets, is now placed over the apparatus so that the folds reach to the floor. Passages for warm air are thus provided on each side of the stretcher. The warm air must be prevented from escaping at each end of the stretcher by some means which need not be described.

Pyjamas, etc., may be hung under the stretcher or placed on the framework supporting it, and thus hot, dry clothing is ensured.

For the sake of economy of space some such method of warming the patient is preferable to those illustrated.

Hot Air Baths.—In dressing stations where there is accommodation for retaining, if need be, a case that has been admitted in a state of cold and collapse,

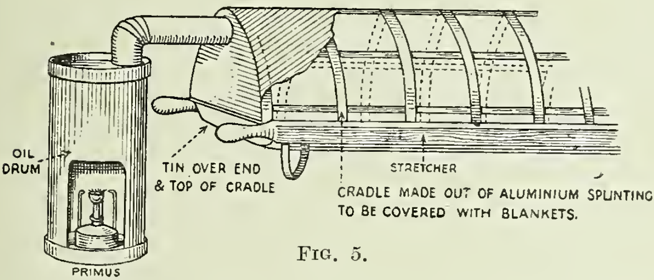


Fig. 5.

a "cooking" apparatus on the lines of those in vogue at casualty clearing stations may easily be improvised. Two methods of manufacturing extempore "cookers" are given. (*See* fig. 5.)

In the above case (fig. 5), where a Primus or a Beatrice stove is the available source of heat, the hot air is collected in an oil drum. A window is cut in the drum below, and an iron or asbestos pipe, let into it above, conducts the heat to the patient. Two or more patients may be heated from the same drum by multiplying the pipes. The cradle in the illustration has been made from the aluminium splinting material in the fracture box. This is, with advantage, reinforced by the addition of two tin sheets A and B, cut out from a biscuit box.

Fig. 6 shows a suitable arrangement when the heat is to be obtained from a small oil stove such as supplied by the Red Cross Society. If no other cradle is available the blankets may be kept off the patient by means of two or three stretcher suspension bars. In this case, instead of an oil drum, a petrol tin is

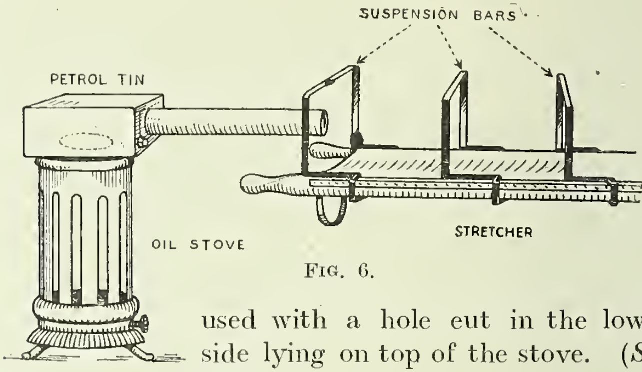


Fig. 6.

used with a hole cut in the lower side lying on top of the stove. (*See* fig. 6.)

In a very short time, by means of one of these forms of cooker, the temperature of a cold or collapsed patient may be raised to normal, and with the rise there takes place a corresponding improvement in his general condition. Indeed, few things are more gratifying than the improvement that takes place in the condition of a shocked patient during his stay in a dressing station, under the influence of warmth, quiet, and freedom from pain. It must be pointed out, at the same time, that there is danger of overdoing the heating, and of thereby causing sweating and discomfort which may exhaust the patient. Careful supervision should prevent this (see page 93).

Avoidance of Exposure.—At all stages of the journey the same care must be exercised in guarding the wounded against cold. During times of great pressure dressing rooms are so crowded that it is necessary to keep large numbers of stretcher cases waiting outside until their turn for dressing arrives. Every effort must be made to provide these men with what shelter is available, and at any rate to see that blankets and, if need be, waterproof sheets, are freely provided. The same precautions must be taken in the case of those awaiting evacuation. Moreover, in cold weather, when the patient is placed in the ambulance the canvas flap must be properly secured and not raised again till just before the stretcher is lifted out. Severe cases should invariably ride in the lower berth, not only because they are nearer the warm exhaust, but also because they are subjected to less lateral swaying in that position.

The Administration of Fluids and of Nourishment.—In view of the fact that the great majority of severely wounded men have suffered a serious loss of body fluid as a result of hæmorrhage, it is extremely important to make good the loss as quickly as possible. Thirst is, next to cold, the complaint that is most frequently voiced in the aid post and during the journey to the casualty clearing station. Not only are fluids urgently demanded, but also nourishment in some easily assimilable form, for many hours may have elapsed since the wounded man had his last meal.

Unfortunately, the digestive organs of severely wounded men are usually at fault, and not only is digestion delayed, but vomiting is only too common. The hot drinks most frequently provided are tea, cocoa, oxo, and bovril. Of these, hot tea, with plenty of milk and sugar, is by far the best. It is the most generally acceptable, and at the same time the least frequently vomited. Cocoa is rich in fats, and, like oxo and bovril, is usually not retained. Hot tea and sugar supply heat, easily absorbed carbo-hydrate, and a certain amount of stimulant in caffeine. The use of alcohol, when a man is to be subjected to further cold, is of doubtful value. When he has reached his journey's end and is in a warm atmosphere, the dilatation of the superficial vessels brought about by alcohol has no dangers, although in other circumstances it may have.

Harm may be done by withholding fluid from a very thirsty man, even though vomiting may possibly result from giving it.

To counteract the great disposition of the severely wounded man to vomit, three conditions should be observed. The first is that the drink should be given after all disturbances and movements incidental to the dressing have been completed. The second is that the wounded man be warm, and the third that drinks be given in small quantities at a time. When these conditions are observed, vomiting is diminished by 50 per cent. If cocoa be employed, the preparation of peptonized cocoa and milk supplied by the Red Cross Society is preferable to the ordinary variety.

When, on account of persistent vomiting, or of the presence of other urgent symptoms, means of making good the loss of body fluids are required, two methods are available in a regimental aid post, or an advanced dressing station—the use of rectal and of subcutaneous salines.

Administration of Sodium Bicarbonate.—To prevent or counteract acidosis, sodium bicarbonate should be given to every seriously wounded or shocked man. On account of the tendency to vomit which such a patient displays, it should not be given, when circumstances permit of his being retained, until he is warmed up or otherwise resuscitated. It may be given by mouth in doses of 30–60 grains in water or sweetened tea, by rectal injection, or intravenously. In the last case it should not be given with gum solution, as it will precipitate the calcium salts in the gum.

Rectal Salines.—These have the advantage over subcutaneous injection in that they are easily administered without fear of accidents from lack of aseptic precautions. Their disadvantage lies in the fact that in a certain number of cases the rectum is found to be loaded, and the saline is not retained. The injection must be warmed and run in very slowly. Glucose (5 per cent.) forms a useful addition to the saline, especially when the wounded man is suffering from starvation as well as loss of fluids. Sodium bicarbonate, 2 teaspoonsful to the pint, may be used with advantage instead of ordinary "saline" infusion.

Subcutaneous Injections. — Although a subcutaneous injection entails the employment of aseptic methods it does not necessarily demand the possession of a special apparatus. When other means are not at hand all that is required is an ordinary ear or new Higginson syringe, an antitoxin needle, a small connecting piece of rubber tubing, and a bottle of sterile saline. The injection is given by means of the syringe which, if necessary, may be disconnected from the rubber tubing, refilled, and connected up again. The whole outfit must be sterilized by boiling before use. The site of puncture is rubbed with picric acid (3 per cent.) in spirit. In order to prevent infection of the puncture from dirty clothing, the needle may be pushed through a few folds of sterile gauze placed on the skin.

Intravenous Infusion of Gum Solution. — In cases of severe hæmorrhage, in which the journey to the casualty clearing station is likely to have disastrous consequences, a solution of the gum acacia, 6 per cent., supplied in sterile bottles, should be given intravenously, 500–750 c.c., according to the estimated loss of blood. The viscosity of this solution prevents its escape from the circulation, as occurs at once in the case of simple saline solutions.

Transfusion of Blood.—This has been successfully carried out in field ambulances, but should only be undertaken by those who are thoroughly familiar with the necessary technique.

The Relief of Pain.—The relief of existing pain and the avoidance of any action likely to produce further distress is not only of importance on humanitarian ground, but also as a therapeutic measure. Whatever be the true pathology of shock, it is undoubtedly provoked and increased by a summation of sensory stimuli bombarding the higher centres. The unskilful handling of a broken limb or the rough treatment of a painful wound is sufficient to plunge a wounded man into a condition of surgical shock. In a regimental aid post or advanced dressing station, apart from ordinary attention to the wound, only that which is strictly necessary for the stopping of hæmorrhage or the splinting of a fracture should be attempted. Manipulations purely for the sake of arriving at a more precise diagnosis are not justifiable. The more skill is exhibited in the dressing of an awkwardly placed wound or in splinting of a difficult fracture, the less will be the shock resulting therefrom, and the smaller the drain on the wounded man's already depleted reserves of nervous energy.

Morphine.—Properly used, opium is the most valuable drug available in the early treatment of severely wounded men. Before discussing the indications for the use of morphia it is advisable to make certain observations on the *method of giving it.* In the first place, the method of administration by means of *tabloids laid under the tongue must be absolutely eradicated.* The buccal method has nothing to commend it, and is a source of confusion further down the line. A note on the tally, merely to the effect that a man has received ½ grain of morphia, may mean either that he has been given a hypodermic injection or that two tabloids have been placed under his tongue. In the latter case it is impossible to know if the drug has been absorbed. Frequently the wounded man spits it out, and even if he retains the tabloids the inhibition of the gastric functions that occurs in shock renders absorption a matter of doubt.

In spite of these many disadvantages the buccal method is still in use amongst regimental medical officers. The reason advanced for its employment is that it avoids the difficulty of sterilizing a syringe

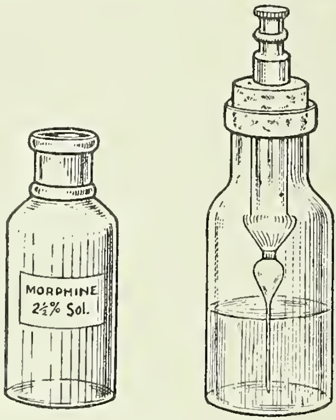


FIG. 7.

in an aid post. This fear of sepsis is surely an exaggerated one. Accidents resulting from faulty technique in giving a hypodermic injection are extremely rare, even when dealing with anti-tetanic serum. In the case of morphia injections they scarcely exist. Moreover, by a simple device, the difficulty may be entirely eliminated. Every regimental and bearer officer should carry two bottles of the kind shown in the accompanying diagram. (*See* fig. 7.)

The first of these is a stock solution ($2\frac{1}{2}$ per cent.) of morphia in a rubber capped bottle of the type in which antityphoid vaccine is now supplied. The second is a bottle with a perforated cork bearing a hypodermic syringe. The needle of the syringe projects into alcohol, and is thereby kept sterile and always ready for use. When an injection is required the cork with its syringe is removed and loaded from the first bottle. A complete syringeful is equivalent to $\frac{1}{2}$ grain of morphia.

A second error that is extremely common in the matter of morphia is that it is not administered early enough. Not only is the maximum benefit of morphia obtained by early administration, but also the maximum safety. Given early, morphia assists in damping down the painful stimuli that are partially responsible for exhausting the badly wounded man. Later on, changes occur in the patients' metabolism that show themselves by a diminished alkalinity of his blood. To counteract the impending acidosis the respirations are increased in amplitude and frequency. Morphine is likely to interfere with this natural mechanism, and should therefore be given at an early period when its administration is less likely to have this disadvantage, and may indeed delay the onset of acidosis. On the arrival of a wounded man at the regimental aid post the first consideration should be his general condition rather than his wounds. If he is suffering from severe pain an injection should be given immediately, and he should be left quiet for a quarter of an hour (unless hæmorrhage is taking place) until the drug has had time to act. If the injection be given intra-muscularly its action will be still more rapid. Other cases can be attended to while the injection is taking effect.

The benefit of an injection of morphine is to a great extent lost if the necessary environment of warmth and quiet be not at the same time provided. Although the latter is not always possible to achieve in an aid post or ambulance dressing station, an effort should be made to provide some corner in which a wounded man may be as little disturbed as possible whilst the injection is taking effect.

As a general rule it is found that nothing under a half-grain initial dose is of any use when dealing with a man suffering from severe pain, and provided it be administered early there is little danger in giving such a quantity. It is in deciding when to repeat that difficulties arise. Extreme restlessness and the persistence of severe pain are the best indications. Persistently restless cases invariably do badly, and are not only a danger to themselves, but are liable to excite other wounded men in their neighbourhood. In addition to these considerations the existence or absence of means of providing the necessary accompaniment of warmth and quiet must be allowed weight in arriving at a decision as to whether it is advisable to repeat the injection. If it is necessary to evacuate the wounded man immediately after his injection and to expose him to all the stimuli of a motor journey over indifferent roads, it is doubtful whether the injection will be of much value.

Cases in which there is marked cyanosis and a suggestion of pulmonary trouble should not be given morphia unless absolutely necessary. The best control for the giving of morphia is the condition of the respirations (rate and depth), and not the size of the pupils.

Other narcotics besides morphine may be used, notably omnopon and scopolamine. The former drug, having a less depressing effect than morphine on the vital centres and on metabolism, is of great value. Scopolamine has probably more action on the mental faculties, and is useful in excitable cases.

Stimulants.—Drug stimulants as a class have been tried and found wanting in the treatment of most cases of wound shock under the unfavourable conditions of a "push." Hot coffee per rectum and small quantities of alcohol by mouth are still recommended by some (see page 24).

The Psychology of the Wounded Man.—The mental state of a wounded man is always worth studying. Psychological disturbance is most marked during the period immediately after wounding, and may take the form of excessive fear of being hit again, irritability, or psychic shock. As a rule, if the wound is slight, this condition soon wears off, but sometimes, when an element of shell shock exists, it may persist. It must be remembered that, although in most cases of surgical shock, the higher faculties are usually somewhat depressed, other cases exist, of the excitable variety, in which these faculties, and especially that of hearing, are extraordinarily acute. Remarks not intended for their ears are sometimes overheard by such patients, and if they are of an alarming nature may have an injurious effect upon them. Emotional stimuli are only seeondary to sensory stimuli in provoking shoek, and the sudden realization that he has lost, or will lose, a limb may reaet in an alarming manner on the general eondition of the wounded man.

Evacuation.—It is often a matter of some diffieulty, when dealing with eases not suffering from injuries demanding immediate operation, but who are at the same time severely shocked, to deeide when they should be evaeuated. This problem is espeeially diffieult during quiet times when pressure of work does not prevent retention, if neeessary, of a wounded man in an aid post or a dressing station. No dogmatie rules ean be laid down on sueh a subjeet, as the eorreet answer ean only be arrived at by a eonsideration of various faetors, sueh as the aeeommodation available, the possibilities of providing warmth, the eondition of the wounds, the general state of the wounded man, the distanee of the easualty elearing station, and the presenee or possibility of a "gas attaek." If, however, the patient is eold, if his pulse is above 130, and, above all, if his lips and nails are at all dusky in hue, it is highly advisable to retain him for an hour or two, and to get him warmer before sending him on the next stage of his journey. Faeilities for evaeuating have beeome so good that it is probable that a eertain number of exhausted men are lost aetually through the rapidity of their journey to the easualty elearing station. It is surprising what improvement takes plaee in the general eondition of a severely wounded man when he is allowed an hour's rest in an advaneed dressing station and begins to react to the magic of warmth and freedom from pain. One hour of such rest, even if it be unaccompanied by actual sleep, is worth more to him than all the therapeutic remedies of the pharmacopeia. It may allow a severely wounded man to support the remainder of a journey that might otherwise easily prove fatal.

Methods of Transport.—Three sorts of mechanical transport are employed in the evacuation of wounded from the forward area—motor ambulances, light railways, and canal barges. Each of these has its advantages and disadvantages. The most commonly used motor ambulances are speedy and warm, but, when the roads are poor, the jolting which takes place is a serious disadvantage. Light railways and canal barges, on the other hand, although they are free from this defect, have the great handicap of cold. In addition to this, they are slow, and, as they are not usually planned merely for the use of the wounded, the route they follow is frequently a devious one. For this reason, when a choice is offered, and the roads are good, the motor ambulance is to be preferred for the majority of wounded.

No little skill is required to load a wounded man into an ambulance car without jolting him and causing him pain. Orderlies should be specially practised in this work and have impressed upon them the importance of handling all stretcher cases with the greatest care. It is also worth remembering that an ambulance with its full complement of cases on board rides much more easily than with a light load. Finally, the degree of inflation of the pneumatic tyres is not without effect on the jolting of the car. A pressure of about sixty pounds is suitable during winter weather and favours the patient without being unduly hard on tyres. Anything over this, although it may assist the life of the tyre, may have the reverse effect on that of the patient, as it produces increased jolting and discomfort.

The position of the patient during transport is often important in that it may obviate a sudden jar from an uneven road. For example, a man with a fractured arm will often ride more comfortably sitting than when lying down. Jolting is dissipated by his yielding body before the shock reaches his arm. In the same way some head cases, with considerable though unsuspected damage to the brain, often arrive as "sitters" in extraordinary good condition. Sudden sharp bumps or lateral movements of the head are particularly bad in cerebral injuries. Such cases must usually be sent lying down. An extra pillow or folded blanket should be placed under the head, and, especially if the man is unconscious, side supports should be so arranged as to prevent coarse lateral movements during lurches of the car. For similar reasons, in the case of fractured femur the Thomas' splint should be slung so as to allow a certain amount of lateral play. Soft stretcher pillows are to be had from the Red Cross Society and are a great source of comfort in many cases.

Local Treatment

Treatment of Wounds.—Much discussion took place during the earlier periods of the war as to the best form of dressing and the most effeetive lotions to be employed in the treatment of wounds. It was hoped that by the early use of suitable disinfeetants much would be done to combat the onset of sepsis. It has been found that antiseptics *per se* have but little influence in this direetion, and that the best hope of averting the danger of severe sepsis lies in early and effieient operation. The use of ordinary disinfectants and impregnated dressings is of little or no value in most cases until such operation has been earried out. Eusol and similar solutions are too evaneseent in antiseptic action when in contact with the tissues to make their use "worth while," and Carrel's method is out of the question at this stage.

Field ambulanee surgery is a surgery of emergency, and no operation that can be safely postponed until the arrival of the wounded man at the casualty clearing station must be undertaken in the less favourable surroundings of the more advanced unit. When time permits, during a rush, and the immediate evaeuation of the patient is not possible, an attempt may be made to diminish sepsis by eleaning up the surrounding skin and removing gross eontamination and blood elot from the exposed area of the wound; but unless a foreign body is aetually visible and easily dealt with, its removal should not be attempted. For disinfection of the skin a 3 per cent. solution of pieric acid in spirit has been found superior to tineture of iodine. If soap and water and picric acid are available, no othcr ordinary antisepties need be provided for work in field ambulanees during a battle.

Contamination is carried so far into the tissues and recesses of a wound that syringing is of very doubtful value. It may even tend to distribute infection to parts which previously were uninfected.

Dressings and their Method of Application. — As already stated, antiseptics alone have little effect in inhibiting the action of bacteria carried into the depths of a wound. For field ambulance work probably plain sterile gauze and wool make the best kind of dressing. Gauze impregnated with mercurial preparations has been the cause of severe blistering when applied over a skin previously painted with iodine. If antiseptic applications are used at all they are probably best in the form of a Bismuth Iodoform Paraffin Paste (bismuth subnitrate 1 part, iodoform 2 parts, and liquid paraffin sufficient to make a thin paste) or preferably of a 1 per cent. solution of iodoform in liquid paraffin. B.I.P.P. casts a strong X-ray shadow, and therefore should not be used. I.P. (iodoform paraffin) is poured into the wound in small quantity or is used to impregnate gauze. Paraffin gauze may be stored in sterilized tins. The tins should have holes cut in the bottom so that excess of paraffin may drain away, be caught in an outside tin, and used over again. The paraffin gauze dressing is soothing, and does not stick. It can be removed easily and without pain—an obvious advantage in shocked cases.

The liquid paraffin dressing prevents the formation of dry crusts under which organisms are likely to flourish and discharges be retained. For this reason, if paraffin is not obtainable, gauze is best applied as a wet dressing, wrung out in saline. All lotions should be warmed before use, even if the warming has the effect of reducing their chemical efficiency. When a wound tends to ooze, or when it is intended to retain the gauze in position by means of adhesive plaster, a dry dressing should be used.

Before applying a dressing to a compound fracture it is advisable to remove carefully any visible *completely detached* and jagged fragments of bone, or foreign body, especially if these be in the neighbourhood of a blood vessel. When applying the dressing the question of drainage must be borne in mind, and any tendency on the part of the gauze to act as a cork in retaining discharges should be avoided. In dealing with large gaping wounds the dressing should be laid loosely into the recesses, and several layers of gauze interposed between flaps so as to prevent their apposition, i.e. *wounds that are already opened should be kept open.* When a small bridle of tissue interferes with drainage it should be rapidly divided with a scalpel or scissors, and the separation of the opposing surfaces maintained by means of loose packing. Application of a flat gauze dressing over a deep valvular wound merely pens up discharge and favours the spread of infection, if the depth of the wound is not previously treated as described. Small punctures of the skin by bullets require no special attention. Between these and large gaping wounds there are various gradations, which require commensurate judgment in treatment.

No more wool should be used than is strictly necessary. The employment of large quantities of cotton wool, as well as being an extravagance, may result in the masking of a serious hæmorrhage. Sphagnum moss pads make a very useful substitute for wool.

Precautions in applying Dressings. — Wounded parts are apt to swell, and if tight bandages are applied great interference with the circulation is apt to occur, and serious results to follow. It has been found, moreover, of great importance to support large

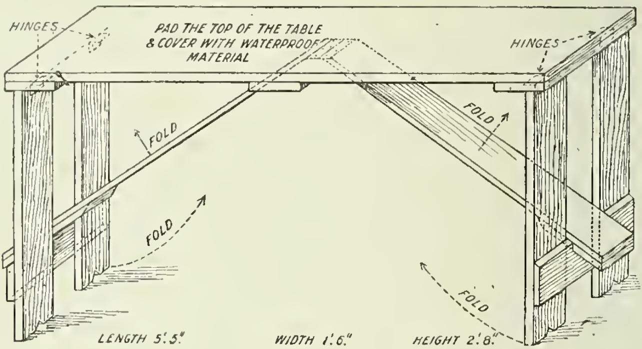


FIG. 8.

and deep flesh wounds with splints, even although no fracture is present. In such cases the encircling bandage should be put on after the splint has been placed in position. Finally, if extension is to be applied to a fractured limb it should be applied before the wound is bandaged. This precaution is taken chiefly because of the swelling that supervenes, but a more serious accident is liable to follow neglect of this rule in the case of a fractured femur. The application of extension sometimes dislodges a clot occluding a large artery. If bulky dressings have been bandaged to the wound, the hæmorrhage that occurs in such a case is likely to be obscured until it is too late to save the patient.

When the accommodation in dressing rooms permits, the use of folding wooden tables is recommended. The top of the table should fit loosely into the space between the stretcher poles and traverses. This allows the poles of the stretcher to fall out of the way, so that wounds of the trunk and lower limbs are more easily dealt with. (*See* fig. 8.)

The Storing of Dressings.—Dressings should not lie exposed to contamination, especially when the surroundings are those of a regimental aid post or an advanced dressing station. The best method of storing them is by means of a Helby's box. This is made out of a four-gallon petrol tin and a tea tin, which will be found to just fit, the one inside the other. The two opposite sides of the tins are freely perforated with holes so placed that when the two tins are in position the holes correspond. (*See* fig. 9.)

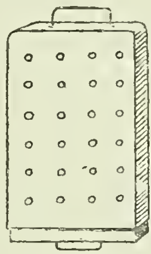


Fig. 9.

The drum thus formed is filled with gauze, and placed in a steam sterilizer. On the completion of sterilizing it is removed, and the outer tin readjusted so that its imperforate sides are in contact with the perforated portions of the inner one. The contents are thus protected from contamination. To facilitate opening, wire handles may be fitted to eaeh tin.

A eomplete steam sterilizer for use with Helby's box may be made out of two biseuit tins and a butter tin. By slightly bending one biseuit tin it ean be made to partially fit over the other. The butter tin is plaeed inside as a support and two inehes of water added. (*See* fig. 10.)

The Helby's box in the "open" position is now

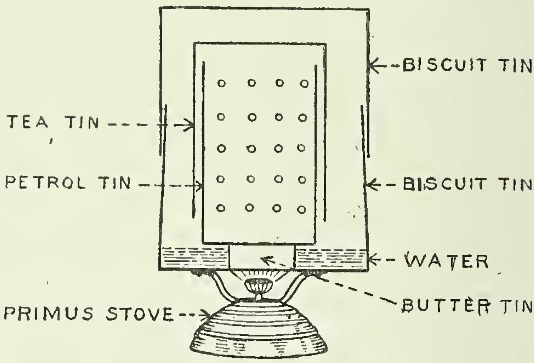


Fig. 10.

made to rest on the butter tin, the sterilizer elosed, and the whole plaeed on a Primus stove. The pressure of steam generated inside the apparatus is suffieient to sterilize a box full of gauze, after half an hour. This sterilizer withstands baeteriologieal tests and exaets no skill in its manufaeture.

When a rush of wounded is antieipated, time will be saved by previously eutting gauze into squares of some eonvenient size, sueh as six inehes. For eaeh dressing as many layers as may be neeessary are lifted off the pile. In the ease of a large wound the layers arc opened out; in the case of a small wound they are folded to the required size. No more eutting is required, and the dressings may be re-sterilized in thc above manner as often as required.

Bowls in whieh dressings, swabs, or sterilized dressings are kept ready for use should be protected from dust by means of eovers cut out of tin. They are sterilized by "flaming."

Over-dressing.—Patients have been needlessly annoyed by too frequent dressing of their wounds. In badly wounded men the extra pain and disturbanee will tend to produce or aggravatc shock. Routine interference at every stopping plaee means waste of time and material and of thc energy and enduranee of the patient. Without definite indieations, therefore, no dressing should be changed. Generally speaking, these indications arc the presence of:

1. A first field dressing, which has usually been applied over a dirty or imperfectly disinfected skin, and, in many eases, has also been tied too tightly. Sometimes, however, when the dressing is dry and the patient's skin is apparently elean in the neighbourhood of the wound, this dressing need not be disturbed.

2. Soaking of the dressing with blood, mud, etc.

3. Unsuitable or imperfeetly applied splints.

4. Too tight bandages interfering with cireulation so as to cause swelling and pain.

5. Too loose bandages which do not support the wounded part, and are allowing the dressings to slip.

6. Inereasing pain, whieh may indicate hæmor-

rhage in the depth or the onset of gas gangrene. In either case, the patient should be expedited to the casualty clearing station with a note drawing attention to his condition.

Operations at Aid Posts or Dressing Stations.—It is not advisable under the conditions of this war to make elaborate arrangements for serious surgical operations on patients within the zone of ordinary shell fire. Therefore, as a routine, only such operations as are absolutely necessary should be performed in units in front of the casualty clearing stations. Operations for hæmorrhage which threatens life, and those for the removal of hopelessly smashed limbs are the only ones which ought to be done, unless under very exceptional circumstances.

Amputations.—Hopelessly smashed limbs which are tending to bleed, or which are hanging by mere shreds of tissue, should be removed. Such limbs, owing to their dragging on exposed nerves, may give rise to great pain and an increase of shock. As a rule the amputation, which the projectile has all but accomplished, can be completed by a single sweep of a sharp knife. A previous injection of morphia, together with the local shock-anæsthesia of the tissues in the neighbourhood of the wound, will generally permit of the operation being performed without the use of a general anæsthetic. If necessary the still undivided skin may be anæsthetized by the injection of a few syringefuls of ½ per cent. novocain. Although the dividing of the still sensitive tissues may inflict momentary pain, it is found that in the long run such cases do better if the use of a general anæsthetic has been avoided. As a rule, a ragged stump of this nature bleeds very little, and what hæmorrhage there is can usually be controlled by packing and elevation. As a precaution, a tourniquet can be laid loosely around the limb ready to tighten if necessary. The patient should be retained for an hour, if circumstances permit, in order to make certain that hæmorrhage has stopped.

If it is considered necessary to administer a general anæsthetic, more attention should be paid during the operation to the toilet of the stump, so that the necessity of repeating the anæsthetic on arrival at the casualty clearing station may be avoided. After the use of a general anæsthetic it is usually advisable to retain the patient for a period of twelve hours, as otherwise such cases travel badly.

When pressure of work is so great or surgical facilities so small that it is advisable to avoid the performance of an operation even so trivial as that of removing a shattered limb, an alternative procedure can be adopted to avoid the possibility of further loss of blood from the torn tissues. A tight tourniquet is applied just above the level of the injury and the patient sent down with a special note calling attention to his condition. On arrival at the casualty clearing station the limb is amputated just above the level of the tourniquet, clear of the tissues that have suffered from the cutting off of their blood supply. This method, although it overcomes the risk from hæmorrhage, does not confer on the patient the boon of removing early a useless and painful limb.

Hæmorrhage.—To ensure that hæmorrhage has been effectually controlled is the most important item in the surgical treatment of the aid post and the ambulance dressing station. As well as being the most important it is often the most difficult, and demands both judgment and promptness of action. The hæmorrhage that takes place when a main artery is divided is usually so rapid and so copious that the wounded man dies before help can reach him. In less severe cases profuse bleeding takes place for about two minutes, and then, owing to the rapid fall of blood pressure, hæmorrhage tends to cease. At any moment during the journey from the trenches an artery that has been temporarily occluded by retraction and the formation of clot may start to bleed again, and it is in these cases that prompt action may save a life.

But apart from the danger of a fatal ending as a direct result of hæmorrhage, there always exists a danger of death from the severe sepsis that almost invariably follows the loss of a large amount of blood from a lacerated wound. Shock, hæmorrhage, and sepsis go hand in hand, and, when bleeding has been severe, virulent sepsis can be confidently predicted. Therefore, to a severely wounded man, the loss of every additional ounce of blood is of utmost importance.

Operations for Hæmorrhage.—When an important artery or vein has been divided in the depth of a wound, the operation required in order that it may be tied may present great difficulties. If, however, the casualty clearing station is some distance away and there is no alternative but that of despatching the patient with a tourniquet that must of necessity remain in position many hours, these difficulties must be faced. In arriving at a decision as to whether to operate or to trust to a tourniquet, it is worth remembering that about 80 per cent. of limbs whose blood supply has been cut off by a tourniquet for a period of three hours or thereby eventually come to amputation.

Once decided upon, the operation must be boldly performed. The essentials are, a helpful assistant, a good light, some strong silk, and a sharp knife. The wound must be freely opened up so that the bleeding point may be seen and easily tied. A second assistant controls the tourniquct and relaxes or increases pressure as may be required. Blind groping in the dark in a haphazard attempt to seize something in the grasp of a pressure forceps is useless, and generally results in the loss of much additional blood. Unless the operator feels confident to face the operation, it is better to rely on a properly applied tourniquet.

Sometimes a ligature cannot be applied easily to a vessel which has been caught up by forceps. If the wound is complicated or is a very deep one, the patient should be sent on with the forceps *in situ.* Arrangements must obviously be made for the immediate return or exchange of tourniquet, forceps, or other special appliances sent down in this way, so that the field ambulances may not suffer from their loss.

Very exceptionally the M.O. is confronted by a case of profuse hæmorrhage from a penetrating wound in some region (such as the neck) where the use of a tourniquct is out of the question. The circumstanccs may be such that any attempt to enlarge the wound and clamp the dividcd artery is impossible, cither on account of the delay entailed in such a proeeeding or on aceount of laek of surgieal facilitics. If paeking fails in sueh a case, the only remedy that remains is to eomplctely close the wound by mcans of sutures embracing not only skin and deep faseia, but also superfieial muscles. By this procedure the case is converted into one of diffuse traumatic aneurysm, in the hopc that after a eertain amount of bleeding has taken plaec into the deep structures the extra-arterial pressure thus produeed will prevcnt further loss of blood.

When the bleeding is in the nature of a general oozing from an extcnsive surface rather than of an active hæmorrhage from some definite vessel it can usually be controlled by skilful paeking. If the wound is not an open one, but has a narrow orifice, it must be laid open before the paeking is applied. The insertion of a cork of gauze into the orifiec of a wound that is bleeding from its depth is to be deprecated. In some cases hæmorrhage is taking plaec from a fairly wcll loealized area of the wound, although no vcsscl ean be seen to whieh a ligature ean be applied. Here it is eonvenient to under-run the area with a curved needle and tie off the enclosed tissue. As a rule, it is preferable to usc strong silk in all these ligature operations, as the catgut in the field pannicrs usually breaks.

A type of wound which, though possibly it may not appear to bc severe, is likely to give risc to serious results, is one from which steady oozing occurs. The medical officer, who first sees such a case, may have applied compression and voluminous dressings in the hope that the oozing may stop. The soaked dressings are removed by the next medical officer who sees the case and who reasons in the same way. This may occur even a third time, so that although at no time is the bleeding at all alarming, the patient arrives at the casualty clearing station in a collapsed and anæmic condition, having lost in the aggregate a large amount of blood. Wounds in the neighbourhood of the articulations, especially wounds of the ankle, the knee, the shoulder, and the scapula are particularly liable to act in this way. They should be opened up in the manner described above, and the bleeding, which is usually venous in origin, controlled by packing. An antitoxin syringe containing a ½ per cent. solution of novocain and a few drops of adrenalin is an extremely useful weapon in such operations. The distal side of a wound can often be incised without pain.

After bleeding has been arrested, the limb should be raised as high as possible, and the patient retained a sufficient length of time to make certain that the hæmorrhage has completely stopped. If any doubt still exists, a tourniquet should be laid loosely round the limb and the patient evacuated with a special orderly in charge. The tourniquet may be tightened in case of necessity.

It must always be remembered that any wound of a limb in which bleeding has had to be specially controlled must be splinted. Sudden movement will often restart bleeding that has been only temporarily checked.

Cases of diffuse traumatic aneurysm, in which the rupture of an important vessel has been followed by extensive bleeding into the tissues and great swelling of the limb, should not be operated on in a field ambulance. They should be well splinted and despatched forthwith to the casualty clearing station, accompanied by a special note. The finding of the damaged vessel in such cases is always a difficult task, and the fact that the distal circulation of the limb is gravely imperilled calls for operation at the earliest possible moment.

The Tourniquet.—The application of a tourniquet must always be considered a temporary measure, to be followed as soon as possible by the adoption of proper methods for the control of hæmorrhage. As before stated, the retention of a tourniquet in position for quite a short time is, in a large number of cases, followed by amputation of the limb.

The elastic tourniquet is not an easy instrument to use. It is remarkable how frequently it is applied ineffectually. It must always be placed in position with the rubber already on the stretch, and then secured without any slackening having been allowed to take place. This task will be rendered much easier if a small triangle of strong wire, such as that used for binding trusses of hay, be prepared for use with the tourniquet. One angle of the triangle, whose sides are about 4 inches in length, is hooked over the anchor of the tourniquet and allows of it being controlled without the fingers getting in the way. It may similarly be used when it is required to slacken the tourniquet. (*See* fig. 11.)

As already stated, if a tourniquet is applied in order to control bleeding from a shattered limb whose immediate removal is, for some reason or other, impossible at the time, it should be put on as low down as possible. It will then be possible to save the maximum amount of limb when the subsequent operation is performed, just above the level of the

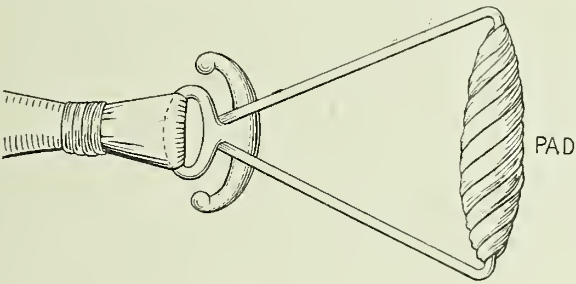


Fig. 11.

tourniquet. Whenever a patient is sent down with a tourniquet in position its presence should be clearly indicated on the tally.

Fractures. — No lesson has been more clearly taught by the experience of this war than the necessity for the efficient splinting of fractures at the earliest possible moment after injury. Improvements in the method of splinting compound fractures of the femur, and the use of the Thomas' splint at a point much farther forward than was formerly considered possible, have led to a reduction of the mortality rate in cases of this nature of at least 30 per cent.

The principle applies equally well to injuries of other bones, for, by early immobilization of the injured parts, not only is the shock of the journey enormously diminished, but also the further damaging of surrounding tissues, by movement of the broken and displaced fragments, is prevented.

General Remarks on Splinting.—For transport purposes those splints are to be preferred in which it is possible to apply "self-contained extension," as is the case with the Thomas' knee splint. The simplest pattern of splints are the best, and they should be capable of adjustment with the least possible disturbance of the patient. When fractures are handled, a pull on the affected limb should always be kept up, so that the fractured surfaces are prevented from rubbing together unduly. It is rarely necessary to administer general anæsthetics, because the opposition of wounded muscles can almost always be overcome by slow and steady traction.

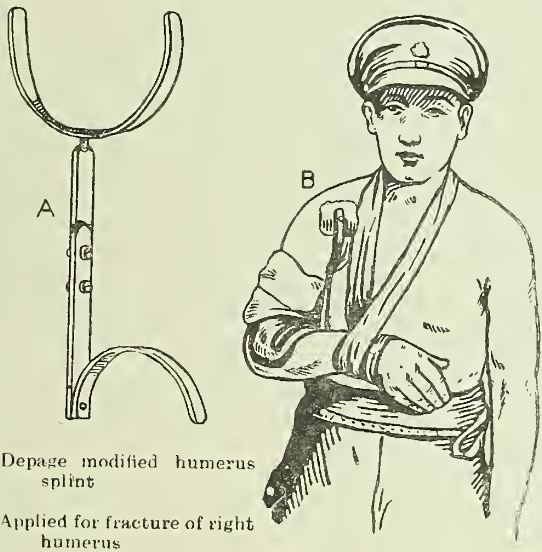
In order to provide greatest comfort for the patients during transport the following three points must be attended to :

(1) Adequate extension.

(2) Adequate support for the wounded part.

(3) Prevention of rotatory movements.

The minimum amount of bandaging must be done so that easy readjustment of the splint is possible. Tapes with buckles are often all that is necessary. Long splints ought to be prevented from displacement by fixing them to the skin, or possibly, as in the case of fracture of the thigh, to the Thomas' splint. A strap of adhesive plaster round the lower and upper extremities of a long straight splint will usually be sufficient. The strip may encircle the limb on the distal side of the wound, but proximal to the wound it should be applied spirally or in an incomplete circle and then not tightly. Care must



A Depage modified humerus splint

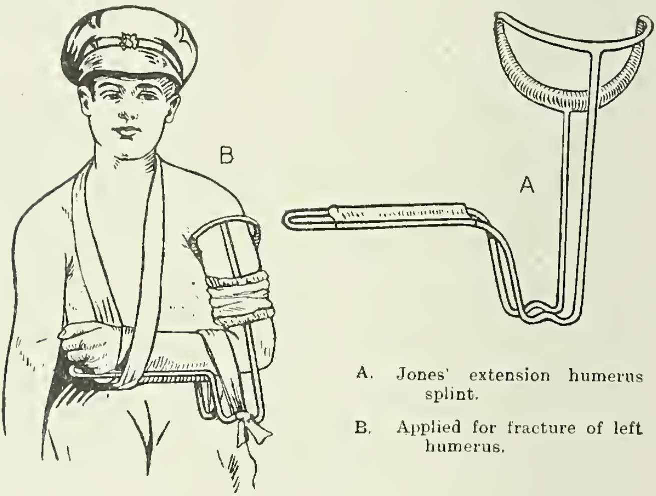
B Applied for fracture of right humerus

Fig. 12.

be taken that the proximal splint strap or turns of bandage in no way constrict the limb.

A variety of splints must be provided for each limb on account of the varying situation and the size of the wound as well as the variation in site and extent of the fracture.

Early amputations for fracture should be done only when vessels and nerves are also destroyed, or if extensive gangrene of the part of the limb distal to the fracture has occurred. As a general rule mere smashing of bone, even with severe laceration of muscle only, is not sufficient justification for early amputation. A combination of circumstances may



A. Jones' extension humerus splint.

B. Applied for fracture of left humerus.

FIG. 13.

arise which compels interference of this sort in an ambulance dressing station, *e.g.* the general condition of the patient, his inability to bear further transport, the distance of the casualty clearing station, and the virulence of the infection.

Whenever possible, the splint should be applied and extension made before dressing or other handling of the wound is carried out.

Fractures of the Humerus.—The splints and their method of application shown in the sketches are those which have been found to be the most valuable.

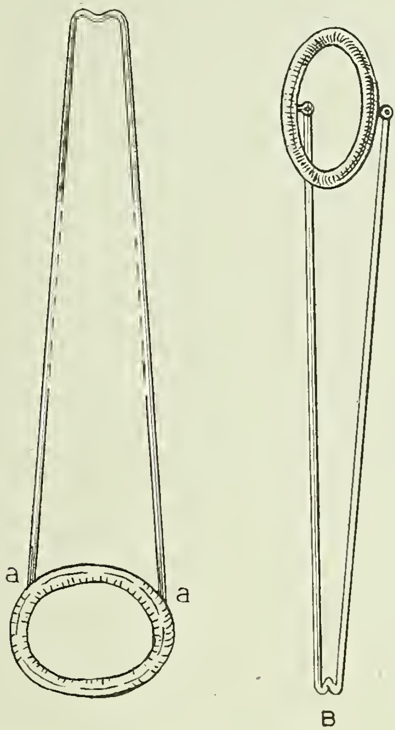
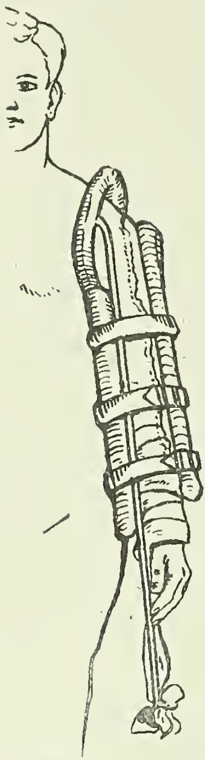


FIG. 14.

A = Small Thomas' splint for arm.
B = „ „ „ with hinge (Major Murray, S.A.M.C.).

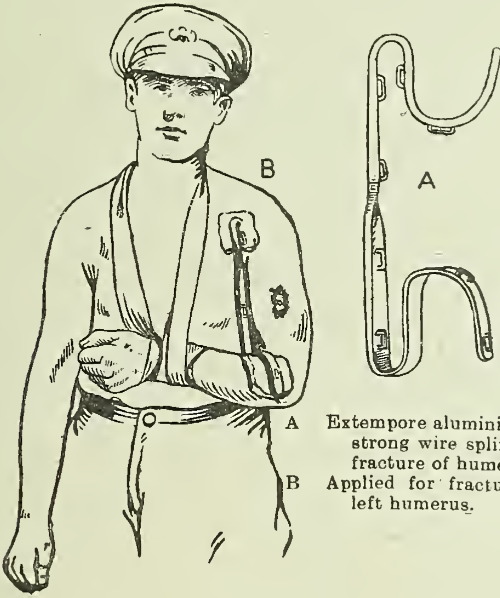
For fractures involving the shoulder joint, or when a wound in that neighbourhood prevents the application of any "crutch" splint, the use of a triangular axillary pad, base downwards, a clove-hitch round the wrist to act as a sling, and a many-tailed or triangular bandage to fix the arm and forearm on the chest, will enable the patient to travel in comfort. In some cases a piece of Gooch's splinting along the outer side of the arm is advisable. If a many-tailed bandage is used, each layer should be fixed by a safety-pin. If the patient can sit upright, a broad roller bandage may be used and fixed in the same way.



Thomas' arm splint (bent near ring), applied for low fracture of left humerus.

FIG. 14*a*.

For fractures of the shaft, Depage's modified splint is practically always applicable. (The curve of the fore-arm piece of this splint usually requires to be "flattened." The swivel joints should be made to move freely before use.) Jones's extension humerus splint has also been used fairly frequently, but is not very convenient for aid post work. For fractures at or near the elbow, whether of forearm bones or humerus, the small Thomas' splint is the best. If the small Thomas' splint be used, an anterior and posterior splint, well padded, should be added for support. For transport on a stretcher this splint is bent (over the edge of a table or stretcher handle), or



A Extempore aluminium or strong wire splint for fracture of humerus.
B Applied for fracture of left humerus.

Fig. 15.

is provided with a swivel one inch below the ring. A very efficient splint can be made rapidly by bending a strip of " strap " aluminium or thick wire in the way shown in the sketch; the crutches must be turned at right angles to each other, according to the side for which it is used.

These cases do not require a great deal of extension force in order to make them comfortable. One must remember that, in applying such a splint as

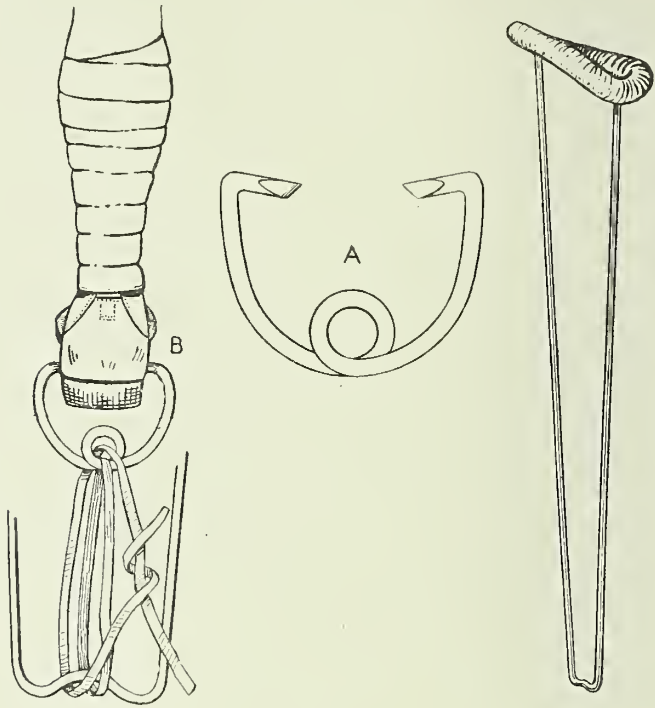
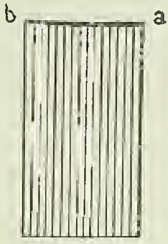


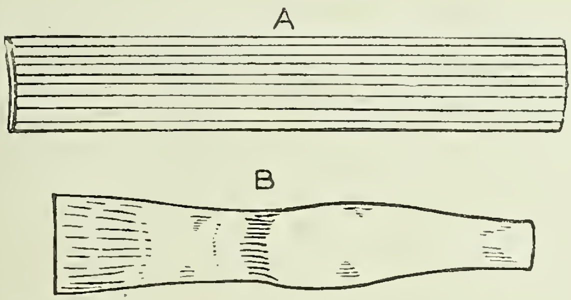
FIG. 16.

A = Tapson's sole clip.
B = Sole clip applied.
C = Thomas' knee splint.

"Depage modified," the long forearm furnishes a very powerful lever. When the small Thomas' splint is used, too strong extension by a bandage round the wrist may result in gangrene of the fingers or hand.



Short anterior thigh piece The corners (a) for right and (b) for left thigh, should be cut away.



A. Gooch's splinting, 26″ × 5″.
B. Wooden " Ham " splint.

FIG. 17.

Fractures of the Femur.—The use of Thomas' splint outfit for fractures of the thigh or leg bones.

Thomas' splint outfit consists of:

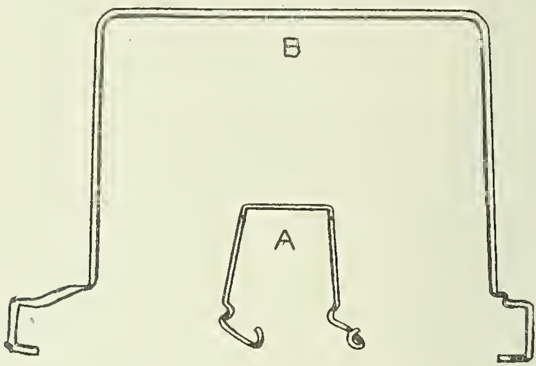
(1) Thomas' knee splint.

(2) A posterior supporting splint. (Gooch's splinting, a wooden "Ham" splint, or Jones's metal fracture or gutter splint.)

(3) A short anterior splint for the thigh.

(4) A strong wire footpiece for preventing wobbling of the foot.

(5) Two stretcher suspension bars.



A. Foot piece—strong wire

B. Stretcher suspension bar.

Fig. 18.

(6) 1-in. adhesive strapping and bandages or splint tapes.

(7) A Tapson's heel clip.

This has proved to be the best method of preventing shock and should be used *as soon as and whenever possible.* The only occasion on which the use of the Thomas' splint is impossible is when the site of the wound corresponds with the back or inner part of the ring of the splint; that is, if a wound of the lower part of the buttock or perineum exists. A wound of the groin or trochanteric region need not prevent its use. No other splint or no modification of Thomas' splint has been so successful in bringing these patients in good condition to the casualty clearing stations. Patients with compound fracture of the femur bear handling particularly badly. Liston's long splint has been favoured by some. Only very rarely indeed do cases treated in this splint arrive without severe shock. One need not detail the reasons. During a severe battle in the spring of 1917 the mortality of cases of fracture of the femur at casualty clearing stations was reduced by at least 30 per cent., even though the comparison was made with the results obtained during previous "peace" times. At this battle period practically every case was sent down in Thomas' splints, whereas in the peace period Liston's and other splints were used as well. The death rate from gunshot fracture of the thigh was at one time of the war about 80 per cent., and nearly 50 per cent. occurred at casualty clearing stations. The death rate at the casualty clearing stations during this battle was 15·6 per cent. in 1,009 cases. Previous to the battle the method of application of the splint was widely domonstrated. Before this, these patients used to arrive in such a shocked condition that they could not be touched for hours. Only 5 per cent. of the cases admitted during this battle were unfit to be operated on immediately after admission. This was owing chiefly to the presence of severe wounds elsewhere, or to the fact that, the patients having been lying out, the wounds were already in a hopeless state of sepsis. Certain surgeons had, previous to this time, been expressing the opinion that more lives would be saved if amputation were done in every case of fracture of the femur, yet the number of amputations in this series was only 17·2 per cent. It is therefore evident that more conservative measures were possible than ever before.

The fact that such patients bear handling extremely badly has led to the general adoption of the

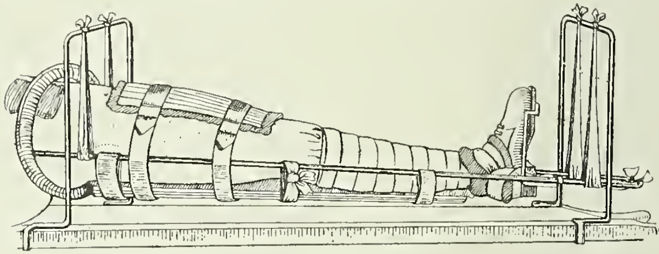


Fig. 19.

plan of putting on the Thomas' splint without removing either trousers or boots. The application of the splint will be gathered from a study of the accompanying drawing. An orderly lifts and steadies the limb, making extension all the time; the trousers opposite the wound are cut open freely; the wound is attended to, and covered temporarily; the splint is applied and extension made with a Tapson's sole clip or a calico bandage or puttee clove-hitch; a pad should be put round the ankle and over the dorsum of the foot if a clove-hitch or other knot is used; the limb is supported behind by the hand of an orderly (after extension is applied, a bandage sling in the neighbourhood of the knee may be used instead, while the orderly holds up or manipulates the end of the splint); the wound is dressed and the supporting posterior splint, well padded so as to flex the knee slightly and support the femur well, is then slung to the side bars of the Thomas' by sticking plaster. An anterior short thigh splint prevents flexion of the upper fragment and gives greater security. The foot-piece is finally fixed in position and prevents "wobbling" of the foot better than anything else. If the boot has been removed the foot must be well padded before the foot-piece is applied. If the boot has been removed on account of wounds of the foot, extension may have to be made by ordinary adhesive plaster strips applied to the leg above the wounds; but, when possible, all things considered, a clove-hitch around the thickly padded ankle, with knot on the outer side, is most suitable.

A long posterior supporting splint is better than interrupted slings.

When extension is made, clot may be dislodged from the lumen of the main artery. As already remarked, death has occurred, in patients previous exsanguine, from this cause. Therefore, in order to get at the wound easily, no encircling bandage should be put around the dressing before extension is made, and the necessity for immediate digital compression of the femoral should be borne in mind.

The extension should be examined at every stopping place and adjusted if necessary. While an efficient pull is of the greatest importance, it must be remembered that gangrene of the skin and even of the foot has been caused by too strong and improperly applied extension.

The splint should be slung, by two pieces of bandage, from the suspension bar so that the foot just swings clear of the stretcher. If a suspension bar is not available these bandages may be tied to the traverse of the upper bunk in the ambulance car. The patient's pelvis may be steadied by a broad bandage encircling both pelvis and stretcher, *but the splint should be allowed to swing freely*, otherwise unnecessary jarring occurs. The plan, suggested recently, of suspending the ring or upper end of the Thomas' splint lightly from a second suspension bar prevents slipping of the ring and provides extra comfort during transport. Careful attention to fixing of blankets must be given when it is used.

Unless there is a distinct indication for changing the dressings of these cases during transport, they should not be interfered with, except to control extension and suspension of the limb and fixation of the foot.

Patients who arrive at casualty clearing stations without these points being attended to are always in worse condition than those who have been properly looked after.

If the suspension bars and footpiece are not available at very advanced posts, the projecting end of the Thomas' splint should be supported on, for example, an empty petrol tin or brick laid on its side, so as to carry the heel free from the stretcher, and the foot should be fixed by a figure of eight bandage. The reversed wire footpiece is too narrow to form a good support, even when it is available. When it is used in this way the splint and limb invariably become twisted.

If a supporting back splint is not available, the leg of the trousers should be cut down in front and pinned firmly over each side bar of the Thomas' splint.

When a patient is picked up on the field, the following device will be found serviceable. A puttee or strong bandage is passed under the perineum and round the "head" handle of the stretcher on the side opposite to the injury, pulled and tied firmly. A clove-hitch is fixed over the ankle and strong extension is made round the foot handle on the same side as the injury. Two or more splints are fixed on the thigh by two strips of bandage or splint tapes. The foot is kept from rotating by the support of bricks, equipment, etc., or the toe of the boot is connected by bandage or puttee to each foot handle. The pelvis should be bandaged to the stretcher.

One of the best methods of procuring extension is by the use of Tapson's sole clip. The clip is made from thick iron wire. (*See* diagram.) The prongs of the clip should be slipped into the groove between the sole and the "upper" of the boot immediately in front of the heel. "Splint tapes" may be used for making extension, as shown in the diagram, but a strong bandage, which is passed through the ring of the clip and over the notch of the splint twice, will prove more reliable and equally easily manipulated.

Removal of the boot is justifiable only when a wound of the foot makes it necessary or when the boot and sock are wet and trench foot is suspected. See previous remarks under " Removal of Wet Clothing " (page 17).

Fractures of Leg Bones.—For those in the upper two-thirds of the leg Thomas' splint as applied for fracture of the thigh is the most suitable. For those near the ankle a long back splint with foot-piece (Barbour) plus two lateral straight splints, which should bear both on the footpiece and on the back splint, should be applied. Owing to its tendency to fall over on its side during transit and cause twisting of the limb, the splint should be anchored to the stretcher by bandage " stays " passing from the top of the foot-piece to the stretcher runners on each side.

Wounds of Joints, especially Knee Joints.—All penetrating wounds should be splinted. In the case of the knee, if the wounds are not accompanied by fracture, a straight gutter splint, well padded to produce slight flexion, reaching from the tuber ischii to the heel, is sufficient. More serious wounds, with fracture, should be put up in a Thomas' splint outfit.

Head Wounds.—The scalp around the wound should be well soaked with picric acid solution. In gutter wounds, any gross dirt, projecting bone, or foreign body should be removed and a piece of impregnated gauze placed to keep the wound open. In a puncture wound no attempt should be made to disinfect the track. In no case should the brain be interfered with, except to remove any visible loose bone or foreign body which during transport might cause further damage. Direct pressure by dressings over a hole in the skull should be avoided, as it may cause cerebral compression to occur. Rather make a "bank" of folded gauze on each side of, or all round, the wound, so that blood or disintegrated brain can readily escape. Head cases should be propped up when possible. If not, a soft pillow should be placed under the head, and sandbags, pillows, etc., placed at each side to prevent lateral movements during lurches of the car.

Chest Cases.—In view of the success which has attended radical operations, severe chest cases should be sent to the casualty clearing stations as soon as possible. Although not so urgent as abdominal cases, yet delay imperils the success of the operation. Cases with open "sucking" wounds and severe intrapleural hæmorrhage may be so collapsed or distressed that they cannot be sent on at once. The closure of an open "sucking" wound brings about very rapid relief and should be done immediately. This closure is best done by suture (local anæsthetics if necessary) or by "corking" the wound with gauze plug, which is prevented from slipping by strips of broad adhesive plaster. The strips should extend to just over half the circumference of the chest. Considerable amount of risk must be taken in sending on many of these cases. The worse the wound the sooner will the patient die if the chest cannot be closed. If suture of a "sucking" wound is made, a note should always be sent with the patient stating that an open wound of the pleural cavity was present and that the patient requires immediate attention.

Abdominal Cases.—These should be sent on at once to casualty clearing stations unless it is obvious that the patient is dying from shock or hæmorrhage. It must continuously be borne in mind that wounds of the chest, especially of the lower posterior parts, and wounds of the loins, buttocks, perineum, or even upper part of the thigh, are frequently associated with penetration of the abdominal cavity. In arriving at a diagnosis it should be remembered that rigidity and absence of free movement are of much greater importance from a negative than a positive point of view. Their absence precludes visceral injury, whilst their presence may be due to other causes such as chest wounds, retroperitoneal hæmatomata, or injury of the abdominal wall alone. Tenderness is more conclusive than pain. Its presence at some distance from the wound, especially when on the opposite side, is almost diagnostic of visceral injury. In cases of doubt always treat as if penetration had occurred.

Multiple Wounds.—These are apt to be associated with very severe shock. All possible care, therefore, should be taken to prevent or assuage it. The patient should be handled as little as possible. It is often preferable to leave such cases absolutely alone for a few hours, simply seeing that they are kept warm. Sedatives may be given if the patient is in pain.

Notes on Field Medical Cards.—Nature and severity of wounds. Time of wounding.

Presence of shock and severity of hæmorrhage.

Dose and time of giving morphia, etc.

Amount of antitetanic serum injected.

A very short description of any operation or special treatment carried out. (*If foreign bodies* or fragments of bone *have been removed, this should be stated.*)

In periods of great stress time will be saved, in the aggregate, by having a special orderly detailed to make notes in the dressing room.

A note to the casualty clearing station should accompany the car, with the names and number of splints, instruments, etc., which are sent from dressing stations, in order to facilitate immediate return or exchange.

The Field Medical Card is meant to provide a consecutive record of the patient's condition and treatment in his passage through the field ambulance, casualty clearing station, and hospitals on the lines of communication.

CHAPTER II

WORK AT A CASUALTY CLEARING STATION

In this description, the conditions which prevail during severe fighting are dealt with. During quiet times the work of the unit should be conducted on identical lines, so that in the active periods simply a speeding up or augmentation takes place.

As in more advanced units, so also in casualty clearing stations, professional instincts and desires cannot be satisfied as one would wish, owing to many considerations connected with the military situation. It has become generally accepted, however, that the casualty clearing station is the "site of election" for operations on men wounded at the front. Only operations of extreme urgency, such as for the control of severe hæmorrhage, should be undertaken at stations farther forward, owing to the impossibility of providing the necessary equipment.

The *value* of pre-inflammatory operations and therefore the importance of the surgical work at casualty clearing stations cannot be over-estimated. The *amount* which has to be done during severe fighting is sometimes very great and can only be gauged approximately beforehand. The *quality* of the work is more controllable. The most skilful and experienced surgeons should be available in sufficient numbers to cope efficiently with the probable amount of work. Operations which are done must be thorough. Timid half measures too often prove valueless in saving life or limb, or result in repeated later operations which can usually be prevented by more radical treatment in the first instance. Radical conservative measures are being attended with increasing success. Experience has shown to many operators that limbs can now be saved which previously would have been sacrificed. Modern methods of resuscitation in cases of profound shock, together with subsequent operation, snatch many patients from what looks like certain death. In view of these considerations, the casualty clearing station is, without doubt, the hospital unit which, surgically, is of the greatest value to the nation from both a military and civil point of view.

It is necessary, therefore, that casualty clearing stations should be equipped with every facility for carrying out surgical work rapidly and efficiently. All possible aids to diagnosis and treatment such as are furnished, for example, by up-to-date X-ray and bacteriological laboratories must be included. At the same time the mobility of these units must be kept constantly in mind.

The surgical and nursing staffs must be of the best. Theatre accommodation and equipment must be ample and adequate to deal with any emergency. Special pre-operative and post-operative wards, for various purposes, must be provided. The organization must be perfect in every department, so that patients may be reeeived, housed, warmed, fed, transported, and otherwise attended to within the hospital without a hiteh. It is obvious, further, that speeial arrangements for rapid evaeuation of patients must prevail. Only sueh patients as will suffer unduly from further immediate transport ean be retained. Put briefly, the funetions of a easualty elearing station during a "push" are to save life, limb, and funetion where possible and, generally speaking, to fortify all patients against the effeets of further early transport. It must also eliminate and dispose of very slightly wounded men to seleeted hospitals or rest stations in the neighbourhood. Sueh patients should be retained as near the fighting line as eireumstanees permit. They are usually fit for duty in a very short time.

Casualty elearing stations must be outside the range of ordinary shell fire, but at the same time be as far forward as the military situation will allow. Apart from the eonsideration of a probable easualty list, the mental effeet on the helpless wounded man of shells bursting in the neighbourhood, or even of the noise of friendly guns, eannot be disregarded. The group of hospitals must be plaeed at a point where roads from the front, passable for ambulanee ears, eonverge, where easy evaeuation by ambulanee train is possible, and where there is a good water supply. A speeial hospital siding from the railway line is essential in order to reduee interferenee with other traffie to a minimum. Other military eonsiderations may prevent seleetion of what seems the best site. Suitable buildings are now rarely available. The hospitals have usually to be pitched in the open. The best site for easiest working is on the side of a smooth, gentle slope, at the top of which runs the main road from the front and at the bottom the hospital siding. A system of light railways, as the Decauville, should be provided within the hospital. It is easily appreciated that all these and many other matters have a great influence on the surgical condition of patients as well as on the question of administration.

The importance of warmth to a wounded man has already been emphasized. During cold weather, under the conditions of campaign which exist on the greater part of the front in France, the problem of furnishing and conserving heat is a most difficult one. The casualty clearing station is looked upon by the wounded man as his first real haven of rest, and that haven must be warm, else it loses much of its physical and mental benefit. No detail should be neglected which will protect the man from cold on a stormy winter day. The temperature of the reception room, evacuation shelter, and other parts of the casualty clearing station is only of less importance than that of the operating theatre. Cold is one of the greatest factors in maintaining or aggravating the condition of surgical shock produced by a serious wound on a man already predisposed to it by enormous physical and psychical strain. The badly wounded man should be under cover and protected from cold from the time he is unloaded from the heated ambulance car until he is evacuated to the base.

Rest is of equal importance. Efficient splinting and careful handling and driving minimize the evil effects of transport over rough roads. In the casualty clearing station itself all arrangements should provide that patients are moved or disturbed as little as possible until they have recovered from the journey and are fit to undergo the surgical treatment which they so urgently require. The less seriously wounded man benefits, comparatively speaking, as much from these arrangements as does his less fortunate comrade.

The usual plan of dealing with patients cannot be discussed in detail. Casualty clearing stations are usually arranged in groups of two to four, and patients are received by each in turn, in numbers previously agreed upon. Two sitting cases are looked upon as equivalent to one lying case. The object of this arrangement is to assign to each unit cases sufficient for it to deal with satisfactorily before the next batch comes along. It is doubtful if it is desirable to set apart any casualty clearing stations to deal with walking wounded alone.

Efficient organization of stretcher bearers and other methods of transport in the casualty clearing station is of immense value in the smooth and rapid working of all departments of the unit.

Ambulance cars drive along a switch from the main road to the **reception room** door, where patients are unloaded. Waiting cars should not be opened up until their turn for unloading has arrived. A large porch on the reception room is advisable, with wide doors on its three sides. Only the door on the lee side should be used on a windy day. Unloading should be done under cover when possible. The reception room must be large so that convoys of cars can deposit their burdens and depart without delay, having been supplied with stretchers, blankets, splints, hot water bottles, etc., in exchange for those brought down with the patients. These are handed over from a store situated farther along the switch. Great care should be taken that the blankets are thoroughly dry. Very simple structures, wooden frames covered with blankets and heated by a suitable stove, have been invented for warming and drying blankets. A large one should be available for general supply, and smaller ones for every "special" ward.

In the reception room, the patients' names and other particulars are entered in the admission and discharge book, equipment disposed of, clothing searched for ammunition, valuables put in a bag which accompanies the patient wherever he goes, etc. Fluid nourishment should always be on tap. Hot tea with plenty of sugar in it is most favoured by British soldiers.

The patients are then taken to the **dressing room** where thorough examination and decision as to their further disposal are made. On this account the medical officers detailed for this duty should, if possible, be men of very sound judgment and wide experience in base as well as casualty clearing station work. The officers in charge of the dressing-room are, in fact, the most important in the casualty clearing station, from a professional point of view. Enough stretcher tables to cope with the work should be available. One medical officer can supervise four to eight tables, provided that one good nurse or orderly is detailed for eaeh table. Another medieal offieer should deal with walking eases, if these have not been diverted to a speeial easualty elearing station. It is preferable to deal with walkers in a separate dressing room. Severely shoeked eases should not be handled at this period, unless they show signs of aetive external hemorrhage. Cases of fraetured thigh should not be "taken down" until they are anæsthetized on the operating table. In both instanees, however, pain or diseomfort should be allayed by suitable remedies.

Cases for immediate evaeuation inelude all eases whieh do not require operation, with the exeeption of most penetrating ehest wounds—with hæmothorax, and eases whieh are suffering from sueh exhaustion and shoek that their eondition would still further be jeopardized by a railway journey. Wounds whieh do not require operation should be earefully dressed. In all other eases it must be remembered that unneeessary handling is very detrimental. If elear notes from a field ambulanee offieer aeeompany the patients it may be unneeessary to look at their wounds till they are on the operating table. If it is neeessary to overhaul and redress wounds, a note should be made of the nature and number of wounds, and whieh are the most severe, for the guidanee of those dealing with the eases afterwards. For this purpose a speeial note clerk will be of great assistanee. Dressings, of eases for operation, should be fixed in as simple a way as possible.

Light eases for operation are sent to a **light pre-operative ward,** where they are prepared. Very wet clothing should be changed, but otherwise it is unnecessary to undress them more than will expose their wounds thoroughly and prevent clothing from being soiled at operation. In turn, they go to a **light operating theatre, light recovery ward,** where they are retained until they have recovered from the effects of general anæsthesia, and finally to the **evacuation shelter.**

Hot drinks for the more severely wounded and more ordinary food for the very slightly wounded must be provided.

Severe cases for operation are distributed to different wards according to the nature of their wounds and their general condition, *en route* for the severe operation theatre. The bulk of these cases are sent direct to the **severe pre-operation ward.** Here they are undressed, washed, and put into warm appropriate clothing. They are warmed by various means and given hot nourishing drinks if they have to wait long for operation. Their wounds should not be interfered with if definite information regarding these has been sent from the dressing room. Otherwise, except in cases of fractured femur, an attempt should be made to estimate the comparative severity of wounds for the guidance of the operators in the theatre. The hair may be softened by soap dressing in head cases, if time does not permit of complete shaving or removal by depilatory paste. The medical officer in charge arranges the order in which cases are to be taken to the theatre.

The **resuscitation ward,** to which very bad cases are sent, is equipped with all necessary appliances and other remedies for restoring animation. Many suffer from sueh severe shoek that they have literally to be eoaxed baek to a eondition of reasonable vitality. Warmth, absolute rest, sedatives, and transfusions of various kinds are the ehief sueeessful remedies. The sisters in eharge should be most earefully seleeted. It is wonderful the amount of sueeess whieh is aehieved by some eompared with others. A "shoek team," medical offieer and assistant, also speeially seleeted, superintends the administration of blood transfusions, ete., and looks after the worst eases. They may be required from time to time in the operation theatre for similar work.

Men with severe penetrating ehest and abdominal wounds should be sent to a speeial preoperation ward for speeial observation and treatment. In 20 to 30 per eent. of ehest eases and in over 90 per eent. of abdominal cases, operation is the only treatment whieh will save life, and that only if it can be carried out early.

It goes without saying, that skilful treatment in these pre-operative departments will save many lives, and that an adequate number of trained attendants must be allotted to them. At the same time, one eannot refrain from remarking that too much attention is almost as bad as too little. Well-organized, preeise arrangements ensure rapid and sueeessful treatment. This applies as mueh to duties like stretcher-bearing as to the most seientifie proeedures. A full supply of warm, dry blankets and of hot water bottles must be available.

It must be remembered that military exigencies will not admit of extravagant arrangements in **operation theatres.** With skilful surgeons, anæsthetists, and attendants, it is found that results are equally good whether operations are performed in separate small theatres or in one large theatre common to all. The latter is therefore, under the circumstances, preferable. The size of the hut usually provided accommodates six tables easily. Everything inside the theatre should be arranged to allow the freest possible movement of stretcher bearers, without interfering with other work. Arrangements for washing and disinfection of hands, instruments, dressings, etc., and disposal of sterilizing, splint, and other rooms depend on local idiosyncrasies of men and locations, and need not be discussed. Easy communication with the X-ray department is essential. The problem of warming the theatre is one which requires most careful attention. The dispensary, or drug-store, and reserve of splints should be within easy reach of the operating theatres.

Patients who undergo severe operations are kept for a varying period in **post-operation wards.** Segregation of different types of wounds in special wards is frequently made.

A large hut, or enough marquees roped together to make adequate accommodation, should be provided at or near the railway siding. Walking cases are kept in one part, stretcher cases in another. As already indicated, warmth is of as much importance here as elsewhere, especially if walking cases have to be sent off in an unheated improvized ambulance train.

It has been found that the detailing of surgical teams, the members of which have worked together and know each others' capacity, has resulted in marked improvement both in the quality and quantity of the work done. A team consists of a surgeon, an anæsthetist, a nursing sister, and an orderly. The number of teams and the number of other attendants must vary according to the estimated amount of work to be done. One or two tables more than those actually in use by the surgical teams working in the theatre should be kept for patients next for operation. An extra anæsthetist, sister, and orderly attend to their preparation. When slightly wounded cases are being dealt with, two or more tables are allocated to each team. Such an arrangement conserves time.

The work of the casualty clearing station should be judged from the condition in which its patients arrive at the base more than by the number of cases which it passes through, although in times of highest pressure the latter function becomes of equal if not of paramount importance. On some occasions, indeed, the casualty clearing station has to be transformed into a glorified dressing station. Operations, unless most urgent and at the same time most hopeful, are given up for the time being. At all times the aim must be the greatest good to the greatest number. Experience alone teaches how that can best be attained. Many patients who obviously require early operation may have to be passed on or left until the excessive numbers have been dealt with.

In conclusion, one feels compelled to say, with regard to the surgical operations which have to be performed, that the surgeon fresh from civil practice will have many failures unless he at once models his work on the lines which bitter experience has taught to others. He will speedily find that war wounds in France behave very differently from those to which he is accustomed at home, unless they are treated efficiently on certain definite principles. If these principles are appreciated, common sense and good technique in their application will ensure at once a great measure of success.

CHAPTER III

THE TREATMENT OF WOUND SHOCK

The nature of wound shoek and the best methods of eombatting it are amongst the most diffieult questions that eonfront the military surgeon. They are problems that trouble the regimental medieal offieer, the ambulanee offieer, and the surgeon at the easualty elearing station with equal insisteney, and the greater the progress that is made in other direetions, the more does " shoek " stand out as the great unsolved riddle of military surgery.

During the last two years great efforts have been made to throw more light on the subjeet of wound shoek, by means of laboratory investigations at home and by elinieal observations abroad. It is not proposed in the present ehapter to deal with the physiologieal aspeets of this research, but rather to epitomize the work that has been done in Franee, and partieularly that portion of the work that has been earried on in the army to whieh the writers happened to belong (see Prefaee). For those who desire information on the physiological or experimental side of the problem of shock the excellent reports, published from time to time by the Medical Researeh Committee, are strongly to be reeommended.

The Nature of Wound Shock.—An enquiry into the nature of wound shock is obviously an exceedingly difficult one. The condition of the badly wounded man is often due to the action of so many different factors, and is complicated by the presence of so many different conditions (*e.g.* shell concussion, hæmorrhage, poisoning by gas, toxic absorption, etc.,) that it is often a matter of great difficulty to unravel the tangle and arrive at a just conclusion. Moreover, in dealing with this subject, it is necessary to distinguish between two conditions, namely, *Primary Shock*, or the collapse immediately supervening on the infliction of a severe wound, and *Secondary Shock*, which develops later as the result of such factors as exposure to cold, pain, hæmorrhage, movement, anxiety, exhaustion, and all the other harmful influences associated with a long journey to the casualty clearing station. Although most observers are agreed on the existence of these two categories, they are by no means in agreement as to the frequency with which the condition of primary shock is met. However, as it is with the manifestations of secondary shock that this chapter is chiefly concerned, discrepancies of opinion as to the nature and frequency of primary shock are of minor importance.

Factors influencing the Development of Secondary Wound Shock.—Although the development of marked secondary shock generally means that the original injury is a severe one, or has been associated with severe hæmorrhage, this is by no means invariably the case. In some instances the secondary exhaustion is quite out of proportion to the severity of the wound

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or the amount of the hæmorrhage. Many instanees have been known of badly wounded men reaehing the easualty elearing station in good eondition, and eonversely of eomparatively lightly injured men developing severe seeondary shoek as the result of their exhausting experienees subsequent to injury. Different individuals vary widely in their eapaeity to withstand shoek, as also do battalions reeruited from different sourees, or from different raees. Indian troops and battalions drawn from large towns, for example, show a greater tendeney to develop shoek than troops reeruited from purely agrieultural districts. Offieers, moreover, are more prone to shoek than men, espeeially when the period preeeding their wounding has been one of great mental anxiety, aggravated by fatigue and laek of sleep. For this same reason "self-inflieted wounds" are frequently aeeompanied by marked shoek. The mental eondition and general state of health previous to wounding has thus an undoubted influenee on the development of seeondary wound shoek.

Hæmorrhage and Shock.—Hæmorrhage is so eonstantly assoeiated with shoek, and plays sueh an important part in its produetion, that the great majority of eases are examples of shoek-hæmorrhage rather than of pure shoek. Unfortunately, it is extremely diffieult to estimate, even approximately, the amount of blood lost by any partieular patient during the first few hours after wounding, but the total quantity is probably greater than is generally supposed. Captain O. H. Robertson, Med. Corps, U.S.A., has shown that a secondary hæmorrhage of even moderate severity is followed by a very large drop in the total blood volume. This drop, in the case of a severe hæmorrhage, may amount to as much as 50 per cent. of the normal blood volume. A similar loss of circulating fluid in normal people, and in favourable circumstances, is rapidly replaced, but unfortunately such is not the case under conditions of war. For some reason, hitherto undiscovered, the normal mechanism which regulates the volume of the circulating blood is upset in the case of the badly wounded and shocked soldier.

The practical deduction that should be drawn from this observation is that every effort should be made at the earliest opportunity to replenish the depleted fluid reserves of the wounded soldier by the administration of large amounts of fluid, preferably through the medium of the alimentary canal, *per oram* or *per rectum.* It must be borne in mind that at all times the supply of drinking water in the front line is very limited in amount, and that the fluid reserves of the unwounded soldier are in any case likely to be below normal. When called upon to make good the enormous amount of fluid lost from the hæmorrhage and from the profuse perspiration that may follow the infliction of a wound, these fluid reserves, already at a low level, are rapidly exhausted. Hence the urgency of replenishing them as early as possible.

Cold.—The importance of cold, in precipitating and in aggravating secondary shock, has been pointed out by all clinical observers engaged in this investigation. Laboratory experiment has confirmed these views, and has shown that cold contributes to the development of acidosis and is a potent factor in aggravating the circulatory disturbances present in shock. Clinical observation and laboratory experiment are thus entirely in agreement on this point.

The importance of cold as a shock-factor having once been realized by those working on the problem, an energetic crusade in favour of warmth was carried on amongst the personnel of the forward medical units in France during the spring of 1917. Special attention was paid to the protection of the wounded man from the action of cold during the earlier stages of his journey, and the use of the hot-air cooker, described on page 21, was advocated and widely adopted. A more extensive use of blankets, mackintosh sheets, hot-water bottles, etc., was urged, and efforts were instituted to ensure better warming of dressing stations, railway trucks, and ambulances. The beneficial results of this crusade were clearly indicated during the winter of 1917–18. Not only did the incidence of secondary shock appear to be diminished by these warmth measures, but the period of resuscitation required in the case of those who arrived shocked at the casualty clearing station was materially curtailed. Earlier operation was thereby achieved, and the danger of sepsis diminished.

Simultaneously with the improvement in the anti-cold measures of the forward units, there were instituted various improvements at the casualty clearing stations. The resuscitation ward became a recognized feature of the latter unit. In this well-warmed ward the badly shocked man received all the concentrated attention and care that his condition demanded at the hands of a sister and orderlies specially experienced in such work, acting under the instructions of a specially experienced medical officer. By these means many badly wounded men in need of special attention and care were undoubtedly saved, and much valuable knowledge gained. The specially trained "shock team" was initiated.

Compound Fractures and Shock.—It has always been recognized that cases of severe compound fracture are especially prone to develop secondary shock during the course of their journey to the casualty clearing station. This is due not only to the fact that such injuries are usually associated with profuse hæmorrhage and severe pain, but, in the light of recent laboratory findings, is also probably due in part to the absorption into the general circulation of various toxic products from the damaged limb. It has been shown experimentally that if the blood from damaged muscle tissue be allowed to enter the circulation by removal of a tourniquet, the entry is followed by a general fall of blood pressure. This experimental finding is not without its bearing on the question of treatment. The extent to which fat embolism may play a part in some cases is not clear.

The beneficial results of early and efficient splinting in the case of compound fractures have been amply demonstrated by the history of compound fractures of the femur. (*See* page 59.) With the introduction of the Thomas' splint into regimental aid posts and advanced dressing stations came an enormous reduction of the amount of shock associated with fractured thighs, and a corresponding fall in their mortality. The same is true to a slightly lesser extent of fracture of other bones. The better and the earlier splinting is applied to a broken limb, the less the patient suffers from the jolts and jars of his journey, the smaller is the amount of damage done to the tissues by the jagged ends of the bone, and, possibly, the less are toxins massaged into the general circulation. The wide-spread recognition of these facts has led to a striking improvement in the splinting carried out by regimental and ambulance officers, and an exceedingly satisfactory reduction in the degree of shock commonly associated with fractured limbs.

There is, however, a limitation to the capacity of splinting to neutralize the harmful effect of a long and rough journey on a wounded man suffering from a compound fracture. When the limb has been so badly damaged that its subsequent amputation is a matter of certainty, the earlier it is removed the better it is for the patient. The splinting of these badly smashed limbs is a difficult and painful process, and, as they are frequently associated with hæmorrhage, conservative treatment becomes still more difficult. Early amputation in the advanced dressing station is called for far more frequently than it is performed. Not only is it the safest treatment from the point of view of shock, but it is often the easiest treatment from the point of view of the medical officer.

The earlier that amputation is performed the less is a general anæsthetic likely to be required. The local shock to the tissues and the long latent period of the patient's nervous system generally allow of the operation being more than half completed before the patient realizes that anything is being done. The site chosen for amputation is that at which the minimum of cutting is required.

The effect on shock of the removal of a painful and shattered limb is striking in the extreme. The patient lapses into a condition of natural sleep, and a few hours later may be evacuated with safety. If a general anæsthetic has been given, the dangers of subsequent acidosis are greatly increased by transport so that the patient must be retained for a longer period—12–24 hours.

Effect of Pain and Anxiety on Shock.—Although secondary shock may develop in the absence of pain, it is found that severe and prolonged pain is a potent factor in producing shock. Crile, in particular, has laid stress on the importance of pain in this connection. Mental anxiety and worry produce a similar exhaustion of the central nervous system, and reinforce the baneful action of pain. The restless and fretful patient rarely does well. All efforts to make him comfortable fail, and even morphia may be without effect. Prolonged consciousness, unbroken by sleep, is in itself capable of producing symptoms of secondary shock. Natural sleep is, in many ways, worth more to the severely wounded man, who is exhausted by all the excitements and exertions of battle, than any other remedy that is known to us.

The journey from the trenches to the casualty clearing station is in any case an exhausting experience, and every effort must be made to spare the wounded man all unnecessary exertion or worry.

Once his wounds have been satisfactorily attended to —and this should be done as far forward as possible— he should be left undisturbed. Redressing and unnecessary stoppages should be avoided. Gentleness in handling is essential at all stages. Nor ean his mental condition be neglected. Much ean be done by quiet assurance and encouragement to put his mind at rest. The badly wounded man has, as a rule, lost the eontrol that carried him through the trials and dangers that preceded his wounding, and due allowanee must be made for his abnormal mental state.

Morphia has long been a bone of contention in this connection. Its use is full of possibilities for good and for evil, and considerable discernment is required in deciding when to give and when to repeat an injeetion. Where the dangers of aeidosis are not imminent its use is likely to be wholly beneficial. When respiration is slow and the skin is dusky in colour, morphia may be produetive of harm. The pros and eons of eaeh case must be carefully weighed, especially when the question at stake is whether an injection should be repeated or not. The opposing dangers of pain and exhaustion, and of cyanosis and aeidosis, must be balanced in arriving at a decision. (*See* also page 30.)

The Replenishing of Exhausted Reserves.—As the result of shoek and of hæmorrhage. the body suffers two great losses, the loss of its fluid reserves and the loss of its alkalis. As a eorollary to the first of these two losses we find a concentration of blood and to the second a diminished alkalinity of the blood. In the treatment of shock hæmorrhage these two losses must always be borne in mind, and steps taken to replace the deficiency as early as possible.

The Administration of Fluids.—Two methods of administering fluids to the depleted body are available:

(1) By means of the alimentary canal.

(2) By intravenous or subcutaneous injection.

When circumstances permit, the first-named channel of administration is of the greatest value. Very large quantities of fluid must be given, a special orderly being detailed to the duty of encouraging the wounded man to drink repeated feederfuls of water. By means of forced fluids alone Captain Robertson has succeeded in raising a diminished blood volume to the normal within a very short period.

Unfortunately, in many cases of shock, persistent vomiting prevents the administration of anything except a small amount of fluid by the mouth. In such cases rectal salines are of value, although even here difficulty may be experienced from the fact that the sphincter acts but weakly, and the injected fluid tends to return. To avoid this it is often advisable, when possible, to administer fluids *per rectum* by means of Murphy's drip.

Where the need of giving fluids is urgent, or where administration by the alimentary canal is impossible, recourse must be had to intravenous injections. Subcutaneous infusion has its value in less serious cases, but is less certain in its results. The various forms of infusions available for intravenous injection will be considered separately.

Intravenous Injections of Saline.—Numerous solutions, of varying formulæ, have been employed for intravenous use, but one and all have proved disappointing in their clinical results. During the last two years much valuable work has been done by various laboratory investigators on the subject of intravenous injections, and a fuller knowledge of their action has thereby been obtained. As a result of this work it has been shown that intravenous salines are very transitory in their action, and are rapidly lost to the circulation. No permanent dilution of the blood, and no sustained raising of the blood pressure can be obtained from the use of intravenous salines in cases of *severe* shock-hæmorrhage. A viscous fluid, which will not readily be shed out of the vessels, is required.

The Infusion of Colloids such as Gum Acacia.—In the course of his investigation into the effect of various intravenous infusions on the blood-pressure, Professor Bayliss tested the action of such colloids as gelatine, soluble starch, dextrin, and gum acacia. A solution of between 6 and 7 per cent. of gum-acacia in 0·9 per cent saline was found to have the same viscosity as whole blood, and the same osmotic pressure as the colloids of the plasma. It was therefore, in theory, a suitable infusion for use in cases of shock-hæmorrhage. In the laboratory the value of such an infusion has apparently been fully established. Clinically it has not achieved the complete success that it was hoped might result from its use. No laboratory experiment can reproduce accurately the conditions that are met with in the field, and although gum may establish its right to a place in the treatment of shock, there is a very definite limitation to its powers in raising and maintaining a fallen blood pressure.

As the length of time elapsing between the hæmorrhage and the injection of gum, *i.e.* the period during which the blood pressure is seriously lowered, seems to exercise an influence on the results obtained, and as the use of gum had met with only partial success at the casualty clearing stations in France, it was decided to push the administration of gum forward into the field ambulances. The injection would thus be given in much more favourable circumstances, a much shorter interval having elapsed since the original hæmorrhage. The treatment is still on its trial. However, sufficient experience has been gained to justify the following conclusions :

(1) That the infusion is more efficacious than normal saline, when given within a few hours of wounding.

(2) That its administration is unattended by any ill effect except an occasional rigor, or a tendency to vomit.

(3) That in wounds of moderate severity accompanied by moderately severe hæmorrhage, the administration of gum-saline improves a man's general condition, and allows of his being transported to a casualty clearing station, where blood transfusion can, if necessary, be performed. (70 per cent. of successful cases subsequently required the performance of blood transfusion.)

(4) That in cases of severe shock-hæmorrhage, or where the interval since wounding is considerable (10–12 hours), gum has little effect, and resort must be had to transfusion of blood.

The Diminution of the Alkaline Reserves in Shock. —The seeond loss that oeeurs in shoek is that of alkaline reserves (Cannon). A similar diminution of alkali in the blood has been shown to oeeur in hæmorrhage (Milroy), in gas gangrene, after serious temporary stoppage of eireulation in one or more limbs, and after exposure to severe eold (Almroth Wright). Although the resulting aeidosis is without doubt a seeondary, rather than a primary, phenomenon in shoek, nevertheless it is advisable to eombat it by the early administration of sodium biearbonate. The assoeiation of shoek-hæmorrhage and gas gangrene is a very eommon one, and the presenee of aeidosis must always be regarded as a disquieting possibility.

Cases of severe wounds aeeompanied by shoek and likely to develop gas infeetion should be treated as early as possible with alkalis by the mouth. Where aeidosis has undoubtedly developed, an intravenous infusion of sodium biearbonate is indieated. In less urgent eases the alkali may be administered *per rectum.* Cases of extensive damage to musele tissue, as in wounds of the thigh and buttoek, partieularly eall for treatment by alkalis. It must be noted that sueh wounds are espeeially prone to the development of gas gangrene.

It must also be remembered that even in the normal person there is a ehange in the blood in the direetion of aeidosis during the eourse of a surgieal operation (Cannon). In the shoeked individual this ehange is proportionally greater, and is attended with eonsiderable danger.

It should be combated by means of alkalis, and by the employment of nitrous oxide and oxygen as an anæsthetic.

Sir Almroth Wright has, moreover, called attention to a possible danger from acidosis when a hot-air bath is used to raise the temperature of a man in a severe state of shock. As a result of the warming of the body and of the improvement in the circulation, acid products are likely to be washed out of the muscles into the blood-stream, producing a sudden and severe acidæmia. To avoid such an event, resuscitation should be preceded by a free use of alkalis.

Blood Transfusion.—Nothing has been more striking than the rapid spread of the use of blood transfusion as a therapeutic measure for the combatting of shock-hæmorrhage. During the first two years of the war transfusion was performed only by a few specially experienced surgeons, and was regarded more as an interesting curiosity than as a practical measure in the treatment of shock. It is only during the last two years that its scope has been realized, and that it has been adopted as a recognized part of the treatment of the severely wounded man.

It is not proposed to enter into a description of the various methods of performing transfusion in use at the present moment, or to discuss their comparative advantages. These details may be obtained from various text-books on the subject, or, preferably, from the memorandum recently published by the Medical Research Committee. It is proposed rather to deal with the scope of blood transfusion in war surgery, and with the indications for its use. In the Army in which the writers have worked, the method that has been almost universally adopted is the citrated method described by Captain O. H. Robertson in the above-mentioned memorandum of the Medical Research Committee. Its chief advantages are its simplicity, and the fact that no special apparatus is required beyond glass tubing, rubber corks, and suitable needles. Not only has this method rendered blood transfusion a feasible proceeding at all casualty clearing stations, but has allowed of its being pushed forward, under certain conditions, into the dressing stations of the field ambulances. Its extensive use throughout this Army has undoubtedly resulted in the saving of many valuable lives.

No transfusions ought to be performed without a preliminary blood test, and a determination of the groups to which the donor and recipient belong. The simple technique of Moss is employed, and, as a rule, only the blood of members of number 4 group (the universal donor) is used. A list of available donors is kept at each casualty clearing station, so that blood may be obtained at short notice whenever desired. Donors are selected from amongst the lightly wounded, from the personnel, and from those convalescing from trifling ailments. While freedom from syphilis, malaria, and other blood-borne diseases is theoretically essential, specific tests for these can be carried out as yet only in rare instances, and reliance must be placed on the statements of the donors. After bleeding, the donor may be kept in bed for 24–48 hours, and is then allowed a few days' rest. No ill effects result from the bleeding, and the blood loss is made good probably within three or four days.

Transfusions at Casualty Clearing Stations.—Transfusions are most successful in those cases of shock in which hæmorrhage has played a considerable part, so that the patient is suffering from acute anæmia. The cases that answer *par excellence* are severe limb injuries, associated with damage to important blood-vessels. Statistics are of little value in determining the value of transfusion, but in a series of cases recently treated at a casualty clearing station by Captain O. H. Robertson the mortality after transfusion was 28 per cent. in the case of large single wounds (chiefly fractured femurs), whereas with abdominal wounds it was as high as 71 per cent. In both classes of wounds only the worst cases, such as would almost inevitably have died without it, were selected for transfusion.

Although satisfactory results are less certain in those cases in which the shock element predominates over the hæmorrhagic, nevertheless transfusion is of use in the treatment of shock, the mortality rate for this class of case in the above quoted series being in the neighbourhood of 50 per cent.

The quantity of blood transfused at a single sitting has varied from 250 c.c. up to 1,000 c.c. When severe hæmorrhage has taken place the quantity of blood should be large. No hesitation should be displayed in giving a second dose, when this appears desirable. In shock, on the other hand, it is preferable to give smaller quantities, and to repeat if necessary. As a remedy for sepsis, transfusion would appear to be of little value.

Indications for Transfusion.—Owing to the fact that blood is an expensive remedy, both as regards time and material, it is particularly necessary to arrive at a clear understanding as to the indications for its use.

During a rush of work at a casualty clearing station, a decision as to the advisability of carrying out transfusion must rest on clinical grounds rather than on more exact methods. Govaerts has stated that help in estimating the severity of the hæmorrhage that has occurred can be obtained from a red cell count. He lays down the rule that if, within six hours of wounding, the red cells are found to be below four million, transfusion should be carried out. In view of more recent work on blood volume in hæmorrhage and shock it is doubtful if the blood count is of so much value as an indication for transfusion as Govaerts would have us believe.

A more convenient aid to arriving at a decision on the question of transfusion is the sphygmomanometer. Successive readings are taken of the blood pressure, and if, as the result of ordinary treatment, such as warmth and rest, reinforced by rectal salines or the simpler intravenous infusions, the pressure shows no tendency to rise, transfusion is generally required. A blood pressure of 85 mm. of mercury is regarded generally as the minimum level at which a patient can be operated upon with safety. If other methods of resuscitation fail to bring the pressure to this level a pre-operative transfusion must be performed.

Pulse rate is of value in cases of hæmorrhage, but gives little information as to the actual condition of the patient when shock is present. A steadily rising pulse rate is, of course, of ill omen. So also are a quickening of respiration and an increase of cyanosis. Care must be exercised not to mistake the "euphæmia" that sometimes occurs with the onset of gas gangrene for a true improvement. The rise in the pulse rate that accompanies the increase in the blood pressure in cases of gas infection should put the observer on his guard. The occurrence of vomiting, and the characteristic change in the patient's facies, associated with the onset of gangrene, should help to prevent mistakes in many of the cases.

It must be remembered that the majority of fatalities after transfusion are due to sepsis, death usually occurring some two or three days subsequently. For this reason, too long an interval must not be allowed to elapse before operation. If, as the result of other methods of resuscitation, the patient is not fit for operation (as judged by the blood pressure and other criteria) within, at most, six hours of entry into the casualty clearing station, he should be given the benefit of transfusion.

When the operation is of necessity a long one or is likely to be followed by dangerous collapse, everything must be ready for the performance of post-operative transfusion should this become necessary. In cases in which bleeding is still going on (*e.g.* in abdominal cases) transfusion should be postponed until the injured vessels have been found and the hæmorrhage controlled, but should then be given at once if possible. Should blood not be immediately available an intravenous injection of alkali or of gum may be given as a temporary expedient, and the patient transfused on his return to the ward.

Transfusion with Preserved Blood Cells.—The fact that blood corpuscles may be preserved by means of dextrose and have been stored on ice for as long as four weeks without losing their viability was first proved by Rous and Turner, working at the Rockefeller Institute. The discovery has a practical bearing, in that it permits of blood being drawn off during periods of quiet and stored ready for future use. Preserved blood was first used on a large scale by Captain O. H. Robertson when working at an advanced casualty clearing station during a battle in autumn, 1917. The results achieved were apparently as good as those obtained from the use of fresh blood, and in no case were ill effects noted.

Since that time preserved blood has been used on a great many occasions, and is now recognized as a very valuable asset in the treatment of shock-hæmorrhage. The chief advantage of this method of transfusion lies in the convenience of having a large quantity of blood on hand for a rush. A second advantage is the fact that, once the blood has been drawn off, it may be transported to wherever it may be required and given with almost the same ease as an intravenous injection of saline. The bearing of this on advanced resuscitation work will be found in the following paragraph. Details of the technique employed in transfusion with preserved blood corpuscles can be obtained from the memorandum published by the Medical Research Committee on that subject.

Transfusion in the Forward Area.—As the hopes that infusion with Bayliss's solution of gum acacia might give results comparable with those obtained by the use of blood were not entirely realized, the question of the possibility of performing transfusion in front of the casualty clearing station presented itself. Considerable difficulties attend the performance of transfusion in advanced positions, but during quiet times these difficulties are by no means insuperable. Already quite a number of early transfusions have been performed, both with preserved and with fresh blood. When supplies of the former are available the difficulties of transfusion are considerably diminished, and arrangements have been made in one of the armies in France for a supply of preserved blood to be sent up when required from the casualty clearing station to the main dressing station in front of it. Such an arrangement can always be made on the eve of a raid or other minor engagement. If any of the blood is not used and is kept cool, in a special small ice-box, it is returned at once to the casualty clearing station and made use of there.

A certain number of transfusions have been performed even as far forward as the regimental aid post by the enterprise of such men as Captain Guiou of the C.A.M.C. Patients have thereby been saved who would not otherwise have reached the main dressing station, but, on the other hand, a certain percentage of those who have been revived by these means have later succumbed to the shock of the long journey back to the casualty clearing station. In any case, the knowledge that preparations have been made in the battalion aid post for the saving of even the most desperately wounded is not without effect on the *morale* of those "going over the top."

Although early transfusion is a valuable asset when it is feasible, it must always merely supplement, and never replace, sound general treatment. To transfuse a man in a forward dressing station, and then send him down with a shattered limb on which a tourniquet is applied, is unsound treatment, since it leaves unremedied the chief cause of his shock. The limb must be amputated and the tourniquet removed.

In times of battle, when great numbers of wounded are being dealt with, early transfusion becomes an impossibility, except, during lulls, at a large, well-equipped dressing station which has been previously stocked with a supply of preserved blood.

After transfusion it is desirable to keep the wounded man for at least an hour before sending him on his journey. By this time the beneficial results of the transfusion will have become manifest, and any tendency on the part of the wounds to bleed will have been detected.

Operations and Anæsthetics in Shock.—The question of when to operate in the case of a severely shocked man is one of great difficulty. A balance must be struck between the danger of operating while the patient is still in a state of shock and the danger of waiting so long that sepsis has got well ahead. A very large number of cases are revived from shock, only to die a few days later from the toxæmia of sepsis, so that it is of the utmost importance that operative treatment should not be postponed an hour longer than is necessary. In deciding when a patient has revived sufficiently for operation, the sphygmomanometer is a valuable help. A blood pressure of 85 or over will generally allow a previously shocked patient to face an anæsthetic and an operation, provided the anæsthetic is suitable and the operation a rapid one. In performing the operation two aims should be kept in view: the first, rapidity, and the second, completeness in dealing with sepsis. When the ultimate saving of a limb is of doubtful achievement it should be sacrified without hesitation. The patient must be left with the minimum possibility of septic absorption, for the danger that lies in front of him is death from the toxæmia of sepsis.

Of the great value of nitrous oxide and oxygen as an anæsthetic in cases of shock there can be no doubt. Its superiority over all other general anæsthetics has been amply proved by various authorities, and its use in such cases has now become general.

On the subject of spinal anæsthesia much less uniformity of opinion exists. Although Captain G. Marshall, R.A.M.C., has found that the use of spinal anæsthesia in cases that have recently suffered a severe hæmorrhage is attended with grave danger, others have employed intraspinal injections with considerable success. Desplas (France) in particular urges its more extensive use in cases of severe injuries of the lower extremities, accompanied by shock. All authorities agree on the importance of the technique to be employed. The anæsthetic should be combined with inhalations of oxygen, and care taken to eliminate, as much as possible, disturbance of a psychical nature. A preliminary injection of morphine, and, when the necessary turning of the patient on his side is likely to cause great pain, an initial use of gas and oxygen, will help to eliminate pain and mental distress. Transfusion should be done before, during, or immediately after the operation according to indications in each case. In other injuries nerve blocking, and, in the upper extremity, Bier's intravenous method of anæsthesia have been employed with gratifying results.

Conclusions.—From the foregoing it will be seen that no sovereign remedy exists for the treatment of shock. Since secondary shock is the outcome of the action of such factors as hæmorrhage, pain, cold, and exhaustion on a severely wounded man, our efforts must constantly be directed to the task of reducing these harmful influences to a minimum, and thereby preventing its onset or further development. This can only be done by constant attention to a hundred little details, which, considered alone, may appear trifling, but considered in their entirety are of the utmost importance.

Establishment of Special Shock Centres.—It will be appreciated that much knowledge and many technical procedures, in which the general body of medical officers had previously no special training, had to be disseminated and demonstrated. This was done, in the Army to which reference has repeatedly been made, by means of conferences, for the discussion of shock problems and for the report of progress in various directions, and by the establishment of a special army shock centre. This centre was initiated in the autumn of 1917, and has proved to be of inestimable value. Its functions were :

(*a*) To co-ordinate as far as possible the work on shock in the casualty clearing stations and units in the forward areas, and to foster co-operation ;

(*b*) To collect and epitomize reports from medical units of the Army ;

(*c*) To test the practicability and utility of remedial measures before they were sanctioned officially, and, in conjunction with administrators, to arrange means whereby approved remedies could be used to the greatest advantage ;

(*d*) To provide facilities in the way of providing materials, special fluids, testing sera, etc., to units which had difficulty in obtaining these otherwise ;

(*e*) To keep in touch with centres where research in shock work was being carried on, especially with the Medical Research Committee, and to keep abreast of current literature on shock ; to disseminate information thus gained to the units or workers whom it especially concerned ;

(*f*) To act as a technical training centre for divisional officers, so that they might be fully conversant with suitable methods of examination and treatment of shock ;

(*g*) To carry out such scientific investigations as required special laboratory equipment ; and (*h*) To issue reports from time to time of the shock work done in the Army.

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CHAPTER IV

CONSIDERATIONS REGARDING THE USE OF DIFFERENT KINDS OF ANTISEPTICS AND DRESSINGS

At the beginning of the war most surgeons were strongly imbued with the faith that antisepties provided all that was essential for sueeessful treatment of the appalling sepsis whieh faeed them. Their ensuing struggle against sepsis may well be likened to that in the present war against the "boehes." In both eases, old weapons and methods of attaek, although not entirely disearded, have been largely replaeed by new ones, while others, older still, have been revived.

Sir Almroth Wright's able and stimulating work had mueh influenee in gradually weaning the profession from the established faith, and in fostering relianee, so to speak, on the powerful natural reserves whieh ean be ealled upon to eope with invading organisms. It had, however, to be demonstrated that no real safety ean be ensured until the strongholds of these organisms have first been demolished. These strongholds are formed in the museles and other struetures torn by missiles. Antisepties affeet baeteria imbedded in these no more than shrapnel or rifle fire dislodges the Hun lurking in fortified dugouts, although both may be quite effective "in the open." To carry the simile further, excision of lacerated tissues corresponds to ruthless but well-planned destruction caused by a bombardment. Intensive "training" of reserves is represented by the reactionary development of anti-bodies, which is aided by the injection of anti-tetanic and other sera. Demoralization of these reserves, comparable in the war of nations to that brought about by long-range shelling, bombs, pacifist propaganda, or other agencies, is counteracted by measures which cope, for example, with the fall of blood pressure or with acidosis produced by insidious pathogenic agencies in so many different ways. The strength of allies has been demonstrated in the marvellous effects of transfusion of blood.

All these are elements really of counter-attack alone. While the best defence is in attack, yet precautions must be taken to prevent a successful break through, whether by raiders or by overwhelming masses. The front positions, in which the defensive attacking forces must congregate and from which they strike, must be made as invulnerable as possible. Their natural advantages must be conserved and strengthened.

Individual cells form the front line of tissues which face the battle-field. A healthy cell will resist the attack of organisms and their toxins until its enveloping membrane is broken down or penetrated in a way comparable to the destruction of resistance offered by wiring or gas-resisting appliances. There is reason to believe that this inherent power is conserved by the use of a defensive insulating medium such as liquid paraffin, which has become so popular recently as a compounding vehicle in applications to wounded surfaces. (1) The question of the regulation of "electrical" energy in the treatment of wounds has come into prominenee in this connection. Formerly only chemical or mechanical factors have been considered. The subject is in such a state of flux, however, that one prefers to leave its elaboration to those more qualified to deal with it. It is to be hoped that the question will be thrashed out fairly by competent authorities.

It cannot be emphasized too urgently that the use of antiseptics will not make up for inadequate operative treatment. It can be safely said also that "the stronger the antiseptic, the worse the result." The reasons for this need not be discussed, but the fact should be remembered when a particularly soiled wound tempts the use of strong remedies, or when one vaunted antiseptic is tested against another. On the other hand, provided that operation is adequate, one kind of rational after-treatment does not seem to influence the patient's chance of life or limb much more than another. The results claimed by the supporters of apparently widely varying methods do not differ very greatly. It is doubtful indeed whether, after proper operative treatment, a wound treated by antiseptic methods behaves any better than one treated by aseptic methods. Even in the same patient one wound differs in behaviour from another treated in identical fashion. This difference seems to depend mainly on the adequacy of the blood supply and the character of the tissues exposed at operation. For example, fibrous and especially aponeurotic or tendinous structures tend to slough more readily than purely muscular tissues. Wounds of the scalp and face heal very kindly and rapidly when properly treated, and at the same time will overcome successfully a relatively greater amount of infection than will wounds of parts less well supplied with blood.

The kind of dressing which will best assist Nature's endeavours in the processes of healing is that which is most to be recommended. If the source of infection and the already deeply infected tissues are removed, it is doubtful, as has already been stated in different words, whether Nature requires any extraneous help in the form of antiseptics. Remedies which will aid the local and general resistance by restoring or enhancing the natural power of cells and body fluids, have been aimed at by many, and are being steadily elaborated; but it is difficult, and, in the present state of our knowledge and training inadvisable, to discard antiseptics altogether. They "catch the enemy in the open." Therefore, although the dressing applied in or on a wound should cause the minimum amount of delay in local reparative processes, yet, because our efforts in procuring asepsis are liable to be inadequate, that dressing should contain a sufficient proportion of a non-poisonous antiseptic, or a harmless amount of a poisonous one, to prevent organisms from developing in the fluids which are exuded from the wound surfaces. These antiseptics will be of use only if the wound has been so prepared that direct action on any remaining sepsis is possible.

A dressing that does not require frequent attention should be used whenever possible. Routine changing of dressings should be avoided. No gauze pack, for example, should be removed without a definite object, such as closure of the wound or investigation of the cause of sudden pain. Dressings should be capable of being easily and painlessly removed.

The writer believes that all these requirements have, so far, been met best by the judicious use of solutions, emulsions, or pastes of various antiseptics in liquid paraffin. When used in a wound, paraffin holds antiseptics in suspension or solution for a longer time than does water or spirit. The antiseptics which have been most frequently employed up to the present, along with paraffin, are flavine (1–1,000), brilliant green (1–500),[(2)(3)] iodoform (1 per cent.) boric acid, and chloramine T. The boric acid is usually mixed with other antiseptics in sufficient quantity to form a paste of the consistency of soft butter. Wounds, after operation, are smeared with one or other of these applications, and are either sutured or packed lightly with gauze impregnated with plain paraffin, or, better, iodoform paraffin (1 per cent.).

Some substances, *e.g.* iodoform, when used in a dressing, exert an antiseptic effect only when they are broken up in contact with body fluids. As this dissolution occurs slowly, their action spreads over a long period when compared with that of such an antiseptic as eusol. The term "depot antiseptic" has been applied to them.

The advantage of a constant supply of antiseptic from a depot is appreciated by users of Carrel's method; but, the more simple and automatic the depot arrangement is, the more suitable it is for work at advanced units. A depot on the spot, that is, *in* the wound, would seem to be the most advantageous.

B.I.P. Paste (bismuth subnitrate 1 part, iodoform 2 parts, paraffin liquidum q.s., recommended by Professor Rutherford Morison) must be used sparingly in recent wounds, otherwise severe symptoms of poisoning may ensue. A small quantity of the paste should be carefully rubbed into the surfaces and pockets of the wound, especially of "suspicious" parts, and thereafter the visible excess should be wiped away with a pledget of gauze.

The "salt pack," founded on Sir Almroth Wright's work on the "physiological" effects of various strengths of salt solution, and introduced by the writer in 1915, gives excellent results, but has largely been given up in favour of the "paraffin pack." Owing to its lymphagogic effect, the salt pack is apt to cause an undue strain on patients already in want of body fluids. Where, however, equilibrium in this respect has been established, and where there is much inflammatory swelling around a wound, it may still be used with advantage. The complete absence of inflammation in or around wounds treated by this method, and the paucity of bacteria in the depth of the wound after twenty-four to forty-eight hours, indicate the practicability of performing delayed primary suture (see page 165). This has been carried out with success in several cases. A disadvantage of this pack is that, during the first five or six days, it is so adherent that bleeding is caused by its removal.

Although the salt pack suffered in repute owing to want of attention to important details in its application, it helped to pave the way for the popular modern method of treating open wounds with gauze fillings, and had considerable influence also in altering the practice of frequent redressing to which patients were subjected in the early days of the war. If the wound is not suitable for delayed primary suture, the salt pack makes an excellent dressing, and may be left undisturbed until it becomes quite loose. At intervals of a few days the superficial dressings should be changed and the surrounding skin disinfected.

The following extract is taken from a paper by J. E. H. Roberts and R. S. S. Statham. Their remarks are of special interest in view of the date of their publication [4] (August 26th, 1916), and of the methods of treatment which they had been using at the Base for more than a year previously.

"The method of dressing wounds with a firm pack of gauze and sodium chloride tablets, devised by Colonel H. M. W. Gray, C.B., combined with a preliminary free excision of the wound and lacerated and infected tissues, has in our hands given results which have effected revolutionary changes in our methods of treatment. During the last twelve months it has gradually supplanted other methods of treatment, until now we employ it in the majority of cases. At first we regarded it with suspicion and used it but half-heartedly; finding, however, that wounds dressed in this way became clean at least as speedily as those treated by other methods, and that the general condition of the patients improved owing to undisturbed sleep, increase of appetite, and absence of mental apprehension of frequent painful dressings, we ended by becoming complete converts to the method.

"The operative details in connection with a wound naturally vary with the site, nature, and degree of infection of the wound.

"For example, wounds of the buttock by shrapnel ball or shell are invariably laid open in their whole extent. If there are separate entry and exit wounds they are joined by an incision dividing the glutei down to the track between them. Foreign bodies are removed and the necrotic tissue lining the track excised. Bleeding points are tied with catgut, and after examination for bony or visceral lesions a salt pack is applied. Such a wound is often ready for suturing within ten days to a fortnight.

"*Wounds of Limbs.*—The superficial wound, if small, is excised so that it will admit a finger. The full extent of the wound is then determined as far as possible by digital examination, and, unless essential structures are involved, the whole area is laid open, all pockets being exposed to the end. Foreign bodies, including pieces of cloth and blood-clot, are carefully searched for and removed, and all necrotic tissue cut away with the scissors until a freely bleeding surface remains. If the deep fascia or superficial muscles tend to come together and close the mouth of the wound, sufficient tissue is excised to ensure that, when the salt pack is in place, the mouth of the wound will be widely open. A conical wound not requiring the use of drainage tubes is thus produced.

"Where there exist entry and exit wounds and their junction would involve the sacrifice of essential structures, such as a large motor nerve, two conical excisions, with their apices meeting in the centre of the track, may be made and a pack applied at each end.

"In all cases side-tracks and pockets are opened up so that they may be packed to the bottom. Where a fracture exists, fragments, unless small and completely detached, are not removed. These proceedings are not really so heroic as at first sight may appear, for, first, most of the muscle excised is infected, and, secondly, it has been shown that muscular tissue, even though not infected, has lost its striation and contains hæmorrhagic areas for a considerable distance around a gunshot wound. Such muscle will not regain its function, and will ultimately be replaced by fibrous tissue. Fascia and tendinous structures are badly supplied with blood and invariably slough when exposed in infected wounds. They should be cut away at the primary operation. On the other hand, the sheaths enclosing intact muscles should not be unnecessarily opened. When infection is confined to a single muscle it is sometimes advisable to remove the whole belly in its sheath; for instance, the rectus femoris or one of the hamstring group. Thrombosed veins should be dissected out to their full extent and excised.

"With the exception of iodine for the skin we do not apply any antiseptic to the wound.

"The wound having been thus prepared, the salt pack is applied in the following manner. A piece of plain gauze, four to six layers thick, is lightly wrung out of 5 per cent. salt solution and earefully laid in the wound so that it is in contaet with the whole of the surface. Care should be taken that this shect of gauze is sufficiently large to cover the whole surface of the wound. If several smaller overlapping pieees are used, small spaees in which pus collects form at the lines of junctions and there is also great danger of the pieces being displaced when the rest of the packing is inserted, thus leaving bare surfaces. When the wound is a deep one the gauze lining is earefully carried down by the fingers within it to the deepest recesses of the wound. No spaces should be left, as they rapidly fill up with pus. A few forty grain tablets of salt * are now placed in the deepest part of the wound, or, if the wound is flat, placed on the surface of the gauze, about an ineh apart. The interior of the gauze-lined wound is now firmly packed, somewhat in the manner of the old-fashioned petticoated tube, with a roll or long strip of gauze moistened in the same way. This strip is carried alternately from one end of the wound to the other and numerous tablets of salt are laid between the successive layers. A handful of tablets should not be thrust in altogether, as when they dissolve a eavity is formed. For a wound 4 in. long by 3 in. deep ten to twenty tablets would be used. When the pack becomes flush with the skin surface a few more layers of gauze are applied and over that a thick wool dressing, composed of at

* These tied up in convenient numbers in small gauze bags may be sterilized along with other dressings in the autoclave.

least three layers, completely encircling the limb. The whole is then firmly bandaged, so that the surface of the wound is kept in intimate contact with the pack, and all spaces which tend to form are obliterated. Really firm pressure should be used both in applying the pack and in bandaging. The elasticity of the thick wool dressing distributes the pressure and effectually prevents anæmia of the wound surface and congestion of the wound below.

" Where a compound fracture is present it is not usually possible to avoid leaving spaces between and around the fragments of bone, and therefore in such cases, after placing the lining sheet of gauze, a large rubber tube is introduced down to the fracture, and the remainder of the gauze and tablets packed around it. This serves to prevent the tracking of pus along the bone. A hole cut in the lining gauze allows any discharge to gain free access to the tube.

" We have frequently packed on to exposed main arteries, such as the femoral, brachial, and subclavian. In no case has the vessel given way, but we have been careful to interpose a rather greater thickness of gauze than usual between the hard tablets and the vessel. If a salt tablet comes into direct contact with the tissues it causes a necrotic area a little larger in diameter than itself, but quite superficial, its depth being not more than a millimetre. This is really of little importance, as it disappears by the next dressing, but is better avoided. It appears to be quite safe to pack on to exposed surfaces of bone.

" During the first twelve to twenty-four hours a copious exudation of serum occurs, soaking the gauze, wool, and bandage. After this no further exudation usually takes plaee, and, if the dressings are inspected during the next four or five days, they are generally discovered to be quite dry. As soon as the outer layers of the dressing become moist a packing of fresh sterile wool is placed outside without removing the bandage.

"It is important that the wound should be kept at rest. In large wounds of limbs we employ a splint, but in smaller wounds the nature of the dressing, with its firm bandage and the faet that the serum-soaked outer gauze dries into a hard mass of the consisteney of a stareh bandage, renders a splint unnecessary.

"After dressing, morphine tartrate, grain $\frac{1}{4}$, is usually given, as most patients complain of pain for a few hours. In many eases, however, the pain is quite slight, and no analgesie is neeessary. In the few cases in whieh pain has persisted, exposed sensory nerve endings have been discovered, and these may be eut short under novoeain. Suecessive dressings beeome less painful, and after the second an analgesie is usually unnecessary. A rise of temperature and inerease of pulse-rate usually follows the manipulations, but unless these persist after twelve to twenty-four hours no apprehension need be felt.

"In the behaviour of the temperature and pulse the cases fall into three main classes. In the larger number the temperature and pulse-rate fall to normal on the second day and remain so, except for temporary slight rises following the first dressings.

"In another class the pulse-rate comes down at once, but the temperature comes down by lysis, taking four or five days to reach the normal. In a comparatively small number of cases, although the pulse-rate remains below 90, the evening rise of temperature may persist for one or two weeks, although the wounds when dressed appear clean and free from retained pus.

" *The pulse-rate and general condition of the patient* is a much better index of the well-being of the wound than the temperature.

" After a few days the outer dressings may acquire a very offensive odour. This is due to decomposition in the dressings themselves, and if they are removed the wound is found to be perfectly sweet. The outer dressings are more offensive than the inner. At one time we changed the outer dressings when they began to smell, leaving the packing in the wound untouched. The objection to this is that it is difficult to change the outer dressings without disturbing the deep pack. We then used various substances, such as sanitas powder, potassium permanganate, and eupad powder, thickly dusted on the dressing immediately beneath the outermost layer of gauze. All these diminish the odour. With Dakin's chloramine-T powder, which we are now using, all odour is practically abolished. Mixing chloramine-T tablets with the salt tablets in the deeper dressing was found to be unsatisfactory, as it did not prevent the smell.

" *The Normal Favourable Course.*—The course of events in an ordinary, fairly severe, infected wound of the soft part is as follows : After excision and packing the dressing is untouched for five or six days : the wound is then dressed, usually under an anæsthetie. In the majority of eases the paek is now loose, and the dressing eomes away as a whole. The surfaee of the wound is eovered with a yellow fibrino-purulent exudate, with here and there a few small yellow sloughs where damaged musele or aponeurosis has been ineompletely removed. A small amount of ereamy yellow " laudable " pus is seen in the wound, quite different in appearanee from the original, brownish, stinking, anaerobie pus. If the surfaee of the wound is swabbed, some of the exudate is removed, exposing a readily bleeding surfaee underneath. The musele is no longer œdematous and does not projeet beyond the skin surfaee, whieh is quite healthy and shows no sign of surrounding inflammation. The skin is swabbed with iodine and a fresh salt paek is applied, smaller in dimensions than the primary one. The pressure of the wound surfaee against the gauze paek is re-established when the firm bandage is applied. This dressing is ehanged in another five or six days, and the whole surfaee of the wound is now seen to be eovered with brilliant red, easily bleeding granulation tissue, all sloughs having separated. If some areas are not yet elean, another paek is inserted, otherwise the wound may be brought together with strapping or may be sutured. The majority of wounds of soft parts are ready for elosure within three weeks. Some have been elosed as early as the tenth day. The time whieh is required before a wound is in a fit state to elose varies in aeeordanee with the nature of the tissues exposed. Thus museular tissue rapidly becomes elean. Tendinous and faseial sloughs take longer to separate. Pieees of dead bone take so long that it is inadvisable to close a wound complicated by a fracture.

" *Indications for changing the Pack.*—Indications that the wound is not doing well and that the pack must be changed are :

" 1. A continuously rising pulse-rate.

" 2. Increasing œdema in the limb.

" 3. Sudden onset of severe pain. This generally means spreading gas infection.

" 4. A persistent *rise* of temperature for which no other cause can be found.

" 5. A change for the worse in the patient's general condition in cases in which a raised temperature has persisted from the beginning.

" 6. Oozing of pus from under the edge of the dressing. This is generally due either to the dressing having been left unchanged too long, or having been too loosely applied.

" 7. The dressing must be reapplied when the pack has become loose from diminution in the circumference of the limb as œdema disappears.

" *Some Other Details.*—Where the innermost layer of gauze is found to be firmly adherent to the wound surface it is not removed, but a new pack is applied within it. If it is removed bleeding is caused, the protective barrier is broken down, and a rise of temperature takes place.

" When once the wound is granulating healthily it is not advisable to continue the salt pack, as the granulations become exuberant, pale, and œdematous. If the wound cannot be closed, any of the simple dressings should be applied.

"Occasionally a wound becomes sluggish, even during the separation of sloughs. A change from the salt pack to a dressing of gauze soaked in pure glycerine usually causes a rapid change for the better. Where a wound is not doing well with a salt pack, and a pure streptococcal infection is present, the use of a 1 per cent. salt solution as a wet dressing, continuous irrigation, or bath will sometimes be found to effect an improvement.

"*Conclusions.*—The salt pack has given very good results. . . . It appears to be of great value in field ambulances and clearing stations, as in time of stress it may be impossible to renew dressings for two or three days. Those cases we have received from clearing stations in which the treatment has been thoroughly carried out have arrived in excellent condition, and contrast very favourably with those treated by other methods. Cases treated by eusol irrigation, however clean they may be when leaving the clearing station, often have their wounds in an unsatisfactory state on arrival at the base twenty-four hours later.

"Our advocacy of this method of treating wounds is based entirely on our clinical experience, and we do not in this place advance any theories to explain its action. It is based originally on the well-known work of Sir Almroth Wright."

The rapid digestion and loosening of sloughs and the characteristic odour which occur in most cases have been stated by R. Donaldson and J. Leonard Joyce to be due chiefly to what they have called the "Reading bacillus."(5) Wounds which are not infected with this bacillus do not clean so rapidly, and indeed may seriously deteriorate, so that recourse must be had to some other form of treatment. These writers have found that the condition of the wound as well as the general health of the patient improves at once if a culture of this non-pathogenic bacillus is smeared over the surface and the pack renewed. They suggest that the culture should be applied deliberately at the end of the primary cleansing operation. (This should only be done if the wound cannot be closed at an early date.) Large wounds are usually ready for closing after two applications of the pack, on an average apparently of about ten days. The amount and density of the fibrous tissue composing the slough influence the length of time required for separation. They have had equally good results from using plain gauze or sphagnum moss packs. (The author thinks that the addition of salt to the first application, in the form of tablets distributed at intervals of an inch or so through the gauze, will probably reduce swelling and other signs of inflammation more quickly than gauze alone will do. These tablets act as a depot for the supply of salt solution.)

Failure to get good results by any of these dressings is evidence either of incompetence in cleansing the wound or impossibility of doing so.

During a period of severe fighting, when hundreds of severe cases pass through a Casualty Clearing Station in a few days, it is obviously essential to use, as frequently as possible, a post-operative dressing which requires the minimum of attention. A wound efficiently treated in any of the ways indicated above can safely be left for many days.

Bandages and splints should be applied in such a way that the wound can be easily inspected.

Any form of dressing which requires frequent attention, whether in syringing or in renewing applications to the depth of the wound, is unsuitable for busy hospitals near the front. It should also be remembered that dread of a daily dressing, to say nothing of the pain inflicted or the anæsthetic required, may turn the scale against a severely wounded man's chance of recovery.

Many surgeons prefer to use Carrel's method in the after-treatment of wounds which have to be left open. The technique of this method is so well known that it need not be described. The disadvantages of it, as compared with other methods used at this stage, are the extra paraphernalia and the amount of attention required.

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CHAPTER V

PRINCIPLES OF TREATMENT OF GUNSHOT WOUNDS AT CASUALTY CLEARING STATIONS

The necessity for going fully into the operative treatment of war wounds is realized when one considers that military surgery was unknown in practice to most medical men before this war, and that many men who have little or no experience as surgeons are called upon, during periods of severe fighting, to lend a hand in the operating theatres.

Reference will be made only in very short and general terms to such matters as the administration of anæsthetics, localization of foreign bodies by X-rays, and the use of sera, although all these have profound influence on the results which attend the efforts of the surgeon.

The greatest obstacle to successful treatment of wounds in France is the virulent inflammation which is prone to intervene, from infection with organisms of most noxious type which have their habitat in the highly manured soil on which fighting takes place. The behaviour of these heavily infected wounds has made us realize what our forefathers had to cope with in the worst forms of hospital gangrene, and possibly our experience is even more bitter than theirs. High explosive missiles lacerate the tissues more than any ancient artillery or surgeons' knives ever did, and at the same time force infection so deep that it develops with more alarming rapidity and over larger extent than ever before. It was difficult for a race of surgeons educated in the principles and practice of modern aseptic surgery to accommodate their procedures to what was required in the treatment of such cases, and, as has already been said, to shake themselves free from too great a trust in the efficiency of antiseptics. In the development of modern war surgery, therefore, it was inevitable that many schools should arise, adherents to this or that antiseptic or method of dressing; but now, fortunately, it can be said that all are agreed on one point, viz. that early opening up and mechanical cleansing of severe wounds are necessary preliminaries to any other form of treatment. It is difficult for a tyro in war surgery to realize how essential this thorough operative treatment is, or how extensive, and in many cases seemingly ruthless, it must be.

It soon became very apparent that, the earlier such treatment is carried out, the better are the results. Every endeavour should be made to operate before infection has gained a hold. In other words, operation—to give the best results—must be performed in the pre-inflammatory stage.

It is perhaps natural that one should sometimes see a tendency to slackness in attention to essential details of aseptic or antiseptic technique during the performance of operations on these very dirty wounds. No greater mistake can be made. Surgeons who get the best results are those who are most thorough and careful with regard to rigid observance of the technique of civil surgery, as well as to removal of lacerated infected tissue.

Difficulties constantly occur owing to the fact that those who have not seen cannot appreciate the appalling virulence and rate of development of infections which may take place in wounds which at first look wonderfully clean. Avoidable loss of life and limb will be prevented if newcomers on this field, of whatever standing in civil life, will take warning from the dreadful experience to which others have had to submit, and if they will follow the principles of treatment which have been evolved.

It is imperative to bear in mind at all times the state of affairs which exists in a gunshot wound, and the objects which should be aimed at in operation. A missile passing through a limb dissipates a considerable amount of its energy in the tissues. These tissues are struck a terrific blow, and the greater the resistance they offer the more energy will the projectile lose in its flight. When the resistance is enough to arrest, for example, a bullet, it is obvious that all the energy of the projectile is spent in the body; but it does not follow that the tissue injury caused by a lodging missile is greater than that caused by one which traverses the part completely. The special gravity of "lodging" wounds depends on other factors. One may say regarding all wounds, that, given an equal resistance to its passage, the damage done will vary as the velocity of the projectile. This damage is not limited to the track of the missile, which imparts its momentum to everything in or near its line of flight, so that a radiating area of vibration is set up, destructive to cellular life. If the tissues vary in density, the more compact will be driven through the more yielding, with a shattering effect.

This is the *first* point of importance—the immediate destructive effect of a projectile is not limited to its path.

The *second* point is that practically every shell wound is permeated with foreign material carrying aerobic and anaerobic organisms, and some of the latter thrive luxuriantly in the lacerated and devitalized tissues into which they are driven.

The *third* point is that the organisms of "gas gangrene" grow rapidly in parts which are deprived of normal blood supply, especially in muscular tissue.

The *fourth* point is that the amount of infection carried in by different kinds of missiles varies enormously. This is dealt with later.

Operation should be performed in such a way that ample access is obtained to every infected part of the wound, in order that all foreign matter and devitalized tissue may be freely and thoroughly removed, and that thereafter adequate drainage may be ensured when necessary. In most regions, direct inspection of the depth of the wound can and ought to be procured. Treatment guided by palpation alone is permissible or advisable only when incision would necessitate division of such structures as the main vessels or nerves of a limb or would involve destruction of the function of other important parts. It is evident, therefore, that incisions must be very free so that sufficient inspection is possible, and, at the same time, that these incisions must not be made in a haphazard fashion.

In the early days of the war, before it was realized that infection was driven into the lacerated flesh far beyond the reach of antiseptics then in use, the usual method was to clean out wounds by swabbing, irrigation with lotions of various kinds and strengths, and so forth. A recently inflicted wound might thereafter look so clean that it was sutured completely, this practice having been successful in civil life. The result in practically every case was appalling. Patients arrived at the Base in a high state of septic intoxication, their stitched-up wounds were red and swollen, and were in the majority of cases badly affected with gas gangrene. The skin, although inflamed, may have looked reasonably healthy, but the deeper parts of the wound were invariably in a stinking condition. Loss of life or limb was too often the penalty. Then the edict went forth that no wounds were to be sutured, that drainage must be established. All sorts of drains were used, preference being given to large-sized rubber tubes. But the old-fashioned method of using them was employed—holes were made just sufficient to admit the tube, which was often drawn through to dependent parts, of course dragging with it the infection from the original wound and merely making matters worse. The condition of limbs was such, and the general condition of the patients was so precarious, that the guillotine amputation became popular: it was rapid, it provided the best drainage, and it was therefore credited with saving lives.

This method of amputation has almost entirely been given up.

The behaviour of wounds widely open from the first was little better. Inflammation of the most virulent type frequently spread in a rapidly widening vicious circle, in spite of well-meant efforts. But now and again certain wounds cleaned up with striking rapidity. A study of these wounds gave the clue to proper treatment. The difficulty was solved to a large extent when attention was paid to the condition of the circulation in the wounded part.[1]

A long time elapsed, however, before the value of free incision combined with excision of lacerated tissue was appreciated, and before it was realized that gas gangrene must be treated on the same lines as a sarcoma. Free incision relieves tension and thereby improves the local circulation. Excision removes parts which have had their circulation definitely obstructed and which will become, or already are, affected with gas gangrene.

It was still more difficult to establish the fact that after a properly conducted, thorough excision of such wounds, the parts could be completely sutured and healing by primary union obtained.

The presence of anaerobic gas-forming organisms is so wide-spread in the soil of France, that all lacerated wounds must be regarded as being infected by them. At the risk of being thought tedious, one

[1] After this book had gone to press, Capt. J. Campbell told me of his recent work on the blood-supply of muscles, which will be published in a short time. It corroborates in every detail the conclusions which had been arrived at by clinical study (Author).

must insist again on the fact that the infecting material is driven into the tissues beyond the range of immediate action of any known antiseptic as ordinarily applied. Therefore antiseptics are useless at the outset, except possibly in retarding the development of organisms *in the cavity* of the wound, or preventing further infection from the outside. No one can say how rapidly the development of gas gangrene will take place in any particular case. One knows that in some it may develop so suddenly and virulently that the patient may *die* within twelve hours of his injury. Therefore a great principle is established, that *a patient who requires operation shall be operated on as soon as possible.* All lacerated wounds require operation if the best results are to be obtained, and if early closure of the wound is aimed at. If his general condition is so bad that immediate operation might kill him, every effort must be made to get the man resuscitated and rendered fit for the ordeal. On the other hand, because he is fit, perhaps very fit, there is no excuse for postponing operation, even in the slighter cases, except in times of great stress, when the more serious cases must be attended to in order to save lives. Time and again has occurred the sad experience of seeing a strong man admitted, apparently well except for his wound, who, after a few hours' delay, has become so toxic that all efforts to save his life were of no avail. Only efficient administration of the casualty clearing station can ensure the fulfilment of this principle.

A second principle in early treatment has reference to the general method of operative attack on these wounds. The necessity for removal of foreign material will be discussed later. As has been mentioned already in Chapter I (Gas Gangrene, page 7), it is recognized that the bacilli of gas gangrene grow most readily in lacerated muscular tissue which is deprived of circulating oxygenated blood. It is necessary, therefore, to *excise* all lacerated or obviously infected muscle until definitely bleeding tissue is reached.

In the case of a lacerated muscle or group of muscles whose main blood supply has been severed by the missile, this principle may entail removal of the whole affected muscle or group. Failure to observe this indication often results in amputation having to be performed later, or, at best, in repetition of the excision operation. "Recurrence" of gas gangrene usually indicates either timidity on the part of the operator or want of appreciation of pathological conditions and developments, unless in cases where, for anatomical reasons, complete removal may have been impossible. Absence of bleeding in freshly incised muscle is of far greater importance as an indication for excision than is the absence of contraction or the presence of so-called "brick-red" discolouration, which is found so frequently in the neighbourhood of parts affected by gas gangrene. The writer has often deliberately left such discoloured muscle, without ill effect, but has always made certain that the discoloured muscle bleeds on superficial incision. It is, of course, apparent that such discolouration does not occur in the pre-inflammatory stage of wounds. Application of the principle now enunciated will alone *guarantee* eradication of the infection. The very rare cases of early systemmic infection may be disregarded. The situation may be summed up by stating that gas gangrene will not develop in tissues in which there is a vigorous circulation of healthy blood.

In carrying out such operations another point must be borne in mind in order to avoid recurrence of the gangrene. If the excision is made at the distal parts first, blood-vessels supplying the tissues left behind may be cut across in removing the proximal parts of the wound. If any bacilli remain in the wound, they may seize upon these devitalized parts and produce gangrene afresh. If again, for example, the lower half of such a muscle as the rectus femoris is completely severed, there is great risk in leaving any part of the detached anæmic portion. If the upper part of the muscle likewise does not bleed on section, owing to severance of its main vessels, it is only tempting Providence if the whole muscle is not removed. Similarly, it has been found that the only safe procedure is to amputate, when the main vessel of a limb (*e.g.* the femoral artery) has been divided and gas gangrene has obtained a hold on the distal parts. In dissecting out affected areas, it is both unnecessary and risky to interfere with neighbouring muscles whose blood supply is intact.

The bacilli of gas gangrene will develop in blood-clot, although much less slowly and virulently. It is, therefore, obvious that blood-clot should be removed with meticulous care from the depth and recesses of wounds of the soft parts and from between the interstices and from the exposed medullary cavity of fractured bones.

Primary operation should not fail in procuring conditions which will be inimical to the development of gas gangrene. In many cases amputation is the only procedure which will accomplish this.

Tension interferes with normal circulation, and should be relieved at once. Decision as to procedure is usually easy in the case of a joint or pleural cavity. Examination of the fluid withdrawn will most likely reveal the presence or absence of sepsis. Positive cytological findings are important in the earliest stages. Bacteriological examination may then be negative. Treatment is discussed in the chapters dealing with such injuries.

It is often difficult to decide whether tense swelling of a limb is due chiefly to bleeding or to infection in the depth. It is not proposed to discuss the treatment of vascular injuries, but, in spite of what has been written and said on this matter, there does not appear to be sufficient reason why, other things being equal, there should be hesitation to interfere with a swelling due to hæmorrhage from a wound of a large artery, while it is looked upon as an urgent matter to deal at once with a wound of such a vessel as the posterior tibial. Want of accessibility or of proximal control by tourniquet or digital compression of the artery involved and absence of a sufficiently skilled operator seem to be the only valid excuses. Immediate operation by suture, intubation, or ligature should give correspondingly as good results as early treatment of other wounds. Many young surgeons have already demonstrated the truth of this statement.

All operations on seriously wounded or "shocked" *men should be completed as rapidly as possible.* The formation of surgical teams, whose members speedily become acquainted with each other's capacity, has done much to reduce the time taken in individual operations, as well as to improve the quality of the work done.

In the treatment of cases of severe multiple injuries, as many operators as can be spared, indeed as many as can have reasonable access to the affected parts, should be detailed to help, and obviously surgeons of quick judgment and rapid technique should be chosen to deal with the more serious wounds.

Men who have suffered from shock do not stand operation well. Routine excision operations are often altogether out of the question, chiefly on account of the time they occupy, and then one has to be content merely with procedures which relieve tension and provide free drainage. If the patient's vitality can be successfully coaxed back, further operation may be performed if necessary. In the earlier days of the war such cases rarely survived if the operation lasted much more than an hour. Even nowadays, with all the available methods for resuscitation, and especially for raising and maintaining the blood pressure by transfusion of blood, etc., it is well to be extremely careful not to put too great a strain on the patient's powers of endurance.

It is evident that, in many cases, decision whether, when, and even how, to operate is one of great difficulty. If operation is performed too early the patient will die of shock; if it is unduly postponed he is likely to succumb from acute sepsis.

The systematic and collaborated investigation of "shock-hæmorrhage" has rendered earlier decision and earlier operation possible in the majority of cases. The gradual education and development of interest of all concerned in the problems, the appreciation of the value of transfusion of blood, and especially the appointment of one or more specialists to take charge of the resuscitation department of each casualty clearing station, have had much to do with the numberless veritable resurrections which have been brought about. To select what appears to be the most important factor at work in these cases, one may say shortly that the blood pressure must be raised to and maintained at approximately normal level. Cases of pure surgical shock are rare. The amount of hæmorrhage which different patients will survive varies enormously. If the patient is very exsanguine, it is obvious that he will not make much headway without the loss of blood being made good by transfusion as soon as possible. In some cases also the blood pressure is so low that recourse must be had at once to transfusion of blood or infusion of a blood substitute.

In other cases it is well to try the "ordinary" means of resuscitation which have been indicated in Chapter I. If the man does not respond rapidly, *e.g.* within an hour, that is, if his blood pressure does not rise satisfactorily, blood or gum solution (6 per cent.) must be given. The longer the blood pressure remains low, the more difficult becomes the success of resuscitation, the more dangerous is anæsthesia, the more profound are metabolic changes, as evidenced by the reduction of the alkali-reserve and the production of acidosis, and the more difficult it is to eradicate the effect of these, superadded to the original shock, and to restore equilibrium and control to the nervous system. Because of this loss of nervous equilibrium, and because of these metabolic changes, it is wise not to be precipitate in operative interference, unless septic infection has become active. Complete rest, especially in sleep, for an hour or two will make an immense difference. The loss of nervous equilibrium is evidenced by the readiness with which patients, who have recently been resuscitated from severe shock, will gradually slide back into a similar or worse condition during the railway journey to the Base.

It is interesting that the laboratory experiments of Professor Bayliss with the use of gum solution should be so strikingly confirmed clinically in man. Unless gum is given fairly early, within three or four hours, results may be very disappointing. When hæmorrhage is a prominent feature the effects of blood infusion are always superior to those of gum. The question of supply and expediency may settle the question of which is to be given. Blood, whether fresh or preserved, should be reserved for the most severe cases. Gum should be used in the less severe cases or as a preliminary or adjuvant to blood.

When acidosis is evident or likely to assert itself, especially in cases of advanced gas gangrene, intravenous injections of bicarbonate of soda (at least one pint of 1 per cent. solution) should be made. A slower, although probably more lasting, effect is produced by administration of the bicarbonate by the mouth or rectum, therefore these routes should be chosen only in the less serious cases. In all cases of gas gangrene the bicarbonate should be given by mouth for several days. If the patient is troubled by vomiting, it should be given *per rectum*.

The *choice of anæsthetic* is of the utmost importance. The indication is again given by reference to the blood pressure. In order of merit come nitrous oxide and oxygen, ether, and chloroform amongst the commonly used general anæsthetics. The use of local or regional anæsthesia is probably safest of all, and should at least be combined with general anæsthesia whenever possible. The principles of "anoei-association" should be observed.

Removal of Foreign Bodies.—It is a counsel of perfection to say that *all* foreign bodies should be removed as soon as possible. As a matter of fact, whether they should be removed at all, and the necessity for their early removal depends, firstly, on their size, shape, and character, and to a less extent on the position of the entrance wound. All of these determine the probable amount of infective material carried in. Secondly, the decision depends on the mobility of the part in which they are lodged and the probable effect on its function. The more important the function the greater is the necessity for early removal.

The amount of infection carried into a wound depends chiefly on the shape and roughness of the missile, and whether it has traversed the patient's clothing. An undistorted rifle bullet carries in a negligible quantity, with which the tissues usually deal successfully. Shrapnel balls, distorted rifle bullets, and fragments of shell practically always carry in sufficient to cause inflammation. But shrapnel balls may be wiped so clean during transit through the tissues that they do not cause infection where they lodge. It may then quite often be observed that while sepsis becomes established around the entrance wound, the deeper parts of the track remain or become sterile, and no inflammation occurs around the missile itself, so that it can often be removed aseptically through a fresh incision.

All are agreed that irregular fragments of shell, distorted rifle bullets, and superficial shrapnel bullets should be removed as soon as possible. Difference of opinion exists concerning the necessity for and proper time of removal of undistorted rifle bullets or shrapnel balls or small pieces of shell which are difficult to reach. The decision should really be governed by the importance of the structure in or near which they are embedded, and the amount of movement which ordinarily takes place. Thus, if buried in bone—in the condyles of the femur, for instance—a rifle bullet almost always, and a shrapnel bullet frequently, heals in, and may remain permanently without causing irritation. A foreign body in the belly of an important muscle, unless comparatively minute, will sooner or later have to be removed. It is dangerous to leave any kind of foreign body in close proximity to a large pulsating vessel. Ultimately it will cause secondary hæmorrhage or aneurysm. The more irregular it is in shape the sooner will trouble occur.

The structures forming a joint lie, ordinarily, in such close apposition during movement that there is no room for any extraneous material. While an aseptic foreign body, lying free in a joint, may cause no irritation so long as the joint is kept at rest, very rarely can the joint be moved to any extent without lighting up trouble, so that removal, as early as possible, is indicated. Much more is this the case when sepsis is present.

Most of the foregoing remarks apply with especial force to the brain—on the whole, of all organs, the most important, the most delicate, and the most susceptible to continued irritation. While small fragments may cause no trouble at first, one must remember that the secondary effects brought about by the presence of a foreign body may not declare themselves for years after the injury, when the results of operative interference are likely to be very unsatisfactory, even although the foreign body is removed. Local conditions, want of necessary appliances, difficulty and danger of the operation, may of course preclude any attempt at removal.

Greater licence is permitted, apparently, in wounds of the thoracic organs and liver. Here, again, trouble may accrue at a late stage from the formation of abscesses, with sequelæ of varying character and intensity.

If suppuration has occurred around a foreign body, common sense dictates its removal whatever be its character.

Antitetanic Serum.—No matter how insignificant the wound, every patient should receive a prophylactic dose of antitetanic serum. If doubt exists as to whether a dose has been given since the infliction of the wound, the surgeon had better make certain by giving one.

In the case of a man wounded for the second or third time, it is probably safer to give it in "fractional" doses, especially if he reports having shown any of the manifestations of serum sickness after previous injections. In all serious wounds the administration should be repeated every seven days until the wound is clean and fit for closing.

If symptoms of tetanus develop, the serum should be given in much more heroic doses than has hitherto usually been the case. Very encouraging results have followed the administration of 60–100 thousand units, or even more, during twenty-four hours. These large doses should be continued daily until acute symptoms subside, when they can be gradually reduced. The quantity is given by all the routes recommended (intraspinal, intravenous, intramuscular, and subcutaneous, especially by the latter two as the symptoms subside). The reports issued by Major-General Sir David Bruce, Colonel Sir William Leishman, and others should be consulted.

Anti-gas Gangrene Serum.—Investigations which are being made as to the utility of this serum, both as a prophylactic and curative remedy, point to its being of value, but it is unlikely that it will permit of any relaxation in the operative treatment which is at present considered necessary. In "open" wounds in which the local circulation has not been seriously interfered with, the serum may help to confine the growth of the bacilli to the wound alone. Yet the disease is so deadly, and in some cases so insidious in its early stages, that it is unjustifiable in any case to take the risk of trusting to drainage alone.

X-rays.—A thoroughly reliable outfit and a competent skiagraphist are essential to a surgical casualty clearing station, even during quiet or "peace" times, while in periods of severe fighting, the necessity for a night and a day staff as well as a spare apparatus in case of break-down, becomes evident. The economic importance of accurate localization has been proved over and over again in most striking fashion. This remark applies to the immediate expenditure of time and material, as well as to the subsequent capacity of the patient, and the ultimate drain from compensations on the national exchequer. Every case of lodgment of a missile which cannot be seen or felt should be X-rayed, otherwise calamitous results may follow attempts at extraction. Close co-operation between the X-ray specialist and the surgeon must be established in all difficult cases. For simpler cases there should be a very definite system carried out in all casualty clearing stations, for making and indicating the localization, which should be thoroughly understood by all surgeons who are detailed for casualty clearing station work. No wound of the limbs from which the foreign body has not been removed should be sutured.

Preparation and Selection of Cases for Operation.—Enough has been said to indicate the great importance of this part of the work of a casualty clearing station, and no further detailed description need be given. Ordinary cases are dealt with in a general pre-operation ward, while others suffering from the effects of shock hæmorrhage are usually treated in a specially equipped and warmed resuscitation ward. The advantage of having selected nurses and orderlies, highly trained in the type of work required, is very striking. Reference has already been made to the necessity of appointing "shock" teams, each consisting of a medical officer and at least one orderly or nurse.

It is unnecessary to dwell at this point upon the selection of cases which require immediate or preferential operation. In subsequent chapters dealing with wounds of different parts of the body, an attempt has been made to indicate these.

It is difficult for those who have not had experience at the front to appreciate that infection can develop so quickly as it sometimes does. It has already been said that men have succumbed to acute gas infection within twelve hours of the reception of the wound. In a very large number it is well advanced within twenty-four to forty-eight hours. Acute septicæmia is frequently present within the same period, and when due to streptococci it is particularly fatal.

To recapitulate—the rate of development of infection depends largely—

(1) On the amount and virulence of the infection. The amount can be roughly estimated at an early stage by the size and character of the foreign bodies and by the extent of general soiling of the wound; immediately after the injury the virulence cannot be estimated.

(2) On the extent of the injury and the amount of laceration present.

(3) On the integrity of the blood supply which is affected by the injury or other mechanical causes, by tension in the wound, by shock, hæmorrhage, etc.

It is impossible to give accurate directions as to the treatment of any particular case. Experience alone will convince most surgeons how powerless they are to help many patients, while others again rally rapidly. The purely operative treatment of the wound is usually the simplest problem.

CHAPTER VI

OPERATIVE TREATMENT OF WAR WOUNDS

Before categorically describing operative technique, emphasis must again be laid on those fundamentals which dominate the method and extent of attack upon war wounds, namely, the character and size of the missile, the time since the wound was inflicted, and the condition of the patient when first seen by the surgeon.

(1) **Character and Size of the Missile.**—These are the most important factors, for on them depend the amount of infection *carried into* the wound at the moment of injury. The mere size of a wound does not determine the difficulty of eradicating infection. A large explosive exit caused by an undistorted rifle bullet is comparatively easily rendered sterile. Infection of its surfaces is *secondary* and at first purely *superficial.* On the other hand, a jagged piece of shell carries in a large amount of infective material and forces it deeply into the walls of the track, so that, even though only small superficial wounds are seen, very extensive incision and excision may be required. It is in dealing with this type of wound that experience and judgment are pre-eminently of value.

(2) **Time since Infliction of the Wound.**—It is un-

necessary to revert to the fact that, taken alone, the best time for radical operation is before infection has had time to develop; but other factors render it necessary that the time, which has elapsed since infliction of the wound, shall be considered in conjunction with the virulence of the inflammation. Gas gangrene demands prompt and extensive operation based on the principles already indicated, irrespective of the time interval since the injury. In other cases, however, where several days may have passed, during which men have been lying out on the battle-field, the question of operation is approached from a special standpoint. Conditions of circulation and drainage have allowed the natural resistance of the patient to prevail, and such as arrive at the casualty clearing station alive, having overcome the tendency for inflammation to spread, may be suffering merely from the effects of retention of pus. Here it is well to defer, if possible, even comparatively trivial operations until the patients have been cared for thoroughly. They are usually suffering from starvation, so that the administration of a general anæsthetic (especially chloroform and, to a less extent, ether) may precipitate severe acidosis. Unless the wound is of such a nature that complete excision *en masse* can be done, any interference is to be deprecated further than removal of foreign or sloughing material and the establishment of drainage of pockets in which retention is occurring. If a man has been seriously wounded, he survives for such a long period only if his wounds have been freely laid open by the missile, and only if the local circulation around the wounds remains good. It is rare to see men with serious shell wounds of other types survive without surgical treatment for a period long enough to allow the formation of granulation tissue. They die on the field within a very few days, or else, when picked up at the end of that time, too often are found to have such a degree of toxæmia that the strain of transport proves more than they can bear.

(3) **The General Condition of the Patient.**—As has been stated in Chapter IV, many patients are in such poor condition from loss of blood and shock that only the minimum of interference compatible with what is necessary to save life is possible. Every endeavour must be made to prevent unnecessary loss of blood during operations. Pneumatic tourniquets are to be recommended instead of the ordinary pattern, because their constricting pressure can be accurately regulated, so that it just stops the circulation without deleteriously affecting tissues whose vitality may already be seriously threatened.

For purposes of discussion of operative treatment, wounds may be divided into three groups.

I. **Simple Perforating Wounds in which the Track is of about the same Diameter as the Skin Aperture.**—The most frequent example of this group is the through and through wound caused by a rifle-bullet traversing at long range the soft tissues of a limb, where the apertures of entry and exit are small, the damage to muscle is slight, and there is no lesion of large vessels or nerves.

II. **Wounds in which the Destruction of Skin and Superficial Tissues is of greater Extent than the Destruction of Deeper Structures.**—In such wounds ("gutter" wounds, explosive exits, superficial lacerations, avulsions) the deeper parts are more or less exteriorized, and what is required is the excision of all damaged tissues, in order to attain the ideal of an open wound with a living uninfected surface.

III. **Wounds in which the Skin Aperture is small in relation to the Extent of Damage inflicted on Deeper Parts.**—This group includes the majority of all wounds, and may be divided into (*a*) Lodging wounds, and (*b*) Traversing wounds.

Except when injury to important structures in other types demands immediate attention, these are the wounds which most urgently call for operative treatment.

OPERATIVE TECHNIQUE

Sterilization of Skin.—The skin should be washed with soap and water around and close to the wound. If it is heavily caked with mud, a soft scrubbing-brush should be used to accelerate cleansing. Hairy parts should be shaved.

During the skin-cleansing process the wound should be covered with an absorbent swab, so that discharge may not escape and soil the skin. In many cases the wound should first be packed lightly with gauze wrung out of picric acid solution (3 per cent. in methylated spirit) or of the more deeply staining solutions described later under (6). Dry the skin and finally rub it over with a swab dipped in the picric acid solution.

All parts to be covered by the bandage which fixes the dressing should be dealt with in this way. In a limb the whole circumference should be cleansed. Hurry and lack of method in cleaning the skin will result in failure to achieve sterility.

In the case of a wound belonging to Group III. the direction of the track should previously be ascertained, preferably when possible with the finger, a search that is often aided by moving the limb in different directions. The limb must be placed in the position it occupied when struck by the missile before a finger, forceps, etc., can be passed along the track. During operation, especially in the neighbourhood of joints, the limb should be fixed in that position. (Compare also page 156, para 7.)

. . . . .

The operative treatment of wounds of soft parts alone will be discussed now. The more elaborate measures necessary when fracture co-exists will be described in later chapters.

Excision by a sharp scalpel is always preferable to excision by scissors. The wound should be treated as much as possible like a sarcoma. When scissors are used, septic material may be carried along the edges of the blades as they close, and the freshly cut tissues are thus immediately infected. The success of an excision operation is thereby imperilled. For this reason it is imperative that expert cutlers should be on the staff of a casualty clearing station. Sixty to one hundred scalpels may be used every day during very busy times. A sharp scalpel is almost as important, from the economy point of view, as a good X-ray picture; indeed, in some cases, it is even more so.

(1) **Treatment of the Severer Types of Group I.**—The majority of these wounds requires no operative treatment, or, at most, a narrow excision of the wounds in the skin and fascia, followed by suture. If no excision is made, the surface wounds should, after cleansing, be rubbed with a little Bipp or other antiseptic paste.

If there is great tension in the depth owing to hæmorrhage, or if paralysis, indicating severance of a motor nerve, is present, immediate operation ought to be done, either to ligature the bleeding vessels or suture the torn nerve.

Small through-and-through surface wounds are sometimes accompanied by great destruction of muscle. The amount of destruction depends usually upon the state of the muscle as regards contraction at the moment of impact. If the muscle is tense, its torn fibres tend to spring apart like broken fiddle-strings. Such cases belong to Group III. When time permits, such wounds should be laid open, clot cleared away, and suture of the torn muscle carried out, followed by complete closure of the usually aseptic wound.

(2) **Excision of Gutter Wound** (Group II).—Small wounds of this nature can always be excised under local anæsthesia by infiltration of the tissues surrounding the wound. In larger, deeper, and more irregular wounds considerable care may have to be exercised in making the injections so that all parts of the wound are anæsthetized. If adrenalin be added to the anæsthetic solution, bleeding becomes negligible. On the whole, in very large wounds, it is better for beginners to use general anæsthesia.

A tourniquet should be used whenever possible, so that swabbing is reduced to a minimum.

The raw surface of the wound is dried and thoroughly soaked with strong picric acid or iodine solution (10 per cent. in methylated spirit). Excess is absorbed by a swab. This has the effect of dessicating the wound. A small wound may be cauterized with the actual cautery. The wound is repacked with sterile gauze. It is then completely excised *en masse* by a series of elliptical or lemon-shaped cuts which should not be less than $\frac{1}{4}$ in. from the edges and deep surfaces. It is advisable to prepare one side of the ellipse completely before cutting into the other, by incising the skin and deep fascia together, and then deepening the cut rapidly until all the wound is undermined. This incision is then packed with gauze. The incision on the other side of the wound is then made in the same manner, completing the ellipse. A wedge of tissue is thus excised, enclosing the wound cavity which is not opened at any part. A very sharp scalpel makes the operation comparatively easy. The use of a finger in the wound sometimes enables one to cut clear of pockets which would otherwise be opened. If this is done, the same finger should be kept in the wound until the excision is completed ; it is then disinfected or the glove changed. The ends of the ellipse may be caught by forcipes and steadied by an assistant, who makes *very* slight traction in an upward and outward direction. The forcipes (tissue or artery) are necessary only during the second half of the excision. They should catch up muscle as well as skin. While the deeper structures are being cut on either side of the wound, the outer surface of the flap may be caught by forcipes and steadied by an assistant, who should remember that it is very easy to tear open the cavity of the wound. If possible, no swabbing should be done during the excision; and, if it is necessary, great care must be exercised that infection from the original wound is not transferred to the freshly made one. All bleeding is carefully controlled.

The wound is sutured in such a way that no dead spaces are left. This may entail the use of buried sutures, preferably of catgut. All sutures should catch up lightly "the layer next below." If mistakes in technique have been made, tight sutures, whether deep or superficial, may be the cause of gas gangrene by interfering too much with the blood supply of the tissues which they draw together. Shallow wounds can usually be closed by a single row of sutures, which should just emerge in the depth of the wound as they cross from side to side. In some cases the part may have to be specially relaxed and fixed in the relaxed position during suturing and the early days of convalescence.

Mastisol varnish dressing is recommended strongly (see page 165). Application of a thick layer of cotton wool, a firm broad bandage, and possibly a splint, completes the operation.

If an important vessel, nerve, or other structure is exposed and cannot be cleaned properly, or if the original wound cavity has been entered at any part during the operation, primary suture should not be done without previous careful antiseptic washing of the fresh wound surfaces and possibly smearing with a paraffin antiseptic paste. In more doubtful cases the wound may be packed or treated by Carrel's method in preparation for delayed primary suture in two or three days' time.

(3) **Excision of traversing Wound with Explosive Exit** (Group II).—If the wound has been caused by an undistorted conical bullet, so that little or no septic material has been carried through the puncture wound of entrance, and if the soft parts only have been injured, the lacerated gaping part of the wound may be excised and sutured, as has been described under (2). The narrow part of the track may be disregarded.

If the wound has been caused by a shrapnel ball or piece of shell, the whole track must be excised or otherwise dealt with. (See under 4 (*b*) and 5.)

(4) **Tunnel Wounds** (Group III).

(*a*) If superficial, draw a strip of gauze, which completely fills the wound, through the tunnel, and excise the whole track as in (2).

(*b*) If traversing the depth, when no suspicion of gas infection exists, and if it is thought that the circulation around the track is good, the tunnel may be cleaned by passing a forceps along it and drawing through a suitably thick strip of gauze which will sweep out gross dirt and blood-clot. Successive strips of gauze are drawn through, in the same direction. On no account should *sawing* motions be made with the gauze in the wound, as this will simply rub sepsis deeper. Another strip of gauze, considerably narrower than the diameter of the tunnel, and impregnated with an antiseptic paraffin paste, is then drawn through and left *in situ*. It can often be removed safely in a couple of days, and the walls of the wound pressed together by dressing pads and bandages.

(*c*) In other cases the wound should be treated as in (5).

In times of severe stress many other types of wound must be treated as indicated in (*b*), but only if gas gangrene has not declared itself. If done carefully, the procedure will, in many cases, cause only momentary pain, so that an anæsthetic may be dispensed with. In cases which require it, the primary anæsthetic period of chloroform or ether, which lasts about a minute, is usually sufficient. The onset of this period is found by making the patient hold an arm vertically as long as he can, while anæsthesia is being induced. When the arm drops he will not be capable of feeling pain, and such short operations as opening an abscess, avulsion of a toe-nail, or the procedure just described, can be carried out. If the anæsthetic has to be continued, the "struggling" or "excitement" stage will be stimulated at the end of this short analgesic period.

Tunnelling or lodging wounds of or near the buttocks should be treated with special consideration and thoroughness. These were particularly dangerous wounds before treatment by free excision was adopted.

(5) **Traversing Shell Wounds** (Group III).—Entry and exit wounds of the skin and deep fascia should be excised by elliptical incisions. Usually it is unnecessary to cut away more than $\frac{1}{4}$ inch of skin all

round. As a general rule, the area of skin excised varies inversely with the skill of the surgeon. If sufficient access is not provided through the superficial excision—and it is only rarely that this is the case—the ends of the ellipse should be prolonged freely so that the sides of the wound may be easily retracted. These incisions should run in the direction of the main track or pockets of the wound which have previously been ascertained. After the freshly incised superficial parts have been retracted, the lacerated muscular tissue in the depth of the wound is seized with tissue forceps and excised cleanly and systematically. Care must be taken, as far as possible, to cut in healthy tissue. If the knife is soiled by contact with lacerated muscle, it must at once be cleaned or preferably replaced by a sterile one. Attention is drawn to this here, as it is more likely to occur in this type of wound, but obviously the same precaution must also be taken in excision of other wounds. Working from both ends, the wound should be excised *en masse* if possible. This is extremely difficult to do in many cases, so that the inferior "piece-meal" excision must be resorted to. In all cases the indications for the prevention of gas gangrene, given in Chapter IV, must be followed.

It is evident that, if treatment on these indications is to be successfully carried out, it is of the greatest importance that incisions are made sufficiently free to allow thorough inspection of the depth of the wound. Inadequate incisions spoil work in another way. They tempt the operator to use forcible and prolonged retraction which bruises the tender muscle fibres and renders them a prey to saprophytes which may be left in the wound.

A very useful procedure for beginners is to stain the dead or dying tissue along the track by injecting 2 per cent. solution of methylene blue or ½ per cent. solution of brilliant green. This can best be done by passing a catheter or other rubber tube along the track and squirting the solution through it. All stained tissue at least should be excised.

(6) **Lodging Shell Wounds** (Group III).—These are dealt with on the same lines as described in (2) and (5), according to the depth of the retained fragment. The fact that there is no exit wound to indicate the direction of the track may cause a little difficulty, because fragments are sometimes deflected by resistent tissues before they finally come to rest, so that the line drawn between the entrance wound and the site of lodgment ascertained by X-rays is by no means straight. This is found most frequently when a shrapnel ball impinges on bone. Every effort should be made to follow and excise the walls of the track in its whole extent. Here again the advantage of long incisions, which allow easy inspection, as opposed to short ones, which compel exploration to be done mainly by touch, is very manifest. In any case, it is sometimes difficult to follow the deeper parts of the track after excision of the more superficial parts. It will be found that if the limb is moved slowly so that the deeper planes of muscle assume different relative positions, the track through them will come into view. A finger can then be gently insinuated along it and may feel the foreign body, when a probe

or forceps can be passed along the finger and left in the track as a guide. The limb should be fixed in the new position till the operation is completed.

The bed in which the foreign body is lodged requires special attention. It happens far too frequently that the operator extracts a fragment, holds it up triumphantly, and considers that all that is required has been done. But pieces of clothing, mud, etc., which have been carried in front of the metal fragment are equally important as factors of infection. The tissues in the neighbourhood are possibly the most heavily infected of all—they have been rendered anæmic by the pressure of the foreign body, and probably form a focus from which gas gangrene will spread. The area must therefore be freely inspected, cleansed of all foreign material, and all lacerated or suspicious tissue carefully cut away.

It is sometimes found necessary to make a counter incision, either for the purpose of obtaining easier access to the foreign body or for drainage. Such counter openings should be free, especially if they are made for extracting a fragment of shell.

While primary suture can be carried out in a large number of these wounds, it must be remembered that the extra manipulation and the piece-meal excision, which is so often compulsory, as well as the often widespread sepsis which may be present, make primary union uncertain. The amount of success in obtaining this forms a very good index of the ability and judgment of the surgeon. The real expert can afford to suture more wounds and at the same time to do without extraneous help from antiseptic pastes, lotions, drainage, and so forth, while the beginner should leave more wounds open for delayed primary suture, and invariably invoke the aid of these extraneous helps either singly or in combination.

(7) **Multiple Wounds.**—These require mention again on account of their frequency, and by reason of the special problems they present. As has been stated, the condition of the patient often will not allow the operator to deal with each wound as thoroughly as could be wished. The first thing at operation is to determine the general direction of the fragments of projectile. Search will usually reveal a graze, a gutter or tunnel wound, which gives a clue to the course of the others. It then remains to decide which wound should be dealt with first and most thoroughly. Excluding fractures and penetration of the body cavities, lodging wounds of the buttocks, thighs, calves, shoulders, and root of the neck should receive preference.

It frequently happens that multiple wounds from lodging bomb splinters are crowded so close together that excision of each separately is not advisable. The patients are often in such bad condition that haste is necessary. A single long incision down to the deep fascia, followed by rapid undermining of the subcutaneous fat to beyond the wounds, will usually reveal the extent of damage to the muscle and facilitate quick decision as to what is best to do. In such cases gas gangrene is apt to develop very quickly. The fragments of bomb cause considerable churning where they finally come to rest. If they are fairly superficial, free excision of the affected muscle is usually advisable. Such cases very rarely permit of primary suture. If the fragments have penetrated deeply or traversed the greater part of a limb, amputation is practically compulsory.

Hæmostasis.—At the conclusion of all these excision operations, great care should be devoted to this, because, if blood is allowed to accumulate in the depth and crevices of the wound, the development of sepsis is favoured. All visible vessels should be ligatured, even although they do not bleed when exposed. It often saves much time, when dealing with vessels adjacent to bone or fascial planes, if the ligature is threaded on a rounded needle and a small part of the unimportant tissues around the vessel caught up by it and tied in with the vessel. This prevents slipping of the ligature.

REMARKS CONCERNING EARLY EXCISION AND SUTURE OF WOUNDS

Excision of infected wounds, whether of soft tissues only or when accompanying fractures, was practised by the writer for many years before the war, and was deliberately applied in the treatment of war wounds in November 1914. The first case was that of a German soldier, who had a filthy, very deep gutter wound of the posterior axillary fold on the right side, sustained three days before operation. Excision and suture was followed by perfect primary healing. A similar wound of his right arm, which was cleaned merely by excision of the sloughing parts, left open, and packed, furnished an instructive contrast.

It was a natural sequence that a principle in treatment, which could be applied with such success in war wounds of soft parts alone, should be extended to wounds involving all kinds of tissues. It has been abundantly proved during the war that the measure and rapidity of success attendant on treatment of all wounds, especially of the more complicated types (skull, knee, long bones, chest), depend on the efficiency with which removal of infected tissue is carried out. Excision *en bloc* guarantees most certainly that healing *per primam* will follow primary suture. Piece-meal excision is, unfortunately, too frequently compulsory, and is bound to be followed by a large proportion of failures.

It is curious and somewhat inexplicable that the technique laid down for treatment of these complicated types of wounds should have been so widely accepted as correct, although only after considerable delay, while that for the simpler types was neglected by the majority of consultants and surgeons in France. The cart was placed before the horse. Several British and Colonial surgeons, however, practised the method in the early days of 1915,[(1)] and have continued to use it with increasing success. It was not blessed by the general body of English-speaking surgeons, however, until it was discovered that our French confrères had also satisfactorily demonstrated its advantages.

While it is obvious that the best results should be obtained from operation in the pre-inflammatory stage, before infection has gained a firm hold on the tissues, yet it must be remembered that excision and immediate suture was done in those early days of the war on wounds which were two to four days old, when infection had become established, in some cases in a very acute degree. Results showed that in capable hands healing by first intention was obtained in over 90 per cent. of the cases. In one series reported (scalp wounds), in which cases showing stitch suppuration were regarded as failures, 400 excisions out of 412, healed by perfect first intention. (2)

The sudden popularity of primary excision and suture of wounds, which developed in 1917, led to abuse of the method in too many instances. It seems absurd, and ought to be superfluous, to have to say that wounds must not be sutured completely unless all gross infective material is previously removed. A careful, thorough excision of superficial parts is neutralized if infective material and foreign bodies are left in the depth of the wound. Suture of such a wound in a limb has led to subsequent amputation, revealing the foreign body and the unpardonable sin of the surgeon.

Although during " peace " times, when patients can be kept for observation for several days, primary suture of large wounds or amputation stumps is attended with gratifying success, yet in periods of active fighting it is not advisable to carry it out unless one is very sure of having procured asepsis. Most of the patients cannot be retained and left at rest in bed. The stress of transport rouses any infection which may have been left, and which would likely have been dealt with successfully by the tissues under favourable conditions of rest. These remarks apply especially to wounds of the limbs and trunk in regions which cannot be absolutely fixed by splinting. Again it must be said that the success with which sutured cases travel to the Base immediately after operation is an excellent criterion of the capacity of the surgeon who has operated on them, and proves that the use of the scissors instead of the scalpel endangers success. *Proper technique and sound judgment are essential.*

Primary suture should be done in all cases when the essential conditions are fulfilled, unless pressure of work makes it impossible to give the extra time necessary. The fact that restoration of function, when that is possible, occurs far more quickly and certainly after careful preparation and primary suture, makes this procedure more than desirable. In some wounds " open " treatment means simply delay in healing and subsequent impairment of function. In other types it may mean grave risk of death or complete loss of function. Certain cases should always be closed as a routine, for example, wounds of the joints, most of which can be absolutely fixed and supported during transport, wounds of the brain and its coverings, chest, and abdominal wounds. Wounds of the knee must usually be kept at the casualty clearing station for several days ; those of the brain, chest, and abdomen perhaps for several weeks.

The following paper on this subject was published by the author in the *Journal of the Royal Army Medical Corps* in June 1915, and in the *British Medical Journal* August 28th, 1915.

" TREATMENT OF GUNSHOT WOUNDS BY EXCISION AND PRIMARY SUTURE

" The number of cases to which this treatment is applicable makes ample justification for attempting to make the method more widely known and popular. I began this method of treatment of certain lacerated 'furrow' wounds in November 1914, and was so impressed by its utility that I have since then urged that it should be carried out whenever possible. The advantages claimed for its use are :

"(1) Healing by first intention is assured in the vast majority of properly selected cases.

"(2) Much time is thereby saved. Some wounds, which would otherwise require months to heal, are soundly united in the course of ten to fourteen days. The soldier is thus available for duty again at a much earlier date.

"(3) The amount of attention required to be given by the medical officers, nursing sisters, etc., is greatly reduced.

"(4) Much pain is avoided.

"(5) The amount of dressings required is reduced to a minimum and in this way expense is lessened.

"(6) Complications which may arise from the presence of a septic wound are avoided.

"(7) A more sightly scar is obtained.

"(8) Because of the absence of contraction which would accompany formation of a large cicatrix, there is less impairment of function in the part concerned.

"(9) In the case of head injuries, excision of the wound, especially in some, apparently trivial, injuries, provides a means of ascertaining, with greater certainty than by any other method, whether depressed fracture and injury to the brain coexist.

"Healing by first intention may be procured in practically all cases in which the surfaces of the new wound can be brought into accurate approximation without much tension. In rare cases, when the wound is deep, approximation in the depth has to be dispensed with and drains are introduced for a short period, until one is assured that aseptic healing will occur. In some cases it is necessary to adjust and fix the parts of the body adjacent to the sutured wound so that the fullest relaxation is secured.

"The mere length of a wound is no bar to operation. Some very long wounds have been excised. A missile may inflict what resembles an incised wound and, because dividing the tissues at right angles to the line of their greatest tension, may, owing to the contractility of these tissues, cause a large gaping wound. In such cases there will be but little tension when sutures are inserted and tied, if too great a mass has not to be excised. One can test roughly what the amount of such tension will be, by attempting to push the surfaces of the wound together.

"It is not necessary to wait until the wound is surgically clean; in fact, in most cases the sooner the excision is made the better. The wound will probably be soundly healed in a shorter time than it will take to clean. During the 'cleaning' process the adjacent parts become so softened that sutures do not hold well. Only when a large 'bank' of inflamed tissue surrounds the wound is immediate excision inadvisable on account of the septic condition of the wound. In such cases it is probable that organisms have penetrated to a considerable depth and will cause trouble when the tissues invaded by them are subjected to the pressure of sutures. By vigorous salt-pack treatment such wounds are usually rendered suitable for excision in twenty-four to forty-eight hours. Other contra-indications are the presence of marked pocketing in the wound and the exposure of vascular or nerve trunks in the depth or of bone which it is inadvisable or impossible to remove.

"Certain bony prominences, such as a vertebral spine or the edge of the acromion process, may be capable of removal with the other infected tissues. The presence of pocketing in a wound is very important. If part of such a pocket, or, indeed, if any septic focus be left, the operation will probably prove a failure.

"The technique is therefore very important. The operation can usually be done under infiltration anæsthesia of the neighbouring parts. It is well to add plenty of adrenalin to the anæsthetic solution so that hæmorrhage during the operation is avoided. Accurate hæmostasis is important for success.

"The parts around are shaved and disinfected very thoroughly. The wound is wiped out, dried, and packed with gauze.

"For disinfecting purposes in these cases I favour the use of very strong iodine solution (5 to 10 per cent. in spirit or ether). (I now use picric acid solution of similar strength.) This is painted thoroughly into every part of the wound and over the surrounding skin for a considerable area. It has the effect of drying the surface of the wound in a remarkable manner. The strong iodine is wiped off the skin with spirit or ether at the end of the operation.

"The skin close to each extremity of the wound is caught up by a tissue forceps or loop of thread and slight traction is made in a direction away from the centre of the wound at an angle of about forty-five degrees with the sound skin. The whole wound is then cut away *en masse* (skin, flesh, and, if necessary, bone) at a distance of about one-third to half an inch from the raw surface. Care must be taken that pockets or general surfaces of the wound are not cut into during this procedure. Bony prominences are removed along with the soft parts by dividing them with bone-pliers, gouge-forceps, or chisel. If the wound is deep it is sometimes of advantage to insert the finger into the wound as a guide to where the tissues must be divided.

" A very sharp scalpel is invaluable. Cutting out the wound in pieces makes success precarious.

" The new wound surfaces should now be washed out with saline solution and packed with gauze, and the surrounding skin wiped free of blood or discharge. Fresh towels, fresh instruments, and, if the wound has been handled, fresh gloves should now be used.

" The wound should be closed by wide sutures which underrun its floor so that no dead spaces are left. It may be necessary to suture in layers. If so, the suture of each layer should include some of the tissue of the deeper layer. The skin should be accurately approximated by a few fine sutures. Further relaxation sutures are not often necessary.

" The following dressing should then be applied. The line of sutures and the adjacent skin for several inches should be painted with a wound varnish, of which mastic, dissolved in some rapidly evaporating solvent, forms the important part (40 to 50 per cent.). When the varnish has become 'sticky,' a covering of gauze, at least two layers thick, should be stretched tightly and smoothly over the sticky area, gently patted down, and cotton-wool and bandages applied fairly firmly. If it is desired to inspect the wound at any time, after removing the bandage and wool, the top layer or layers of gauze should be peeled off by traction at right angles to the surface, the layer next the skin and wound being at the same time retained by the other hand. Perfectly satisfactory inspection can be made through the single layer of gauze. The loose edges of the gauze should be neatly trimmed. In many cases no further dressing is required until the stitches are to be removed. The final layer of gauze is then peeled off.

"If fine catgut sutures have been used for the skin, it is often found that the knots come away with the layer of gauze, the deeper parts having been digested. A fresh application of the mastic varnish and gauze should then be made and left until the wound is firmly healed.

"The varnish should on no account be painted over the gauze after it has been applied, otherwise the gauze cannot be peeled off as described. The varnish and gauze dressing is important for success. It is the best I know. It gives wide support, relieves tension, and prevents any dragging on the stitches. These factors are of great value in preventing stitch abscess." (See page 212.)

"Delayed Primary Suture."—This, when anatomically possible, is performed if, after two to four days, the wound is found to be free from inflammation. Such wounds should be dressed for the first time in the operation theatre, so that delay and possible preventible infection does not occur between the dressing and suture. "Cultures" may be taken from the surface of the wound.

The presence of hæmolytic streptococci in a wound contra-indicates suture. If their presence is detected only after the wound has been sutured, it becomes imperative to open up the wound entirely and immediately when the slightest symptom of local or general sepsis is apparent.

Secondary Suture.—The operation of "secondary suture" is performed for such cases as can be closed only after granulation of the wound surfaces has occurred and all sloughs have separated. Many surgeons have relied on the "bacterial count" in smears from the crevices of the wound as an indication of when it is safe to close such wounds. It may be looked upon as heresy to say that, in the great majority of cases, such examinations are unnecessary and, unless carried out with the greatest care and skill, are unreliable.

Fixation and support of the wounded part must be secured, in mild cases by proper bandaging, in severe cases by splints, even although soft parts only are affected. Efficient fixation in an appropriate and comfortable position will limit effusion and consequent swelling as well as suffering for the patient. Soft parts must be prevented from sagging, especially where deep lacerated wounds accompany fractures of such a bone as the femur. In these cases support is best provided by suitably shaped gutters or slings of perforated zinc, properly padded and covered with waterproof material, which are placed under the limb. The edges of the gutter are bent over the side-bars of the Thomas's splint, which is now universally used. The slings should be arranged so as not to interfere with easy access to the wound or with drainage. Clean ones are substituted when required. The slings should be reinforced, especially during transport, by suitably sized pieces of Gooch's splinting.

Drainage and Kind of Drain.—The primary object of drainage is, of course, to prevent accumulation in dead spaces of fluids which will form favourable media for the growth of pathogenic micro-organisms, and which also, on physical grounds alone, will prevent or delay healing by keeping the tissues from adhering. However, if the dead space left after suture is not large, and can be obliterated by suitable bandaging, if the effusion is likely to be small in amount, and if the wounded part has been rendered aseptic, there is no necessity for drainage. In certain cases also, when, for example, slight infection of the knee-joint or brain has been found, the presence in the affected part of a foreign body, such as a rubber drain, and still more a glass or metal one, will probably allow sepsis to gain a firm hold, especially in parts bruised by the drain—the very thing the latter is meant to prevent. It seems absurd to take a deal of trouble to remove one unyielding foreign body and forthwith to insert another, unless for very definite and well-considered reasons. Such drainage after thorough mechanical cleansing of a wound can usually be dispensed with, and should be avoided when possible.

Drainage of large wounds is effected best by inserting a fairly firm pack of plain or, better, paraffin impregnated gauze. In the case of the antiseptic paraffin pack, discharge finds its way readily first between the walls of the wound and the pack and later into the pack itself.

The more delicate or highly organized a structure is, the more likely is it that damage will be caused by the introduction of a drain, especially of a rigid one. Experience has shown that, if drains have to be employed, the principle of introducing them "down to but not into" the important cavity or injured structure is sound. It matters not whether brain, shattered bone, pleural or synovial cavity has to be drained—the principle holds good. This refers to the preventive function of a drain which is used when infection has not yet obtained a firm hold.

When infection is really well established, and is already causing suppurative encephalitis, osteomyelitis, or synovitis, the matter is more difficult and requires much judgment. The presence of decomposing blood-clot, loose purulent lymph-clot, or even offensive pus in a joint, although accompanied by swollen and injected synovial membrane, does not mean that the joint is inevitably doomed to destruction. Many brilliant results have been obtained, even in the knee-joint, which was thought to be particularly vulnerable, by cleansing the cavity thoroughly of foreign bodies and purulent contents, washing out with appropriate solution, and then draining for twenty-four hours or so by a tube which reached down to but not into the hole in the synovial cavity. In some cases—and this depends a great deal on the character and position of the wound left after operation—it seems to be an equally efficient method merely to leave the wound open, and to protect it from secondary infection by an antiseptic pack. Absolute fixation of the joint during transport after such operations seems indispensable to success. It must be said, however, that the treatment advocated in septic joints by Belgian surgeons (Willems) of making the patient carry out repeated *active* movements of the joint, as soon as possible after operation, so as to force out septic material through open incisions, although in direct opposition to previously accepted ideas, has been followed by some impressive, favourable results. The jars and vibrations experienced on a railway journey may be the cause of the lighting up of sepsis in these cases just as much as the passive movement so much objected to by our Belgian friends. (See chapter on Joint Wounds.)

Drainage of the brain, when abscess has formed round imbedded bone or foreign body, is a very difficult matter. Rigid drains are particularly harmful to the brain. This is especially true if holes are cut in them, because the intracranial pressure forces even normal brain through the holes or the end of the tube, and, moreover, the constant friction of the pulsating brain against the hard foreign body must have a bad effect. The most satisfactory drain in this case seems, on the whole, to be a piece of rubber tissue or similar substance, rolled into a cigarette or folded concertina-wise. If, however, the pus be particularly thick or profuse, it may be necessary to insert, in addition, a tube for a short distance and for a short time.

A drainage tube thrust amongst the fragments of a shattered bone will tend to carry infection and to cause necrosis of the fragments in contact with it. A drain on each side, down to but not into the shattered mass, will do all that is required.

Rigid drains in contact with pulsating vessels predispose to secondary hæmorrhage. In a septic wound they are practically as efficient in causing this as are displaced fragments of bone or pieces of missile.

It is not good practice to draw a *non-collapsible* drain through the whole length of a wound. It is especially dangerous to insert tubes between the bones of the forearm or leg. The tube is likely to cause, by its pressure, sloughing of the interosseous membrane, secondary hæmorrhage from the vessels which lie close to the membrane, and paralysis from destruction of the nerves which accompany those vessels. In some cases, as has been pointed out, a "draw-through" gauze wick, impregnated with antiseptic paraffin, is sufficient to prevent development of acute infection.

Removal of Drains.—When one is certain that the wounds are healthy, that is, if there be no necrotic tissue or other infective material in the depth, it is desirable to remove tube drains altogether, but it is probably safer practice to shorten them gradually, *e.g.* about one inch at a time. Rigid drains should give place to soft drains (jaconet, battiste, torn glove, or absorbent bandage) as soon as the discharge ceases comparatively to be profuse. These serve to keep the superficial part of the wound open, and do not cause sufficient irritation to keep up the discharge, as rigid drains may do.

Tension.—Tension in a wounded part militates against successful treatment. It interferes with the efficient circulation essential for the combatting of infection. Tension must be relieved, whether in a joint, in the thigh, in the chest, or in the brain. Aspiration of a joint or pleural cavity *may* suffice. (See chapters on these special injuries.)

General After-treatment. — The great indication during the early stages of this period is to provide as much rest and nourishment as possible. The severely wounded man has previously come through such a period of mental and physical stress that his nervous system is more or less exhausted, and this exhaustion reflects itself in impairment of the functions of all important organs and of his power of repair. It is, therefore, necessary to treat him with the utmost consideration in every possible way. This remark applies in a comparative degree also to the man who has received minor injuries. Every wound should be treated with respect, and careful watch must be kept even on the most trivial, because every now and then, with sometimes very little warning, complications such as tetanus, gas gangrene, or acute streptococcal septicæmia may set in and cause rapid death.

Rest must be procured by sedatives if necessary. Usually some preparation of opium is used. The preparation should vary with the particular case. While morphia is the drug hitherto generally chosen, it is not so good as omnopon or heroin for chest cases, or omnopon for abdominal cases. In abdominal cases morphia has a much greater inhibitory effect on the bowel than omnopon.

The severely wounded man must be given nourishment which he can digest.

Patients who are in danger of developing gas infection should be "flooded" with alkalis, by the mouth, by the rectum, and, possibly, intravenously. While the danger lasts, proteid foods should be given sparingly. Easily assimilable carbohydrates should form the staple diet, including candy sugar by the mouth, glucose intravenously or per rectum, and so on. The writer has found peptonized cocoa and milk of considerable value in many cases.

The patient must be kept cheerful, encouraged in every way. The presence of moribund cases has a depressing effect, and an excuse can usually be found for removing them to another part of the hospital or at least to one end of the ward.

For patients who have suffered from severe shock, it is a good working rule not to evacuate them to hospitals farther down the line until at least twenty-four hours after their blood pressure has become approximately normal and the pulse rate has descended below a hundred, except when a distinct, and not dangerous, explanation for the continued acceleration exists. Cases of this nature, when evacuated too early during periods of severe fighting, have died on the train or shortly after arrival at the Base, from a recrudescence of surgical shock, or from a fulminating septicæmia stirred up by transport in a patient whose resistance is feeble.

In other respects each case must be treated on its merits. No wound should be dressed unless some special indication is present, and every wound should be closed as soon as its condition will permit. The general principles indicated already and in later chapters on regional wounds should be followed throughout convalescence as well as at operation. Some patients have to be retained in casualty clearing stations for considerable periods. Massage of the surrounding parts and movement of the neighbouring joints should be begun as soon as such procedures do not produce local or general reaction. Active movements should be encouraged in gradually increasing degree.

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CHAPTER VII

WOUNDS OF THE BRAIN AND ITS COVERINGS

If wounds of the brain are left untreated until inflammation has obtained a hold, results to life and function are, on the whole, more disastrous than in comparable wounds of other parts of the body. Because of the importance and delicacy of the structure, abnormalities, whether in the form of microbic infection, displaced fragments of bone, foreign bodies, blood-clot or pulped tissue, are apt to have far more serious, and sometimes more rapid, lethal effects than in other structures. Further experience has not inclined me to deviate in the least from the principles which I enumerated in a paper published in the *British Medical Journal* of February 19th, 1916. The following chapter embodies that paper with very slight alteration and addition.

The principles then enunciated were:

That infected gunshot wounds of the skull and brain require more careful consideration and prompt attention than similar wounds of any other part;

That we can combat and prevent sepsis best by early and complete operations;

That we can prevent further permanent disability in most cases by systematically removing foreign material or displaced bone from the surface or substance of the brain whenever these are accessible to legitimate surgery;

And further, that, by these precautions, the immediate results in the saving of life and more rapid restoration of function, when that is possible, are better than those obtained by more conservative procedures.

From time to time during this war there has been manifest a tendency to imagine that modern brains are more submissive to insult than those of our forefathers apparently were. Even yet it is too early to decide this point. All previous experience has shown that the brain, sooner or later, resents the presence of any abnormality in its immediate coverings or in its substance. It is true that some small lesions of the skull or small foreign bodies in the brain have caused apparently no trouble to the patient, even after years have passed; but others, seemingly equally insignificant, have caused intolerable inconvenience, due to late effects on the brain, which removal of the exciting cause has not succeeded in relieving. This is more true, of course, in cases of actual lesion of the brain than in injury to its coverings. There was a considerable number of men injured in the head during the South African War who afterwards became a burden to the State owing to derangements of the brain, and it must be remembered that the maiming effects of sepsis in that campaign were not apparent to anything like the same extent as in this one. At the same time, it must be said that there is evidence to show that much of the subsequent disability may be functional in nature and will clear up under suitable treatment.

It has hitherto always been the aim of military surgeons to remove or ameliorate the physical defects produced by missiles. Removal of displaced bone, of foreign bodies, of blood-clot, or of any substance which might interfere with rapid and smooth healing of the brain has been considered of the utmost importance no less than the combatting of sepsis. We have discovered in this campaign no valid reason to depart from this line of thought. The immediate effect of sepsis, both in increasing the severity of the focal lesion and in causing diffuse inflammation of the brain and its coverings, have been impressed on our minds with dreadful force. The power of the brain to accommodate itself to extraordinary conditions, or, one might say, the power of one part of the brain to disregard even excessive injury of another part, so that what is left "carries on" in a marvellous way, has also been very striking. But who can foretell that, later on, such cases are to be free, as never before, of sequelæ which experience has shown to be so frequently inevitable?

Because of that experience, and because no one can foresee how soon trouble will arise, it is surely right that we should do all in our power to prevent probable trouble. It is a matter of the greatest importance to establish the best method of preventing or eradicating sepsis, which is such a hindrance both to rapid healing and to successful attack on physical defects in the skull or in the brain. One is not justified in formulating rules which are based on results of operations performed at a period in the war when methods of dealing successfully and rapidly with infected wounds were not generally properly appreciated. It has been found that septic wounds of the scalp and skull are particularly easy to deal with when compared with others, in that they can usually be completely excised, and the scalp sutured without danger. One might almost say that this procedure, in the hands of those who have mastered the necessary technique, has robbed operation of its danger and has enabled surgeons to obtain results which compare favourably with those of equal magnitude in civil practice under ordinary aseptic conditions. These remarks do not apply, of course, to cases in which sepsis has already obtained a firm hold in the lacerated brain. The problems connected with such cases are much more difficult. Apparently success is then dependent chiefly on the provision of suitable drainage—a very easy thing to say !

Fragments of bone, when driven into the brain, are not usually septic at first, but tend to become infected fairly rapidly. Jagged pieces of shell almost invariably carry infection along with them. If large pieces lodge in the brain, results are very bad. Very small pieces, on the other hand, may not cause any trouble, but even they have been found sometimes, later on, to become surrounded by large abscesses. A rifle-bullet does not often carry in sepsis which the tissues cannot overcome, but, after lodgment, in virtue of its weight, it travels through healthy brain tissue in the direction of the most dependant part. The brain becomes diffluent under the pressure. One has repeatedly seen such bullets alter their position within a week to the extent of an inch or more. Here there seems to be an indication for treatment by posture—to make the wound of entrance the most dependant part. At operation rifle-bullets have been shaken out along the wound track, a procedure recommended by Bier. It is likely that they would find their own way more readily along a pulped track than through healthy brain. If inaccessible at first they may soon become accessible and be removed by a secondary operation.

The following remarks have, of course, no reference to very severe wounds caused by large pieces of shell, in which such an extensive part of the skull and brain is blown away or where a rifle-bullet causes such explosive intracranial effects that the patient does not survive more than a few hours.

We have seen many patients who, on admission, have been suffering from complete hemiplegia, and whose symptoms have cleared up in such a marvellous and rapid way after operation that only a negligible amount of paresis has persisted. On the other hand, we have seen cases showing few or no symptoms, who later developed serious complications and died rapidly, in spite of operation. It appears, therefore, that one ought not to pay too much attention to focal symptomatology as a guide to treatment, or even, in many cases, to prognosis.

We have seen many cases of extensive superficial injuries with little or no damage to the brain, and, on the other hand, many cases in which an insignificant-looking wound of the scalp and skull was associated with most extensive injury to the brain. Whilst large, lacerated wounds are usually most septic and suppuration in the brain apt to become severe, yet we have seen cases of trivial and comparatively clean-cut wounds of the scalp associated with extensive fracture, and, after a few days, with such acute suppuration in the brain that only immediate operation saved the patient's life. The size or condition of the wound, therefore, is no indication of how the case will behave.

It has been said that œdema of the brain and shock or concussion accompanying a serious injury are such that operation at an early stage is dangerous. Yet we know of many patients who are brought into clearing stations in practically a moribund condition who, after immediate operation, in a few hours have so far recovered that they are able to speak intelligently and take food. Their injuries heal up perfectly well afterwards. It would thus appear that so-called œdema and concussion are no bar to success. Indeed, it is likely that both will pass off more quickly when physical defects are remedied—all the sooner the more thoroughly this is done. In wounds of other parts, œdema and tension due to interference with the circulation are relieved very rapidly by incision, removal of foreign or lacerated material, and drainage. How much more must relief of the circulation be called for in a closed box like the skull! In such cases delay does not, therefore, seem advisable. The use of the life-saving steel helmets has undoubtedly introduced a difficulty in some cases, which is absent in those who have not been wearing a "tin hat" at the time of wounding. Usually when a wound is caused by a missile which has sufficient momentum to penetrate the helmet, a variable amount of general brain concussion is produced. This must be allowed for in formulating an opinion. The general concussion is, roughly speaking, greater and more lasting than that caused by a small focal force which has to overcome the resistance of the skull alone. A wound caused by a missile which has penetrated a steel helmet is more deadly than one of apparently equal severity which occurs in a patient who had not been wearing a helmet.

In passing, one may be permitted to draw attention to the value of local anæsthesia for most of the cases, and especially for the type just referred to. The solution need be injected only into the scalp tissues and pericranium. The skull, dura, and brain will thereafter be found to be insensitive. If adrenalin is mixed with the solution, bleeding from the scalp is reduced to a minimum. If the patient is conscious, it is advantageous to "dope" him with morphia, or preferably omnopon, until he is decidedly sleepy. In some cases nitrous oxide or a few whiffs of chloroform or ether can be given if much complaint is made of the pain of the injection. Local anæsthesia is now widely used in head cases, with gratifying success. Anæsthetists should acquire the necessary technique in order to prevent loss of time.

After consideration of all these facts we are driven, in deciding upon a course of action, to pay more attention to the probable mechanical effects of the injury, and the potentialities for infection rather than to worry much over the presence or absence of definite symptoms. The lesion is a traumatic one, the possibility of sepsis is great, and things should not be left to chance or until the development of some particular symptom. One must risk misinterpretation when one says such things. One does not wish in the slightest to depreciate the value of clinical investigation. Timely and effective operation does not interfere with that. There is no doubt that the lesions to be dealt with are chiefly mechanical and microbic, and must be treated by mechanical and anti-microbic remedies. If the mechanical disabilities are not relieved, the complicating infection has potentialities greater and more serious than in wounds of other parts.

Treatment of Cases sent to the Base without Operations.—While it is evident that the thorough removal of physical defects is desirable at as early a date as possible, there are objections to this, of which the most important is that patients do not travel well until at least a week or ten days after operation. During a period of active fighting it may not be possible to treat them all at the front. Only the least serious should be sent to the Base at once, so that they may arrive before sepsis has got a firm hold. At the front nothing should be done in such a case further than to remove any visible foreign material, to clean the wound of the scalp, and keep it open by gauze or rubber tissue, after possibly using some of the recently recommended antiseptic pastes to antisepticize the surrounding skin, and to apply a suitable dressing. This dressing should not exert direct pressure on the wound, which will prevent escape of discharge. A small roll of folded gauze on each side will obviate this. Mere excision of the scalp wound in an attempt to prevent septic developments only makes the task of the operator at the Base a more difficult one, and apparently entails greater risk to the patient. Incomplete operations give bad results. If operation is undertaken, the accessible parts of the wound should be treated thoroughly or not at all—all or nothing! It must be remembered that average cases arrive at the clearing stations really in a less septic condition—although the wounds may be superficially badly soiled—than they do at the Base, and results in similar cases should on that account be more favourable. Every effort should be made to operate during the pre-inflammatory stage.

Minor Operations.—Excision and suture of scalp wounds are said by some to be unnecessary. Such a judgment depends on the point of view. These excisions, while they do no harm when proper technique is employed, make the patient fit for duty again in a much shorter time; they clear up diagnosis with regard to fracture in most cases with absolute certainty; there is no doubt that thereby they occasionally save life, and they certainly prevent troublesome sequelæ; they save time and trouble on the part of the attendants, and they save expense in dressings. (The original mastisol and gauze dressing may be left until the wound is healed ([1])). Major J. E. H. Roberts, recording 412 cases of excision of scalp wounds, states that only in twelve did failure to obtain healing by first intention occur. Three wounds gave way completely. In the others, slight gaping, sloughing, or stitch suppuration occurred. In one case a gap, 6 inches by 3, was successfully closed by sliding flaps.

Reasons for opening apparently Unwounded Dura.—It has been shown repeatedly during this war that a pronounced depressed fracture of the inner table, although the dura may not be lacerated, is accompanied by a localized, usually more or less cone-shaped, bruising or pulping of the underlying brain. The base of the cone corresponds roughly to the area of comminution of the inner table. Owing to its elasticity the inner table must always be depressed considerably before it fractures, and the sudden localized blow on the brain causes the pulping. It must be remembered that the fragments of the inner table may show little displacement at the operation. The depth and severity of the pulping varys with the depth to which the inner table has been depressed. The amount of depression necessary to cause fracture varies in different parts of the skull. Such injury to the inner table and brain may exist without a trace of injury to the external table. In very rare cases intra-cerebral hæmorrhage, sufficient to cause severe pressure symptoms, may occur.

The pulped area—a mixture of useless brain matter and blood—is an *immediate* source of irritation to the surrounding brain, because it is virtually a foreign body. In the process of healing a great part of it is replaced by "fibrous" tissue—a scar—which forms a *remote* source of irritation. The pulped mass is liable to become infected, and to form a localized abscess or to lead to spreading encephalitis or meningitis, especially if the wound superficial to it is not rendered aseptic at an early date.

In cases where the force has been so great that the dura has also been ruptured, although pieces of bone have not penetrated, a definite pulped track, extending even for a couple of inches into the brain, may be found. This, when explored by the finger, resembles closely the track made in the brain by a foreign body. This shows the necessity for using X-rays before operation, to reveal whether or not a metallic foreign body is present. Operation should not, however, be unduly delayed in order to have this done. If the foreign body is beyond the reach of the finger, it is usually beyond the reach of legitimate surgery so far as the primary operation is concerned. By fitting together the fragments of the inner table one can often ascertain, with fair accuracy, whether any fragments of bone have been forced into the brain.

The mass of disintegrated brain matter and blood, whether on the surface or in the depth of the brain, interferes with the local circulation, and by this alone causes irritation similar to a solid foreign body. After its removal from either situation, pulsation usually returns at once. (See later, 7.)

Such lesions may be accompanied by persistent headache, focal spasm (often evanescent) or paralysis, or even "optic neuritis." Their presence can usually be recognized, after the dura has been sufficiently exposed, in that the dura is somewhat discoloured, the brain does not pulsate freely, and the area feels doughy instead of elastic or springy.

The dura is usually opened by a small crucial incision ($\frac{1}{2}$ in.–$\frac{3}{4}$ in.). The angles of the flaps can be drawn together again accurately by a single suture (passed through them), if it is thought desirable and safe. The pia-arachnoid may also be unruptured. In such cases it is necessary to help out the pulped material by inserting a small forceps and carefully opening the blades. It usually wells out, however, like grease from a collapsible tube. By getting the patient to cough gently, lumpy pieces of clot or detached brain are forced out. The "cavity" may also be cleared by suction through a soft catheter, as Major Harvey Cushing has advised.

Pulsation returns very quickly. If healthy brain matter is forced out, this indicates excessive intracranial pressure, and lumbar puncture should be done at once. A small drain, down to the hole in the dura, may be left in the wound for twenty-four hours.

Symptoms are usually relieved within a very short time. This relief is often most striking when the dura is opened at a second operation, the first (removal of depressed bone) having failed to relieve the symptoms.

To my knowledge the dura has been opened deliberately in many scores of cases, with only one fatality. The effect has been immediately and uniformly beneficial. In *four* cases, at Base hospitals, in which the operators thought that the procedure was inadvisable, death occurred from abscess of the brain, spreading encephalitis, or meningitis. It is essential for safety that, before opening the dura, an aseptic field of operation is obtained. Neglect of this precaution was, in my opinion, the cause of death in the fatal case referred to.

Operations where Wounds of the Blood Sinuses are present.—These should be done as a matter of course, because it is advisable to remove depressed fragments of bone or foreign bodies :

(*a*) which cause obstruction to the return of blood from any part of the brain, and

(*b*) which may be, or may become, infected, and cause septic thrombosis.

It seems all the more desirable to remove such fragments, if they actually penetrate the wounded sinus. The operation is, *per se*, not a dangerous one if proper technique is employed. For example, fourteen cases in one series after a battle were operated on. Only one died, and he had severe laceration of both cerebral hemispheres, besides the wound in the longitudinal sinus.

Drainage of the Brain.—It is difficult to formulate any hard-and-fast rules for drainage of the brain. On the whole, it is probably best not to drain unless one is forced to do so. The presence in the brain of actual pus, of infected blood-clot, of inaccessible, definitely infected foreign bodies, or of profuse oozing from a seriously lacerated area, are the chief indications for it. It is usually unnecessary to drain, even some days after receipt of the wound, if it is found that pus is absent from a track which foreign bodies have made. In some cases one may feel, however, that it is safer to insert a short drain for twenty-four hours or so. When aseptic foreign bodies, such as bone fragments, have been extracted, or when an area or track of pulped brain matter has been evacuated in which no penetration of foreign bodies has occurred, it is unnecessary to drain the cavity in the brain, but folded rubber dam should always be inserted, from the angle of the wound, " down to, but not into," the opening in the dura, for twenty-four hours. If pus, " smelly " blood-clot, clothing, hair, or a jagged large piece of metal is evacuated from considerable depth, a drain should be inserted into the track, and it should be brought straight out through an unsutured part of the excised wound. Bacteriological examination of what is removed should always be made, even though actual pus is absent. If streptococci are found drainage should be maintained until the organisms disappear or become very few in number. If streptococci are absent it is fairly safe to be guided by clinical signs alone, as to time for removal of drains.

It should be remembered that foreign bodies, especially flat pieces of bone, compress the brain in front of them; therefore, although they may be found at a depth of, say, $1\frac{1}{2}$ in. to 2 in., it is not necessary to push a drain to that depth. The distal end of the track will, after extraction of the foreign body, be found to have approached considerably nearer the surface of the brain. If one attempts, in such a case, to push a stiff drain in for a couple of inches, there is great likelihood that the lateral ventricle will be perforated by it. One should, immediately before inserting the drain, gently explore the track with the finger, and push the drain in only so far that it will not quite reach the extremity of the track.

As a rule, the drain should be shortened slightly every day or every second day, unless pus continues to discharge from the depth in fair quantity. It should be borne in mind that a drain, especially a rigid one, acts like any other foreign body, and may stimulate pus formation, besides providing a channel for possible entrance of fresh infection. All drains should, on this account, be removed as early as possible. In most cases they can be taken out after twenty-four to forty-eight hours.

Rigid drains are harmful to the brain, especially those with holes cut in them. The intracranial pressure may force normal brain through the holes or end of the tube. The constant friction of the pulsating brain against a hard foreign body must have a bad effect. The most satisfactory drain, on the whole, seems to be a piece of rubber dam, jaconet, batiste, or similar substance, folded concertina-wise. No apparent harm has followed the insertion, on the point of the finger, of a small amount of a paraffin paste (B.I.P.P., flavine, brilliant green, dichloramine-T, etc.). In certain cases, where the pus is particularly thick or profuse, or where streptococcal infection is present, it may be advisable to insert, in addition, one or two narrow tubes. A few drops of a thin antiseptic paste may be instilled gently, after the tubes have been inserted and again before they are removed.

One must be careful, when inserting a drain, that no damage is done to the healthy brain lining the track. One must, therefore, note the direction of the track very carefully.

So long as a drain is in use, the surrounding scalp should be smeared with an antiseptic paste, or painted repeatedly with picric acid solution.

Points constantly to be kept in Mind. — (1) There may be multiple injuries, therefore always have the whole scalp shaved.

(2) The force causing the injury is usually very circumscribed, and its effects are, therefore, likely to be localized to the immediate neighbourhood of the part which has been struck. Injury by contre-coup has not often to be considered, although examples of this are more frequent since the introduction of the steel helmet.

(3) Such localized forces, if they have been great enough to cause depressed fracture of the inner table, result, practically always, in definite injury to the brain, which asserts itself by immediate or remote cerebral disability. This may occur in pronounced form, although the dura is uninjured ; in rare cases it has occurred even when no fracture of the external table has been seen. One need not refer to cases of immediate disability. Some interesting examples of remote disability have turned up even in France. We have seen a good many cases now of men who were wounded early in the war, and whose wounds were considered so insignificant at the time that the patients were not even sent down the line. Later, they were invalided on account of symptoms caused

by the physical defect of the skull—to wit, depressed fracture of the inner table—which, of course, was treated without more delay.

(4) Experience has shown that a properly conducted, complete operation, while it cannot undo the already existing damage to the skull or brain, facilitates repair, gives better immediate results, and tends to prevent troublesome sequelæ more surely than an incomplete one.

(5) Practically in all cases which survive longer than a couple of days, death is due to the effect of sepsis on the damaged brain. In any case, sepsis will increase the amount of damage to the brain. The local injury, when thus complicated, is likely to "interfere with intellect or set up permanent paralysis." Apart from that, sepsis may cause necrosis of bone, and thus prolong convalescence. The necessity for early operation is evident.

(6) As our efforts will, therefore, be nullified in large measure unless sepsis is overcome, all operations must be preceded by removal of the sepsis from the area to be dealt with. Excision or cauterization of the infected parts is the most rapid and certain way of doing this. It is only in very rare cases that this is not feasible. If it is not, the patient has probably very little chance of pulling through. The wound of the scalp and pericranium must be removed *en masse*. The fractured area must be dealt with in the same way, although, if a hole in the bone already exists, its margins can be nibbled away with equal success. Proper technique is essential. It must be pointed out that to excise the wound after turning down the

flap is merely courting disaster. The brain cannot be dealt with so vigorously, but removal of pulped, useless material, and of foreign bodies, will allow it to combat any infection more successfully. "Healthy brain substance possesses considerable power of limiting microbic invasion," but one cannot say that pulped brain, or brain with foreign bodies embedded in it, is healthy! As already indicated, in the majority of cases in which bone fragments alone are forced into the brain, the track leading down to them is not infected at first, but it rapidly becomes so.

(7) Foreign bodies in the brain act deleteriously in four ways: (*a*) By their direct effect on the delicate pulsating brain tissue. (*b*) By favouring the development of sepsis. It is practically an everyday occurrence, when cases arrive late during a "rush," to find suppuration around pieces of bone lying at the end of a track in the brain. (*c*) By interfering, in rather an obscure way, with the circulation of the brain. A mass of pulped brain matter acts in the same way. It is very common to find that the brain, when exposed at operation, does not pulsate, or does so only to a slight extent, until the fragments of bone or disintegrated matter are removed from the depth, when it begins to pulsate freely. A normal circulation is essential to satisfactory recovery. (*d*) By causing, when they become encapsuled, a localized, connective tissue mass, which may act as deleteriously as a tumour. If recovery of function is possible, early removal of foreign bodies will procure this more certainly, more rapidly, and probably more completely than is otherwise feasible—a great improve-

ment is frequently noted within twenty-four hours. If carefully done, further damage to the brain is not appreciable. Only once have I seen any *immediate* increase of paralysis follow, in a case where an unusually large piece of bone had to be removed from a suppurating track. One will probably do less harm to the brain in removing a foreign body through an already existing track than by cutting a way through a mass of fibrous tissue, or, worse still, healthy brain, as has to be done when the operation is postponed until the scalp has again become intact.

(8) It is highly desirable to try to prevent the formation of cicatricial tissue, whether on or in the brain, even though in the latter case it may resemble neuroglia. Such scar tissue acts as an irritant chiefly by preventing normal movement of the brain, by interfering with the circulation, and, in many cases, by causing pain. The nature of the injury, the amount of sepsis, the presence or absence of foreign bodies, and the treatment employed have much to do with the amount formed. Operation and after-treatment should be carried out in such a way that the minimum quantity of cicatricial tissue results. Unsuitable drains, especially when kept in for a long time, stimulate its formation. The trephine opening should be covered completely with healthy scalp. If plastic flaps are used at the end of the operation to cover the defect, it is found that the line of suture usually lies over intact bone. If incisions are made which merely radiate from the wound, the apices of the resultant flaps meet over the hole in the dura. Such incisions should be used only when it is obvious

that free drainage will be necessary. Because fragments of bone are likely to be infeeted, it is dangerous to replace any of them. The scalp wound, after exeision, can usually be accurately sutured—in some cases it may be necessary to perform a plastic operation, by sliding sealp flaps. This is greatly preferable to merely eovering the exposed brain by a flap of muscle, pericranium, or aponeurosis. Such a flap, if exposed at the bottom of a wound, is apt to neerose. In any case, the amount of cicatricial tissue and of permanent adhesion is greater in a wound which heals by granulation than in one which heals by first intention. It is true that Nature has a marvellous capacity for remedying defeets—even by making a new dura. The greater the amount of abnormality, however, with which she has to cope, the greater will be her difficulty in imitating the *status quo ante.* Therefore, we should help her in every possible way. When this help is given efficiently, the wound responds by healing *per primam.* Surgeons who have kept statistics will support the statement that, in patients who recover, at least 90 per eent. of the wounds behave in this desirable way.

Objects of Treatment.—The objects of treatment can now be shortly summed up.

(1) To prevent or remove infection, thereby preventing further destruction of tissue.

(2) To establish diagnosis in some cases of doubt.

(3) To remove all sources of irritation to the brain, if this can be done without eausing further serious damage to it. One cannot undo the initial surface wound or eerebral lesion, but one can try to procure

a condition which will allow healing to occur more rapidly, more normally, and with the least possible permanent impairment of function.

(4) In any case to procure rapid healing of the superficial parts, provided that the brain is safe.

The charge of being too zealous in operating on head injuries may be made. I cannot remember death occurring after any operation which was not one of urgency. We have regretted that we have not operated, or operated sooner, on some patients who have done badly. In all injuries it is claimed that operation furnishes an additional and usually accurate means of diagnosing the extent of the lesion. In minor injuries it has done no harm so far as can be ascertained, and it renders the patient fit to return to duty at a much earlier date than could otherwise be the case.

It is better to send a patient home with a healed scalp and healthy skull, inside which are the fewest possible potentialities for future brain trouble, than that he should go with the prospect of a later operation on an area which is obscured by many abnormalities. If it can be shown that this is done with as great safety as attends more conservative methods, the procedure is more than justified.

Sepsis and the exigencies of war will always make the proportion of failures a relatively high one. Unless military exigencies permit of "head" cases being retained near the front for operation and for a fairly long after-treatment, mortality and loss of function are increased.

The Routine of Treatment.—On admission of the patient the hair should be shaved off or removed with a depilatory paste, the wound thoroughly examined (the use of a probe is deprecated), two skiagrams taken in planes at right angles to each other, and neurological examination made. If all the hair is not removed, other wounds, sometimes more important than the most noticeable one, may be overlooked. An aperient should be given, and the administration of urotropine (15 to 20 grains every three or four hours) begun. If the brain is injured, it is well, if possible, to make a bacteriological examination of the discharge, for future guidance. If brain matter is exposed or is exuding from the wound, operation should be carried out as soon as possible. In most other cases, in absence of urgent symptoms, there need be no great haste, but in no case should operation be postponed for longer than a couple of days. The superficial wound should meantime be treated as already described (p. 181).

Wounds of the Scalp.—The majority of wounds of the scalp should be excised, and the bone beneath carefully examined. The wound itself should be cauterized, or dessicated by thorough rubbing with 5 to 10 per cent. picric acid in spirit and drying with a swab. After disinfection of the wound and surrounding scalp the damaged soft tissues are excised by a lemon-shaped or elliptical incision, *down to bone*, about a quarter of an inch from the lacerated margins. If the periosteum is carefully divided, especially at the ends of the incision, it is easy to remove damaged scalp and pericranium *en bloc*, with the handle of the scalpel or with a periosteum elevator. If no further interference is made, the wounds can be sutured, usually without drainage. It may be necessary sometimes to slide flaps in order to make up for defects. Sufficient access to the bone and brain can, in almost every instance, be got through the incisions recommended. Turning down a U-shaped flap introduces a needless complication, and frequently prevents suture of the excised original wound. If this wound cannot be closed, healing by granulation must take place directly over the wound in the dura and brain—an obvious disadvantage. Covering the exposed brain with pericranial or muscular flaps, which are left exposed in the depth of the wound, is rather a precarious procedure. In practically all cases, the area of operation can be covered in by healthy scalp, by simple suture, or by a plastic operation such as described later.

The use of the U-flap of civil surgery is advisable (*a*) in removing a foreign body through an unwounded area, and (*b*) in contra-lateral decompression operations for hernia cerebri.

Depressed Fracture.—Every case in which depressed fracture of the skull is suspected should be explored without undue delay, whether sepsis is present or not. Delay, which used to be indulged in—waiting for surface wounds to clean—too frequently leads to dangerous intracranial developments. If the edge of the wound is much inflamed and infiltrated, treatment with hypertonic saline applications, or a paraffin paste, usually makes it fit for excision in twenty-four to forty-eight hours. In most cases it is possible so to excise the wounds in both scalp and bone that an aseptic field of operation is left. If sepsis has already penetrated to the depth of the brain, the sooner operation is done the better.

The injury comes under one of the following varieties :

(1) **Cases without Definite External Signs of Depressed Fracture.**—Because fracture with displacement of the inner table or some other subcranial lesion may be present, it is important that operation should be carried out.

(*a*) When the entrance and exit wounds are separated so far by a bridge of scalp that the line joining them traverses the bone, or if the patient has been stunned at the time of injury, the presumption is that the bone has been damaged. Such wounds, and the track between them, as well as single gaping wounds of the scalp, should be excised *en masse*, including the pericranium. Injury, even mere bruising, of the periosteum usually means that the internal table has suffered. If focal loss of function (even although evanescent), persistent headache or giddiness, or other more definite signs of cerebral compression are present, especially if optic neuritis coexists, trephining should be done, even in the absence of definite laceration of the periosteum.

(*b*) If fracture of the outer table without depression is found, or even if the bone is merely bruised, the external table should be removed by a small trephine, and the inner table examined. Depressed fracture of the inner table may exist without any apparent injury to the external table or any cerebral symptoms, and only the very best skiagrams will show such a fracture. If the internal table is fissured or depressed, discoloured, or infiltrated with blood-clot, and if focal or other symptoms described in (*a*) have been present, the internal table should also be removed and the dura examined.

(2) **Fracture with Depression, but without Laceration of the Dura Mater.**—The fractured and probably septic bone is excised either by making very small trephine, or "burr," openings, outside the soiled area, and completing the removal with a skull-cutting forceps (*e.g.* Montenovesi or de Vilbis) just wide of the shattered bone, or by the "nibbling" method, using a properly devised small gouge forceps. It is better to work with a small forceps and nibble the bone away in small pieces, than to use a large, powerful forceps, which may cause extensive fissure fracture. After removal of the soiled edge of the wound in the bone, a fresh forceps should be used to nibble away a further portion. The former trephining method is theoretically the better technique, but the latter is simpler, gives equally good results, and does not entail removal of so much bone. It is not necessary to trim the edge of the resultant opening in the bone accurately. It seems likely that bone grows out more readily from an untrimmed margin, so that the opening may become greatly reduced in size. If the dura is apparently normal and the brain pulsates well, the operation can then be completed by suture of the scalp, with or without drainage. If, however, the dura is muddy-looking ; if there is loss of pulsation and circumscribed loss of elasticity, especially if focal symptoms have been present after the wound was

received, the dura should be opened. This is usually best done by a small crucial incision. Disintegrated brain and blood-clot are squeezed out by the *vis a tergo*. If the pulped matcrial does not come out quite readily, it may be helped out by inserting a small artery forceps for a short distance, and opening the blades so as to dilate the hole in the dura and underlying membranes, or by getting the patient to cough gently. Only the useless matter will exude unless the intracranial pressure is high, in which case lumbar puncture is indicated.

(3) **Injury of Dura without Foreign Body or Evident Sepsis.**—Fracture with injury to dura mater, when no foreign body is present and the wound in the brain is at first probably aseptic, occurs frequently. After excision, *en masse* as before, the scalp wound may be enlarged in any desired direction in order to procure adequate access. The bone around the fracture is cleared. A " trephine " opening is really rarely required. The spicules are removed, and the skull cut away carefully with forceps to an extent varying with the injury to the dura. A clear margin (one-third of an inch) of uninjured dura should be exposed. Great care must be exercised to separate the dura from the bone while this is being done. Ragged edges of dura should be excised. If a " track " exists in the brain, this should be carefully explored, by the finger if possible, and any collection of pulped brain tissue allowed to escape. If the opening in the dura admits the index finger, there need be no fear of injuring the brain to a greater extent if the procedure be carried out with sufficient

care. Otherwise, the debris should be sucked out by catheter. If thought advisable, a piece of aponeurosis may be placed across the opening in the dura and the operation completed by suturing the scalp wound. A drain should reach from the opening in the dura through one end of the wound. It should be removed after twenty-four hours. If sepsis asserts itself, the wound should be opened up freely at once.

(4) **Injury to the Dura complicated by a Foreign Body in the Brain and by Sepsis.**—The position of the foreign body is previously localized by X-rays. At the operation (as in 3), the track through the brain matter can usually be explored by the *index* finger. It may be necessary to enlarge the wound in the dura slightly. The foreign body having been located, a suitable, slightly curved, scoop is passed along the finger, and under the foreign body, which is then pressed against the point of the finger, and all three are carefully and gently withdrawn. The greatest delicacy of touch is required during this procedure. The finger, in a flexible manner, must follow the previously formed track, and must not break through uninjured brain substance. Any stiffness of the finger must be avoided. *The use of a forceps is apt to increase the damage to the brain.* A foreign body or piece of bone may often be coaxed out by making *very* slight flexion movements with the distal phalanx of the examining finger. If the track will not admit the finger, the foreign body can, as Cushing has suggested, frequently be extracted by allowing a round-bodied 4-in. steel nail, with smooth, blunted "point," or a similar specially made searcher, to slip

along the track, actuated by gravity alone, and then connecting it with wires from a magnet of sufficient strength. If the foreign body is magnetic it adheres to the nail and is carefully removed (p. 205).

A catheter is now passed along the track, and suction made until every particle of debris and clot is removed. This should be done with special care if the lateral ventricle has been opened.

A drain should be inserted in all cases, as already described (3). If definite sepsis is present drains should be inserted in the superficial part of the track leading straight out through the wound. In the worst cases the scalp wound should not be sutured till all danger has passed.

The exploration for foreign bodies by the finger at the primary operation, when the existing opening in the dura is large enough to admit it, is justified by the following considerations : (1) A track through brain substance is already present ; (2) only very rarely is further injury to the brain caused by the procedure ; (3) the frequency with which an abscess develops, should the foreign body be left in the brain ; (4) if the wounds are large, sepsis has almost certainly penetrated along with, or following, the foreign bodies, and, as has been said, the sooner they are dealt with the better.

As already indicated, foreign bodies imbedded in the brain, by their direct influence and by their interference with the cerebral circulation, may produce symptoms of focal irritation and of compression, or increased intracranial tension. If their removal does not immediately relieve these, and especially if hernia cerebri is threatened, lumbar puncture should be resorted to, and repeated several times if necessary. If this fails to relieve the intracranial tension, contralateral subtemporal decompression may give relief, but has, on the whole, proved an unsatisfactory operation under these septic conditions.

Major Harvey Cushing, in his excellent paper on penetrating wounds of the brain, published in the *British Medical Journal*, Feb. 23, 1918, makes the following remarks with regard to treatment of the track and of retained missiles.

"Much more serious is the retention of the disorganized and devitalized cone or cylinder of cerebral tissue which lines the track, and in which the indriven bone fragments are embedded. Though extraction of these fragments is advocated, no special emphasis has been laid on the desirability of thorough removal of the pulped tissue which surrounds the pathway of the missiles, and which, like devitalized tissue of any kind, is a soil favourable to the growth of organisms.

"As Colonel Gray has suggested, if the patient is encouraged to cough, clots and cerebral débris oftentimes may thus be expressed, and some have employed gentle curettage or irrigation ; but, if a finger is introduced in the track for purposes of exploration, the disorganized and soiled cerebral tissue lining its walls will be crowded inward, whereas every effort should be made to get it out.

"Almost from the outset reliance was placed on the use of a flexible, soft-rubber catheter as a means of determining the exact direction taken by the missiles, whether a metallic body, or bone fragments, or both. Without the production of additional trauma one may investigate in this way even the narrowest track, and it will be found that the presence and situation of any indriven bone fragments can be detected with almost as great delicacy as by direct palpation.

"By attaching to the end of the catheter a Carrel-Gentile glass syringe with its rubber bulb it is possible to suck up into its lumen the softened brain, which can then be expelled from the catheter as paste is expressed from the orifice of a tube. The process should be repeated until the cavity is rendered as free as possible of all the softened and infiltrated brain. It will be found that the adjoining normal cerebral tissue, unaffected by the original contusion, will not be drawn into the tube by the degree of suction which can be applied by the average rubber bulb.

"Not infrequently bits of bone come away in the eye of the catheter, and on one or two occasions a small foreign body has thus been withdrawn. Meanwhile, as the track becomes clean and the tension and tendency of the brain to herniate subsides, it is possible with delicate duck-billed forceps to pick out from the track one by one the bone fragments, whose depth and position can be determined by the unmistakable sensation they impart to the catheter, which thus supplements the information given by the x-ray plates. The technique of the performance will quickly be acquired by any one who may wish to put it into practice.

"In not a few cases in the series the missile and bone fragments have been driven through into the ventricle, and in the process of suction the cerebro-spinal fluid spaces have been sucked completely dry. These ventricular penetrations have been met with in twenty-five cases, and it is by no means as desperate a condition as is generally supposed. Many cases with opened ventricle, when treated in this way, have made perfect recoveries, as will be related in a more detailed communication which will permit of case reports.

"Any procedure is capable of being abused, and even a soft flexible catheter may possibly be forced to do damage. Even those who advocate digital exploration admit that damage may be done thereby unless the greatest care is exercised; but we must recognize that the surgical profession contains its Little Jack Horners, and it is better, on the whole, for all of us to keep our fingers out of the brain so far as possible.

"**Retained Missiles.**—It goes without saying that it would be the ideal treatment, at a primary operation for a penetrating wound, if the foreign body could always be removed. Otherwise the operation must be regarded as incomplete, with a far greater likelihood of subsequent abscess formation than if removal of the missile has been accomplished. It is equally true that foreign body extraction, no matter how desirable as a means of avoiding these possible secondary complications, should never be forced to the point of increasing the damage to the nervous tissues already done by the penetration. Some say 'avoid infection at any cost'; others 'better a fatality from infection than the eertainty of perpetuating paralyses.' Between these two schools one must deeide in the individual case.

" It is well known that many, even sizable bodies—a shrapnel ball, for example—may be retained without provoking symptoms; but, even so, the writer has known of abseess formation around such a missile first giving evidenee of itself a year after the injury. The middle ground position is the safest one—namely, always to extract a foreign body if it can be accomplished without increasing the damage already done.

" This discussion applies solely to deeply implanted missiles, for all agree that superficial and easily accessible ones should of course be removed. Extraetion with a magnet is the only justifiable method applicable to deep-seated bodies, and can often be accomplished after suction of the track in the usual method by gently sliding into it, to the proper depth, a French wire nail with rounded point. Contaet with the proximal end of the nail is then made with a portable electro-magnet, which need not be a weight greater than can be easily handled, and if the foreign body is magnetizable and proper contact secured it will be withdrawn along its own track of entry.

" The extraction was successful in eleven cases in the series in which the missiles would otherwise have been inaceessible. It would have been preferable to place the interposed nail in exact contact with the foreign body under the direetion of a fluoroscope, but our situation did not permit of this. The procedurc is capable of great development, and next to the eye the brain is the most favourable place for employing the magnet.

"All of the foreign bodies from which cultures were made gave a growth of organisms—usually streptococcus, staphylococcus, or some gas-producing bacillus."

(5) **Fracture with Injury to one of the Blood Sinuses.**—Operation in such cases may be difficult on account of the alarming hæmorrhage which may occur during exposure of the sinus. It should not, therefore, be undertaken by an inexperienced operator. The size of the superficial wound of the scalp or skull gives no indication of the extent of the injury to the sinus. The results of such operations have been very favourable. Three of the procedures recommended for control of such hæmorrhage have practically been given up—namely, lateral application of suture or forceps, plugging with gauze, and ligature. Plugging and ligature especially must be avoided behind the entrance of the parietal lacunæ or cerebral veins. It has been found that practically all cases, which survive the immediate effects of the injury, are amenable to treatment by the application of a piece of aponeurosis, cut from the edge of the scalp wound or from the fascia lata of the thigh. The procedure is known as the "postage stamp" operation.

It is often advisable to remove the fractured area of bone *en masse*, as described under (2). Care must be taken not to dislodge any piece of bone which may be plugging the sinus. In other cases the fragments can be lifted out, and, if necessary, better access obtained by rapidly elipping away adjaeent bone. During this proeedure the bleeding may have to be controlled by gauze plugs.

After free and rapid exposure of the hole in the sinus, hæmorrhage therefrom being controlled by light gauze pressure, the " stamp " should be cut and spread on the palmar surface of the point of the operator's gloved index finger, or on a small swab covered with batiste or rubber tissue. The perforation is then blocked by a finger of the other hand. All blood-elot is carefully wiped away, the eontrolling finger is removed, and the " stamp " applied rapidly over the perforation. Fairly firm, equable pressure is kept up for a few minutes, when the graft will have adhered to the wall of the sinus. If the tear is a large one, the " postage stamp " and swab may be bandaged in position for ten minutes or so. A hole, measuring $\frac{3}{4}$ in. by $\frac{1}{2}$ in., has been elosed successfully in this way, and, judging by the ease with whieh this was done, it should be possible to close even larger ones. In rare cases it may be necessary to suture one side of the graft to the dura before plaeing it over the opening. It may thus more easily be held in position. The graft should always be eovered by scalp at the end of the operation. In these eases it is practically always possible to suture the scalp wound eompletely. A small, soft drain is inserted elose to, but not on to, the graft, and is withdrawn in a day or so.

Lumbar Puncture.—Lumbar puneture has frequently been found to give relief in eases of loeal circulatory disturbance after operation—evidenced, for example, by persistent headache, recurring focal muscular spasms, or slight hernia cerebri. The amount of cerebro-spinal fluid withdrawn varies with the pressure of the fluid. It is rarely necessary to remove more than 25 c.cm. or thereby. Usually, the withdrawal of a much less quantity suffices. The process may be repeated several times if thought advisable. It ought to be resorted to *before* any *marked* signs occur.

Certain cases of large fungus cerebri have been cured by this procedure. If fungus is present, however, while it is to be regarded as a symptom of increased intracranial tension, it must be remembered that this last is frequently due to the presence of foreign bodies or abscess in the brain, or to more diffuse encephalitis or meningitis, and suitable remedies must be used for these conditions. If meningitis is present, or if the fungus is fairly recent, rapid removal of cerebro-spinal fluid may allow infection to spread.

The wound should always be exposed for inspection when lumbar puncture is done, as this may cause the herniated brain to sink back to a considerable depth, and protective adhesions may be torn. If lumbar puncture fails to alleviate the condition, a contralateral decompression operation may be tried.

Spirit dressing is usually employed for such cases. Picric acid ($\frac{1}{2}$ to 1 per cent.), or some astringent preparation may, with benefit, be added when discharge is free. The free application of B.I.P.P. has been found of great value in many cases. The dressings should be tucked into the gutter between the base of the hernia and the bone.

In most cases of hernia cerebri it will be found that posture has a marked effect, the protrusion being lessened when the patient is propped up in the "Fowler position." This position should be adopted in all cases immediately after operation. A smart intestinal purge is also sometimes effective. If a very large amount of cerebro-spinal fluid has to be withdrawn, the patient should be laid flat until the intracranial and intraspinal pressure has had time to become equalized.

It is not advisable to make lumbar puncture in the early stages after a wound of the brain has been caused, unless the dura is intact, or until the exact local conditions have been revealed by operation. Adhesions in the neighbourhood of the wound are very slight at this period, and sepsis may easily be dissipated.

Closure of the Scalp Wound.—In the great majority of cases the elliptical wounds resulting from excision can be closed, owing to the mobility of the scalp, if "all layer" sutures are used with superficial sutures between. It is well to work from each end in tying the sutures.

In cases where complete closure cannot be obtained by this method, one must not hesitate to make a plastic operation, to which the scalp is particularly adaptable.

A successful and widely used method is by extension of the original incision to form a large U or S flap.

14

FIG. 20.

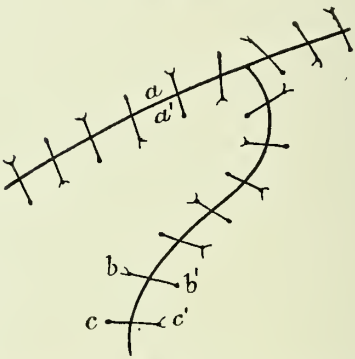

FIG. 21.

FIGS. 20 and 21. Cranial Injuries. To illustrate plastic operation for closure of an elliptical loss of tissue in the scalp. Fig. 20. —First stage showing lines of incision for detachment of flaps. A = S flap. B = U flap. FIG. 21.—Operation concluded.

The ends of the wounds may be sutured to reduce the amount of plastic necessary (fig. 20).

An "S" incision is made as indicated by the dotted line (fig. 20). The end A should extend well beyond a line drawn at right angles to the main axis of, and through the end of, the raw area. The scalp is undermined completely to any desired extent, as indicated by the shaded area. This is easily done

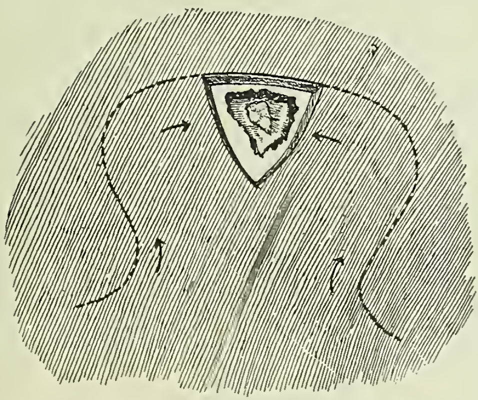

FIG. 22.—Cranial Injuries. Diagram of plastic operation for triangular defect.

by thrusting a curved, blunt-pointed scissors, concavity towards the skull, between the aponeurosis and pericranium, opening the blades and withdrawing. Here and there it may be necessary to cut resistant strands of tissue. Suture at *a-a′* to see how the flap comes up. Sutures at the base of the flap should be inserted obliquely as at *b-b′*, *c-c′*; when tied they help to remove tension. When fully sutured, there should be little tension—if there is much, the scalp should be scarified repeatedly between the sutures, sufficiently to draw blood.

The line of sutures, when tied, lies frequently completely to one side of the wound in the dura. This method thus has an advantage over that of turning down a flap, and is no more elaborate. For a triangular defect, proceed as shown in fig. 22.

General Remarks about Operation.—The operation necessary in the majority of head injuries is a comparatively simple one. If preceded by infiltration of the scalp with local anæsthetic and adrenalin, hæmorrhage and shock are obviated to a very great extent, and the operation is made even more simple. The dangerous hæmorrhage which may occur from large flap incisions is entirely prevented by infiltration of the incision area with adrenalin solution, and, if some local anæsthetic has been added, the amount of general anæsthetic required is either nil or negligible.

The use of mastisol (p. 165) is recommended for fixing the gauze dressings. Drains are drawn through small slits in the gauze, and can be removed without disturbing the wound.[1]

All *serious* cases should be kept at the casualty clearing station for two or three weeks after operation, and even longer if one is not quite satisfied with their condition.

[1] An excellent preparation of "Mastisol" varnish may be obtained from Burgoyne, Burbridge & Co., Coleman Street, London.

CHAPTER VIII

PENETRATING WOUNDS OF THE THORAX

In the early stages of the war it was generally thought that men wounded in the chest, who survived to come under medical or surgical treatment, had a comparatively good chance of recovery. Operations on the chest at that time were limited practically to the draining of empyemata, but even they were often too long delayed. When experience of work in advanced units became better known, it was appreciated that the mortality of chest cases was really high, and that, with very few exceptions, only those with the more trivial types of wound lived to reach Base hospitals. Statistics taken during a big battle showed that the mortality in the more severe types of chest wounds was very high, in fact, in the case of so-called "open" or "sucking" wounds, unless immediate operation was performed, it was *quite exceptional* for patients to get to the base at all. They died in advanced hospitals or *en route.* It was long before the general body of surgeons recognized that, if great loss of life was to be avoided, such cases must be treated on principles which govern operations on wounds of other parts of the body. The statistics referred to showed that, of 1,500 cases diagnosed as penetrating wounds of the chest, roughly 30 per cent. were included in this dangerous category. The result of active and common-sense treatment, which has now reached a high state of efficiency, is that, instead of a practically negligible number being despatched from the casualty clearing stations, the best operators send over 70 per cent. of such patients down the line with every prospect of being at least useful citizens. Some of them have returned to full duty again.

The term " penetrating " is used to indicate actual injury of the pleural or mediastinal areas of the chest, whether the missile has pierced these or not. Tangential wounds of the parietes, especially if the ribs are involved, may be accompanied by intrapleural lesions almost as severe in effect as are those of wounds made by missiles which actually traverse the pleural cavity or lung. It is, therefore, necessary to include these tangential wounds under this heading. Injuries confined entirely to the parietes will not be discussed.

Penetrating chest cases, which arrived at casualty clearing stations during the period covered by the statistics quoted above, were in the proportion of about one to forty wounded men.

Chest wounds, at an early stage, divide themselves, from the clinician's point of view, into four classes : (*a*) the largest group, cases which do not require operation ; (*b*) cases which demand operation at the earliest possible moment ; (*c*) a class intermediate between (*a*) and (*b*), in which the size of the wound or the severity of the symptoms makes decision as to immediate treatment a very difficult matter; and (*d*) moribund cases, who probably succumb within a few hours of admission to the casualty clearing station.

Treatment on Arrival.—The majority of "penetrating chests" arrive at the casualty clearing station in an exhausted and frequently alarming condition. They should be rapidly examined, put to bed, and propped in the most comfortable position, which is usually the semi-recumbent. They must then be carefully warmed and stimulated. If they are excited and anxious a sedative should be given hypodermically. Omnopon is, for many reasons, superior to morphia in such cases. If an open "sucking" wound is present, it should be made air-tight by sutures which include both skin and muscle, or by gauze plug fixed by a long strip of broad, adhesive strapping. Alarming symptoms usually gradually subside within an hour or two.

Further active treatment depends on the severity of the symptoms which persist or develop, and on the size and character of the wound.

Cases requiring Immediate Operative Intervention.—Severe respiratory distress may persist, owing to the amount of hæmothorax or hæmopericardium present. Persistent severe pain is probably due to irritation of pleura or pericardium by a rough foreign body or fragment of rib. Pericardial pain may be referred to the shoulder or side of the chest, one or both. A foreign body actually imbedded in the lung or heart does not usually give rise to such pain. The diaphragm is fairly frequently injured and irritated by such foreign bodies projecting into it, and painful dyspnœa is then apt to be intense. Increase of respiratory distress may be due to increase of the hæmothorax, or to rapid development of infection of the blood-clot, especially by gas-forming organisms. More rarely it is due to increase in size of a hernia through a rent in the diaphragm. All these conditions demand immediate operation, and every effort should be made to get the patient into condition fit to undergo it.

Moribund cases which arrive at casualty clearing stations die chiefly from the effects of hæmorrhage and shock. During periods of severe fighting little can be done for them. "*C'est la guerre*"*!* During quieter times a small number may be saved by transfusion of blood, which should be done on the operating table, so that if hæmorrhage recurs as a result of the transfusion it may be tackled without delay.

Necessity to combat Sepsis.—As in wounds of other parts of the body, no case can be pronounced free from the danger of sepsis. The earlier it develops, the more serious it is likely to be if not nipped in the bud. Many patients who are sent to the Base without operation, in apparently favourable condition, reveal sepsis on arrival there, or develop it soon after, and mortality is high amongst them. Liability to early and fulminating sepsis depends chiefly on the size of the wound, especially of the entrance wound, which again depends on the size and nature of the missile. Sepsis has been the cause of early death in most of the "sucking" wounds which reaeh the casualty clearing station. Much success has attended efforts to prevent this, in cases which were previously thought to be beyond the reach of surgieal aid.

Cases of "Closed" Hæmothorax.—Most patients with punctate entrance and exit (E. and E.], or through and through (T. and T.], bullet wounds, and wounds caused by lodging shrapnel balls or small pieces of shell, who survive until they reach the easualty clearing station, usually recover from their initial symptoms fairly quickly. All of them require careful watching. Many cases of E. and E. bullet wounds eause but slight anxiety. There may be little or no hæmothorax. If the hæmothorax does not reach higher than the nipple line and shows no sign of increasing, and if there is no evidence of infeetion, such eases may be sent to the Base without danger in the course of three to six days, according to the amount of accommodation available in the casualty elearing station. In any case of hæmothorax, if the high temperature, quick pulse, and rapid respiration, which are usually present during the first twenty-four hours or so, do not subside, recourse should bc had to the use of the exploring syringe, and the fluid removed should bc tested bacteriologically. A erimson-purple colour of the froth in the barrel of the syringe, and a foul odour of its contents, are suffieicnt proof of anærobic infection. The withdrawal of foul-smelling gas alone is conclusive evidencc. Sueh examination should be made every day, or every second day, aeeording to the nature of the case. The tcst is by no means infallible, because sepsis may develop in islands or areas of the clot or fluid which are not tapped by the needle. Increase of pneumothorax, or development of resonant patches in previously dull areas, should make one suspicious of gas infection, and if, in such a case, other symptoms pointing to infection are sufficiently prominent, operation should be undertaken without waiting for bacteriological confirmation. If for any reason, such as the presence of severe wounds elsewhere, a case of limited aseptic hæmothorax has to be kept in the casualty clearing station, there is, in most cases, no need to aspirate the chest, as the fluid is usually absorbed fairly rapidly. If it is not, aspiration should be done and bacteriological examination made. In some cases there is found a mild infection, which repeated aspirations may cure.

If the hæmothorax is a larger one, the patient should be kept for a correspondingly longer period. During the first three days, aspiration may be required at any time in order to relieve symptoms of distressed respiration, even although no infection be present. Fresh bleeding, rarely, or effusion of serum, may increase the intrapleural pressure. The aspiration should be done slowly, and no more fluid removed than what is necessary to make the patient reasonably comfortable. Aspiration of a large quantity during this period may cause hæmorrhage to recur. If urgent symptoms develop again, it is probably best to operate at once, make a large opening in the chest wall, clear out the pleural cavity, control the source of the hæmorrhage, and close the opening completely. In other cases, after the critical three days have passed, the bulk of the fluid may be withdrawn, preferably with replacement by air or oxygen. If the patient is fit to travel to the Base, however, he should be sent there before this "final" aspiration is done.

These remarks regarding sepsis, the use of the exploring syringe, and other procedures, apply with greater force to cases of large hæmothorax than to those of minor degree.

As already stated, between cases with "closed" chest wounds and those with "open," possibly "sucking" wounds, there exists a number, fairly large, in which decision as to treatment is fraught with great difficulty and anxiety. The possibility of giving relief to the patient and preventing a problematical development of sepsis, must be weighed against the danger which the operation necessary for such a double purpose involves. Statistics show that the ordinary empyema operation in these early cases is attended by a very high mortality. In many early cases more thorough cleansing operations, followed by complete closure, have been attended by very striking success, but a sufficient number of cases has not yet been recorded to permit of reliable judgment being made. One cannot help thinking that the more frequent use of blood transfusion in the early stages will lead to better results, and permit of successful radical operation in a greater number of "intermediate" cases.

The mortality from sepsis at the Base appears to indicate interference, in a larger number of cases, at the casualty clearing station. The small piece of shell, or the shrapnel ball, has apparently a more deleterious effect than is thought possible by those who light-heartedly remark that "it can't do much harm."

Severe Open Wounds.—There now remains a large number, 25 to 30 per cent., of cases which, from the nature of their wounds, demand operation at the earliest possible moment. Operation is performed in such cases with a two-fold desire—to tide the patient over the acutely dangerous period brought on by hæmorrhage, collapse of lung and displacement of organs, and to prevent the onset of sepsis. Mere closure of the opening in the chest wall will attain the former object, unless as already pointed out, the position and character of the lodged missile, or displaced fragments of rib, cause too great interference with the function of vital organs. But mere closure of the wound will in no measure prevent development of sepsis, which in this class of case is usually extremely virulent and lethal. Therefore, thorough excision of lacerated tissue and removal of blood-clot and foreign bodies are as essential to ultimate success here as in other parts of the body. The incidence of sepsis at different stages, with the resultant mortality, in the earlier days of the war, when compared with what occurs now, furnishes complete justification for the radical operation in severe cases. The operation must needs be attended by a high mortality. The decision as to the proper time for its performance should result from the close collaboration of a skilled surgeon, a shock specialist, and, when possible, a level-headed, enterprising physician.

Many publications have been made recently on the treatment of these severe cases, and to these attention is recommended. (See references, page 229.)

Major J. Anderson, D.S.O., classifies the cases belonging to this group as follows :—

(1) Wounds caused by large irregular fragments of high explosive shell, which have lodged in the thorax. These are almost always associated with (*a*) clothing and infection carried in, and (*b*) open "sucking" wounds of the chest wall.

(2) Tangential wounds of the thorax, enfilading the ribs and driving portions of the bone, etc., into the pleura and lung.

(3) Entrance and exit bullet wounds, in which the exit wounds are explosive in character.

Those belonging to the first variety are most serious and fatal. Those belonging to the last are probably least so, and respond most favourably to excision and closure of the wounds, because infection of the pleural cavity in them is caused by secondary advent of organisms through the open wound.

Discussion of the extraordinary variations of the lesions, which occur in the thoracic viscera, and of the positions which foreign bodies take up, is not necessary or desirable in such an article as this. Suffice it to say that they may be extraordinarily simple and easy to deal with, or they may demand great skill and dexterity, combined with ample courage, on the part of the surgeon. Fortune has shown her favour for the brave on repeated occasions. Immediate fatal hæmorrhage, as the result of removal of a large piece of shell from the root of the lung, need not deter the surgcon, keen to accept his responsibilities, from tackling thc next apparcntly similar case. In the second case the piccc of shcll may not be blocking a hole in the pulmonary artery ! The heart, as well as the lung, has shown itself to be tolcrant of manipulation and attaek of the surgeon's knife. There must be a considerablc number of mcn alive to-day who have had this part of their anatomy penctrated by bullets and other missiles during this war. Foreign bodics, in the wall or cavity of thc heart, have been rcmoved with wonderful case and succcss on several occasions. Suceessful suture of penetrating wounds has been still more frequent.

X-ray localisation is of inestimable value in eases where bullets or fragmcnts of shell have lodged in the chest. It indicates, often, that a route of approach other than through the wound must bc chosen, and of eourse facilitates preeision and prevents unneeessary manipulation and loss of timc during the intrathoraeic part of the operation.

Choice of Anæsthetic.—As there is considerable likelihood of inflammation appearing in the contralateral lung, the use of ether should be avoided when possiblc. If a general anæsthetic is used, nitrous oxide gas and oxygen is the onc to be preferred. Many of the cases can be done perfectly easily and painlessly after local infiltration of the tissues round the wound or site of fresh ineision, aided by bloeking of the intereostal and other nerves supplying the part. Thc teehniquc nceessary for sueeess in most cases is easily acquired. The patient should be given a hypodermie dose of omnopon or morphia half an hour beforehand. (Omnopon $\frac{2}{3}$ grain and scopolamine $\frac{1}{150}$ grain, Hoffmann, la Roche & Co., or morphia $\frac{1}{4}$ grain and atropine $\frac{1}{120}$ grain.)

Technique of Operation.—Rapidity and thoroughness are imperative. It is important to obtain ease of access to all parts of the pleural cavity. Since drainage is not made at the end of the operation, there is no need to make the opening low down. If the wound is high up on the front of the chest or involves the body of the scapula, a fresh wound should be made, but otherwise the approach is obtained through the wound made by the missile, after excision and possible enlargement thereof. The opening should be large enough to admit the surgeon's hand freely, and to enable him to inspect every part of the cavity. If a fresh incision is required, it will probably be found most suitable, as a routine measure, to remove four to five inches of the fifth or neighbouring rib in the infra-axillary region. If several adjacent ribs are involved in the smash and require removal, usually there will be adequate access procured through the original wound, unless the subscapular ribs are the ones implicated.

The original wound or wounds are excised, *en masse* if possible—skin, subcutaneous tissue, muscle, bone and edges of pleura, in one piece. The pleura should be preserved as much as possible. If this wound does not give suitable access to the pleural cavity, it is stitched up, layer by layer. If the pleura has been destroyed too much to allow apposition of its edges, then the muscles are sutured, catching up the remnants of pleura so as to present as smooth a surfaee as possible to the expanding lung and to prevent poeketing. If both pleura and musele are shot away in great extent, the hole ean still be eovered over completely, by sliding a flap, possibly eontaining musele, and suturing eompletely.

Then a fresh incision is made through the ehest wall over the fifth rib, whieh is reseeted, and the pleura-periosteum is divided by a elean eut along the middle of the bed of the rib. It may be neeessary, in order to get still freer aeeess, to divide the rib above or below.

If the lung is collapsed, the edges of the wound are strongly retraeted. A self-retaining retraetor is found to be of considerable value. The fluid blood is siphoned off through a wide drainage tube or the patient is tipped over in order to let it run out. Blood-elot is seooped out with the hand. Swabbing out the blood takes up too long time and should not be done exeept to remove the last ounce or two. Isolated adhesions may have to be broken down or divided in order to get the pleural eavity thoroughly eleaned, but, if not reeent, they should be left intaet. A rapid survey is made of the interior of the cavity. The lung is dealt with as is found neeessary—seized and pulled out, foreign bodies or fragments of rib removed, or the part where they lie is elamped, exeised and sutured ; the traek in the lung is eleaned out, possibly rubbed with antiseptie, and bleeding controlled by ligature, suture, eautery or gauze plug ; gangrenous or very badly laeerated lung is exeised and the part sutured, and so forth. Speeial foreipes (*e.g.* Duval's) and clamps are not really necessary. The use of a cotton glove or gauze on the hand which controls the lung will make manipulations easier. If accessible, foreign bodies imbedded in the spine or mediastinum are removed and the bed in which they lay is chiselled or gouged away or cleaned out and antisepticized. The pleural cavity is then wiped dry and the wound in the chest wall closed completely.

If it is unlikely that immediate expansion of the lung will cause hæmorrhage, the air in the pleural cavity should now be slowly aspirated, completely or partially according to the extent of the pulmonary lesion.

If the lung is adherent all round the wound, the latter half of the operation entails simple removal of F. B., excision and suture, or cleansing and draining the track.

The application of the mastisol dressing referred to in chapter VI, page 165, is of value in the after treatment by giving extra support and preventing strain on the sutured area.

Wounds of the Diaphragm.—If the diaphragm is torn, repair of the rent, by trimming and suture, should be the first step of the intrapleural procedure after the cavity has been cleared of fluid blood and clot. Wounds of abdominal viscera frequently accompany such an injury and a variable amount of prolapse into the pleural cavity may be present. Some such cases may require treatment through an anterior abdominal incision, but others are more readily treated, especially if the periphery of the diaphragm is affected, by enlarging the original wound, resecting a rib or ribs, dividing the diaphragm parallel to its

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fibres downwards from the rent in it, and then prolonging the incision downwards and forwards to any required extent in the abdominal wall. In such cases the lung frequently escapes injury and, after removal of fluid blood and clot, the pleural cavity can usually be closed off (and aspirated) before the abdominal part of the operation is undertaken, by suturing the diaphragm airtight to the chest wall around the upper periphery of the original wound. It is astonishing to what a height and at what tension the diaphragm can be sutured in this way with practically no subsequent distress to the patient.

In several cases in which the lower ribs have been blown away, the diaphragm has been used in this manner in order to close the pleural cavity. The hiatus in the chest wall is then filled up by sliding a flap.

In multiple injuries the treatment of a "sucking" chest wound should always take precedence.

Routine Aspiration during the Period of After-treatment.—Physical signs are apt to be misleading as to whether fluid is collecting in the pleural cavity or not after such operations. Routine aspiration should therefore be made, within twenty-four hours of operation and at least every second day thereafter. Resection of rib and drainage will thus be rendered unnecessary in many cases. Even although definitely purulent fluid tends to accumulate, repeated aspiration is often all that is necessary to effect a cure. If, however, severe constitutional symptoms appear, a drainage operation should be carried out.

Evacuation to the Base.—Such cases should be retained at the casualty clearing station if possible until they are able to be out of bed and move about the ward without detriment. Even in very busy times they must be kept until it is fairly certain that a secondary drainage operation will not be required.

. . . . .

The following are the results obtained by Major J. Anderson, D.S.O : (*a*) during two months in 1917, and (*b*) during two months in 1918.

(*a*) Taken from Major Anderson's paper in *British Medical Journal*, November 3rd, 1918 :

Total cases of Group B. operated on and chest wall closed	58
Evacuated apparently doing well	44
Died	14
Required secondary operation (drainage, etc.)	12
Number of cases with multiplo wounds	29

(*b*) Report sent by Major Anderson to author.

" Cases of G.S.W. of Chest treated from April 2nd, 1918, to June 2nd, 1918).

" In order to compare the results in the type of cases with those which I published in November 1917, I have collected and recorded these over a similar working period of two months in this year.

" Wounds of chest wall not opening pleura are not included in this record.

		Cases.
" Total number of patients, with penetrating wound of chest (4 deaths occurred in pre-operation ward)		74
Caused by bullet	17	
Caused by shell, bomb, etc.	57	
Operative procedure in		55
Number of these cases with multiple wounds		34
Cases with wounds of thorax and abdomen, involving and requiring suture of diaphragm		20
Cases with foreign body lodged in lung, or chest cavity		17
Foreign body removed		14

" The majority of eases were operated on between eight and twenty hours after wounding.

" *Results :*

"Cases evacuated to Base apparently well . .	44
Died at Base (Sub-phrenic abscess and shock) . .	1
Required secondary drainage of empyema at base and recovered	1
Under treatment (one with secondary drainage for B. welchii and strep, infection)	2
Died at casualty clearing station after operation .	9

" *Analysis of Deaths :*

"Chest abdomen	5
Peritonitis	3
Septic lung	2
Infection of hæmothorax caused by hæmolysing streptococcus, multiple, E. and E. bullet. (No other case of Strep. H. found)	2
Pure chest, shock, E. and E. bullet, involving lung and root of neck	1
Both chest cavities and cervical spine . . .	1

One German prisoner went to base with open thorax, local.

" *Remarks.*—There was an unusually large proportion of shell wounds and of chest-abdominal injuries.

" Most of open thorax eases arrived with temporary suture and travelled well to easualty elearing station, when compared with purely abdominal cases, who travelled badly. Nearly every case required aspiration, some six or seven times.

" Prevailing infection, B. Welehii.

" All exeept two cases remained closed and required no secondary operation exeept aspiration.

REFERENCES

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CHAPTER IX

INJURIES OF THE SPINAL CORD

This chapter, except in a few minor details, is identical with a paper written two years ago. One might say that there has been too much stagnation in this branch of war work. Possibly this may be due to an overpowering sense of hopelessness in treating the majority of war injuries of the spinal cord, but on the other hand late observation has revealed occasional surprising improvement in cases which appeared to be doomed to life-long paraplegia. While ill-considered interference cannot be too strongly deprecated, yet it is probable that, if early operation is carried out, such cases will recover more quickly and completely, and an appreciable proportion of those who, without operation, would remain unrelieved of their miserable incapacity may become partially or even wholly restored. Be that as it may, the fact remains that one meets, in several quarters, great reluctance to tackle such injuries by operation. One knows that operations on this class of cases are productive of striking results in a proportion less than in any other type. But the results of treatment without operation are apparently no better.

Only a few of the injuries directly due to a bullet or shell fragment can be compared with those met in civil practice. The outlook seems to be that operation in all but undoubtedly hopeless cases will, although attended by many failures, give quicker improvement and more complete recovery, when that is possible, than a less active line of treatment in which the abnormalities surrounding or actually in the spinal cord are not removed. Recovery of function is obtained in such a small proportion, however, that only the most hopeful cases should be tackled when great pressure of work exists.

To judge from the greater vulnerability of the spinal cord, its lesser capacity for recovery, and from the anatomical arrangement of the narrow spinal canal, owing to which displacement of bony fragments or other abnormalities are apt to produce more deleterious effects on the cord, it might have been thought that the general desire to interfere in spinal injuries, and to prevent secondary complications, would have been as great as that shown with regard to cranial injuries. This has not been the case. The technical difficulties of the classical operation of laminectomy, the loss of blood entailed by it occasionally under general anæsthesia, and the doubtful results of deferred operations, seem to be the chief factors in preventing patients, suitable for early operations, being treated on principles similar to those which govern treatment of wounds in other parts of the body.

In late cases the patients are usually in poor condition, and may suffer from bedsores, or from pulmonary or urinary complications, while the affected area has become obscured by masses of fibrous tissue. In early cases the presence of fractured laminæ usually makes the operation a comparatively simple one, easy to perform under local anæsthesia, and, with the use of good adrenalin, practically bloodless. Pulmonary complications are not predisposed to, or influenced by, this anæsthetic. Operation in the early stages can, in fact, be done with extraordinarily little upset to the patient. Out of a large number, I have never seen a death which could be said to have been hastened by it.

As already indicated, the fact that so many cases improve without operation, in spite of the abnormal conditions surrounding the cord, would lead one to hope that more rapid and material improvement would result from early operation to remove these abnormalities, and that some cases, otherwise permanently paraplegic, would be sensibly relieved. The cord, to a greater extent than most parts of the brain, is deleteriously affected, and retarded in recovery, by pressure of fragments of bone, foreign bodies, and other debris. There seems reason to believe that, if capable of recovery, it responds well to prompt removal of these unnatural conditions.

In a casualty clearing station, however, during a "push," a hurried selection of cases for evacuation must be made, and only those which are most favourable for immediate treatment must be retained. In all cases sent by ambulance train, the urine should first be drawn off, if retention be present.

Some general considerations in making the decision as to operation are here mentioned.

There are three types which arrive at a casualty clearing station showing paraplegia—one in which the symptoms are due to local concussion, another in which the cord is organically severed, and a third in which paraplegia has developed since the injury.

The paralysing effects of local concussion are often very marked. This may be caused even by the flight of a missile close to but outside the spinal canal; for example, temporary paraplegia may follow the passage of a rifle bullet from side to side between the spinous processes. In such cases the paralysis usually begins to clear up within a few days. If no sign of return of function occurs within nine or ten days, the question of operation for removal of blood-clot, or possibly of depressed bone, arises. This usually must be decided at the Base.

If, on the other hand, a rifle bullet, causing a through and through wound of the trunk, traverses the spinal canal, the cord is usually hopelessly pulped. An estimate should, therefore, be made of the probable track of the bullet, bearing in mind that the position of the patient during examination may not correspond to that in which he was hit.

It is obvious that cases of complete, sudden paraplegia should not be kept in the casualty clearing station, if they are otherwise fit to travel.

If, however, the paralysis has developed since the man was wounded, it is probably due to pressure from blood-clot (when it is not likely to be absolute), or to displacement of fragments of bone during movement. In both these cases early operation may be indicated, but in the latter only if X-rays show a minor degree of displacement. If displacement is great, the cord is probably pulped.

If conduction, either motor or sensory, is present in the affected part of the cord, when the patient is admitted to the casualty clearing station, it is usually found that fragments of bone are pressing on the cord, or that the missile causing the injury is in close relationship to it, and will probably have carried in sepsis. There may or may not be partial division of the cord. A missile with momentum sufficient to carry it far past the cord usually produces complete early paraplegia, even although it may not cause complete section. If then X-rays reveal fracture, or the presence of a foreign body partly or wholly in the spinal canal, operation should be done at once, with the quadruple purpose of relieving pressure, cleansing the wound, restoring normal circulation as soon as possible, and, thus, of combating sepsis.

In some cases pain is so excessive and uncontrollable by other means, that, whatever the amount of paralysis, operation is imperative in order to relieve the pressure on the nerve roots.

In a considerable number of cases, spinal injury is so extensive in itself, or is associated with other injuries of such a nature, that when the collective results are computed, it is extremely doubtful whether it is justifiable to take up the time of the surgeons to the exclusion of more hopeful cases. Of course, whenever possible, it is desirable, from a humanitarian or family point of view, to treat the wound on general principles, so that the patient may have a chance of reaching home alive.

Selection of Cases for Operation.—Roughly speaking, it may be said that operation is indicated or advisable at a casualty clearing station :—

(1) In the presence of incomplete paralysis of motion or sensation below the lesion, especially,

(2) If X-rays show displaced fragments of bone or the presence of a piece of metal in or near the cord.

(3) When the symptoms of paralysis have developed some time after the infliction of the injury, unless due to inflammation, in cases which have been " lying out," when operation is practically hopeless.

(4) When pain, due to pressure on nerve roots, is excessive and uncontrollable.

(5) In very exceptional and ultimately hopeless cases, when the character of the wound is such that sepsis, although not already evident, is otherwise likely to develop and cause rapid death, and it is important to keep the patient alive as long as possible.

In all other cases it is better, when feasible, that the patient should be evacuated without delay.

In cases which are retained for more than a few hours in a casualty clearing station, urotropine should be given as a " routine " in an attempt to prevent cystitis. The greatest care must be exercised in performing catheterization.

Certain Operative Details.—(1) Local anæsthesia, by infiltration down to and including the periosteum of the laminæ and articular processes, is as effective as in a trephining operation, and even more easily carried out. The patient should receive a preparatory dose of morphia or omnopon-scopolamine, sufficient to cause drowsiness. It is rarely necessary to use a general anæsthetic at any stage of the operation, unless the track of the missile is followed into non-anæsthetised tissues. A few whiffs may be given if the patient complains much of the pain of the injection, but the latter should be gone on with during the administration. Adrenalin renders the field practically bloodless.

(2) If the wound is in or near the mid-line, it should be carefully excised down to the bone, as in a trephining operation. If the wound is well to one side, a fresh, free incision should be made in the mid-line. This is sutured at the end of the operation. The track of the missile is cleaned, antisepticised, and used for drainage purposes.

(3) Set operations should be avoided. A typical laminectomy is rarely indicated. The laminæ can usually be nibbled away, as is done in many cases of trephining for depressed gunshot fracture, until healthy dura is exposed all round behind the injured area. All obstruction to the easy removal of fragments should be removed before any attempt is made to lift them out. The greatest delicacy should be exercised, especially if movement of these fragments causes pain or twitching. One of the greatest advantages of local anæsthesia is that the patient is capable of feeling such pain. This fact may prevent further gross injury to the cord.

(4) If the wound is not sutured, if the dura has been opened, Carrel's method of after-treatment,

with the patient lying on one or other side, should be carried out. The rubber tubes should be stitched to the muscle so that they may not become displaced and press on the cord. If the dura is unopened a gauze pack may be used.

It will be seen that the operation, in cases suitable for it, is on the same plane with trephining the skull in gunshot injuries, both as regards technique and indications for dealing with dura, etc.

(5) In cases retained in the casualty clearing station, the question presents itself as to whether suprapubic drainage of the bladder should be done. If operation on the spine shows that early improvement is to be expected, it may be advisable to postpone drainage of the bladder. In any case, if cystitis threatens, drainage is indicated.

CHAPTER X

COMPOUND FRACTURE OF THE FEMUR

The principles of treatment here described apply equally to compound fractures of other long bones, except that, for various reasons, amputation is indicated less frequently in fractures of the upper than of the lower extremity. Sepsis in the upper extremity is, on the whole, less virulent, radical conservative operation is frequently much easier and produces less shock, and the general condition of the patient is better able to withstand the longer operation and the greater strain during convalescence, while it must be remembered that an artificial lower limb is comparatively more satisfactory than one fitted to the upper extremity. It must also be remembered that, while a "gunshot wound," causing compound fracture of the femur, was at one time looked upon as one of the gravest of war injuries, a more wide-spread appreciation of sound principles of early treatment and a thorough application of these principles, have led to a marked reduction on the previously high rate of mortality and to improved functional results.

In no class of cases is it more important that *adequate treatment* should be begun *early* than in the large one comprising fractured femurs. The ratio in which this injury occurs is roughly one in fifty to sixty. It varies with the nature of the fighting. During an advance the proportion is greater than during trench warfare.

Experienced surgeons at casualty clearing stations bear warm testimony to the great improvement which has taken place in the early treatment of these cases by regimental medical officers and field ambulances, and reports from Base hospitals indicate that the "goods are now delivered in very good order" from the casualty clearing stations. In the hands of skilled, experienced surgeons the immediate results will probably be better still as an increasing number of wounds are sutured primarily, or within a very few days. Thus a prolonged, weary and precarious convalescence will be avoided. A word of warning must again be given against undertaking primary suture until the essentials necessary for successful early treatment of wounds are fully mastered. Attention to this warning will save many limbs and lives.

The treatment carried out before the patient reaches the casualty clearing station has been described fully in Chapter I.

All cases of fractured femur should pass through the operation theatre of the casualty clearing station, because often, when thorough examination is made, a case which, in the reception room, has appeared comparatively simple and not likely to require operation, shows that operation is urgently required.

Unnecessary handling should be avoided, and examination in the theatre alone is the best way of ensuring this.

Anæsthetics to be used.—If wounds of other parts of the body exist, a general anæsthetic is required. If shock is, or has been, pronounced, especially if amputation has to be performed, " gas and oxygen " is the anæsthetic of choice. Spinal anæsthesia (novocain 10 per cent., 1-2 c.c.m.) is preferred by some surgeons. If the patient has lost much blood, transfusion should be carried out before the spinal anæsthetic is injected. (See Chapter III.) Two or more surgeons, according to the number of wounds and the staff available, should deal with such cases.

General Considerations.—Although most cases arrive in such good condition nowadays that they are fit for operation without delay, yet in many the effects of shock, hæmorrhage and sepsis, are present to such an extent that they require the employment of special combative measures.

The general treatment of surgical shock and hæmorrhage has been discussed. Transfusion of whole blood, in addition to warmth and rest, provides the most certain restorative. Active hæmorrhage may require the use of a tourniquet, if not already applied, and prompt removal to the theatre. Both sepsis and shock require the administration of bicarbonate of soda, by various routes, in order to prevent or neutralize acidosis.

One may well be pardoned for reiterating certain points in connection with these injuries. All cases of compound fracture of the femur should be disturbed as little as possible after their arrival at the casualty clearing station. They should be sent without delay to the pre-operation or resuscitation ward. They should not be evacuated to the Base without first passing through the operation theatre. Small superficial wounds are deceptive, and almost invariably cloak much extensive damage of the deeper tissues. When lodgment of the shell fragment causing the damage has occurred, however small the aperture of entrance, operation must not be postponed or omitted, as may sometimes be done when an undistorted rifle bullet is the cause. It must be appreciated, even in the latter condition, that postponement of operation incurs considerable risk, because a bullet which lodges travels at a low velocity, and is more likely to carry in sepsis than one whose momentum carries it through the limb. Some such cases may be treated as simple fractures.

Cases in which hæmorrhage is taking place, or is controlled by a tourniquet, will naturally be given precedence in going to the theatre. Whenever possible, inadequately splinted cases should go next, or when this is not practicable the fixation should be improved. If the limb is not put up in an efficiently applied Thomas's splint, no attempt should be made to remove any clothing until after full anæsthesia has been established, or until proper fixation has been achieved.

When the patient reaches the operating theatre, care must be taken that no increase of shock occurs from unnecessary or rough handling. Probably the soundest plan in all cases is to lift the stretcher on to the operation table, to anæsthetize the patient and remove his clothing before the stretcher is taken away. Thereafter, bandages and splints are removed, and the nature of the injury investigated. In suitable cases the limb is then raised from the table by the

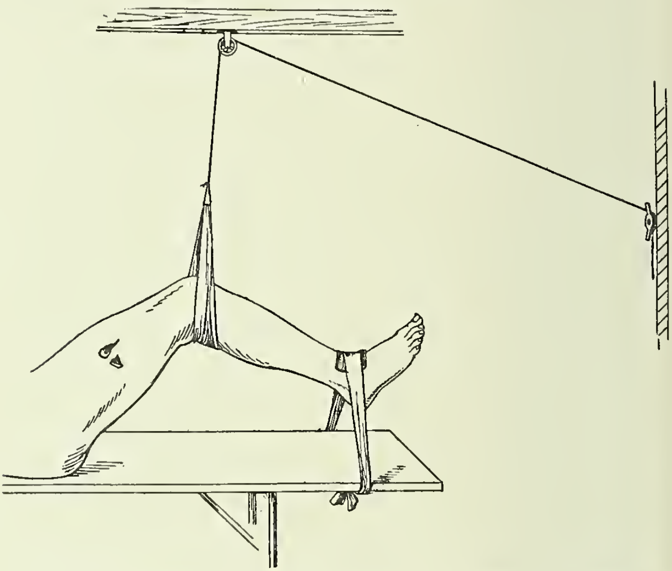

Fig. 23.—Diagram of rope and pulley apparatus for raising leg from operating table.

apparatus shown in the diagram (fig. 23). This simple device frees the orderly from the arduous task of holding up the limb during the whole period of the operation. It can be easily unhitched when neces-sary. Some surgeons advise to operate without removing the Thomas's splint and extension. Ade-quate operation under such conditions can be done only in the most simple cases, and therefore this procedure is not recommended. Captain R. D. Laurie has invented a special operation table which provides excellent facilities for such cases.

In order to make quite sure of finding and removing all septic material, it is advisable, when *easily* possible, to project both broken ends of the bone out of the wound. This manœuvre can obviously not be carried out satisfactorily when the splint is not removed.

The ordinary ritual for disinfection of the skin, and the subsequent general technique, need not be described.

The first step in the actual operation should be excision of the superficial wound. It should then be freely extended by incisions in the long axis of the limb, or else in the direction of the main pockets, unless the latter entails the division of important structures. The full extent of the injury to muscles and bone must be *seen*. The eye must be guide more than the finger. It is only when a thorough survey has been obtained that the operator is in a position to decide the subsequent course he should adopt in each particular case. The size of superficial wounds is no indication of the deeper damage. Most extensive laceration of muscles and severe comminution of bone very frequently underlie apparently trifling skin wounds. The superficial incision must be very free.

The Question of Amputation.—The full extent of the wound having been appreciated, the question of amputation will arise in a proportion of cases. In some hopelessly mangled limbs the decision is easy even without previous incision. There are many borderland cases where there is great difficulty in deciding what is the proper course. It is a good plan to hold an informal consultation in such cases. Amputation should be performed :—

(1) When the main vessels, both artery and vein, are divided, and collateral circulation has not been established. In a few early cases, some form of blood-vessel anastomosis can be performed, *e.g.* by intubation with a paraffin-covered glass tube, or a Tuffier's metal tube, in order to carry on the circulation until collateral vessels have become dilated. The tube gradually becomes occluded with blood-clot, and is removed when pulsation in the part of the vessel immediately distal to it has ceased (usually twenty-four to seventy-two hours). Suture is rarely possible.

(2) When gas gangrene is definitely established in more than one group of muscles, or where, for anatomical reasons, complete excision of any gas-infected part cannot be carried out without entailing serious disability.

(3) When either the main artery or vein require ligature, and there is evidence of even a localized patch of gas gangrene beyond the point of injury to the vessel.

(4) When the sciatic nerve is hopelessly destroyed for several inches.

(5) When virulent sepsis is already established in extensive wounds, the patient being in low condition.

In cases where the general condition of the patient is bad, especially as a result of shock-hæmorrhage, one's leaning should be towards amputation, unless blood transfusion completely changes the picture.

Involvement of the knee or hip joint does not by any means necessarily call for amputation. The same may be said of extensive laceration of muscles and severe comminution of bone—if the circulation is good, and there is no evidence of gas gangrene in the wound.

When amputation is decided on, the circular or modified circular method—as low down the limb as possible—is the one which should be employed. The "guillotine" operation is practically never necessary or justifiable. In some cases, where speed is essential, the amputation is made at the site of fracture, the bone being trimmed at a later date. In ordinary cases, when sawing the bone, a strong metal plate, with a slot in it to admit the femur, is useful in keeping muscles out of the way and in saving time. For the purpose of preventing superficial necrosis of the end of the bone, a layer of deep muscle fibres may be stitched over it. If immediate primary suture is not advisable, the dressing used is either a "pack" or Carrel's method. Open amputation stumps are ideal wounds for the application of a pack. The flaps are drawn over the pack, and fixed by widely placed sutures or by strips of adhesive plaster. A practical point is, that room should be left between the skin edges for drainage, when the sutures or strips of plaster are being applied. Delayed primary suture should be practicable in the majority of cases.

Conservative Treatment.—If conservative measures are decided on, the operator must make up his mind to perform a thorough operation on the lines described in Chapter VI, page 153. It cannot be too often emphasized that, in addition to the careful removal of foreign bodies, the superficial wound must be completely excised, and all badly lacerated fascia, muscle, and soiled periosteum cut away. With regard to the muscles, contraction alone is not a sufficient guarantee of the necessary degree of vitality—definitely bleeding muscular tissues must be reached before one holds one's hand. Great care must be taken that the vascular supply of muscles previously treated be not cut through during the later stages of the operation. Once embarked on such an operation there must be no half-measures. Most extensive dissections may have to be carried out. There must be no hesitation in cutting wide. One small piece of devitalized muscle left in the wound may be sufficient to render the whole procedure useless.

Bone fragments, unless completely separated, should be removed only if they are badly soiled. They should be thoroughly wiped or scraped, so that all possible infection and blood-clot are removed, and very lightly smeared with antiseptic paste. Completely detached fragments should be removed. If possible the periosteum should be retained.

If a joint has been directly opened by a missile, the operation is carried out as indicated in Chapter XI.

Perfect hæmostasis is essential. The whole wound cavity may then be thoroughly washed out with saline solution.

Immediate primary suture should be performed if there is reasonable likelihood of asepsis having been secured. This should be possible in the majority of cases operated on within twelve hours of the injury.

Previous to closure, the whole surface and all crevices of the wound may be rubbed gently with a solution or paste of one of the recently introduced antiseptics (flavine, brilliant green, or even Bipp, etc.). Great care should be taken to obliterate dead spaces as far as possible by well placed, *not tight*, deep sutures. These must not interfere with the blood supply of the parts. A drain should be inserted, for twenty-four to forty-eight hours, "down to but not into" the area of fragmented bone. After the skin is sutured, the whole wound area should be rubbed over with picric acid solution.

In cases of doubt it is safer to use a paraffin or salt pack. In two to four days, if no inflammation occurs, delayed primary suture can usually be done.

Operation having been completed, all that remains to be done is to immobilize the limb. Incomplete fixation may lead to failure, in spite of the most careful operative treatment. Thomas's knee splint is the one now used for the vast majority of cases. A satisfactory splint for all cases of high fracture associated with wounds of the buttock or perineum has yet to be discovered. Abduction frames have many drawbacks but are so far the best available for transport. Unless great care is taken, pressure sores develop rapidly when these are used.

Fixation by Thomas's Splint.—A "Thomas's splint outfit," properly used, is the simplest and most efficient method of obtaining complete fixation at this stage.

The detail of the application is, shortly, as follows :—

(1) The suspensory sling is removed from the knee, and the limb is supported and pulled upon by an orderly.

(2) **Application of Extension Bandage.**

It is not necessary to shave the limb. Paint the entire circumference from the malleoli upwards, sufficiently high to allow the extension to get a good pull on the lower fragment, with a glue solution, of which the formula is :—

Glue	
Water aa.	50
Thymol	$\frac{1}{2}$
Glycerin	
Calc. Chloride aa.	2

(A shaving or small paint brush is used for applying the glue. During a " strafe " a pot of this glue should always be kept ready melted. The glue will become too thick after a time, and a little water should then be added. The glued-on bandage can be removed with warm water.)

Next place, lengthways, on both sides of the limb, a strip of bleached calico bandage, and apply a roller bandage over the whole.

(3) **Application of Splint.**—The ring of the splint is passed over the foot and pushed upwards, until the posterior part of the ring presses firmly against the ischial tuberosity. In some cases of low fracture the splint may be slightly bent opposite the knee.

(4) **Tightening of Extension Bandages.**—The surgeon takes an extension bandage in each hand and, making strong traction, passes one of them over, the other under, the lateral bars of the Thomas's splint. First one bandage and then the other is thereafter passed round the notch in the cross-bar,

a complete turn being taken in each case. The turns are taken in opposite directions, and the last overlaps the first. The ends are made secure by tying a half-bow. This method of fixing the extension bandages can easily be undone and adjusted again, when necessary, without relaxing the pull on the limb.

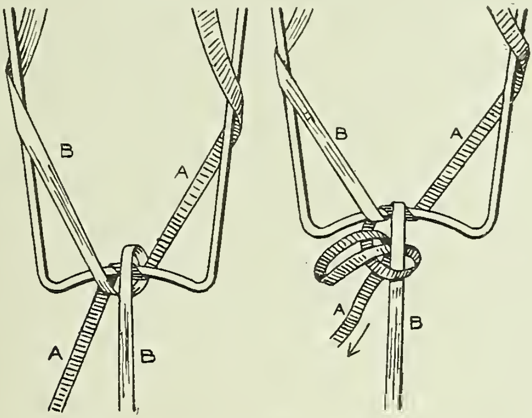

FIG. 24.—Method of tying the extension bandage in fracture of the femur so as to prevent slackening of the extension and loss of time during adjustment. First pull on both bandages; then pull especially on A, fix* as in diagram and hold taut. Pull on *B*, take a turn round notch of splint over *A* and hold taut. *A* may now be left loose. Tie loop knot with *A* on *B*.

When adjusting, hold *B* taut; undo knot; hold *A* taut and slip to its own side. Pull on *B* and proceed as above from*, substituting *B* for *A*.

(5) **Application of Slings.**—In cases where the wounds are in such a position that it will be necessary to remove the ham splint for dressing purposes, slings formed by bandages or, better still, perforated zinc strips, should be applied at this stage. The zinc

strips are thinly padded and covered with waterproof material. They are applied so as to leave the wound clear, but at the same time support the fragments when the supporting ham splint is removed. One such sling should always support the lower fragment and upper part of the calf.

(6) **Application of "Ham" Splint.**—See page 57. This should be padded to suit each case. Moss pads serve the purpose well. Over these a sheet of jaconet is placed to prevent soiling. The ham splint is now slung to the side bars of the splint by three strips of adhesive plaster—the adhesive side being next the ham splint. This effectually prevents its lateral movement. The posterior padding should be enough to cause slight flexion of the knee. Sagging of the thigh must be prevented also by suitable padding.

(7) **Application of Anterior Thigh Splint.**—This splint consists of a piece of Gooch's splinting applied to the thigh, canvas side towards the limb. It should extend from near the ring of the Thomas's splint to just above the patella. Before a "push," a number of suitable lengths of Gooch's material should be cut. The whole roll may be sawn through. and an orderly can cut off any breadth required. The thigh splint is fixed by the bandage, which is now applied to the limb from the ankle upwards. This bandage encircles all the splints.

A bandage passing across the extreme upper part of the thigh, from bar to bar of the splint, may be necessary to prevent flexion of the upper fragment. Care must be taken that any padding or small splint used does not press on the main vessels.

(8) **Application of the Footpiece.**—The foot must be supported at a right angle by means of a metal foot rest, which is part of the outfit.

A "gutter" of perforated zinc sheeting is fixed on the footpiece. The foot, or gutter, is padded. This arrangement allows free dorsiflexion of the foot, a movement which the patient should be encouraged to make frequently. The circulation of the limb is thereby assisted. Rotation of the leg can be prevented by various simple means, *e.g.*, by a strip of sticking plaster fixed to one bar of the splint and encircling the ankle.

(9) **Two Stretcher Suspension Bars should be used during Transport.**—To one, the more important, the lower end of the Thomas's splint is slung by two pieces of bandage, one attached to either bar of the splint. If no suspension bar is available, the leg must be supported by some other means so that the heel is carried clear of the stretcher. To the other bar the upper end of the splint is slung as shown, just high enough to make the ring press very lightly on the tuber ischii. The sciatic nerve must not be unduly pressed upon.

If the patient cannot be evacuated, the injured leg must be slung in the wards. A simple method is the use of two bandages, each passed over a beam of the hut. The two ends of one bandage are then tied to the bars of the splint close to the ring. The ends of the second bandage are secured to the bars at the level of the foot.

Many modifications of this method of fixing fractures of the femur have been introduced, but

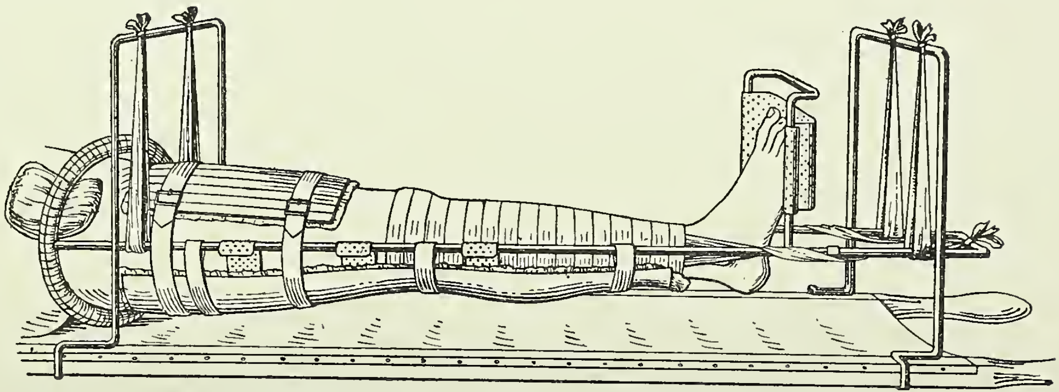

FIG. 25.—Application of Thomas's splint outfit—for transport to the Base.

it still remains the simplest and not the least efficacious.

Various forms of elastic or spring extension, attached to the lower end of the Thomas's splint, have become popular. They are used with the object of "taking up the slack" which may occur during transport. They are of value only when the space between the sole of the foot and the notch of the splint is great enough to allow sufficient play of the spring extension. When such elastic extension is employed, a "spreader" should be used to carry the lateral extension strips clear of the malleoli. The strips should not pass round the lateral bars of the splint.

Evacuation.—Many cases of compound fracture of the femur may safely be evacuated as soon as they have recovered from the anæsthetic. Before evacuation the extension should always be inspected—the bandages may require tightening or loosening. A pad of wool may be required between the ring and antero-external part of the thigh, so as to prevent the ring from nipping the scrotum or slipping off the tuber ischii.

In cases which have to be kept at a casualty clearing station for more than twenty-four hours, the superficial dressing should be changed before evacuation, on account of oozing. Care also must be taken of the skin pressed on by the posterior part of the ring—it should be pulled up to change the point of contact, and carefully dusted. Alteration of the degree of elevation of the splint, or propping up the patient, frequently adds to his comfort.

CHAPTER XI

WOUNDS OF JOINTS

Of wounds of joints sustained in the early part of the war, the same tragic tale has to be told as of wounds of other regions, and most strikingly so in the case of the knee. The remarks made by a high official in those days were only too true—that the results of wounds of the knee-joint were a deep reproach to surgery—that surgeons were apparently impotent to prevent loss of limb or of life. At a joint meeting of French and British surgeons held towards the end of the first six months of the war, it was painful to hear, from representatives of both nationalities, the reiteration of deplorable results—amputation—death. At the record of a healed stiff joint one felt almost inclined to cheer, while a story of movement following an operation sounded like a fairy tale. Now, what were fairy tales are commonplace, and great is the satisfaction to those who were out in the dark days of surgery! It was demonstrated shortly after that meeting that knee-joint injuries responded well to treatment by excision, and nowadays, in competent hands, they yield as brilliant results as any other class of wounds. The line of treatment laid down in the Spring of 1915 has required but little important modification.

Knee-joint.—Wounds of the knee-joint are more frequent and liable to be more disastrous in their consequences than those of any other joint. Their treatment, therefore, will be indicated, and the principles advocated can be adapted for other joints.

The enormous improvement in the treatment of these cases is due chiefly to the early pre-inflammatory stage at which most operations are now performed and the thoroughness with which they are carried out, and to a great extent also to careful fixation during transport. The evil effects of transport are manifest to a greater degree in wounds of the knee-joint than in most other types of wounds.

In many cases enforced delay in operation still means absolute disaster. The nature of the injuries and the virulence of the infection, coupled with the unfavourable conditions under which the wound is received, and the impossibility which may exist of giving adequate attention to such injuries in the early stages, still frequently give rise to such an exceedingly rapid inflammatory disintegration of the joint and breakdown of the patient's general resistance that amputation is the only means of saving the patient's life. And at later stages, now as at the beginning of the war, one must not be tempted, because of the apparently quiescent and fairly painless condition of the joint in certain cases, to postpone radical operation too long. In consequence of the communication of the wound in the bone or joint with the exterior, symptoms due to increased tension in the part are absent, and therefore the ordinarily described type of osteomyelitis or arthritis is not usually found. Patients with such injuries usually have an obstinately high temperature, and, if the cause of this and of the steady, but probably insidious deterioration in the general condition cannot be speedily overcome, amputation must be done.

Willems and other Belgian surgeons have stimulated the hope, however, that even in suppurating joints, once the site of primary infection has been removed, a useful movable joint may be obtained. The theory on which their success is said to depend, that only by *active* movements can a joint be thoroughly drained, is so opposed to what surgeons have hitherto believed to be the proper treatment, that caution in adopting the method is excusable. But many old-fashioned notions have been upset during this war —one can remember well the incredulity with which the results of excision of wounds were received, and one cannot afford to neglect some of the brilliant results which have been demonstrated by our Belgian friends. It would appear necessary that, if success is to attend such treatment, it must be initiated at a very early stage—long before erosion of cartilage has begun. It must not be instituted as a last resort if it is to have a fair chance.

Types of Injury.—Certain common types of injury may be summarized :—

(1) Cases of effusion without lodgment of the projectile in the joint—(*a*) In which it is uncertain whether the synovial cavity has been traversed or whether the synovial membrane has been merely bruised. (*b*) In which the synovial cavity has been

traversed by a clean rifle bullet without injury to the bones. (*c*) In which the bullet has cleanly perforated one of the bones entering into the articulation.

In connection with injuries of this class the common association of effusion into an intact knee-joint with a fracture of the shaft of the femur is to be borne in mind.

Cases included in Class 1 are obviously subjects for expectant treatment. If suspicion as to infection arises, the joint should be tapped and the effusion of blood or synovia examined bacteriologically. If organisms are found, a usually successful plan is at once to open the joint freely, wash out thoroughly with saline solution or some warm non-irritating antiseptic, and to close the wound carefully again.

Retained Missiles.—(2) Cases in which the projectile has lodged; (*a*) within the synovial cavity, and (*b*) in one of the articular ends. In (*b*), the synovial membrane may not be injured, or only slightly. Cases with more severe synovial injury come under (3).

When a retained rifle bullet lies within the joint, if the superficial wound is small and not inflamed, it may be left for a few days, the joint being meantime immobilized, but the better plan is to take no risks and operate immediately.

Free fragments of shells or bombs, shrapnel or distorted rifle bullets must be promptly removed.

Missiles imbedded in the Bones.—Clean rifle bullets so situated as not to interfere with the movements of the joint need not be interfered with at an early

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stage. They may do no harm and have frequently been left indefinitely. Fragments of shell come into a different category. Here infective material has practically always been carried in, and the retained body must be removed by the shortest and safest route. This may be by the original wound, although sometimes the localizing skiagrams may indicate a much shorter route, but, as the bed of the missile is certainly infected, no advantage except that of direct access is gained by a special incision. As the extraction is commonly a matter of considerable difficulty, the incision for the removal of impacted bodies should be free. The bone surrounding the fragment must be removed. The lining of the track and the original superficial wound must be similarly dealt with. Although after such treatment many cases have been sutured completely with success, it is safer, especially if the patient cannot be retained for observation, to leave the wound completely open for a few days, treating it with a paraffin pack, or intermittent irrigation, as seems most suitable. A gauze pack, if too tightly inserted, will favour necrosis.

Open Wounds of the Joint.—(3) Cases in which the synovial cavity has been more or less widely opened; (*a*) without damage to the articular surfaces, and (*b*) where fissured fracture or slight comminution of the articular ends of the bones co-exists.

These require the primary measures which are detailed later on, and often make remarkably good recovery, especially if operated on within twelve to twenty-four hours.

(4) Cases in which serious comminution of one or more of the constituent bones has occurred.

Seriously Comminuted Fractures. — The majority of cases in which gross comminution and soiling of either femur or tibia is present require amputation. Severe compound T-shaped fractures of the lower end of the femur can rarely be saved, and primary amputation is frequently advisable. Extensive comminution of the cancellous tissue of the head of the tibia or condyles of the femur may prove very dangerous, owing to the severe constitutional symptoms which follow septic absorption from the injured spongy bone. The early treatment of favourable cases should include chiselling or gouging away infected bone, if possible, followed by pack or Carrel dressings.

Fractures of the Patella.—Comminuted fractures of the patella form a special class. The loose fragments, sometimes amounting to the entire bone, should be removed. They can often be removed *en masse* with the wound of the overlying soft parts. If part only of the patella is removed, the raw surface of the remainder should be carefully sawn or chiselled off. The synovial cavity is flushed clean. The synovial cavity can safely be closed in early cases by suture of the synovial membrane and an attempt made to obtain a movable joint, but free drainage is usually necessary if infection has gained a hold.

This recommendation does not refer to the rare cases in which an ordinary transverse fracture of the patella has been produced by sudden muscular contraction following a bullet wound of the thigh, even though the bullet should have traversed the knee-joint. Neither should it be extended to some clean puncture fractures of the bone produced by direct passage of the bullet.

At Regimental Aid Posts and Field Ambulances.—In view of the importance of the treatment of such injuries at regimental aid posts and field ambulance dressing stations, it is well to elaborate what has already been said on this subject. (Chapter I.)

Severe injuries should be treated on the same lines as fracture of the femur, that is to say, they should be put up in a Thomas's splint outfit. In small penetrating wounds the limb should be fixed in a long gutter splint, *e.g.*, a long Jones's fracture splint or Gooch material, reaching from the tuber ischii to the ankle, with a large graduated popliteal pad. The upper and lower end of the splint should be fixed to the skin by strips of adhesive plaster, of which the lower may encircle the limb, but the upper should, if applied at all, be applied spirally. The plaster prevents displacement of the splint. A broad bandage is then applied from end to end. Dressings and bandages must be so applied that circulation of the limb, or exudation from the wounds, is not interfered with.

Movements of the joint may turn the scale in favour of extension of sepsis, and may make all the difference to the patient's future.

The question of amputation at this stage arises only in cases where the limb is hanging on by lacerated remnants—the bones, vessels and nerves being hopelessly destroyed.

The skin should be painted with picric acid in spirit. Visible foreign bodies and absolutely loose protruding pieces of bone and superficial blood-clot should be removed. No other interference with the wound is justifiable unless to stop hæmorrhage. No drains should be inserted. If a large gaping or valvular wound exists, loose folds of gauze wrung out of weak antiseptic, preferably 1 per cent. iodoform in paraffin, should be inserted to prevent apposition of infected surfaces.

At Casualty Clearing Stations.—The splendid results which can be achieved make it desirable that all cases requiring operation should be treated here within a few hours of admission; but, as this is out of the question during severe fighting, a selection must be made of cases likely to be able to travel to the Base without serious risk.

This selection, so far as the injury of the joint alone is concerned, will depend chiefly on the size and position of the wounds, especially of entrance wounds; on the size and character of the missile, especially if lodgment has occurred, and on whether it is visible or palpable; on the size of the wound in the synovial membrane, and on whether it communicates freely with the surface wound so that infection will occur easily; on the amount and character of comminution of bone; on the presence or absence of injury to large vessels; on whether intra-articular tension is present or absent; and finally, on whether definite sepsis has developed or not.

Cases for Transfer to Base during Severe Pressure.—That is:—If the wound of entrance is small, especially if due to an undistorted rifle bullet, if there is no external evidence of a foreign body, if there is no comminution of bone or injury to large vessels, if there is no painful tension, and if there is no inflammation, the patient may be sent on to the Base, after thorough disinfection of the skin, suitable dressing of the superficial wounds, and fixation of the limb, the knee being slightly flexed, in a splint of proper length. The "Thomas's splint outfit" is the best for the purpose, and those cases in which penetration of the synovial cavity is even merely suspected should be fixed in it.

It may be noted here that an "open" wound of the back of the joint is usually less serious than a similar one on the anterior aspect, possibly because, in the latter, sepsis is more likely to gain access during transport.

Cases for Retention at Casualty Clearing Stations.—If the superficial entrance wound is large, even, *e.g.*, like that caused by a shrapnel ball, and especially if it communicates freely with the synovial cavity, if there is a visible or palpable foreign body which has opened the joint, if there is much comminution of bone, if there is a hæmatoma in the popliteal space or hæmorrhage from a wound there, if there is undoubted inflammation, the case should be kept at the casualty clearing station for immediate operation.

On admission the limb should be dressed, fixed if necessary in a suitable splint, and, if X-ray localization is required, the patient should be sent to the radiologist, who should take two skiagrams, one antero-posterior (toes pointing straight forward) and one lateral, on the same plate if possible. This method is probably the quickest and best in the circumstances. The patient is then sent to the pre-operation ward. The splint should not be removed till the patient has been anæsthetized. The strapping of the splint permits examination of the wound without moving the knee.

General Remarks regarding Operation.—In no other class of cases is technique and judgment in early treatment reflected so much in the results obtained.

The surgeon who exhibits the greatest eare in teeh-nique, espeeially when removing foreign bodies and infeeted tissue, whether of the soft parts or of bone, gets the best results. Conservative operations on gunshot wounds of the knee-joint, however, in order to be sueeessful, demand sueh eare that they should be handed unreservedly to the surgeon in the unit who has demonstrated speeial skill in their per-formanee. Most of the failures are attributable to want of appreeiation of what is essential in totally exeising the soiled wound in sueh eases.

Excision of Wounds.—The ultimate objeet of treatment of these eases is to seeure mobility of the joint. The primary objeet in the easualty elearing station must therefore be to seeure asepsis. The surest and quiekest way of doing this is to exeise eompletely, if possible *en masse* and with a sealpel, all tissue whieh is definitely or probably infeeted. This having been done, the wound remaining ean be treated on aseptie prineiples. This, of eourse, entails the exelusion of all instruments, gloves, towels, ete., whieh may have eome into eontaet with infeeted parts. A large pereentage of these wounds are sutured, and heal by first intention. A suitable plastie operation may have to be done. In many eases it is advisable to provide drainage by tube or rubber tissue "down to but not into" the joint eavity or bone fragments for twenty-four hours.

Although, in many eases, the wounds eannot be elosed, yet it is usually possible, for example after exeision of the patella, to suture the synovial mem-brane of the front of the joint, espeeially if the suprapatellar pouch is loosened from its upper and anterior connections and pulled down. The lateral parts of the synovial membrane may likewise be undermined. Closure of the synovial cavity is of very great importance.

Fixation.—Fixation of the joint during transport is essential to success even in the simplest wounds. It is found that the best method of ensuring this is to put up the limb, slightly flexed, in a "Thomas's splint outfit," just as in cases of fracture of the femur, with the exception that the extension strips are applied with the object merely of keeping the Thomas's splint in position. No traction is necessary. If a back splint only is used, it must reach from the *tuber ischii to the ankle.* Shorter splints are worse than useless.

Foreign Bodies. — Removal of a foreign body, lodged within or near the joint and not visible or palpable from the surface, should *never* be attempted without X-ray localization when that is available. Otherwise probably more harm than good will be done by interference. If X-rays are not available, these cases should be transferred without delay to a unit which is provided with an installation. Of course, in any case where the foreign body can be seen or felt or where synovitis is already very marked, the sooner operation is done the better. It may be disastrous to send the patient on another journey.

Amputation. — If the injury has implicated the main vessels so that the foot is already cold and dead, amputation should be done, just above the knee, if the wound is likely to remain clean and can be sutured, and through the knee, if sepsis is present and the condyles undamaged. In the latter class of cases re-amputation is frequently necessary, and, when the condyles are left, it can be done so as to provide the longest possible thigh stump. If, as sometimes happens, one or other popliteal nerve is shot away so extensively that it cannot be sutured, and if, at the same time, the bones are much soiled as well as comminuted, the probability is that primary amputation is the best course. If sepsis is well established in presence of much comminution, especially if there be gas gangrene and the patient in low condition from hæmorrhage or toxic absorption, amputation *must* be done.

In considering the question of amputation, the following points are of great importance: the possibility of successfully removing or neutralizing infective material, the amount and kind of comminution, the concomitant injury to vessels or nerves, and the condition of the patient.

Resection.—If, in less severe cases, the opposing ends of the long bones are so comminuted that smooth articular surfaces are not available, it is probably best to do primary resection.

As little bone as possible should be removed at these primary operations—only what is soiled and badly comminuted. At the same time free drainage must be obtained. A patient will often bear removal of a shattered infected condyle when a book-type resection would kill him. Better adjustment of the joint surfaces can be made at a later date.

Conservative Treatment of Fracture Cases.— Where large fragments have resulted from the injury, if the patient has been got early and is in good condition, and if one is fairly sure of getting away infective material, the case should be given a chance and treated on conservative lines. Simple nailing of bone fragments in some cases facilitates after-treatment.

Removal of Patella.—As a general rule, if the patella alone has been shattered, as happens fairly frequently, the fragments should be removed. If possible the synovial cavity should be closed except for a small drainage opening. This is attained by suturing the lateral edges and aponeuroses, possibly after undercutting the synovial membrane on each side, or by loosening the suprapatellar pouch as already described. If this cannot be done a pack should be used. The same procedure should be carried out, if concomitant injury to other bones is not extensive. It is wonderful how infection tends to remain limited to the anterior part of the joint if the limb is thoroughly immobilized—plus a flat pad in the popliteal space.

Conservative Treatment. — When conservative measures are decided upon, the following are the most important operative details :—

(1) Determination of the track which leads to the depth. The knee may have been bent when the patient was wounded, so that when the limb is straight the track is distorted. Excision of the track is best made when the knee is held in the same position as when injured.

(2) Thorough disinfection of skin and track. The

whole of the skin *around* the knee, and for at least six inches above and below, should be shaved and disinfected. For final disinfection use picric acid (3 per cent. in spirit). The external wound and track are disinfected (*a*) if not very large, by the actual cautery, or (*b*) by rubbing thoroughly every part with 10 per cent. iodine or picric in spirit. The strong solution has the effect of drying the tissues.

(3) Careful and complete excision of external wound and track, including the edges of the wound in the synovial membrane, if possible in one piece. Incision, using a sharp scalpel, must be made quite clear of the deep as well as clear of the superficial wound. Pockets must not be cut into. Clipping infected tissue away piecemeal courts disaster. While the blades of the scissors are closing, infective material from their proximal parts is forced along to the distal. The least little bit of infected material left behind may prevent success.

(4) Provision of ample access to foreign bodies or comminuted surfaces in the joint. Blind groping with the finger is to be avoided, because the foreign body or infective material is thus frequently pushed beyond easy reach, and further struggles to attempt removal pave the way for disastrous inflammation. Extra incisions may be necessary, therefore, to give easier access, and they must be free enough, even to the extent of dividing the ligamentum patellæ and turning up a flap, etc., to enable one to *see* the foreign body and obtain plenty of room for manipulation of instruments. If complete excision of the infected wound has been made under proper technique,

one should be able to get first intention after suturing, however large the wounds may be. Results have steadily improved, in this as in other types of war injury, *pari passu* with better planned and freer excision.

(5) Careful removal, under direct vision whenever feasible, of all foreign material, whether free in the joint or imbedded in the articular surfaces. If the latter, the bone surrounding the foreign body must be carefully chiselled or gouged away, *en masse* if possible. The joint cavity is then flushed out with 5 per cent. saline, 1-1,000 flavine solution, etc. Bone cavities may be treated sparingly with "Bipp" or other paraffin paste in cases where complete eradication of sepsis is doubtful. In aseptic cases the cavities may be filled with a "fat" transplant, paraffin wax, etc.

(6) Closure of the wound in layers, using fine catgut for the synovial membrane. Drainage tubing should not project into the joint. Of course, if tubes are required for the introduction of fluid, as in the Carrel-Dakin method, they should be carried to the deepest recesses of the joint, or inserted through a fresh incision. They should be removed as soon as possible.

(7) If the wound in the synovial membrane cannot be closed, a small salt or paraffin pack, separate from any other which may be required for the rest of the wound, should be inserted firmly "down to but not into" the hole in the synovial membrane, and should be left until it is absolutely loose. A small tube may be placed in the centre of the pack, reaching to the

hole, and it may be removed in a couple of days. If attempts are made to pull the pack away, adhesions shutting off the main cavity of the joint are likely to be broken down, and infection is then liable to occur.

(8) Tendinous or ligamentous structures, exposed during operation, should be covered by skin and subcutaneous tissue, otherwise they are very apt to slough, and this postpones closure of the wound and therefore prolongs convalescence.

(9) If there has been much effusion into or from the joint, of whatever nature, or if raw surfaces, whether of bone or soft tissue, are left in the joint at the end of operation, a tube should always be inserted "down to, but not into," the synovial cavity. Pressure of effusion, *i.e.* tension, must be avoided at all costs, because it interferes with healthy circulation in, and absorption by, the synovial membrane, and these are essential to successful combatting of any infection which may have been overlooked.

(10) The injection of ether, formalin-glycerine, or hypertonic (5 per cent.) saline solution into closed joints, is of doubtful value. They all are irritants. Success is claimed for all three, although their actions are different. The common factor in their application is preliminary aspiration of the joint. This removal of tension, along with the stimulation of the circulation, is possibly the explanation of their apparently beneficial action. The injection of or washing out by a non-poisonous, non-irritating antiseptic like flavine, whose antiseptic action is said to be enhanced by mixture of the substance with body fluids, may be of value in many cases, and has been frequently

used with no apparent detriment. The joint is completely closed thereafter.

(11) In cases where drainage of the suprapatellar pouch is made, vertical suspension of the limb in the way recommended by Colonel Sir A. W. Mayo Robson has been found of mueh value. The position makes the pouch the most dependent part of the joint, and on that account some are inelined to adopt the method as a routine in early eases which require drainage.

(12) The paramount importance of obtaining X-ray skiagrams has already been indicated.

Hæmarthrosis with Small External Wound. — One other type of injury, that which produces hæmarthrosis in presence of small through and through wounds, and where only slight damage to soft tissues or bone is present, may be discussed. If the effusion cannot be aspirated, owing to the fact that firm elotting has occurred, best results will be obtained by deliberately opening the joint, by free ineision on one or both sides, washing out the clot with sterile salt or flavine solution, and stitching up again without drainage. If the wounds are very small, one need do no more than sterilize them superficially, unless they come in the line of the fresh incisions, when they should be completely excised. Such a blood-clot, after a few days, forms excellent pabulum for the growth of organisms, and, even though it does not beeome infected, it is often the cause of much distress and disability in later stages, owing to formation of intra-artieular adhesions. Offieers at Base hospitals in France appreciate the disastrous results of insidious infection in such cases. Hospitals in England have beds occupied unnecessarily long even by non-infected cases, because, owing to the adhesions, they require skilled massage and so forth. Arthrotomy, in this type, must not be undertaken lightly. Technique must be perfect, else dreadful disaster is incurred.

Retention of Cases after Operation.—Operated cases should be retained for at least twenty-four to forty-eight hours. If the joint looks quiet and the general condition is good, many can be evacuated with safety at the end of that period, but in doubtful or more serious cases evacuation should be postponed, if possible, till all danger from sepsis has passed. Firm compression, under a very thick layer of cotton wool and fixation in the "Thomas's splint outfit," should be employed in the early stages. The knee should be slightly flexed. A pad of wool in the popliteal space, tapering to each end, tends to prevent inflammation spreading from the back of the joint.

While the "ham" splint of the outfit is best for transport, and for cases in which the wounds are in front of the joint, yet if there is a large wound on the posterior aspect, the thigh and leg should be suspended on separate slings of perforated zinc, well padded and covered with jaconet, so that access to the wound is provided without running risk of moving the joint.

Gentle movement, to a few degrees at first, should be begun as soon as one is certain that the parts are healing aseptically. If no reaction occurs, active movements should be stimulated and increased from day to day—very carefully in un-nailed fracture cases. Splints may usually be left off as soon as passive movement is begun.

Sepsis.—If sepsis develops, all wounds should be opened up freely, possibly bilateral openings should be made, and the synovial cavity treated by intermittent flushing with Dakin's, flavine, or other suitable solution; or else, as the Belgians have recommended, active movements, as free as the patients can be tempted to make, should be encouraged. This treatment, apparently, requires great fortitude on the part of both patients and attendants. If improvement does not occur within twenty-four to forty-eight hours, a transverse or flap incision should be made, followed by resection; or, after free division of the lateral and cruciate ligaments, by packing and fixing the joint in nearly full flexion in a specially made splint. If the articular surfaces of the bone have been injured, the former method is preferable. A salt or paraffin pack is preferable at first to Carrel-Dakin's dressings. In many cases amputation is compulsory.

In conclusion, attention must again be directed to the importance of rigid technique, and the necessity for thorough and complete operation. Half measures are worse than useless. "All or nothing" is a sound watchword. If the fulfilment of these principles is not possible, far rather fix the limbs properly and send all patients on for treatment at the Base.

Special Remarks about Other Joints

The Question of Primary Resection.—The removal of shattered and soiled bone may be so extensive that a "flail" limb seems unavoidable, but the success of modern orthopædics is so great that amputation is unjustifiable merely on that account.

On the other hand, the provision of efficient drainage is essential to save life in many cases. If the main vessels and nerves of a limb are intact, one must, therefore, remove on the one hand as much bone as will procure safety to the patient, and on the other hand as little as possible to avoid a flail joint, and at the same time provide efficient drainage. These problems are, apparently, of least importance in the hip and shoulder, and of most importance in the elbow and knee. One must remember further, that the results of late excision, for ankylosis, are more favourable so far as useful joints are concerned than those of early excision. It is, however, unfair to compare the two, because of the variability in severity of the original injury and the problems which have therefore to be faced. At casualty clearing stations the endeavour must always be to save life, limb, or function, in the order named, but the limb or the function must frequently be sacrificed in the attempt to save the life or the limb.

Shoulder Joint.—If the articular surfaces are shattered, limited excision with free drainage, preferably posterior, should be carried out. Amputation is not often necessary. If ankylosis is likely to result from the injury, and if the patient, for any reason, must be kept in the casualty clearing station, the arm should be fixed in the abducted position from the first.

In the "position of choice," the humerus is placed so that its axis makes an angle of 70° with the vertebral border of the scapula, and the patient can touch the skin over the middle of the clavicle of the opposite side.

Elbow Joint.—Limited excision is advisable in all severe cases when the bones are shattered but when movements of the hand are preserved. Those cases in which one or other of the bones remain intact are the most favourable. Incisions are planned according to the position of the wounds. In many cases it is possible to leave the epicondyles of the humerus, so that the muscular attachments thereto are left intact.

Wrist Joint.—Excision of the shattered carpal or adjacent bones is frequently advisable. Very free drainage must be provided. Under recent treatment amputation is rendered less frequently necessary. In all cases it is preferable to place the forearm and hand in a splint, which holds the hand in slight dorsiflexion. If ankylosis at the wrist occurs in this position, the functions and power of the hand and fingers are better preserved than they are in any other.

Hip Joint.—In addition to routine wound treatment, free posterior drainage, with fixation in a suitable abduction frame, is sufficient in most cases. Excision is frequently, and amputation only rarely, advisable. A rapid cleansing operation may be all that is feasible in such cases.

Ankle Joint and Tarsal Joints.—If the injury is severe, or if the infection is not likely to yield to free incision, resection and drainage, amputation should be performed without hesitation. The safety, assured by the removal of the infected limb, and the art of the artificial limb maker compensate, in great measure, for the loss of the foot.

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POSTSCRIPT

It has no doubt been appreciated that the methods of treatment of varying types of wounds recommended in this book are based on definite principles, and that the greatest principle of all is that of wisely assisting Nature in her attempts to cure. The principles and the methods of applying them must vary in the different stages of treatment, according to the amount, character, and virulence of the opposition to Nature's efforts. If a principle can be applied with success in the treatment of all types of wounds at the same stage, one is assured that the principle is correct. From the basis thus established, further progress can be made.

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