**A field surgery pocket book : memoranda mainly based on experience in the present war / prepared under the direction of the Director General of Army Medical Services.**

### Contributors

Great Britain. Army Medical Services.

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G.B. ARMY MEDICAL SERVICES.

# A field surgery pocket book

London: War Office, 1944

# CONTENTS

# GLOSSARY

## I. OFFICIAL ABBREVIATIONS

| | |
|---|---|
| R.A.P. | Regimental Aid Post. |
| A.D.S. | Advanced Dressing Station. |
| C.C.P. | Casualty Collecting Post. |
| C.C.S. | Casualty Clearing Station. |
| F.D.S. | Field Dressing Station. |
| F.S.U. | Field Surgical Unit. |
| Gen. Hosp. | General Hospital. |
| M.A.C. | Motor Ambulance Convoy. |
| M.D.S. | Main Dressing Station. |
| M.T. (Malaria) | Malignant Tertian (Malaria). |
| W.W.C.P. | Walking Wounded Collecting Post. |
| A.E.C. | Army Education Corps. |
| F.M.C. | Field Medical Card. |

## II. SOME DEFINITIONS OF TERMS

**Team.**

Two or more individuals grouped and working and training together for a specific object. The term does not necessarily imply that they possess the requisite equipment.

*Surgical Team.* A team concentrating on surgery, generally with a surgeon in charge. A unit of the surgical service in the field should be in possession of the requisite equipment at all times but may be detailed to proceed without this to work at a surgical centre, there to share the equipment belonging to a similar team.

**Unit.**

A self contained group of individuals with an authorised W.E. to which an individual may be legally posted. Normally fully equipped in accordance with the purpose for which it was authorised. Generally independent and self-accounting. In the case of some smaller medical units, however, (F.S.U., F.T.U., M-F.U., N-S.U.) is always attached to a parent unit for pay, discipline, rations, etc.

**Mobile.**

Capable of being moved and possessing its own transport. Some units or teams are only partly mobile.

*Motorised.* Possessing motor vehicles temporarily or permanently.

*Moveable.* Possessing no transport but is capable of being moved, i.e. transportable.

**Surgical Centre.**

A locality where a unit or group of units is situated, staffed and equipped not only for major surgery but for holding and nursing patients.

*Special Surgical Centre.* A centre staffed and equipped for treating a special type of case and where such cases are segregated.

**Forward or Advance.**

Not at the base: terms often loosely used; merely serve to indicate position relative to the rear or "base" and in a direction towards "the front."

# FIELD SURGERY POCKET BOOK

## INTRODUCTION

### (by the Consulting Surgeon to the Army)

1. This Pocket Book should be regarded as a directive on Surgery in the Field. It is in no sense of the word a treatise on what is commonly called "Military Surgery." Its aim is to raise the standard of surgery in the Field to the highest possible level by directing the efforts of Army surgeons into certain channels and by stimulating their interest. To this end it indicates and recommends the lines on which they should work when dealing with casualties. The advice proffered and the methods described in the various sections are those which the Army Surgical Consultants and other experts who advise the War Office consider most likely to produce the best results in the light of our present knowledge and experience. Moreover, because the views and opinions of the surgeons who have been engaged in doing this work in the Field have been incorporated, this Pocket Book may be regarded as reflecting the views of Army surgeons and recording the trend of Field Surgery in the British Army in 1944.

**2. The Place of Surgery in a Medical Organization for a Field Force.**

There can be no two views on the importance of surgery in the Field, particularly that which is done in the "forward areas." None will deny that surgery alone can save the lives or limbs of many wounded men, nor that these primary operations, if performed early, constitute one of the most potent factors, not only in maintaining an Army up to strength, but in keeping up fighting morale. Wounds promptly and properly treated heal the quicker and leave a minimum of residual disability. It is, therefore, a matter of National as well as Military importance that this surgery should be as effective as we can make it. There is no place here for the inexperienced surgeon. The work is difficult, often extensive, and calls for the finest judgment. It entails severe physical and mental strain, and during a "rush" period the strength of any surgeon who is not young or physically fit enough to stand up to it will be severely taxed. We know that often a surgeon with considerable experience of civil or "blitz" surgery, working for the first time under Field conditions, is liable to make costly mistakes. Under these circumstances, which are at first entirely new and strange to him, he may be prone to forget even basic surgical principles. What is more, by adhering too closely to an individual technique which had always been found to work well enough in civil practice, he may jeopardize the patient's chances. He may forget, in the first place, that the conditions are completely different, and secondly, that the case cannot remain under his personal care but must be evacuated at once to become the patient of another doctor who may neither understand nor appreciate the method or the lines on which he was working. Herein lies the argument for as much simplicity and standardization in method as is practicable. There are times, of course, when circumstances, or the military situation, may demand the adoption of a much modified technique.

When a surgeon joins the Army he will find that his equipment includes everything that is really necessary, but he will have to accustom himself

to working with the minimum of essential items. Simplicity of design, general practicability and standardization are essential in the interests of supply. It is a matter of common knowledge that the greater the experience of the surgeon in this type of work, the fewer items of equipment he will tend to require. He soon learns not to miss his own pet gadgets, or those which a respected chief taught him to like. He will find that he will get along quite well at any centre and in an emergency can often improvise useful things: an art highly developed by our Colonial and Russian colleagues.

### 3. Organization of the "Surgical Service" in the Field.

The reader is referred to R.A.M.C. Training Pamphlet No. 2 (1943), in which the present Field organization of the Medical Services is described.

The main function of the medical units during battle periods is to relieve the combatant formations of the encumbrance of non-effectives by clearing them from the battle area. All sick or wounded who are unlikely to respond within twenty-four or forty-eight hours to rest, or such treatment as is available in the Divisional or Corps Areas, must be evacuated as soon as possible. With regard to men actually wounded or otherwise injured, this organization from the advanced medical post, right back through the various stages along the Lines of Communication to the Base, fails or succeeds according to the adequacy of the surgical service that it provides. When planning to deal with casualties we no longer think in terms of individual surgeons, but of available surgical teams. The team, not the surgeon, is the unit of this service, so that the surgical potential of any centre will depend primarily on the number of teams working there. The centre output—the "patient-hour turnover" will be greatly influenced by the way in which the centre is organized. Unless this is good and unless reliefs are arranged both for the surgeons and for the members of the teams, the work will not only be slowed up, but will tend to deteriorate, either from sheer fatigue or staleness.

### 4. How Far Forward should a Surgical Centre be Placed?

This question can be answered only by the staff, the decision under any particular set of circumstances must be left to them. The opinion of the Consulting Surgeon to the Force is often very valuable, because he makes it his business to ascertain or to see for himself the condition of the wounded as they arrive at the various centres. When the fighting is straggling and mobile columns are skirmishing over tracts of flat country or desert, multiple mobile centres may be the only answer; but small scattered centres are difficult to control, to service, or to clear. From the administrative point of view the fewer the centres the better. A large medical unit makes a good centre because accommodation and nursing are good and the equipment is on a more lavish scale. A centre at a C.C.S., for instance, will have the advantage of electric light throughout, X-ray service, sterilizing facilities, etc., and here, under most circumstances, skilled nursing is provided by the officers Q.A.I.M.N.S. Grouped C.C.Ss. make a very efficient centre, each one receives up to a hundred cases (all types) and then the intake is switched to its neighbour. Unfortunately, such a grouping is not always practicable. These larger units are conspicuous and it may not be possible to site them sufficiently far forward to prevent the time lag of the wounds rising beyond the accepted limits of surgical safety. And again, it must be remembered that the C.C.S. has

another function to perform, that of dealing with the lighter wounds. Surgery is just as important for these cases, and indeed from the point of view of saving man-power, even more so.

**5. Some Factors which have influenced the Medical Organization and Surgery in the Field.**

All doctors who served in the Army during the last war and any surgeon who has studied the official Medical History will appreciate how certain factors influenced both the medical arrangements and the surgical technique as the war progressed. Some of these stand out like milestones on the road of progress.

It will be remembered how the introduction of the motor ambulance which replaced the old horse-drawn wagon not only speeded up the transport of wounded, but added greatly to their comfort during the journey.

Again, the wholesale adoption of the Thomas leg splint effected a reduction in the early mortality from serious wounds of the lower limb by approximately 50 per cent. Before this splint was used, large numbers of these cases died before they reached the table, or were moribund from shock or haemorrhage on arrival at a surgical centre.

It was not until the extent of the trauma produced by fragments of H.E. shell, etc., and the seriousness of secondary infection which invariably followed, was recognized, that excision of wounds became the order of the day. There followed an increased demand for surgeons and surgical facilities. In spite of this obvious first line of attack against the infection, it was some time before it was agreed that antiseptics played but a secondary part : many and varied were the types of local antiseptics advocated.

The static nature of the trench warfare in France and Belgium enabled large centres to be formed close up to the front. During a battle it was not uncommon to see eight surgical teams working by day and five by night, all at the same centre.

Blood transfusion was in its infancy, although whole or citrated blood was used considerably in the last eighteen months.

The segregation of special cases at centres was very limited.

1939–1944.

In the same way in this war there have been factors which have tended to mould surgical arrangements and modify surgical methods. The effects of mechanization are seen in the increased mobility in medical units. The medical service as a whole is more flexible, surgical teams are more self contained and because of the transport provided, enjoy a freedom of movement which they never possessed hitherto. But mechanical transport, although it tends to quicken the tempo in the forward areas, does not necessarily produce the same effect behind the front. Indeed, in the back areas because of the masses of transport on roads and tracks, both evacuation and inter-communication may even be slowed down.

The ever present possibility of deliberate or misdirected air attack has taught doctors to dig. Concern for their patients, as well as the team demands that precautions be taken.

"*Specialism.*"

The tendency to specialize, which is now international in medicine has exerted a marked influence. Specialists have to be catered for, but this is by no means always easy. The detailed arrangements which are necessary are apt to embarrass the staff. Although some general surgeons

express the view that it has been overdone, a patient who really requires that extra skill and attention which only special training and special equipment can provide, is most certainly entitled to expect it. The practical answer to the problem is to segregate such patients at a specially staffed and equipped centre. In spite of some opposition the specialist organization has developed, is now accepted, and the results clearly prove the wisdom of the policy. The effect on dependants and relatives at home must not be overlooked. It is an essential element of this policy that the specialists instruct and broadcast all information likely to be of benefit to the general surgeons. Head, chest and maxillo-facial injuries are dealt with mainly by mobile teams or units and at the base there are special centres for orthopaedic injuries.

Plaster of Paris is employed so extensively as a medium for splinting damaged limbs, etc., that it is common to hear this referred to as a " plaster war." P.O.P. is not without danger in the hands of those who are not practised in plaster technique or where the potential dangers associated with post traumatic oedema and superadded sepsis are not appreciated. Closed plasters undoubtedly save many harrowing dressings.

If this is a " plaster war " from the doctors' point of view, it is a " petrol war " from the combatants'. The section on burns refers to the considerable numbers which have occurred.

Air evacuation has been used for the first time to any extent. Many thousands of cases have been speedily and comfortably transported by air.

The resuscitation service has developed and expanded very considerably. There are few situations where the patient who requires it cannot get reconstituted plasma, if not whole blood. This service, together with increased knowledge of blood transfusion technique and clearer understanding of the problems of shock and blood loss, has saved many lives and given many a patient his one chance of withstanding an essential and life-saving operation.

In the anaesthetic field, pentothal sodium has established itself as a quick, pleasant, and relatively safe drug. It is devoid of serious after effects and has saved surgeons much time. The " Oxford " Ether Vaporizer is also popular.

*Sulphonamides and Penicillin.*

Both these substances have exerted their influence on wound surgery. Of the " three enemies " of the wounded man, shock, haemorrhage and sepsis, the last is still the most insidious killer. Sulphonamides have been extensively used since supplies became available. How much the local application of sulphanilamide powder to wounds has contributed to the attack on wound infection, cannot be answered with any degree of certainty. Several attempts have been made to organize large scale control investigations designed to provide some evidence on this point. For various reasons, which cannot be disclosed here, it was not found possible to carry them through. All that can be said is that there is a general belief that the powder applied to a wound after an adequate excision, does appear to reduce wound toxaemia and to limit bacterial growth without effecting any material alteration in the types of bacteria commonly found in these wounds. There is enough evidence to indicate that when the drug is given in adequate doses by mouth, the onset of cellulitis, particularly the streptococcal type, is considerably delayed. The sulphonamide drugs have a very limited effect on the anaerobes.

Penicillin, the latest arrival, is being subjected to an extensive trial in the Field under a special team of investigators appointed by the War Office, and much is expected of it.

# SECTION I

## CARE OF THE WOUNDED IN THE FORWARD AREA

1. The principle controlling the handling of the seriously wounded man in the forward zone is *rapid collection and evacuation to an appropriate surgical centre*. Such a centre may be an Advanced Dressing Station, Field Dressing Station or Casualty Clearing Station according to circumstances and the location of field surgical units.

2. It is essential to aim at rapidity in this process, but each Medical Officer dealing with a case should endeavour to ensure that the wounded man reaches the next stage on his journey back in a better condition than when he was received, so far as is possible.

3. Wounded are collected from the field of battle and carried to their Regimental Aid Post. From there, after adequate first aid has been rendered, they are transferred to the Casualty Collecting Post. From the Collecting Post they are taken by ambulance to an Advanced Dressing Station and here are grouped according to their need for either (1) resuscitation, (2) immediate operation, or (3) later operation, and sent respectively to a Field Dressing Station, an advanced Surgical Centre, or direct to a Casualty Clearing Station.

### AT THE REGIMENTAL AID POST

4. Medical officers should always bear in mind that their R.A.P. is surgically dirty, and therefore, that it is not possible or advisable for treatment of a more elaborate nature than essential first aid to be carried out. Bleeding is stopped, splints are applied, etc. Rarely, a limb hanging by a little tissue may be amputated. The administration of morphia, sulphonamides, or the application of a tourniquet must be noted clearly on Army Form W.3118 which must be made out here and also by an " M " or " T " marked on the patient's forehead with a grease pencil. Medical Officers must write clearly on the A.F. W.3118 and print their names plainly on it. However, the nature of the military situation at the time will have an important bearing on individual procedure.

5. Every endeavour should be made to make the wounded man as comfortable as possible. Bleeding having been stopped, and adequate splintage applied, the next thing is to see he is warm and as cheerful as possible, and has had hot sweetened drink and food if he can take them.

6. Every minor casualty does not require evacuation. Some only need the application of a dressing, the injection of A.T. Serum and a meal, after which they are returned to their unit for duty or to a Rest Station.

7. It is seldom that the use of a tourniquet can be justified, and its application should be limited to the occasions on which local pressure is not adequate to control bleeding.

The fact that one has been used MUST be recorded on the A.F. W.3118 and on the forehead. Evidence is accumulating that a tourniquet once applied should not be released. The release of pressure may allow bleeding

to recur, further weakening the patient and it also permits of the absorption into the circulation of toxic breakdown products from damaged tissue. This lowers the blood pressure and aggravates shock.

8. It is not safe or advisable to attempt intravenous therapy at an R.A.P.

9. All A.F.Vs. carry first aid outfits including "tubunics" for the administration of morphia, and "craquettes" containing chloroform. The teaching of first aid is even more important to these A.F.V. crews than to the Infantryman, and any equipment expended should be promptly replaced.

**Burns.**

10. As a first aid application a 5 per cent. solution of bicarbonate of soda is useful, and in an emergency, gauze soaked in this solution may be applied to the burnt surface even without cleansing. Better results are often obtained from gauze soaked in liquid paraffin, or from a sulphonamide-vaseline gauze. The use of Tannafax has been condemned and it should never be applied to face or flexures. Sulphonamide paste is now supplied to forward units.

11. Burns of the face are best treated by face masks of vaseline on lint, with vaseline applied especially round the nose and eyelids. (*See* page 158.)

12. Extensive burns of the extremities, like tissue lacerations are made far more comfortable, and travel better, when immobilised by splinting.

**Fractures.**

13. Thomas splints, Kramers wire, and Gooch splinting are available. It should be remembered that the application of a splint, however good the method, does not guarantee immobilisation indefinitely, and may be followed by swelling, and the need for inspection *en route* is therefore stressed.

**Chest Wounds.**

14. When "open" their closure is a matter of urgency. This is effected by an adequate dressing retained by tight bandaging, or overlapped strapping. Such wounds should not be sutured.

**Abdominal Wounds.**

15. The administration of an adequate dose of morphia, and rapid evacuation, is all that is usually possible. If there is prolapse of the omentum or gut, this should not be reduced but protected by an adequate moist dressing. Morphia should not be given unless the diagnosis of perforated gut is quite clear.

**Medical Conditions.**

16. As distinct from battle casualties, most cases of disease, however trivial, have to be evacuated.

## CASUALTY COLLECTING POST

17. Casualties are cleared from a Casualty Collecting Post by motor ambulance, though frequently motor ambulances may clear direct from the Regimental Aid Post, in which case the C.C.P. may be short-circuited. The C.C.P. should be cleared promptly to the A.D.S. or C.C.S., for it is

only in a very few selected and urgent cases that transfusions will be carried out at this stage.

## ADVANCED DRESSING STATION

18. This is the unit in which Triage is first undertaken. Triage means that the casualty is checked in, his particulars recorded and the diagnosis made, the casualty labelled, if this has not already been done, such immediate treatment as may be essential is given, and sorting into one of three groups is effected preparatory to evacuation.

These three groups are :—

*Group* 1.—Those which require urgent resuscitation, and are not to be transferred to an advanced Surgical Centre, or a Casualty Clearing Station, before they have received such treatment. They are sent to a Field Dressing Station opened as a resuscitation centre. Later, at the F.D.S., they will become re-grouped according to whether surgical treatment is imperative or whether any further treatment is unlikely to be required before arrival at a Casualty Clearing Station.

Wounded in this group should not be transferred unless they can be operated on on arrival or unless arrangements can be made for the transfusion to be continued during the journey. Ideally, therefore, the Resuscitation Centre should be at the advanced Surgical Centre.

*Group* 2.—Are severe wounds and cases requiring urgent or early surgery. This group is sent to the advanced Surgical Centre.

*Group* 3.—Includes all other cases, including the urgent surgical cases not included in Group 2—the non-urgent, lying, the sitting case, and walking wounded, the sick and the gassed, etc. Group 3 therefore contains by far the larger number of wounded and sick, and they should be evacuated to a C.C.S.

Note that the apparently moribund form another category. These should be segregated and not evacuated, nor should the dead.

Triage is an important function and should be in the hands of a capable and experienced officer. He should remember that an advanced Surgical Centre can deal only with a limited number of casualties in any one day, and so considerable discrimination may be required in the proper grouping of urgent surgical cases. One surgeon cannot deal with more than fifteen cases in twenty-four hours.

## MORPHIA

Morphia should not be given as a routine to all battle casualties. When pain or anxiety indicate its use, as a general rule, ½ gr. may be given by the first M.O. to see the case, the time and dose being noted on the F.M.C.

The intra muscular route assures more certain and rapid absorption than the subcutaneous.

Repetition of the dose at short intervals is dangerous and instances of poisoning have been observed in the field and elsewhere from the administration of multiple doses.

*Wounds of the abdomen* should not be given morphia unless the diagnosis of perforated gut is quite clear.

*Wounds of the chest* may be given the full dose advised above.

*Wounds of the head.* Small doses (⅛ gr.) may be used to allay restlessness. A large dose raises the intracranial venous pressure, and increases the liability to haemorrhage.

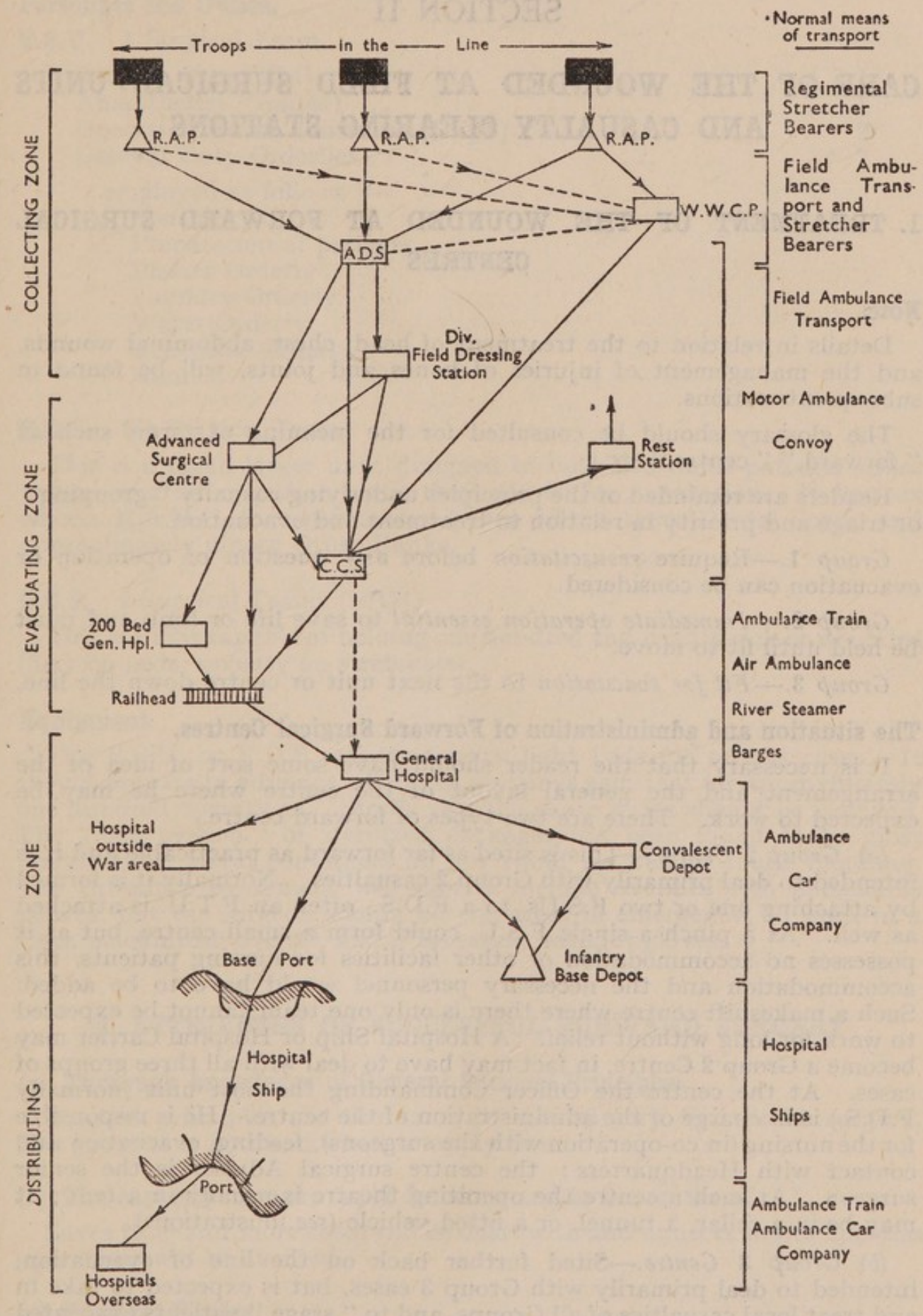



FIG. 1

Diagram to show chain of evacuation.

# SECTION II

# CARE OF THE WOUNDED AT FIELD SURGICAL UNITS AND CASUALTY CLEARING STATIONS

## 1. TREATMENT OF THE WOUNDED AT FORWARD SURGICAL CENTRES

**Note.**

Details in relation to the treatment of head, chest, abdominal wounds, and the management of injuries of bones and joints, will be found in subsequent sections.

The glossary should be consulted for the meaning of terms such as " forward," " centre," etc.

Readers are reminded of the principles underlying casualty " grouping " or triage and priority in relation to treatment and evacuation.

*Group* 1.—Require *resuscitation* before any question of operation or evacuation can be considered.

*Group* 2.—*Immediate operation essential* to save life or limb and must be held until fit to move.

*Group* 3.—*Fit for evacuation* to the next unit or centre down the line.

**The situation and administration of Forward Surgical Centres.**

It is necessary that the reader should have some sort of idea of the arrangement and the general layout of the centre where he may be expected to work. There are two types of forward centre.

(*a*) *Group* 2 *Centre*.—This is sited as far forward as practicable and it is intended to deal primarily with Group 2 casualties. Normally it is formed by attaching one or two F.S.Us. to a F.D.S., often an F.T.U. is attached as well. At a pinch a single F.S.U. could form a small centre, but as it possesses no accommodation or other facilities for nursing patients, this accommodation and the necessary personnel would have to be added. Such a makeshift centre where there is only one team cannot be expected to work for long without relief. A Hospital Ship or Hospital Carrier may become a Group 2 Centre, in fact may have to deal with all three groups of cases. At the centre the Officer Commanding the host unit (normally F.D.S.) is in charge of the administration of the centre. He is responsible for the nursing (in co-operation with the surgeons), feeding, evacuation and contact with Headquarters : the centre surgical Adviser is the senior surgeon. At such a centre the operating theatre is usually in a tent ; it may be in a cellar, a tunnel, or a fitted vehicle (*see* illustrations).

(*b*) *Group* 3 *Centre*.—Sited further back on the line of evacuation, intended to deal primarily with Group 3 cases, but is expected to take in and treat local casualties of all Groups, and to " stage " patients evacuated from the advanced centres. A Group 3 Centre is sited normally at a C.C.S. which is reinforced as occasion demands by attaching F.S.Us.

**Personnel and Duties.**

**F.S.U.** 1 Surgical Team.

| | |
|---|---|
| Surgeon (Specialist) .. .. .. .. .. .. | 1 |
| Anaesthetist (Graded) .. .. .. .. .. .. | 1 |
| Operating Room Assistants (1 Cpl.) .. .. .. .. | 2 |
| General Duty Orderlies .. .. .. .. .. .. | 7 |

employed as follows :—
Sterilizer
Preparation of patients
Plaster Orderly
Laundry Orderly
Water Orderly
Generator Orderly
Runner.

**F.D.S.** No Surgical Team.

This is a much larger unit, designed to hold and nurse patients either before or after operation until they are fit for evacuation. It has six officers R.A.M.C. (two non-medical), one officer Army Dental Corps, and approximately ninety Other Ranks.

**C.C.S.** 2 Surgical Teams (1942).

This is a unit capable of holding one hundred and twenty sick or wounded (fifty on beds, seventy on stretchers).

**Equipment.**

The F.S.U. or F.D.S. carries twenty light beds for serious cases. It should prepare in advance, stocks of dressings sufficient for approximately one hundred operations. Sterile vaseline gauze strips should be included. The "bag system" of sterilized packages has been found to be most practicable. Metal containers do not stand up well to rough handling. The Ordnance equipment will shortly include overalls with detachable sleeves, but the surgeon should be prepared, in emergency, to work in a clean mackintosh overall, and if necessary without gloves.

## 2. ATTRIBUTES OF SUCCESSFUL FORWARD SURGERY

(*a*) **Thorough knowledge of General Surgical Principles.**

Surgical principles are the same in war surgery as in civil surgery. The problem is how and when to apply them.

(*b*) **The capacity to make rapid decisions and to act on them.**

Saves time and more cases will be dealt with and unnecessary or hopeless operations will be avoided.

(*c*) **Physical Fitness.**

Keep fit and get as much rest as possible. Stamina will be severely tested during times of stress.

## 3. WAR WOUNDS

**Missiles.**

| | |
|---|---|
| Mortar Bombs and H.E.* Shell fragments | 60% |
| Machine-Gun Bullets | 15% |
| Rifle Bullets | 10% |
| Others :— | |
| Land Mines, Grenades, Booby Traps, Anti-Tank Shell, Aerial Bombs | 15% |

*Wounds caused by High Explosive Shell fragments *should not be described as "Shrapnel wounds."* Shrapnel, a type of explosive shell, filled with round leaden pellets, is now seldom, if ever, used. The shell was named after a Royal Artillery officer of that name.

**Types of Wound.**

The types of wound met with are generally as follows :—

| | |
|---|---|
| Limb wounds, including fractures | 80% |
| Chest wounds | 8% to 10% |
| Abdominal wounds | 2% to 4% |
| Head wounds | 2% to 4% |
| Others | 2% to 8% |

Wounds are frequently multiple, requiring several operations on the same patient.

## 4. RECEPTION OF THE WOUNDED

The wounded may start to arrive late in the evening. Make sure that the lighting is functioning and be prepared to work all night if necessary. A certain amount of regrouping may be required and a priority list for the table started. Amendments can be made from time to time as worse cases arrive. The information on Field Medical Cards must be checked up. It is annoying to discover that essential information has been omitted when a patient is already anaesthetized. Do not waste energy by operating on patients who should be evacuated. Indeed, it may be less hazardous to evacuate a wounded man than to operate. Particularly is this the case if the patient's general condition is good and it is known that the journey to the next stage down the line of evacuation is relatively comfortable and will not take long. Bear in mind that the majority of the wounded have probably had an exhausting time and a very rough journey before they reach the centre. Most, if not all, will require rest, fluids and warmth. By " warmth " is not meant baking the patient until he begins to sweat. Heat so applied will do more harm than good.

**Regrouping at the Centre.**

1*st Priority* (operation necessary).

Abdominal cases, including severe perineal or buttock wounds
Open wounds of the thorax
Mangled limbs probably requiring amputation
Open fractures
Severe head wounds, burns, maxillo-facial wounds
Certain complicated eye wounds, etc.

*2nd Priority* (for operation if time permits, otherwise for evacuation or rest).

Less serious open fractures
Multiple minor wounds
Less serious amputations
Less serious burns
Some scalp wounds, etc.

*3rd Priority* (for evacuation).

The remainder.

*Do not rush cases to the table* unless (*a*) there is free or continuous bleeding, (*b*) the general condition is deteriorating from some obvious cause, i.e. mangled limb, penetrating wound of the abdomen, etc.

There is always one best time to operate, try to seize it, because once past it never returns. Transfusion should be started before operation in all exsanguinated patients and continue during and after it. Give fluids freely by mouth if possible, otherwise into a vein. Keep a check on the amount of morphia which has been given. Patients with a low blood pressure absorb slowly from the subcutaneous tissues. Such injections injudiciously repeated may lead to cumulative effects after some hours (coma and respiratory distress).

## 5. TREATMENT OF THE WOUND

The number of each type of case to be dealt with obviously depends on the situation of the unit. The further forward it is, the more 1st priority cases there will be. The average time taken for a 1st priority case is an hour. Any one team cannot be expected to deal with more than twelve to sixteen heavy cases in twenty-four hours, under best conditions. Wounds are frequently multiple and the average number of operations per case is two. After twenty-four hours continuous work organization tends to break down and judgment may become impaired from exhaustion. It will be necessary to take time off at regular intervals for hot drinks and food, or to have a look round the post-operation ward or renew a dressing.

A feature of the reports on the surgery of the forward areas during the last four years has been the tendency for certain technical mistakes to recur. Comments on the casualties after arrival at Base Hospitals after each battle have always contained references to these faults. Whether they are due to lack of experience or over-optimism on the part of surgeons, is of little practical significance. It is important, however, that all medical officers should be made aware of them.

## 6. THE GENERAL PRINCIPLES OF WOUND EXCISION AND SOME FAULTS

Every operation for wound toilet (débridement, " trimming," excision—call it what you will) should be performed with one or all of the following objects in view :—

(*a*) To remove, especially in early wounds, all tissue so damaged that it is already dead, or its blood supply rendered so precarious that it will fall an easy prey to bacterial invasion.

(*b*) To open up the wound for inspection of pockets and corners, to remove any accessible foreign body, dirt, etc., and to control bleeding ; to ligature any torn or damaged larger blood vessel.

(*c*) To relieve local tension by incising fascial compartments so as to permit the escape of blood clot and above all to design the operation in such a way that the wound will drain freely. Counter incision may be required.

Accomplish these three things, finish off by applying a simple sterile non-adhesive dressing, splint the part and you have done *all that is really necessary in the way of surgical operation for the majority of war wounds.* Any further treatment at this stage must be regarded merely as an adjunct. It will not be possible to carry out this complete wound toilet in more than a proportion of the cases. Indeed, it is neither necessary nor advisable in many of them. Unless the wound be so small that it can be excised *en bloc*, you cannot expect to sterilize it by using a scalpel alone, but if you have completed the operation as described above you will at least leave a wound with walls lined by tissues having a useful blood supply which will form an active barrier to bacterial invasion : a wound, in fact, into which it may be worth while to insufflate some sulphanilamide or penicillin powder. Neither of these adjuncts could be expected to exert a maximum or certain effect without the preceding operation. In certain localities where the blood supply is free, for instance the face, genitalia, etc., excision is contra-indicated and not necessary. Through and through wounds with a small entry and exit, and without bone damage, may usually be left alone ; but if there is any local tension, the skin and deep fascia should be freely incised. Cases will frequently be seen with literally dozens of small wounds, involving almost every part of the body ; complete excision is obviously out of the question : excise the most severe, incise others, slitting the deep fascia, and leave the small wounds. Judgment will be acquired fairly rapidly.

**Technique of Wound Excision** (taking as an example an average large wound of soft parts of eight to twelve hours duration).

Cleanse the surrounding skin, using soap and water (CTAB, Dettol, etc.), keeping a swab over the entrance or exit.

Remove either no skin at all, or restrict excision to the badly contused tags round the edge.

Enlarge the wound, by incising skin and superficial fascia in the long axis of the limb, if possible. In the first place enlarge only sufficiently to see the condition of the muscles at the mouth of the track. Err on the conservative side.

Incise the deep fascia freely. The extent to which this is done will depend on the length and depth of the wound and its locality. Err on the liberal side. This step is particularly necessary where there are deep pockets, bleeding which cannot be seen, a deep haematoma in a tense swollen limb, or where infection has obviously got a hold.

Remove as little of the undamaged (bleeding and contracting) muscle as possible, but on the other hand remove enough to make sure that the wound will drain.

Control haemorrhage. " Frost " the surface with sulphonamide. Pack *only* if there is worrying bleeding. (Note on Field Medical Card " *Wound Packed—Haemorrhage.*")

Protect the wound surfaces with vaseline gauze. Cover with sterile absorbent wool, and bandage.

## 7. RECORDS

*Write clear, concise notes on* A.F. W.3118. The case has to be assessed at each stage; inaccuracy and illegibility of these notes may mean the loss of a limb, even a life, especially if some essential information is lacking. The *surgeon should print his name in BLOCK CAPITALS and initial.* (A colleague further down the line may want to know further details later—or a series of similar cases may be followed-up.)

1. Missile (whether removed).
2. Time after wounding when operated on.
3. Resuscitation given.
4. Operative findings and technique (whether any main nerves were seen to be divided (where there are neurological signs) or whether the trunk appeared intact).
5. Antisera given.
6. Brief post-operative directions and WARNINGS.
   "Watch for gas gangrene."
   "Watch the foot—? amputation."
   "Watch joint, etc."

## 8. SOME DON'TS

Do not waste time searching for foreign bodies, except in vital situations, especially in the absence of X-rays.

Do not insert rubber drains or wicks (unless part of a special technique —Penicillin, etc.).

Do not PLUG the wound or track. It is no use designing an operation to drain a wound if you plug up the drainage system.

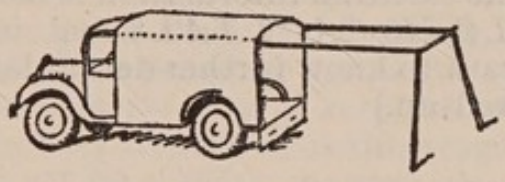
Do not suture the wound. (Exceptions—certain head wounds, abdominal wall, chest wounds, or where the local condition is so good that delayed primary suture is contemplated and the CASE IS TO REMAIN UNDER YOUR OWN CARE for at least seven days.)

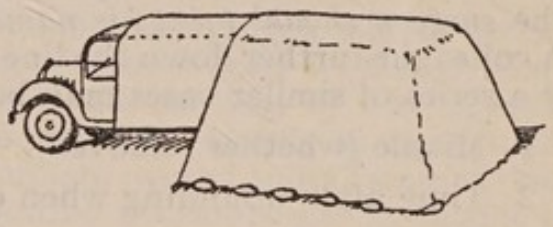
Do not apply circular strips of gauze or bandage under the absorbent wool of the dressing. Strapping used to prevent a dressing slipping should be applied in the long axis of the limb.

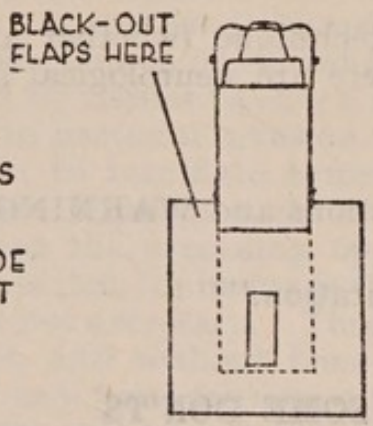
NOTE.—Figs. 2, 3 and 4 illustrate types of operating theatre lay-out which have been used either in the Western Desert or North Africa, and suggest how a theatre can be improvised in an emergency or laid out. They do not illustrate the latest official equipment (Ordnance) or transport.

This Pocket Book must not be quoted as authority for demands for Ordnance or medical equipment. The only authority for such demands are A.Fs. G.1098 and I.1248.

TYPES OF PENTHOUSE OPERATING CENTRE (WESTERN DESERT 1942)

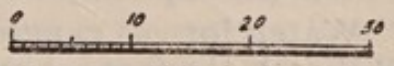




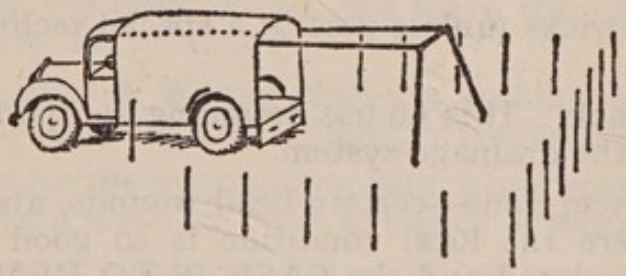


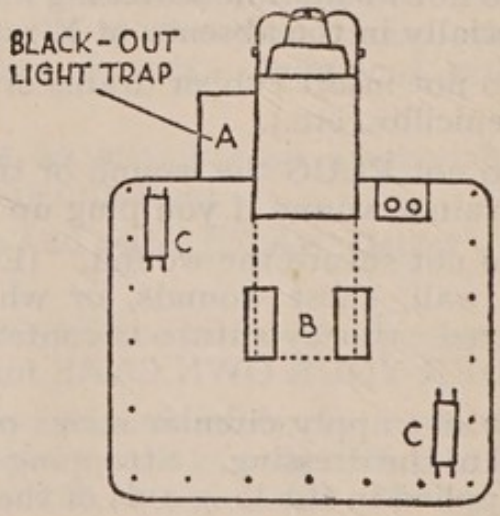

MAJOR BAMFORD'S PENTHOUSE

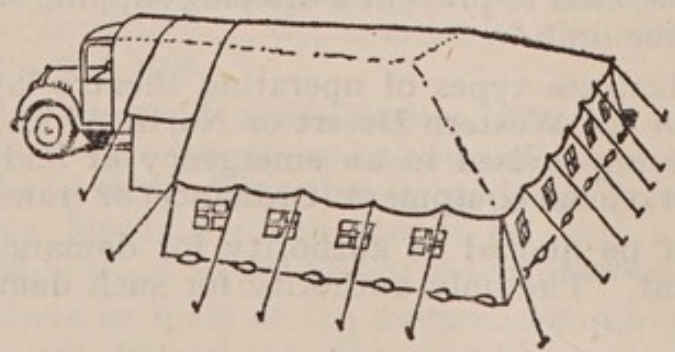
(THE SUPPORTS SLIDE FORWARD WITHOUT DETACHMENT)




ROUGH SCALE (FEET)





ABOVE ENLARGED BY EXTENDING 10 FEET ALL ROUND ON 6 FEET POLES

DIAGRAM SHOWS LIGHT TRAP (A), TWO TABLES (B), AND STRETCHERS WITH WAITING PATIENTS (C).

OPERATING PENTHOUSES

FIG. 2

## GENERAL LAY-OUT FOR AN OPERATING THEATRE USING MARQUEE G. S. DOUBLE

(MAJ. C GLEDHILL. R.A.M.C.)

THIS LAY-OUT IS ADAPTABLE FOR ALMOST ANY TYPE OF LOCATION

**STERILISING ANNEX:** AS FAR AS POSSIBLE THE USE OF PRIMUS STOVES SHOULD BE AVOIDED IN THE THEATRE AS THERE IS A REAL DANGER OF FIRE.
ALL PRIMUSES SHOULD HAVE METAL SHIELDS AND THE TABLE COVERED WITH A LIGHT METAL SUPERSTRUCTURE MADE TO FOLD FOR CARRYING IN THE TRUCKS.

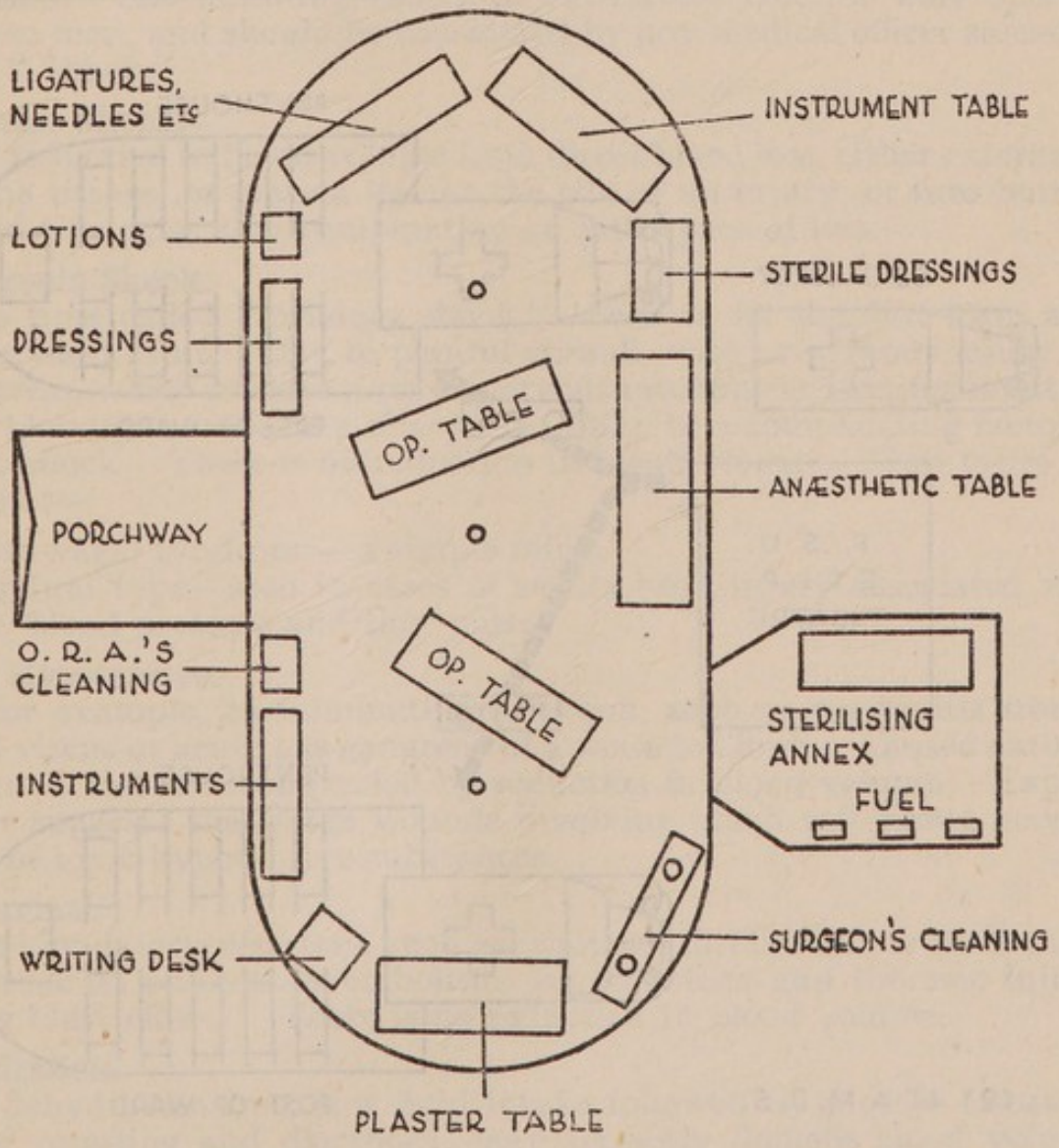



FIG. 3

(Maj. W. D. Hamilton, R.A.M.C.)

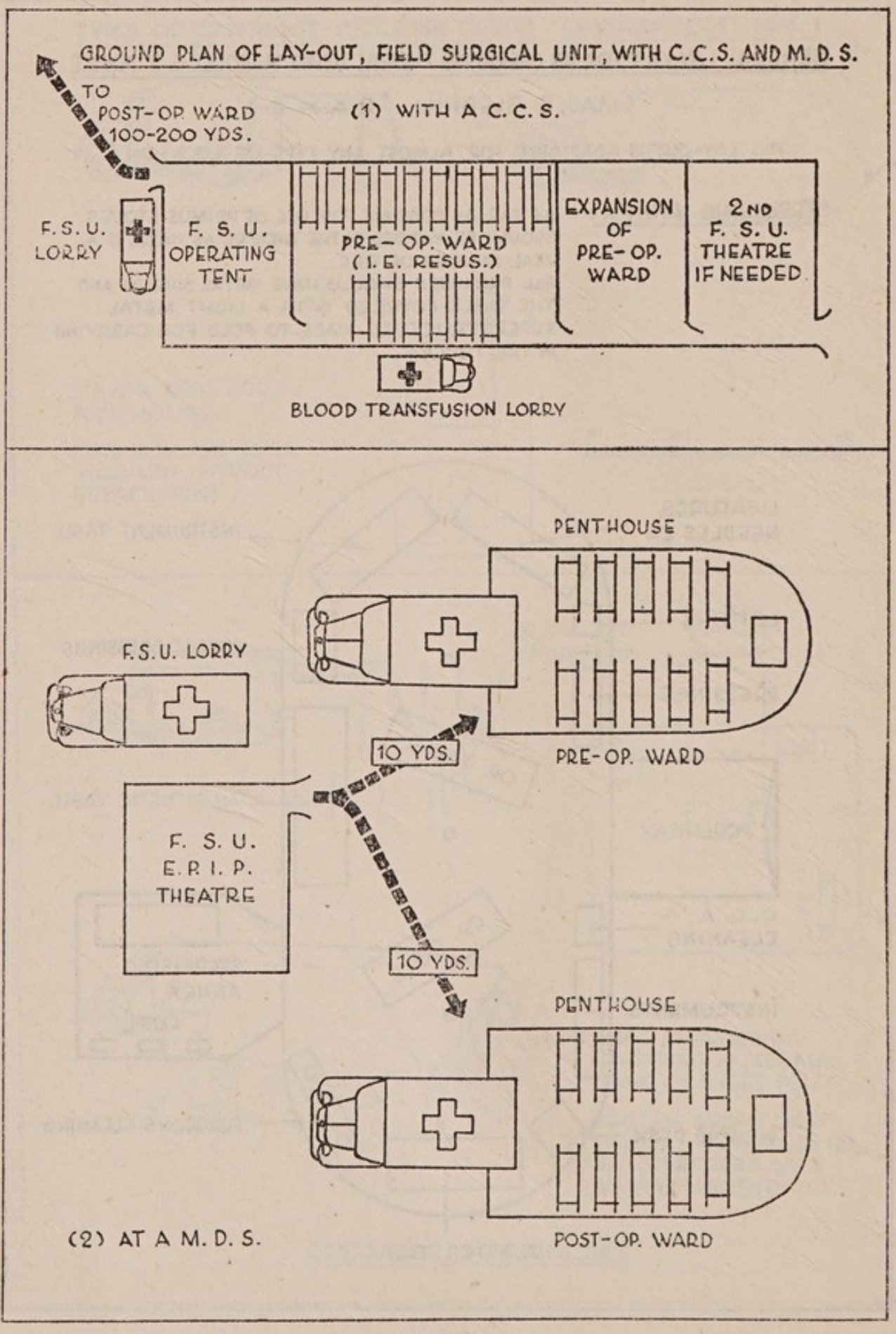



FIG. 4

# SECTION III

# WOUND SHOCK, RESUSCITATION AND TRANSFUSION

## WOUND SHOCK—DEFINITION

A state of lowered vitality following upon injury, manifesting itself by general and peripheral symptoms, due to circulatory embarrassment, which frequently progresses, to terminate in circulatory failure.

## CIRCULATORY COLLAPSE IN CASUALTIES—TYPES OF "SHOCK"

A considerable number of aetiological factors may be concerned in the production of the clinical picture, loosely and conveniently termed "Shock." Failure to appreciate this accounts for much of the controversy on the relative merits of different therapeutic measures employed in resuscitation. The following causes of circulatory collapse may operate in wounded men, and should be considered by any medical officer assessing a case of "Shock."

1. **Oligaemic Shock.**
Due to reduction in blood volume from direct blood loss, either externally or into the tissues, or plasma loss at the site of an injury, or into burned or crushed tissue, or, to a combination of both types of loss.

2. **Neurogenic Shock.**
At one time called "primary shock." Seen in its simplest form as a straightforward faint. Due to painful stimuli, with or without injury, or mental stress, which initiate a reflex nervous mechanism manifesting itself by a low blood pressure and a *slow pulse*. May be a complicating factor in oligaemic shock. There is no reduction in blood volume. Two types are recognized :—

(*a*) Vaso-vagal syndrome—a simple faint.
(*b*) Cerebral type—seen in cases of severe head injury associated with low blood pressure and slow pulse.

3. **Toxic Hypotensive.**
Due, for example, to fulminating infection, such as peritonitis from a ruptured viscus or acute gas gangrene of a wounded limb. Caused entirely by toxaemia and unaccompanied by reduction in blood volume. Experience now suggests that large wounds involving much soft tissue may be a source of toxic hypotensive substances.

4. **Mechanical.**
Due to circulatory disasters, such as coronary thrombosis, or mechanical factors, such as pulmonary embolism, fat embolism and thoracic injury, including blast effects. There is no reduction in blood volume.

5. **Dehydration.**
Gross dehydration from low fluid intake followed by profuse sweating, excessive vomiting and diarrhoea, may seriously deplete blood volume, and lead to a state the equivalent of oligaemic shock. Rare, but may be met with in tropical countries, especially as a factor contributing to oligaemic shock and hindering natural recovery.

**6. Carbon Monoxide Poisoning.**

Not uncommon under war conditions in casualties injured in a confined space to which escaping coal gas or explosive gases have access or in a burning building. Symptoms of shock arise from toxic myocardial changes and from pulmonary oedema.

Under war conditions, many of these types may be met with either singly or combined. By far the commonest is obviously the OLIGAEMIC type brought about by bodily injury, with subsequent blood and/or plasma loss. Additional toxic factors may be prominent with large wounds.

In defining the various types of " shock," stress has been laid on the occurrence or absence of blood volume reduction. This is because transfusion is rightly regarded as the most common single specific for the resuscitation of the majority of injured men, but only when the cause of all or part of the condition is a gross reduction in blood volume. Treatment of " shock " must be governed by cause because shock is not a specific condition for which there is a set routine treatment. Let the medical officer, therefore, catechise himself as to cause before he initiates treatment and when he is assessing the results. He will then hold the keys to success.

## CLINICAL PICTURE

(*a*) **Classical Case—Oligaemic Shock.**

A sequence of events follows acute blood volume reduction. The symptoms and the seriousness of the state are progressive and dependent on the amount of loss. Some hours are usually required for the full development of the unmistakable picture, but in others the onset may be quick and deterioration rapid. It is important to make an estimate of the phase which a case has reached as well as to realize that gross circulatory embarrassment, as shown by a falling blood pressure, is a late and serious phenomenon, which should be forestalled wherever possible.

The immediate reaction to acute and severe blood volume reduction is intense peripheral and visceral vasoconstriction, enabling the circulation to make the best use of such blood as remains. Thus the patient appears *intensely pale* and the periphery is *cold*. At the same time, by reflex action, through vagal and sympathetic centres, the *pulse becomes rapid*, *sweating* is marked and there may be a tendency to *vomit*. Consciousness of *pain* is very variable. The mental state, though sometimes *apathetic*, is more often deceptively *alert* and euphoric though sometimes tempered with apprehension or an ominous garrulity. Nature's first attempt at repair is to absorb tissue fluid into the circulation in an effort to restore blood volume ; this leads to a sensation of *thirst*. The natural process of repair takes many hours to be effective and in cases of severe blood loss cannot be accomplished quickly enough to prevent circulatory collapse. In these circumstances, a vicious circle then begins. There is loss of compensatory vasoconstriction (or constriction inadequate to compensate) leading to imperfect cardiac filling and inadequate cardiac output, manifested by a *falling blood pressure; peripheral cyanosis* and other early signs of circulatory failure which, unless treated, will soon lead to an irreversible state, and finally to death.

(*b*) **Variable Features.**

Neither the presence nor absence of the symptoms underlined above is an exact indication of the gravity of the condition. The falling blood pressure is always a definite and ominous sign, but individual capacity for

compensatory vasoconstriction is a variable feature; it may be intense and maintain the blood pressure for a time, only to collapse suddenly and precipitate a more serious state than if the deterioration had been gradual. Some, indeed, react to blood volume reduction by overcompensation, so that even in the presence of serious injury, the blood pressure may occasionally be deceptively high. Some react to blood loss with a slow pulse instead of a fast one, and this feature cannot be accepted as a reliable sign of the condition. Likewise, the peripheral manifestations of pallor, sweating, coldness and cyanosis may be variably exhibited.

Under war conditions, and especially with large wounds, features such as toxaemia from infection or damaged tissue may modify the picture of the classical case as well as the expected response to treatment.

## AGGRAVATING FACTORS

Serious symptoms of circulatory collapse may be hastened, aggravated or precipitated by fear, by fatigue, by exposure to cold, by pain, by movement, particularly painful movement of an injured part, by dehydration, by continuing or renewed blood loss, by infection, by too much morphine, and by an anaesthetic.

## ASSESSMENT AND SURVEY OF THE CASE

Ideally, the treatment of " shock " should " begin before its onset " for he who awaits the fully developed clinical picture with definite circulatory disturbance and the blood pressure at a dangerously low level, will have many disappointments. Late cases have frequently reached what is known as the irreversible state of which treatment is all too often unsuccessful or only temporarily effective. The good clinician should, therefore, recognize not only the definitely established condition, but also the prodromal features which may be expected to precede it, facts such as the types of the wound which are known to lead inevitably to it, features which may mask symptoms and signs, as well as aggravating and contributory factors. He should bear in mind that though oligaemia is the commonest cause of " shock " under war conditions, the other causes already described may nevertheless operate singly or in combination. *Assessment on common sense grounds according to the extent and severity of the injuries and the general condition of the patient is more important than any one particular sign or symptom.* Most information is given by the reaction to treatment. Serial observations as to general condition and such recordable features as pulse and blood pressure are the most informative. Cardinal points for the preliminary assessment are to determine whether it is possible to arrest haemorrhage, to immobilize an injured part and to relieve a mechanical factor such as a sucking wound of the chest. After this, the main decision is whether symptomatic treatment needs to be supplemented by more active treatment, such as transfusion, to the extent of the facilities available. When there is gross oligaemia the need is obvious, bearing in mind that a number of factors may intrude to reduce or nullify the expected effect (infra). The main object of the assessment is to ensure, as far as possible, that the patient reaches the surgeon in good condition for operation and this may require good judgment as to when to transfuse, when to evacuate, and whether to provide for transfusion during evacuation.

## ORGANIZATION FOR RESUSCITATION WORK

Prompt treatment saves many lives. Preparations should, therefore, be as complete as possible, so that there is no delay once a casualty has been received. Fixation of responsibility is desirable. The appointment of a resuscitation officer and the allotment of a trained staff is advisable in any unit where there are facilities for the more elaborate types of treatment. A high degree of co-operation and mutual confidence between the admitting officer, the resuscitation officer and the surgeon is essential if large numbers of wounded are to be completely and rapidly treated. A separate resuscitation ward is required for orderly and smooth work. This, wherever possible, should be sited near to both the admission point and the operating theatre and be furnished with its own supply of beds and trestles, as well as instruments and drugs (*vide* treatment). In smaller units, which operate in forward areas, a knowledge of what can be done to forestall serious deterioration should be universal, whilst the facilities for the symptomatic and conservative treatment of shock need to be provided.

## TREATMENT

The principles of treatment are to relieve symptoms, reduce or remove aggravating factors, and deal with the primary cause. This last in battle casualties will usually be oligaemia from blood loss. Hence, the most frequent single requirement for arresting the progressive deterioration in general condition is adequate and prompt restoration of blood volume, and thereby of tissue metabolism. Wherever possible, this must be preceded by or combined with control of haemorrhage, otherwise the improvement in condition can be no more than temporary or can only be maintained by transfusing at a rate greater than the rate of loss. Early operation is also an important factor favouring survival in cases with very large injuries.

Treatment may be conveniently divided into :—

(*a*) *Symptomatic and Conservative.*—Applicable to all wounded men no matter what form of circulatory collapse they are suffering from, and available for use under almost any working conditions.

(*b*) *Specific and Active.*—The treatment required for the complete relief of oligaemic shock which calls for bulky equipment, including facilities for transfusion, and which is best combined with provision for prompt surgical treatment and after care.

### Symptomatic and Conservative.

*General.*—Restoration of peace of mind by encouragement and reassurance is important and should be positively practised ; it assists in stabilizing nervous factors and in permitting manipulations associated with treatment. All movement must be gentle and reduced to the minimum. Orderlies need to develop the deliberate, purposeful, but gentle, technique of a good nurse. Movement of injured parts must be avoided. Immobilization is a primary duty at the first opportunity, and this should not be tampered with unnecessarily. Wet clothing should be cut off, provided dry and preferably warmed covering can be provided. A large pair of scissors is essential when clothing is removed for any purpose. All wounded, except walking cases, should be placed in the lying position with the foot of the stretcher raised. Exceptions are

abdominal cases and head wounds, which are better lying flat, and certain chest injuries, some of which are more comfortable when propped up, and others when lying on the side with the head low, in order to assist drainage of blood and mucus. Disturbance from noise and movement must be reduced to the minimum and the patient encouraged or helped to sleep.

*Relief of Pain and Restlessness.*—Pain aggravates both oligaemic and neurogenic shock. In most cases it will be necessary to use morphine, which is of exceptional value when used with discrimination. It should be borne in mind, however, that whereas morphia will relieve pain, allay restlessness and encourage sleep, it will also cause respiratory depression, histotoxic anoxia, a fall in blood pressure and an increased tendency to vomit and sweat. The object is to attain the beneficial effects but avoid the disadvantages.

Morphia is contraindicated with penetrating abdominal wounds unless the diagnosis is quite clear. It should be given only in small doses to head wounds ($\frac{1}{8}$ gr.). Morphia should be given to chest injuries if they are in pain; abolition of the pain assists the coughing up of blood and mucus. An almost immediate morphine effect can be obtained (regardless of the state of the circulation) by intravenous injection. Up to gr. $\frac{1}{4}$ may be administered intravenously; it should be diluted with sterile water to about 1 ccm. and injected slowly (Army Injectio-morphinae: gr. $\frac{1}{4}$ in mins. X is eminently suitable).

The dose should not be repeated until at least four hours later, and the size of dose, with time of administration, must always be clearly recorded on the Field Medical Card or on the patient's forehead if the danger of excess dosage is to be eliminated.

As an alternative to the intravenous route, gr. $\frac{1}{4}$–$\frac{1}{2}$ may be given subcutaneously or intramuscularly or placed under the tongue. Of these routes, the intramuscular is probably the best in the presence of severe shock when the circulation is feeble and absorption abnormally slow. But even so, the result may be disappointing and there is considerable temptation to repeat the dose too quickly. If this be done and at the same time the circulation be restored to normal by transfusion, a rapid absorption of a large dose may have serious effects.

*Administration of Fluids.*—Most battle casualties are dehydrated to some extent and complain of thirst; this may reach an intolerable point if there has also been great loss of blood. Administration of fluid not only relieves an unpleasant symptom, but is also of first importance for assisting the natural restoration of blood volume. *If sufficiently hydrated with copious and frequent drinks, those who have bled only a moderate amount may restore their own blood volume spontaneously. Drinks should be freely given to all save those who are unconscious or who have abdominal wounds.* The best fluids are hot sweet tea, hot coffee, water, or any other non-alcoholic drink. As it is impossible to lose body fluids without losing salts, all drinks should contain half a teaspoonful of salt to the pint. Drinks should be provided at all R.A.Ps. and casualty collecting posts along the chain of evacuation, including motor ambulances. Casualties too weak to lift a cup or in whom morphia has dulled thirst, must be helped and encouraged to drink. For these, an automatic delivery device (*e.g.* enema can with rubber tube, or pail with tube to act as a straw) is a great help. The source of fluid should be below the level of the mouth, to avoid the danger of siphon action. In general, a wounded man requires at least eight pints of fluid in the twenty-four hours following wounding.

Rectal administration may supplement the oral route; it has the advantage that neither complicated apparatus nor carefully prepared fluids are required.

*Warmth.*—Warming is undoubtedly beneficial to those suffering from cold and exposure, but if vigorously applied as a routine ritual in the treatment of oligaemic shock, it may do great harm. A " shock cage " can be hardly less lethal than a baking oven. It has already been stated that an important protective reaction to blood loss is an intense peripheral vasoconstriction which automatically gives rise to peripheral coldness. Excessive warmth causes peripheral dilatation with a diversion of blood to the non-essential periphery, an increase in the capillary bed and often a dangerous fall in blood pressure with sudden collapse, unless its application be simultaneously associated with blood volume restoration. Common sense is necessary. Wet clothing should be removed, and dry, warm pyjamas substituted; draughts should be eliminated; dressings should be performed with the minimum of exposure; warm drinks should be given. The case should be placed in a warm bed, wrapped in blankets, supplemented by hot bottles or bricks to the point of comfort.

More vigorous methods (shock cages and primus stoves) should not be used unless the environmental temperature makes them necessary. Warming should never be enough to cause sweating. Limbs with injured main vessels, with a crush injury, with an established infection, or on which a tourniquet has been placed, should never be warmed. Warming of unconscious patients is particularly dangerous, as they are unable to give warning of distress. The virtue of reasonably applied warmth is seen to best advantage when it is combined with blood volume restoration by transfusion.

*Oxygen.*—Patients with chest wounds in whom blood oxygenation is impeded, benefit greatly from the administration of oxygen (haemothorax, pneumothorax, fluid in air passages, gas casualties). Oxygen supplies in field units should largely be reserved for such cases.

Most casualties with severe oligaemic shock show some degree of cyanosis (stagnant anoxia) and some improvement in this, as well as in comfort, may be achieved by oxygen administration. The treatment, however, is only palliative and is not a specific directed towards eliminating the primary cause. Many will not tolerate the application of a BLB mask, the only efficient method of administration, which itself calls for careful nursing and attention. To be efficient, the oxygen must be administered at a rate of six to seven litres a minute, which exhausts a 40 cu. ft. cylinder in two to three hours. Oxygen is not required as a routine in field work. It is of considerable value as a post-operative measure.

**Specific and Active Measures—Transfusion.**

Early, rapid, adequate and permanent restoration of blood volume is the fundamental treatment of oligaemic shock. The procedure is not, however, entirely a mechanical one. Questions as to when to transfuse, what fluid to use, how much to transfuse and how fast, need to be considered, as well as the circumstances under which transfusion may fail or be deleterious.

*When to Transfuse.*—Ideally, restoration of blood volume should begin as soon as the diagnosis of oligaemic shock is made. Those who are severely injured or who have obviously suffered gross blood loss need to

be transfused regardless of the blood pressure, and those in whom the pressure has already reached a low figure (80 mm. or less sys.) likewise brook no delay. In less severe cases, considerable clinical judgment is necessary. In general, if the blood pressure be obviously declining or if it remains below 90 mm. sys. for one hour, transfusion should no longer be delayed. Ideally, the restoration of condition should be followed by immediate surgery during and after which the patient may need to be maintained by further transfusion.

Some modification of these ideals is necessary under battle conditions because modern developments in apparatus and technique enable transfusions to be given much further forward than surgery can be practised. Transfusion in a forward area may be life-saving. At the same time, there is little point in fully restoring a casualty in a forward area, only for him to deteriorate from continuing haemorrhage during a subsequent ambulance journey and arrive at the surgical point requiring to be revived again. Such secondary transfusion is always less effective and more difficult than on the first occasion. Forward transfusion needs great judgment as well as the choice of time for evacuation.

Transfusions during an ambulance journey have been successfully exploited. All that is required is an orderly in attendance to shut off or regulate the flow, as required, and some device for fixing the bottle and apparatus, to prevent swaying; the simplest method is to suspend the bottle from the ventilator with bandages, and to anchor the apparatus with bandage tied to a full petrol can of water (Fig. 5, page 34). Many casualties will require no more than to be embarked at once in an ambulance with a transfusion in progress. Others can be partially restored in a forward area, leaving the ambulance transfusion to complete the work. This should bring the case to the surgeon in good condition and permit him to operate within a few hours of wounding, which, especially with large wounds, is the most favourable period. Every attempt to control haemorrhage should be made before the journey is undertaken.

*Choice of Fluid.*—Permanent blood volume restoration can only be achieved with a protein fluid. Crystalloid solutions (saline, etc.) remain only temporarily in the circulation, being quickly absorbed into the tissues or excreted; as such they are invaluable for the treatment of dehydration, but not for oligaemic shock.

Theoretically, blood is the best fluid for those who have suffered direct haemorrhage, whilst plasma or serum, fluid or dried, is best for those who have lost plasma (burns, crush injuries). But the fundamental requirement is volume restoration, rather than oxygen carrying power. With volume restoration the improved circulation enables the best use to be made of such blood as remains. Death from lack of oxygen carrying power is rare provided volume be restored. Hence the theoretical necessity for blood is not essential in practice, nor is it altogether desirable, in that there is considerable evidence that an embarrassed circulation responds better at the outset to the introduction of the less viscid fluid, plasma. In practice, too, blood is less readily available in the field because the supply of large amounts of safe stored blood requires a highly complex system of collection, delivery and storage. Experience has shown that the collection of fresh whole blood from the walking wounded is impracticable on any large scale. Plasma or serum, which, in dried form, will keep well in any climate, are the routine fluids of choice under battle conditions. Blood should be reserved for selected cases, as described below.

As a general rule, all transfusions should be begun with plasma or serum, and all of the order of three pints should be completed with it. Above three pints, and especially if exceeding five, a proportion of blood is desirable, but not essential. The ideal, if supplies are available, is probably one pint of blood to two of plasma. Lack of blood should never prohibit the pursuit of plasma transfusion to the full.

Blood is especially required for abdominal cases, for septic cases, for maintenance of condition during and after operation, for cases of massive haemorrhage in whom equally massive plasma transfusion has reduced the oxygen carrying power below a tolerable level. Cases who have received large plasma transfusions in a forward area and who have subsequently deteriorated, fall into this last category ; secondary resuscitation almost always requires blood.

*Volume and Rate.*—Much of the criticism of the transfusion treatment of oligaemic shock has arisen from failure to appreciate that the volume required may be very large and that the rate of administration may need to be extremely rapid. Theoretically, the volume transfused should approach the volume lost, and this may be as much as seven or eight pints. If this can be done rapidly the result is remarkable, except in some cases of massive injury (*vide* infra). In the presence of circulatory failure, however, both the volume and the rate should be controlled by the response, as judged from serial observations of general condition and of the blood pressure. If the reading is below 80 mm., the rate should be rapid (one pint in seven to ten minutes). Transfusion should continue until the blood pressure rises to a normal level (110–120 mm.) and at the same time the rate be gradually slowed. When the blood pressure is in the region of 100 mm., signs of overloading of the right heart need to be watched for, though this is an unlikely complication. When normal level has been reached, the transfusion should continue as a slow drip until the patient is taken to the operating theatre. Here, too, the drip should continue so that any sudden collapse due to vasodilation induced by anaesthesia, or to blood loss at operation may be immediately countered. It has to be borne in mind that certain individuals will not tolerate a fast rate even though such a rate is required. Intolerance to rate is shown by a rigor, which ceases as soon as the rate is slowed.

## FACTORS INHIBITING OR PROHIBITING RESPONSE TO TRANSFUSION

### General.

A classical response to transfusion is a rise in blood pressure of 10–20 mm. for every pint transfused. Extensive and overwhelming injuries, continuing haemorrhage (commonly an undetected internal haemorrhage), inadequate volume, too slow a rate and delay in beginning treatment will all reduce the expected result. Thus the early phases of a delayed case may be disappointing and some may be found to have reached an irreversible state. Cases that have been revived once and who afterwards deteriorate are always more difficult to revive again. None of these features should lead to the abandonment of transfusion, but rather to its well judged pursuit, supplemented by other aids such as cardiac stimulants when it is felt these are required. *Most cases of failure as well as so called " delayed shock," that is, a recrudesence in a case successfully revived, are due to undetected internal haemorrhage.*

**Special Types of Injury.**

*Massive injuries* may inhibit response. The circulatory symptoms may be temporarily or partially abolished yet the case may deteriorate or die from causes not fully understood but which are believed to be concerned with toxic substances derived from the damaged tissue. *In such cases early operation is almost as important as blood volume restoration. When adequate transfusion is apparently ineffective, operation should no longer be delayed as it offers the only chance of survival.* Transfusion should continue during operation.

*Central nervous system injuries* respond poorly to transfusion ; little or no response may be anticipated with spinal cord injuries, whilst head injuries are hardly less satisfactory. In general, these cases should not be transfused unless injuries elsewhere are a complicating factor, and massive transfusion is usually harmful.

*Thoracic injuries* often respond badly, especially if there is mechanical interference with circulation. In certain types of thoracic injury transfusion is contraindicated (*vide* infra).

*Abdominal injuries* may fail to respond until the source of bleeding has been controlled.

*Infected cases*, such as those suffering from ischaemia and massive gas gangrene of a limb, or pneumonia, respond badly, as do patients with developing *fat embolism* or *acute dilatation of the stomach.*

## CONTRA-INDICATIONS TO TRANSFUSION

The primary indication for transfusion is blood volume reduction. Nevertheless, no harm is done by mistakenly transfusing a case, say, of neurogenic shock, which will often respond with extreme rapidity to quite a small transfusion, even though the primary indication is not present. Nevertheless, certain types of case are definitely made worse by transfusion, and these must be borne in mind. Obvious primary cases which should *not* be transfused are those suffering from *toxic hypotension, coronary occlusion, mechanical causes such as haemopericardium, pulmonary embolism and fat embolism*, and, frequently, those suffering from the *cerebral type* of shock.

The diagnosis of fat embolism is extremely difficult, but its likelihood should always be borne in mind in cases of fracture, and its occurrence should be considered in any injured person who develops pulmonary or cerebral symptoms without obvious cause. Transfusion definitely makes these cases worse.

Certain types of pulmonary damage also are a contra-indication to transfusion. With *blast lung* transfusion increases alveolar haemorrhage, and the condition should be thought of with the apparently lightly injured who do not readily respond to treatment, especially when a ruptured tympanic membrane is also present. Those who have been affected by *pulmonary irritant gases* (phosgene, especially) should never be transfused, as the procedure merely increases the exudate.

## SUPRARENAL CORTICAL EXTRACTS AND DRUGS

There is as yet no fully established evidence that suprarenal cortical extract has any place in the routine treatment of oligaemic shock. Likewise, many vasoconstrictor drugs—adrenaline, ephedrine, caffeine, pitressin and others, have been advocated with a view to supporting a declining

blood pressure. Unfortunately, their action is to dam up the blood in the arterial system and to diminish the supply to the tissues. All that can be said is that they may have a beneficial action when combined with infusion of a crystalloid fluid (which temporarily restores blood volume) whilst making arrangements for a protein fluid transfusion. Their use is seldom necessary, and their value slight except for the treatment of the vaso-vagal phenomenon in which case 30 mgm. Methedrine intravenously is extremely eflective.

## BURNS

Burn shock arises from oligaemia caused by plasma exudation into the damaged tissues. It is consequently associated with haemoconcentration which adds to the embarrassment of the circulation. The onset of shock is variable in time, but may be rapid ; it is almost always to be expected in adults who have burns of 15 per cent. or more of the body surface. With burns to this extent, treatment for shock should be undertaken without delay in anticipation of symptoms. Since the oligaemia is due to plasma loss, the replacement fluid should be plasma. The treatment has to be *continuously* maintained for at least the first twenty-four hours, after which time the local fluid loss usually begins to subside, and the danger of oligaemic shock disappears. Whenever facilities are available, the volume and rate of the transfusion should be controlled by haematocrit and/or haemoglobin estimations and/or serum protein determinations. Failure to overcome the oligaemia of burn shock is almost always due to inadequate administration or too slow a rate, matters which are very difficult to estimate without laboratory control. Formulae for calculating the amount required according to the extent of the burn have been found to give a result far too low. Experience has shown that moderate burns (20–30 per cent. of body surface) may require as much as five to ten pints of plasma in the first twenty-four hours, whilst severe cases (30 per cent. or more) may need fifteen pints or more (in the early stages, at the rate of a pint an hour). Glucose saline is useful after the initial period, in order to overcome the dehydration induced by the vomiting, which is so common in the early phases.

When burns are associated with carbon monoxide poisoning, transfusion requires great judgment on account of the frequently associated pulmonary oedema caused by lung irritation.

## CRUSH INJURIES

Men who have been trapped for an hour or more beneath debris should be considered as potential cases of crush syndrome, and hence likely to develop delayed and fatal renal failure. History is not always obtainable but the possibility of this type of injury should always be suspected in the presence of unexplained erythema, blisters, loss of sensation, paralysis or gross swelling of an otherwise uninjured part. Symptoms of shock arise from oligaemia due to plasma loss into the crushed tissue, but prophylactic treatment to avoid the delayed renal failure is a first priority measure ; it must be instituted without delay and if the general condition warrants it, even before the circulation is restored. Plasma transfusion for the oligaemia will, as always, be regulated by general condition and blood pressure readings. To avoid renal complications, it is essential to ensure continuous alkalinity of the urine and a good urinary output, in

order to ensure excretion of myohaemoglobin and other little understood toxic metabolites which, with an acid urine, cause irreparable renal damage. Alkalinization can be attained by administering sodium bicarbonate two drams hourly by mouth until the urine is alkaline, and thereafter eight drams during each succeeding twenty-four hours for two to three days. For rapid alkalinization, or when vomiting prohibits oral administration, either sodium lactate 2 per cent., sodium citrate 3 per cent., or sodium bicarbonate 1.4 per cent. may be injected intravenously, at first rapidly and later at slow drip rate, to a total of three litres in twenty-four hours. A measured fluid intake of at least six pints per day should be given either by mouth or by vein.

## DEHYDRATION

Dehydration implies deficiency of tissue fluid as distinct from fluid in circulation ; when severe it may also reduce circulatory fluid. Adequate hydration can be accomplished, as a routine, by oral administration of fluids, and this safe route should always be used unless circumstances forbid. Rectal administration as a supplement is sometimes useful ; the usual fluid is 0.45 per cent. sodium chloride. Tap water may be used.

The intravenous route is necessary with severe dehydration when a rapid result is required, when vomiting or other features prohibit the oral route, as a post operative measure to replace the considerable fluid loss that sometimes occurs during operation. In the immediate post operative period, and, in abdominal cases in which the intravenous route is the only practical and satisfactory way of giving fluid. Intravenous solutions have to be carefully prepared from pyrogen-free distilled water. The fluids used are 0.85 per cent. (physiological) saline ; 5 per cent. glucose ; isotonic glucose-saline consisting of equal parts of the two first named ; 5 per cent. glucose dissolved in 0.85 per cent. saline. In making choice of fluids, it should be borne in mind that if saline is used alone in large amount there is a danger of oedema, especially of the lungs, and oliguria, because excess of sodium chloride is not easily eliminated. It is better to alternate saline with 5 per cent. glucose or to use one of the glucose-saline solutions. Glucose promotes diuresis, reduces acidosis and provides energy yielding material. When hydrating by the intravenous route, the ordinary requirement is five to six pints in twenty-four hours. The rate of administration should not exceed one pint in two hours, and is more usually one pint in four hours.

The most practical index of adequate hydration is a urinary output of two to three pints in twenty-four hours. Gross symptoms of dehydration include dry mouth and scanty urine, which suggest a body water deficit of as much as seven to ten pints, whilst a low blood pressure, rapid thready pulse and cyanosis, if solely due to dehydration, indicate a deficit of twelve to fifteen pints.

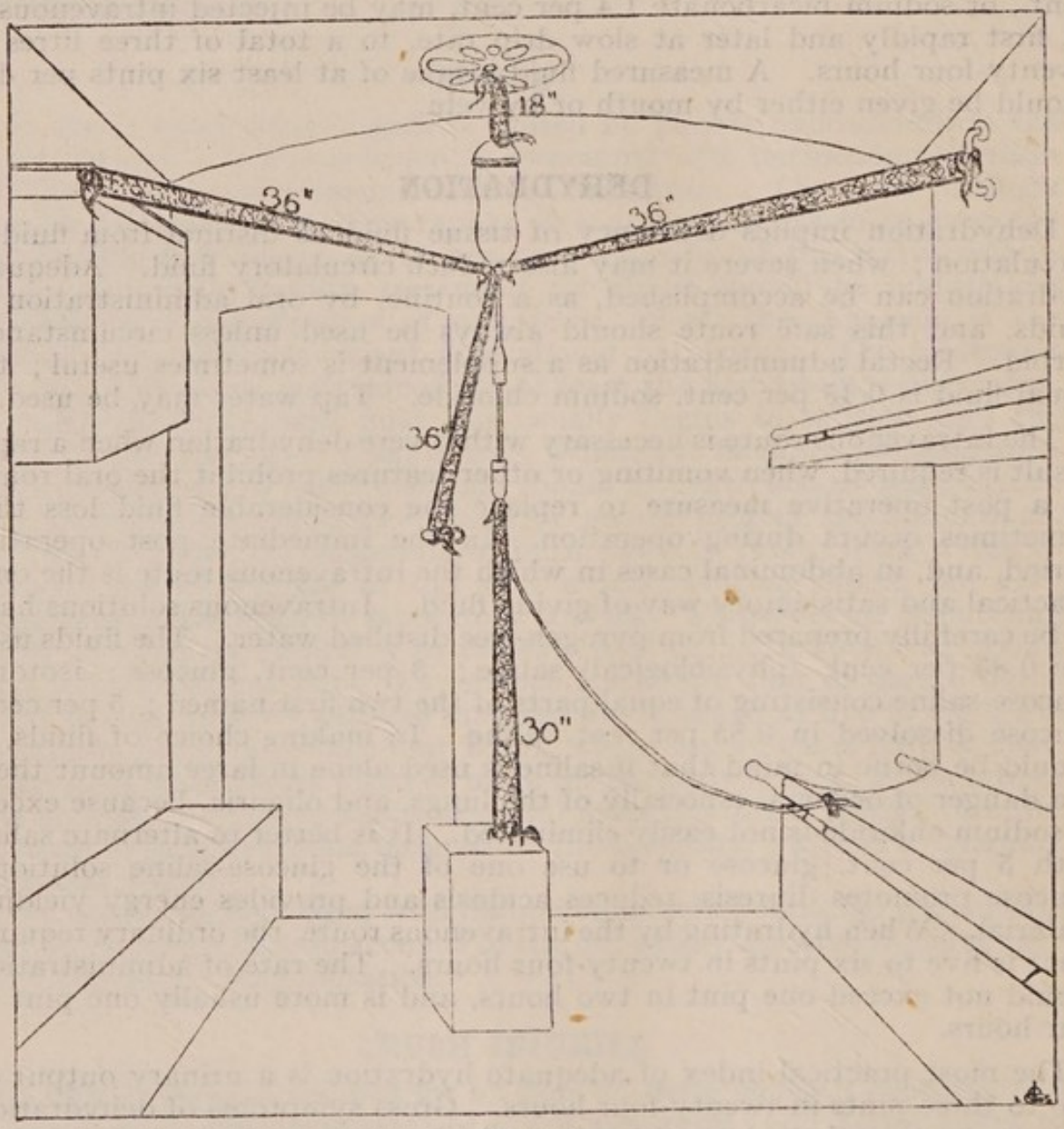



FIG. 5

Method of suspending and fixing a transfusion bottle for an ambulance journey (Lucas's method).

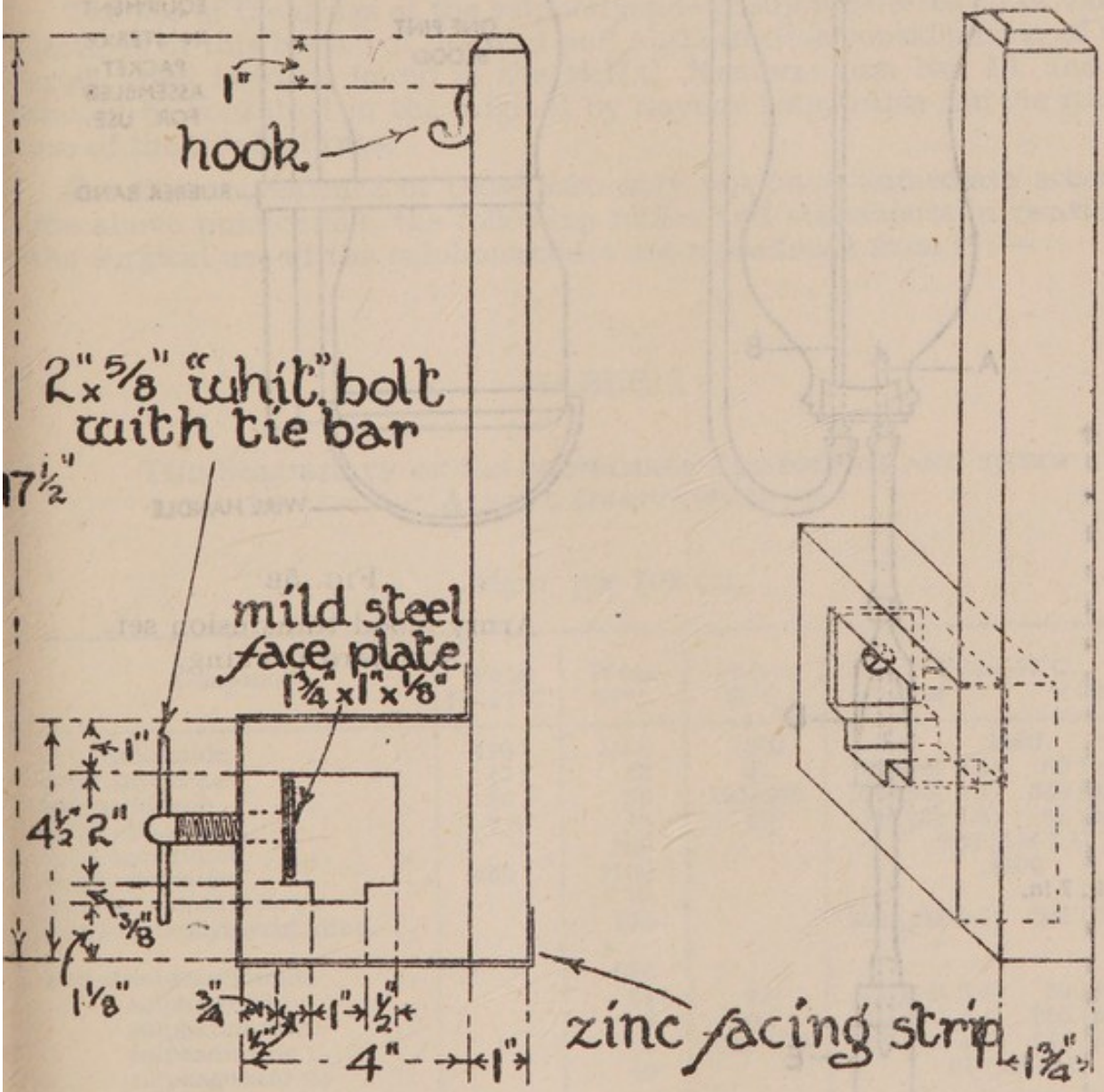



FIG. 5A

Improvised transfusion stand for stretcher. (*A.M.D. Bulletin*, 1943, Nov., No. 29. Para. 228.)

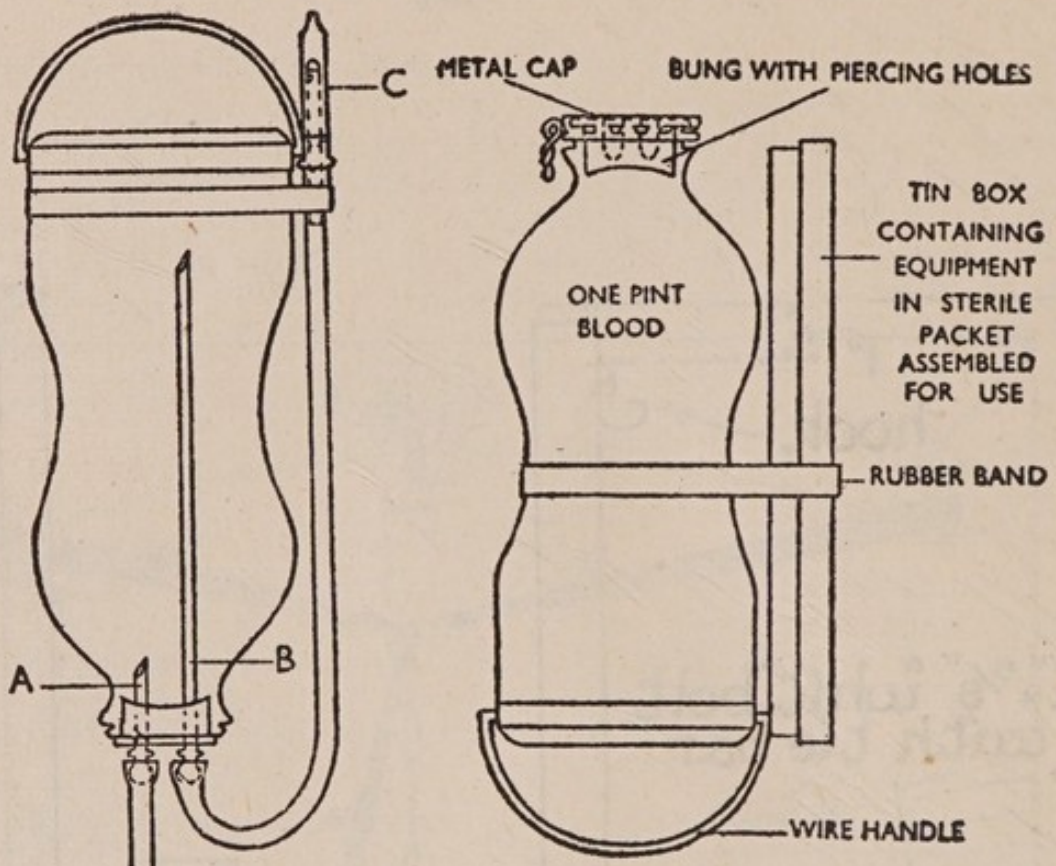



FIG. 5B
Army blood transfusion set.
Standard packing.

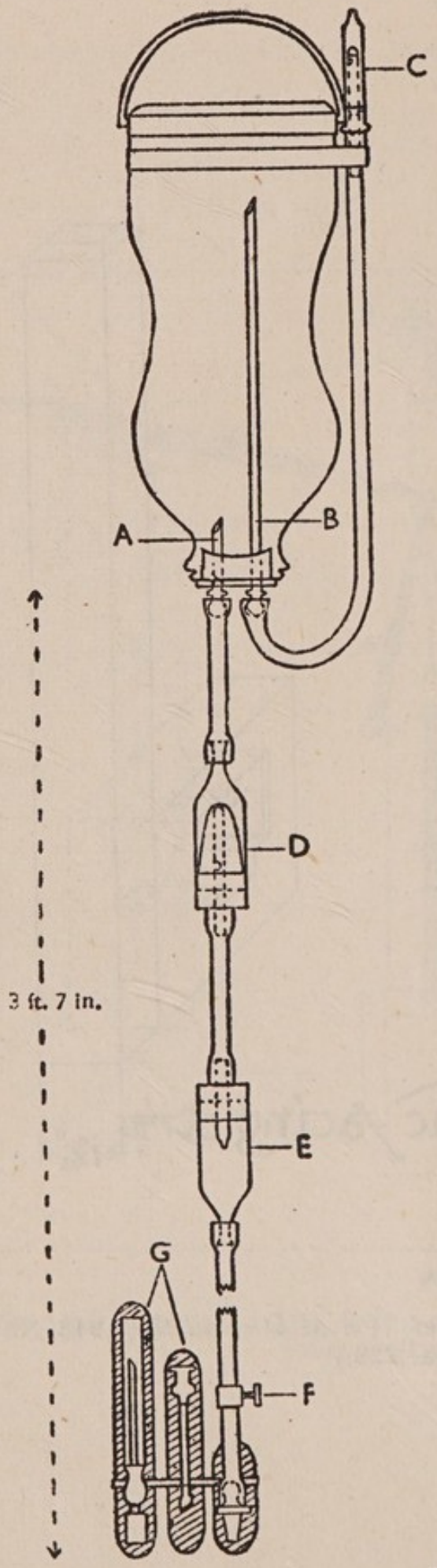



FIG. 5C
Details of Army blood transfusion set.

# SECTION IV

## CHEMOTHERAPY

The use of the drugs of the sulphonamide group is referred to in various sections of this book. A detailed and authoritative consideration of their application is to be found in the M.R.C. Memorandum No. 10, and this should be consulted in the original by anyone responsible for the routine use of the sulpha drugs.

For the convenience of those who may not have immediate access to the above publication, the following tables and statements in relation to the surgical use of the sulphonamides are reproduced from it :—

### TABLE I

THE SOLUBILITY OF SULPHONAMIDE COMPOUNDS AND THEIR ACETYL DERIVATIVES

Mgm. per 100 c.c.

| *Compound* | *Water* 16–17°C. | *Water* 37°C. | *Serum* 37°C. | *Urine* 37°C. *Acid* | *Urine* 37°C. *Alkaline* |
|---|---|---|---|---|---|
| Sulphanilamide | 440 | 1500 | 1970 | 1500 | |
| Sulphapyridine | 17 | 52 | 61 | 39 (*p*H 5.4) | 89 (*p*H 8.2) |
| Sulphathiazole | 36 | 96 | 184–330 | 102 (*p*H 5.4) | 859 (*p*H 8.2) |
| Sulphadiazine | 7.8 | 15 | 160 | 18 (*p*H 5.5) | 52 (*p*H 7.5) |
| Sulphaguanidine | | 220 | | 220 (*p*H 7.1) | |
| Sulphacetamide | 460 | 1100 | | 2200 | |
| Succinyl sulphathiazole | | 70 | | | |
| Sulphadimethylpyrimidine | | 190 | | 191 (*p*H 5.5) | 297 (*p*H 7.5) |
| Acetyl sulphanilamide | | 534 | | | |
| ,, sulphapyridine | | 24 | 33 | 11 (*p*H 5.4) | 89 (*p*H 8.2) |
| ,, sulphathiazole | | 6 | 104 | 10 (*p*H 5.4) | 265 (*p*H 8.2) |
| ,, sulphadiazine | | 30 | 126–198 | 26 (*p*H 5.5) | 248 (*p*H 7.5) |
| ,, sulphaguanidine | | 40 | | 81 (*p*H 7.1) | |
| ,, sulphacetamide | | | | | |
| ,, sulphadimethylpyrimidine | | 115 | | 115 (*p*H 5.5) | 176 (*p*H 7.5) |

The solubility of the compounds named above is greatly increased by making the fluid alkaline. Acetyl sulphacetamide is not involved in the excretion of sulphacetamide, which is eliminated as a mixture of sulphacetamide, sulphanilamide and acetyl sulphanilamide.

The sodium salts of the sulphonamides are extremely soluble.

## TABLE II

### Dosage of Sulphonamides for Adults

*Severe Infections (endangering life)*

| | *Adults* |
|---|---|
| Initial dose .. .. .. .. .. .. .. .. | 2–4 gm. intravenously<br>1.5 gm. by mouth |
| Followed by :—<br>1st period, 2–3 days .. .. .. .. .. .. .. | 1.5 gm. 4-hourly |
| 2nd period, 2 days (approximately two-thirds of dose of 1st period) | 1 gm. 4-hourly |
| 3rd period, 2 days (approximately one-third of dose of 1st period) | 1 gm. 6-hourly |

*Milder or "Moderate"*

| | *Adults* |
|---|---|
| Initial dose .. .. .. .. .. .. .. .. | 2 gm. |
| Followed by :—<br>1st period, 2 days (unless otherwise stated) .. .. .. | 1 gm. 4-hourly |
| 2nd period, 2 days (unless otherwise stated) .. .. .. | 1 gm. 6-hourly |
| 3rd period, 2 days .. .. .. .. .. .. .. | 1 gm. 8-hourly |

The duration of a course is normally 6–7 days, and it should rarely be prolonged beyond the seventh day.

## METHODS FOR ORAL, INTRAVENOUS, INTRAMUSCULAR, RECTAL AND SUBCUTANEOUS ADMINISTRATION OF SULPHONAMIDES

Oral administration is the routine method. The tablets should be crushed to aid absorption and they may be taken with water or, preferably, added to ½ oz. to 1 oz. of a mixture containing sodium bicarbonate and sodium citrate, 20 grs. of each to 1 fl. oz. The mouth should then be rinsed with water or a glucose drink, since the powder, in acute infections, tends to lodge in the crevices of the mouth. In comatose states, the drug may be given by nasal catheter or stomach tube, but care must be taken to dilute the powder well, otherwise it may sediment and block the tube.

Intravenous administration is indicated when it is desired rapidly to raise the concentration of sulphonamides in the blood (*e.g.* at the beginning of treatment of a severe infection), or when oral administration is temporarily impracticable.

Intramuscular administration may be used as a substitute for intravenous administration when the latter is impossible, but it is less satisfactory and, with the sodium salts of sulphapyridine, sulphathiazole, and sulphadiazine, is not devoid of risk (*see* below).

Rectal or subcutaneous administration may be adopted as a substitute for oral administration when the oral route cannot be used (*e.g.* after an operation on the stomach), and there is no need to raise the blood level rapidly.

**Preparations for Intravenous or Intramuscular Injection.**

(*a*) *Sodium Salts.*—Solutions of the sodium salts of the sulphonamides are used for intravenous or intramuscular injection except in the case of sulphanilamide. There is no sodium salt of sulphanilamide, and the method of preparing this drug for injection is different (*see* below).

The sodium salts of sulphathiazole or sulphapyridine are conveniently given in 10 per cent. solution ; sodium sulphadiazine is at present recommended by the makers for use in a 5 per cent. solution. These solutions, being highly alkaline, are irritating, and cause some necrosis when injected into living tissues. They can safely be injected intravenously, provided that care is take not to let the material escape outside the vein and that the injection is given *very slowly*. Intramuscular injections are particularly liable to cause tissue damage, and, if it is necessary to give them, they should be limited in number, spaced at distances of at least 3 inches from one another, and given deeply into the muscle, remote from any important nerve, *e.g.* the sciatic : the vastus externus is the muscle recommended. Injection in the neighbourhood of an important nerve may cause toxic neuritis. *Solutions of the sodium salts must never be injected intrathecally.*

Sodium sulphapyridine and sodium sulphathiazole are supplied as dry powders, in ampoules containing the equivalent of 1 gm. ; for intravenous or intramuscular use, the contents of one ampoule should be dissolved in 10 c.c. of sterile distilled water immediately before use. Sodium sulphadiazine is at present issued in bottles containing the equivalent of 5 gm., for use in 5 per cent. fresh aqueous solution. It is seldom necessary to give more than one intravenous injection, but in cases of sustained coma or vomiting treatment may be continued by the intravenous injection of (*e.g.*) sodium sulphapyridine 3.5 gm. every twelve hours for an average adult of 60 kgm. (9½ stone) (Winter : *Amer. J. med. Sci.*, 1941, **201,** 216). In suitable cases the sodium salts may be administered by continuous intravenous drip infusion in saline.

(*b*) *Sulphanilamide.*—A saturated solution of this drug (0.8 per cent. solution) may be prepared by dissolving 1 gm. of crystalline sulphanilamide in 125 c.c. of sterile normal saline solution. This solution, although very dilute, can be given by the intravenous route, by continuous drip. Alternatively, the soluble form of sulphanilamide known as " sulphanilamide L.S.F." may be used ; it is issued as a 15 per cent. solution in ampoules for parenteral injection.

**Rectal Administration of Sulphanilamide.**

A saturated solution is prepared by adding an excess of sulphanilamide to warm water (*e.g.* 26 gm. to a Winchester of 2250 c.c.) and allowing it to cool to room temperature. The supernatant fluid is decanted off ; at room temperature this contains about 0.8 per cent. of the compound. For use, the required quantity is brought up to a total volume of 300 c.c. (10 fl. oz.), if necessary, by admixture with 1 per cent. glucose in normal saline or with normal saline alone. This treatment may be given four-hourly, in doses slightly larger than those shown in the schedule for oral administration. Blood levels are lower than those following oral administration and there is a longer time lag. Sulphapyridine cannot be given in this way. (Wood : *Canad. med. Ass. J.*, 1941, **44,** 592.)

**Subcutaneous Administration of Sodium Sulphapyridine, Sodium Sulphathiazole or Sodium Sulphadiazine.**

In patients who cannot take sulphonamide drugs by the mouth, a solution of 5 gm. of one of these sodium salts in 1,000 c.c. of normal saline may be given subcutaneously by continuous drip (hypodermoclysis). The *p*H values of the solutions are 10.0, 9.5 and 9.2 respectively, but, in spite of their alkalinity, they cause no serious local reactions. The blood concentrations obtained by this method show decided variations. (Taplin, *et al.: J. Amer. Med. Ass.*, 1943, **121**, 313.)

## REGULATION OF DOSAGE BY THE SULPHONAMIDE CONTENT OF THE PATIENT'S BLOOD

To ensure the best results in the treatment of severe infections, the concentration of drug in the patient's blood ought to be ascertained at least once or twice during the first two or three days, preferably six to twelve hours after the beginning of treatment, and again at twenty-four to thirty-six hours. It cannot be assumed that the desired concentration will always result from a standard dosage. Absorption from the alimentary tract is somewhat variable, and an uncertain amount of the dose absorbed is rendered therapeutically inert by acetylation ; vomiting too, if it occurs, will affect the calculations. With children, in particular, dosage is apt to be too hesitant, and, although the collection of blood from their veins may present difficulties, the bedside micro-method recently introduced by Fuller makes it possible to obtain a rough estimate of the blood concentration with a very small drop of blood from the finger or the ear.

The value of these estimations during the early stage of therapy is that they give warning of inadequate dosage without the need to wait upon clinical events, the interpretation of which may be difficult. Similarly, when patients fail to respond to treatment after three or four days, an estimation of the drug in the blood—combined with a test of the sensitivity of the organism—may go far to explain the failure and to suggest the next move in therapy.

While the great advantage to be gained by following the sulphonamide content of the blood in severe cases is emphasised, it is not, of course, suggested that such a procedure is essential in treating conditions of urgency—or that sulphonamide drugs should be withheld when laboratory facilities for estimating the blood concentrations are not available.

## THE SURGICAL USE OF THE SULPHONAMIDE DRUGS

**Wounds.**

All wounds should receive thorough surgical treatment at the earliest possible moment. Sulphonamides are not a substitute for surgery, and operative treatment should never be delayed because they have been used. Sulphonamides can be of help :—

(*a*) in the prophylaxis of infection before or after surgical treatment, or in controlling infection which has begun—especially the earlier stages of infection with haemolytic streptococci ;

(*b*) in the later stages, in ridding a granulating surface of haemolytic streptococci, so that healing is quicker and skin grafting safer.

**Local Application of Sulphonamides to Wounds.**

(1) *Prophylaxis.*

For the prophylaxis of wound infection during the period between wounding and surgical treatment, local application of a sulphonamide—provided the wound is of such a type that it can be satisfactorily done—is considered by British workers to be preferable to oral administration, because it gives a higher local concentration of the drug. The organisms introduced into wounds at the time of injury (enterococci, staphylococci, coliform bacteria and clostridia) are relatively insensitive to sulphonamides, and only a high concentration will inhibit their growth. (American experts favour the systemic use of sulphadiazine.)

*In the Field, at Aid Posts or at Field Ambulances*, a superficial or open wound should be sprinkled by the medical officer with 5–15 gm. of sulphonamide powder. In general, sulphanilamide, being the most soluble, will be the drug of choice for local application as a powder, since it will quickly reach a high concentration in the fluid bathing the injured tissues. A mixture of sulphanilamide powder (3 parts) to sulphathiazole powder (1 part) will, however, maintain the local concentration for a longer time and may be preferable if surgical treatment is likely to be long delayed. The possibilities of a mixture of sulphathiazole and an acridine antiseptic are also under investigation. Sulphapyridine and sulphadiazine are less suitable than sulphanilamide and sulphathiazole for local application to wounds.

It is doubtful whether sulphonamide powders can be effectively introduced, without surgical intervention, into small-aperture penetrating wounds, or wounds with deep recesses, and in such cases it may be better to use a fluid preparation which can be injected through the sterile nozzle of a suitable container. A sterilised 15–20 per cent. microcrystalline suspension of sulphathiazole is under clinical trial for this purpose, but it is not yet generally available. It should be injected only by medically qualified personnel.

Sulphonamides in general should be applied only sparingly to wounds involving the brain ; sulphathiazole, in particular, should never be applied to the brain, since it has been shown to cause epileptiform convulsions. Sulphonamides—including microcrystalline sulphathiazole—should not be applied in the immediate neighbourhood of important nerve trunks.

*In the Operating Theatre*, after wound excision or other surgical procedure, sterilised sulphanilamide powder (from a sterile container) may be sprinkled or insufflated over the exposed tissues, to reduce the risk of infection. This thorough local application of the drug on the operating table should be made whether or not a sulphonamide has been applied locally to the wound at an earlier stage. By gently massaging the powder into the tissues, any caking will be prevented and dissemination facilitated. On no account should the wound be " packed " with the drug, otherwise an undissolved mass will remain as a foreign body, and it may delay healing. The amount of sulphanilamide to be used will depend upon the surface area of tissues to be covered, 1 gm. being sufficient to cover approximately 10 square inches. In general 5 to 10 gm. will be sufficient for a single large wound, and it will seldom be wise to use more than 15 gm. in all.

It is not yet demonstrated to what extent the local application of sulphonamides to war wounds will increase the chances of success with primary suture ; this will presumably depend largely on the sulphonamide-sensitivity of the organisms with which the wound is infected. *Primary suture of battle wounds is generally undesirable.* On the other hand, the application of sulphanilamide powder to a wound after excision is no contra-indication to the closed plaster treatment.

Where the risk of septic infection or gas gangrene is great—*e.g.* in compound fractures of the long bones associated with much damage and soiling of muscle—the local application of a sulphonamide should be supplemented by oral administration (*see* below). When sulphanilamide has been inserted into a wound, the rate of absorption will depend upon the area and vascularity of the surface involved. Absorption from a wound is usually somewhat slower than that from the peritoneal cavity ; as a rule, the blood concentration reaches its peak about six hours after insertion, the level then being about 0.5 mgm. of free sulphanilamide per 100 c.c. of blood for each 1 gm. of compound inserted. The concentration in the blood falls rapidly during the period from six to twenty-four hours, and after forty-eight hours it is negligible. About half the amount inserted is excreted in the urine in the first two days, and after that the urinary excretion is small ; the remainder of the drug is presumably destroyed in the body. When sulphathiazole has been inserted, its absorption is rather slower, and the blood level is lower but more sustained. When a thorough application of sulphonamide has been made locally, the quantity given by the mouth should be reduced (*see* below), and the dosage should, when possible, be controlled by determinations of the blood concentration of the drug.

(2) *Treatment.*

To eliminate haemolytic streptococci from superficial granulating wounds, the area may be powdered with sulphanilamide for five or six consecutive days, the thin layer of powder being covered with paraffined tulle and moist gauze. Streptococci, if typically sensitive, will usually disappear within three to five days.

When sulphanilamide is applied to extensive wounds or burns, the risk of toxic absorption should be borne in mind. Blood concentrations exceeding 50 mgm. per 100 c.c. have been recorded after the insufflation of extensive burns with sulphanilamide powder on three successive days (Gordon and Bowers : *Lancet, Lond.*, 1942, **ii**, 484).

The local application of sulphonamides is unlikely to eliminate bacteria from deep wounds, or from wounds which are suppurating freely or have sloughs. The bacteriostatic action of these drugs is inhibited by the presence of pus and necrotic tissue, and their value when applied locally to wounds in the stage of suppuration has therefore been disputed. Green and Parkin (*Lancet, Lond.*, 1942, **ii**, 205) have reported, however, that good clinical results may be obtained in suppurating wounds by the repeated local application of sulphathiazole powder in amounts sufficient to maintain a saturated solution in the wound for at least a week ; owing to the slow absorption of sulphathiazole from the tissues, the risk of toxic effects when the drug is applied as recommended by these authors appears to be small.

*Effects of Sulphonamides upon Wound Healing.*—Sulphonamides have been stated to have a harmful effect upon granulations and so to delay the healing of wounds. It is probable, however, that this will occur only

when the amount of drug introduced into the wounds has been excessive. It is generally unnecessary to apply sulphonamides repeatedly to open wounds which are healing satisfactorily. On the other hand, as indicated above, the local use of sulphonamides may be valuable in the early stages of wound infection, particularly by haemolytic streptococci, and in the later stages of healing by granulation tissue, when this is retarded by the presence of streptococci. In the latter case, there is good evidence that the drug, by inhibiting the bacteria, actually accelerates rather than slows the rate of healing, but its application should not be continued for too long.

**Systemic Administration of Sulphonamides to the Wounded.**

(1) *Prophylaxis.*

The question whether it is advisable to supplement local prophylaxis with the sulphonamides by administration of a prophylactic course of one of these drugs by the mouth is difficult to answer categorically. In general, systemic prophylaxis with the sulphonamides should be reserved for the more severely wounded, and for those in whom the risk of septic infection or gas gangrene (*see* below) is great, or in whom there is likely to be considerable delay in securing operative treatment.* Sulphonamides should not be given to aircrews or to lightly wounded personnel who will remain at their posts, lest the effects of the drugs should interfere with the efficient performance of their duties.

In deciding whether to administer a prophylactic course of sulphonamide to the wounded, either before or after the primary operation, the following considerations should be borne in mind :—

(*a*) The concentration of sulphonamide reached in the blood by prophylactic oral administration (moderate dosage) will not be sufficient to inhibit the growth of most of the relatively insensitive organisms which are commonly found in fresh wounds, *e.g.* the staphylococci, faecal and non-haemolytic types of streptococci, coliform bacilli and clostridia.

(*b*) Typically sensitive strains of haemolytic streptococci will probably be checked for a time if the prophylactic administration of sulphonamide induces a blood concentration of 2.5 milligrammes per 100 c.c., and *if the cocci are freely accessible to this sulphonamide-enriched blood.* It cannot be assumed, however, that the cocci will usually be thus accessible ; more often they will be enclosed in a blood clot,in which the diffusion of sulphonamide in sufficient strength will be uncertain. Moreover, it must be remembered that the incidence of primary infection of wounds by haemolytic streptococci is relatively low—2 to 10 per cent., according to Stokes and Tytler (*Brit. J. Surg.*, 1918–19, **6**, 92) ; Fleming and Porteous (*Lancet, Lond.*, 1919, **ii**, 49) ; Miles, *et al.* (*Brit. Med. J.*, 1940, **ii**, 855, 895) ; and Spooner (*Brit. Med. J.*, 1941, **ii**, 477). Streptococcal infection is much more prone to occur at a later stage in the patient's treatment, usually in hospital, and, since the actual time cannot be foretold, it is almost impracticable to guard against it effectively by the prophylactic administration of sulphonamides. This would require their continuous administration for at least seven days from the time of wounding.

* In the United States Army, a package containing 0.5 gm. tablets of sulphadiazine is issued with the First Field Dressings, and the men are instructed to take eight of these tablets immediately on being wounded. This practice has not been adopted in the British Army.

(*c*) The administration of a routine prophylactic course of sulphonamide is not without risk. Thus, if sulphathiazole, sulphapyridine or sulphadiazine is given, it will be necessary to maintain a large urinary output, in order to minimise risk of urinary obstruction, and this may not be easy in hot climates, where sweating is profuse and water is in short supply. Moreover, there is abundant evidence that if a first course of sulphonamide treatment is followed later by a second, to control (*e.g.*) an acute streptococcal infection, destruction of white blood corpuscles (granulocytopenia) will ensue in a certain number of patients, and in some may lead to fatal agranulocytosis. This risk of sulphonamide therapy is not so rare that it can be overlooked. Recent evidence (Lyons and Balberor : *J. Amer. Med. Ass.*, 1942, **118,** 955) indicates, also, that febrile reaction to a second course, particularly of sulphathiazole, is by no means uncommon, and, although perhaps in itself of no great consequence, this gives warning of a state of sensitisation.

When it is considered that the circumstances call for the prophylactic administration of sulphanilamide by the mouth, the drug should be given in the following dosage. The first dose should be 2 gm. The tablets should be crushed and swallowed with water or with the alkaline solution mentioned on p. 38 if available. Subsequent doses, starting two hours later and continuing at four-hourly intervals for four days, should be of 0.5 gm. each. If the beginning of treatment has been delayed, or if the nature of the wound, or the patient's general condition, gives reason to fear the likelihood of gas gangrene, the first two doses should be doubled, and sulphathiazole, sulphadiazine or sulphapyridine should be given instead of sulphanilamide. If a sulphonamide has been inserted deeply into the wound at operation, the quantity inserted may be regarded as equivalent to an intramuscular injection of half the amount applied, and, except in late or very severe cases, treatment by mouth during the first twelve to twenty-four hours afterwards may be correspondingly reduced, the dosage—or the spacing of the doses—of the prophylactic course being adjusted accordingly. Shock and haemorrhage are not contra-indications to sulphonamide therapy, but it should be remembered that a reduced blood volume and urinary output may increase the risk of renal complications when sulphathiazole, sulphapyridine, or sulphadiazine is given.

There is no evidence that administration of the sulphonamides has any prophylactic effect against tetanus. The official instructions regarding the administration of tetanus antitoxin (or, for Canadian and U.S. military personnel, of tetanus toxoid) should therefore always be carried out as soon as possible after wounding. Severely wounded patients should also receive the recommended prophylactic dose of polyvalent gas gangrene antitoxin.

(2) *Treatment.*

Oral administration of sulphonamides will not usually eliminate streptococci or other bacteria from granulating wounds, and the drugs should not be given in prolonged dosage for this purpose.

## TOXIC AND OTHER SIDE EFFECTS

It should be remembered that with extended dosage and under certain conditions almost all the sulpha drugs have toxic effects and may cause death. The table below shows most of the adverse effects which have been reported in adults treated with the sulphonamides named :—

## TABLE III

### Toxic and Side Effects which may occur in Patients Treated with Sulphanilamide, Sulphapyridine, Sulphathiazole, Sulphadiazine or Sulphaguanidine* (See page 46.)

This table has been modified, by kind permission, from Circular Letter No. 17, issued by the Surgeon General, Washington, 23rd February, 1942. Toxic effects from sulphanilamide and sulphapyridine have apparently been less frequent in British than in American experience. In comparing the data for sulphadiazine with those for the earlier drugs, the fact that experience of its use is shorter should be borne in mind. Many of the toxic manifestations listed below are very rare.)

| *Reaction* | *Sulphanilamide* | *Sulphapyridine* | *Sulphathiazole* | *Sulphadiazine* |
|---|---|---|---|---|
| Nausea, vomiting | Occasional | Common | Occasional | Uncommon |
| Dizziness (with or without headache) | Common | Common | Uncommon | Uncommon |
| Cyanosis | Common, early and late | Faint, common, early and late | Uncommon | Rare |
| Fever† | Common; generally 5th to 9th day | Common; generally 5th to 9th day | Common; generally 5th to 9th day | Uncommon |
| Rashes† | Occasional; may take any form | Occasional; may take any form | Occasional; may take any form | Occasional; may take any form |
| Primary or acquired hypersensitivity, with fever, rashes, lymphadenopathy, etc.‡ | Rare | Occasional | Occasional | Rare |
| Leucopenia with granulocytopenia‡ | Occasional; early or late | Occasional; early or late | Occasional; early or late | Rare |
| Acute agranulocytosis‡ | Occasional | Occasional | Occasional | Reported |
| Aplastic anaemia‡ | Very rare | Very rare | Very rare | Very rare |
| Thrombocytopenia with purpura‡ | Very rare | Very rare | Very rare | Very rare |
| Mild haemolytic anaemia | Not infrequent; early or late | Not infrequent | Not infrequent | Probably not infrequent |
| Acute haemolytic anaemia (occasionally with haemoglobinuria)‡ | Rare | Very rare | Very rare | Very rare |
| Haematuria† | Not reported | Common; generally early | Common; generally early | Common |
| Anuria with azotaemia‡ | Not reported | Not uncommon; generally 1st ten days | Not uncommon; generally 1st ten days | Many cases have been reported |
| Acute nephrosis‡ | Not reported | Reported | Reported | Not reported |
| Hyperleukocytosis† | Rare; generally in presence of acute haemolytic anaemia | Rare; generally in presence of acute haemolytic anaemia | Not reported | Not reported |
| Injection of sclerae and conjunctivae† | Not reported | Reported | Not uncommon; may occur with rash and fever, 5th to 9th day | Rare |

(*Continued on page 46*)

TABLE III—*continued*

| *Reaction* | *Sulphanilamide* | *Sulphapyridine* | *Sulphathiazole* | *Sulphadiazine* |
|---|---|---|---|---|
| Pleural effusion† | Not reported | Occasional; about end of first week | Rare | Rare |
| Ocular and /or auditory disturbances† | Rare | Occasional | Reported | Reported |
| Mental disturbances† | Occasional; occur early | Occasional; occur early | Rare | Rare |
| Peripheral neuritis‡ | Very rare | Very rare | Very rare | Very rare |
| Hepatitis‡ | Occasional; early or late | Occasional | Occasional | Not reported |
| Jaundice‡ | Rare; with acute haemolytic anaemia or hepatitis | Rare; with acute haemolytic anaemia or hepatitis | Rare; with acute haemolytic anaemia or hepatitis | Not reported |
| Gastro-intestinal tract disturbances (other than nausea and vomiting) | Bleeding, rare, diarrhoea uncommon | Rare | Very rare | Not reported |
| Focal necrosis, or cellular infiltrations, in heart, liver and other organs | Reported | Reported | Reported | Not reported |

* Sulphaguanidine has shown little toxicity to date. Nausea, drug rash and fever have occasionally been noted. In hot dry climates and in dehydrated patients the possibility of blockage of the urinary tract by crystalline deposits should be remembered.

† Best to stop drug.

‡ Imperative to stop drug.

# SECTION V

## GAS GANGRENE

Gas gangrene is due to infection of muscle, by anaerobic bacteria of the Clostridium genus. It is one of the most serious and rapidly progressive complications of war wounds, with a mortality rate of between 30 per cent. and 50 per cent. Clostridia may be found as simple contaminants in as many as 50 per cent. of all war wounds, the great majority of which never show any sign of gas gangrene ; furthermore, even when Clostridia are the most important infecting organisms in a septic wound, the condition may be a localised " anaerobic cellulitis," and not a gangrene affecting muscle. Thus the diagnosis must be made on clinical grounds, and not by the identification of gas-forming organisms in the wound.

### PATHOLOGY

Gas gangrene is essentially a progressive myositis, going on to destruction of muscle and the appearance of gas in the tissues. Usually several species of Clostridia occur together in the wound. The chief species causing toxaemia are *Cl. welchii, Cl. oedematiens* and *Cl. septicum.* The toxins of *Cl. welchii* and *Cl. septicum* have a destructive action on tissue, which favours the spread of infection ; *Cl. oedematiens* is relatively non-invasive but it liberates a potent toxin. In addition relatively non-pathogenic Clostridia such as *Cl. sporogenes* and *Cl. histolyticum* may be present, potentiating the action of the pathogens (" anaerobic synergism"); and there may be many varieties of aerobic organisms. The Clostridia are found in soil ; *Cl. welchii* is usually present in the intestinal tract of man and lower animals. The features of the disease are due, first to a local action of the organisms on the sugar of muscle producing acid and gas (the " saccharolytic group "), and on muscle protein causing digestion (the " proteolytic group ") ; and second, the production by the organisms of soluble toxins which diffuse into the tissues, cause further tissue destruction, and ultimately toxaemia.

Gas gangrene occurs principally, though not exclusively, in the lower limb, buttocks, and upper limb, and is most dangerous in the massive muscles of buttock and thigh. An anaerobic cellulitis may also occur primarily in subcutaneous or areolar tissue into which blood has been extravasated, *e.g.* retroperitoneal haematoma. Usually a group of muscles is involved, but the infection may involve a whole limb or limb-segment, especially when there has been interference with the main blood supply. Occasionally, a single muscle, such as the sartorius, is alone affected.

The infection spreads up and down the muscle from the site of the lesion, and has little tendency to spread from muscle to muscle. Even in well established gas gangrene the blood stream is rarely invaded until immediately before death. The gross *muscle* changes occur in three characteristic phases :—(1) At the point furthest from the source of infection the normal purplish-red colour of the muscle changes to brick red, contractility is lost, and the cut surface does not bleed. Gas bubbles may be seen or felt in the muscle, the fibres of which are swollen, more prominent and friable. (2) The brick red colour changes to olive green, and the muscle is more friable. (3) The muscle becomes purplish-black

and glistening, and softens to a pultaceous mass. The *wound*, if of an open type, shows swollen and discoloured subcutaneous tissue and fat, and may expose the dark infected muscle. At first the wound is relatively dry, but later a thin exudate containing droplets of fat and gas bubbles can be expressed from beneath the skin edges. The exudate becomes increasingly dark in colour and offensive, with the smell characteristic of such wounds ; this odour may be absent when the infection is not a mixed one. The *skin* changes are variable and usually of less extent than the infection in the underlying muscle. In the early stages there are no marked changes in the appearance of the skin, apart from some blanching round the wound from pressure. As swelling increases, the skin becomes brownish, with marbling of the surface from stasis in the subcutaneous veins. Mottled white patches then make their appearance, and finally greenish-yellow areas in which blebs may form. The *gas*, produced in and between the muscle fibres, is partly responsible for the swelling of the affected part. It eventually escapes into the subcutaneous tissues under pressure, through holes in the fascia ; whence it spreads rapidly beyond the confines of the infected area.

These pathological changes are modified when the infection is due to a single species ; *e.g.* in *Cl. oedematiens* infection, which is relatively common in certain geographical areas, such as the Middle East, swelling and serous exudate are specially marked features, while gas and smell are minimal.

## CLINICAL FEATURES

There are certain conditions under which gas gangrene is particularly liable to develop : (1) where there has been extensive laceration of muscles, *e.g.* in compound fractures of the long bones ; (2) where there has been interference with the main blood supply to the affected part ; or prolonged application of a tourniquet ; (3) where the wound is grossly contaminated with soil and dirt, and where fragments of clothing and contaminated foreign bodies have been carried deeply into the tissues ; (4) where operation has been delayed by difficulties of evacuation, or owing to shock.

The time of onset is variable, though it is usually between twenty-four to forty-eight hours after wounding ; occasionally it may occur within four hours of wounding, and it may be delayed for four to five days or even longer. There appears to be no correlation between the length of the incubation period and the severity of the disease.

The essential features, without which the diagnosis of gas gangrene should not be made, are pain, swelling, and toxaemia. A feeling of weight or tension in the affected limb may be complained of. The first symptom is usually *pain*, due to pressure caused by gas and exudate, and indeed, any increase in pain in the area of a war wound should always suggest the possibility of anaerobic infection. In infection of single muscles or of muscle groups the *swelling* may be localised and not readily detected. In massive infection of a limb the swelling is generalised, tense and tympanitic. Gas-crepitation may be detected beneath the skin, though it is not co-extensive with the infection. *Toxaemia* is invariable, and causes circulatory failure. A rising pulse rate in a wounded man who has recovered from shock and is not suffering from continued haemorrhage is highly suggestive of gas gangrene. Pyrexia is usually present in the early stages, a subnormal temperature in severe toxaemia. The patient's mental condition is usually anxious but clear till near the end ; occasionally he is

apathetic, or even euphoric. Vomiting may be a feature in severe cases. The characteristic *smell* of gas gangrene can be detected before the dressings are removed ; and the alert clinician can frequently note the change in smell as he enters a ward and be quick to trace it to its source ; on the other hand smell may be absent, especially when the infection is due to *Cl. oedematiens*. It must be emphasised that in these Clostridial infections of muscle, *gas* is a variable and, by itself, a valueless finding. In established gas gangrene it is always present to a varying degree, but until the later stages it is often not clinically apparent ; on the other hand it may be palpated subcutaneously in cases of localised anaerobic cellulitis. Gas bubbles may be seen in an X-ray film of the affected part, and support the diagnosis of anaerobic infection ; but they may be confused with air carried into the wound by the missile.

In brief, the clinical picture is one of a toxic patient, with a swollen painful limb and a dirty offensive wound. The course of the disease is short and acute ; in twenty-four to seventy-two hours the patient will either have succumbed in a fulminating illness or will have mastered the infection.

## TREATMENT

The problem of controlling the established disease is twofold. In the first place any toxin should be neutralised by ensuring the presence in the blood of an adequate amount of antitoxin to the particular toxin present. The second necessity is to check bacterial growth and stop the production of toxin. This may be done by prompt excision of the wound, which removes infected and necrotic tissue, and also by the use of drugs which kill the bacteria or prevent their multiplication. Thus the treatment of gas gangrene involves the combined use of surgery, chemotherapeutic agents, and antisera. Owing to the rapidity with which the disease progresses, full therapeutic measures should be instituted as soon as the diagnosis is made.

### (1) Treatment with Antitoxin.

An adequate dose of antitoxin should be given intravenously as soon as possible, *i.e.* before or during operation rather than after. The dosage of polyvalent gas gangrene antitoxin recommended is not less than 67,000 International Units (27,000 units *Cl. welchii* antitoxin, 13,500 units *Cl. septicum* antitoxin, and 27,000 units *Cl. oedematiens* antitoxin) (*see* Note at foot). This should be repeated at intervals of four to six hours if there is no improvement in the patient's condition, and can conveniently be given in a slow drip with blood, plasma or glucose-saline.

### (2) Surgical Treatment.

Radical surgery is the most important part of the treatment. Where the disease is limited to one group of muscles or a single muscle, the operation consists of an uncompromising excision of all gangrenous and infected muscular tissue. The muscle is cut back until its fibres bleed and contract under the scalpel, care being taken to avoid damage to the blood supply of adjacent muscles. For this purpose the exposure must be wide, but skin should not be sacrificed unduly because it resists infection well.

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NOTE.—In view of the fact that antitoxins available vary in their content, it is at present customary to express the dosage in terms of the *Cl. welchii* antitoxin. On this basis the initial therapeutic dose of the polyvalent serum would be given as 27.000 units (*Cl. welchii* antitoxin) and the prophylactic dose as 9.000 (*Cl. welchii* antitoxin).

In cases of segmental gangrene, where the whole limb or segment is involved, amputation is usually necessary, particularly in the lower limb. The question of amputation must be seriously weighed. It may be necessary as a life-saving measure, but the present chemotherapeutic agents give hope that it may be performed less frequently in future. Before amputation is resorted to, it is justifiable to make incisions in order to estimate the extent of the disease.

Following surgical treatment the wound should be insufflated with sulphanilamide or other antiseptic powder and left widely open, covered by gauze dressings, and immobilised by some form of splintage.

Almost equally important as operative surgery is the transfusion of blood or plasma, which may be required in large amounts to counteract the circulatory failure and serous discharge.

**(3) Treatment by Chemotherapy.**

Of the present known chemotherapeutic agents Penicillin has the most marked bacteriostatic action on the Clostridia in general. The sulphonamides are more uncertain, but of them sulphathiazole is the most effective.

It is probable that chief reliance should be placed on the parenteral administration of sodium Penicillin, in dosage of 500,000 units spread over five days, beginning with 25,000 units intramuscularly before operation. This should prevent multiplication of the infecting organisms and spread of infection, but will not prevent absorption of toxin from gangrenous muscle to which the blood stream cannot gain access.

Sulphathiazole, failing which sulphapyridine or sulphadiazine, should be given in large but not massive dosage : 15 gm. per day for one or two days of sodium sulphathiazole intravenously, in saline drip with oral sodium bicarbonate to prevent crystallisation and anuria, followed by a short routine oral course of sulphathiazole, 4–6 gm. daily.

In addition to this systemic medication, the wound should be insufflated initially with 10–15 gm. Penicillin-Sulphanilamide powder (2,000 units Penicillin per gm.), or 10–15 gm. sulphanilamide powder.

## PREVENTION OF GAS GANGRENE

The prevention of the disease involves early and efficient surgical treatment of war wounds, associated with chemotherapy. As a minimum prophylactic dose 9,000 units of *Cl. welchii* antitoxin (22,500 international units of polyvalent antitoxin) should be given in the case of wounds that are potentially the type to develop gas gangrene (*see* Note p. 51).

## OTHER ANAEROBIC INFECTIONS

**Anaerobic Cellulitis.**

This is a Clostridial infection of the superficial tissues of the wound track, which may occur in any dirty wound that has been inefficiently treated or not treated at all. It resembles gas gangrene in that the wound is dirty and offensive, and gas-crepitation may be well marked ; but the pain and swelling of progressive myositis are absent. It is not to be regarded lightly, for it may spread rapidly and extensively in the tissue spaces; though it responds well to adequate drainage and surgical removal of dead tissue.

**Anaerobic Streptococcal Infection.**

The anaerobic streptococcus may be the principal pathogenic organism in any severe and intractable septic wound. It is also responsible for the rare but definite condition of *anaerobic streptococcal myositis*, in which, in the absence of Clostridia, there is none the less massive infection of muscle with oedema, serous exudate, gas-formation, and sometimes actual gangrene of muscle. The condition develops relatively late, the average time of onset being four to five days after wounding. Toxaemia is not a constant feature, and seems to depend on concomitant organisms. The disease progresses, with insidious increase in the extent of the oedema and copious serous exudate, and it frequently ends fatally. Treatment consists of deep incisions through the fascial sheaths to relieve tension; transfusions; and chemotherapy. Amputation is not indicated as an early measure.

The following notes will assist in the differentiation of the condition from Clostridial gangrene :—

(i) In streptococcal myositis cutaneous erythema is usually well marked, and there is more discoloration of the skin than of the muscle; in gas gangrene the opposite is generally the case.

(ii) The discoloured muscle in streptococcal myositis is coppery in colour, but it has not the boiled and coagulated appearance found in typical gas gangrene; further, the muscle is alive and will react to stimuli.

(iii) Smell is neither so pungent nor so sweet as in gas gangrene.

(iv) Films of muscle in streptococcal myositis, when strained by Gram's method, show large numbers of streptococci and many pus cells.

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NOTE.—Further information will be found in M.R.C. War Memorandum No. 2 (Revised second edition, 1943) : *Notes on Gas Gangrene.*

# SECTION VI

# TETANUS

Tetanus, or lockjaw, is due to the action of the toxin of *Cl. tetani* on nervous tissue. The disease is marked by severe spasms of voluntary muscles which usually begin about the face and neck and rapidly become general. As a sequel to wound infection tetanus has formerly been one of the most dangerous and dreaded diseases of the battlefield; it can now be largely prevented by an enlightened application of the principles of immunology and modern surgery. But it is necessary to understand the mechanisms of infection and immunity so that the factors which govern successful prevention may be fully understood and applied.

## MECHANISM OF INFECTION

The organism responsible for tetanus (*Cl. tetani*) is a sporing anaerobic bacillus which is readily found in cultivated soil, especially if it has been enriched by stable manure, since the organism is often found in the intestine of the horse. Contamination of wounds with tetanus bacilli thus frequently occurs and has been noted in a significant proportion of men wounded in the desert where anaerobic bacteria as a whole are

relatively scanty. The highly cultivated soil of France and Flanders over which so much of the war of 1914–18 was fought, provided infinitely greater opportunities for contamination and it must be borne in mind that our measures of tetanus prevention have not as yet been tested in this war on the maximum scale. Other sources of tetanus spores—imperfectly sterilized catgut, cotton wool, talcum powder, gauze packs and sulphonamide powders—have accounted for outbreaks of tetanus in hospitals; the importance of proper sterilization of all dressings applied to wounds cannot be too strongly emphasised. The presence of tetanus spores in a wound has been frequently noted where the clinical disease has not developed. One reason for this is that the diffusible exotoxin which produces the signs and symptoms of tetanus is not produced by the spore itself but by the actively growing vegetative bacillary forms which germinate from the spore. *Cl. tetani* is a strict anaerobe; that is to say its spores will germinate and give rise to actively growing bacilli only in an environment from which free oxygen is excluded. Thus it becomes apparent how tetanus organisms may be cultured from the wounds of men who are not suffering from the disease. If necrotic areas and foreign bodies have been removed from a wound and if its blood supply is adequate, then all parts of it are freely oxygenated and the spores, though present, do not find conditions suitable for germination. Conversely if a wound contains pieces of clothing, blood clot, or areas of necrotic tissue or if its blood supply is precarious, conditions readily become suitable for the germination of spores and the production of toxin.

## PREVENTION OF TETANUS

### Surgery.

From what has been said of the mechanism of infection it will be apparent that the first essential step in the prevention of tetanus is adequate surgical treatment of all wounds. This involves thorough cleansing, free removal of devitalised tissues and pieces of clothing, the arrest of haemorrhage, removal of blood clot and the application of measures appropriate to control pyogenic infection which, in certain circumstances, may produce the conditions favourable to the development of tetanus. Fatal tetanus has developed in certain instances in spite of surgical toilet and immunisation because masses of necrotic tissue remained unsuspected in the depths of wounds healing superficially. Conditions were thus so favourable for the development of large amounts of tetanus toxin that the protection afforded by immunisation was insufficient to save the life of the patient.

### Immunisation.

Since the war of 1914–18 *active immunisation* against tetanus has been developed and the evidence already available shows that this is a procedure of the greatest value. Active immunisation is conferred by the use of toxoid, a modified tetanus toxin which has been so altered that its power to produce pathological effects has been removed, but its capacity to stimulate the production of anti-toxin remains. An important point is that antitoxin production in response to injection of toxoid is relatively slow and does not reach significant levels after a single inoculation. The first injection appears to do little more than sensitize the source of antitoxin production, but a second injection after an interval of at least six weeks produces a significant level of antitoxin in the blood. Although this level gradually falls the body now has a sort of " shadow factory "

ready to produce large amounts of antitoxin in response to the stimulus either of toxin or of further injections of toxoid.

The practice in the British Army is that each man shortly after enlistment is inoculated either subcutaneously or intramuscularly with two doses of 1 c.c. of tetanus toxoid at an interval of six weeks. After a further interval of at least six months—often a year—a third dose of 1 c.c. is given, which is thereafter repeated at yearly intervals or more frequently where local conditions make this seem necessary. Tetanus toxoid causes little or no reaction especially since the peptone used in its manufacture has now been altered so as to make the rare anaphylactic reactions still less frequent. It is, however, a good precaution to have a syringe charged with adrenalin at hand during inoculations.

Without entering into detail it may be said that experience in this war has fully justified active immunisation with tetanus toxoid. But there is a limit to the amount of toxin which can be neutralised and a further point of importance is the delay of about five days before the " shadow factory " can be relied on to produce a useful amount of antitoxin in response to a specific stimulus either from toxin or further injections of toxoid. In the light of experience, as well as on purely theoretical grounds, the British Army combines active immunisation as described above with passive immunisation in the event of wounding.

*Passive immunisation* is conferred by administration of antitoxic serum. In this way antitoxin is immediately available to neutralise toxin elaborated in a wound where tetanus organisms have found conditions favourable for growth. Since antitoxin does not stimulate antibody production its effects are essentially transitory and the injection must be repeated. In the first six months of the war of 1914–18 the incidence of tetanus was so high that it was decided from that time to give antitoxin to every wounded man irrespective of the nature of his injury, instead of leaving the administration to the discretion of medical officers. A dramatic fall in the incidence of tetanus resulted and from that time onwards this grave disease was kept within very narrow limits.

In this war the procedure in the British Army is to give each wounded man, as soon as possible after an injury is inflicted, an intramuscular injection of 3,000 international units (I.U.) of tetanus antitoxin. This is intended to cover any gaps in the protection afforded by active immunisation and its administration is important. It covers the danger-period of several days before the " shadow factory " set up by active immunisation begins to produce antitoxin in quantity. It has the additional advantage that it covers any men who may have refused or escaped active immunisation ; but such men will need two extra doses of 3,000 units at weekly intervals to make them safe. Further weekly doses may be indicated if the wound continues to be one in which tetanus organisms might develop. Nor should it be forgotten that tetanus spores may be latent for long periods—up to ten years at least—in healed wounds. Before operating on such wounds or on any individual with a previous history of tetanus, a further prophylactic dose of antitoxin is necessary.

*Modified procedure in American and Canadian Soldiers.*—In the U.S. and Canadian Armies a modified procedure of active immunisation aims at maintaining a level of circulating antitoxin so high that passive immunisation after wounding is unnecessary. American and Canadian soldiers are given a final " boosting " dose of 1.0 c.c. of toxoid after wounding

instead of a dose of antitoxin. This difference in immediate treatment does not, of course, affect the later use of antitoxin in established cases of tetanus or where the man has not previously been actively immunised.

*Summary of British procedure.*—The following summary of active and passive immunisation procedure in the British Army may be helpful :—

*Active immunisation.*

| | |
|---|---|
| On joining, first dose .. .. .. .. .. | 1.0 c.c. toxoid. |
| Six weeks later, second dose .. .. .. .. | 1.0 c.c. toxoid. |
| Six months to one year later, third dose .. .. | 1.0 c.c. toxoid. |
| Annual dose (maintenance) .. .. .. .. | 1.0 c.c. toxoid. |

NOTE.—According to local conditions the maintenance dose may be repeated at shorter intervals.

*Passive immunisation on wounding.*

If toxoid previously given (at least two doses), 3,000 I.U. A.T.S.

If toxoid not previously given (or one dose only), 3,000 I.U. A.T.S. at weekly intervals for three weeks or longer as may be necessary.

## ESTABLISHED TETANUS

Application of the best surgical and immunisation technique has gone far to eliminate the clinical disease as an entity. Unhappily, flaws in execution may defeat the most carefully regulated plans and the disease may break through the defences. The best hope then lies in early diagnosis followed by prompt treatment.

**Symptoms and Signs.**

Immunisation may greatly modify the incubation period, signs and course of the disease. The first evidence of infection often appears between eight and twelve days after wounding, but the incubation period is extremely variable, especially after immunisation. Much tetanus toxin may be produced in a wound ; while the part is at rest this may be absorbed only in small amounts which are easily neutralised by circulating antitoxin. But movement, especially if sudden, may release a flood of toxin too great to be neutralised by the available antitoxin and symptoms abruptly develop. It is thus equally impossible to say when the risk of tetanus is past or when it may be expected to appear. So long as a wound remains favourable to development of the organism there is need for constant vigilance to detect the earliest indications of the prodromal period when a dose of antitoxin is worth all that may be done twenty-four hours later.

Early indications may be of a general nature such as irritability, shivering, insomnia, increased reflexes, muscular tremors, or they may be local such as spasm or rigidity in the muscles near the wound. Sore throat, painful dysphagia, stiff neck, and difficulty in starting micturition, have all been noted as early evidence of the muscular irritability which is an essential feature of the disease. In favourable cases where immunity is relatively high the disease may remain no more than local tetanus. When the earliest stages are passed the sinister evolution of signs permits no doubt as to their serious import. Trismus and *risus sardonicus* due to spasm of the masseters and muscles of the face, are signs of established generalised tetanus and are soon accompanied by arching of the spine—usually backwards but sometimes forwards or to the side—and by respiratory difficulties from intercostal spasm. Painful generalised convulsions with widespread rigidity lead to death from respiratory or cardiac exhaustion, or from hyperpyrexia, which is often a feature.

**Differential Diagnosis.**

Difficulty in diagnosis seldom arises. Stiffness of the jaw from dental causes, Vincent's angina, tonsillitis or osteo-arthritis are seldom associated with neck rigidity. In strychnine poisoning the jaw and neck muscles are not specially affected, there is complete relaxation between spasms and a normal temperature is the rule. In tetany the extremities are mainly affected, and the posture is characteristic. In rabies the history is different, psychological disturbance is prominent and the spasm is chiefly laryngeal and pharyngeal. Wounded men who know the symptoms of tetanus may develop hysterical trismus, but other evidence is usually lacking. Neck rigidity due to meningitis may cause difficulty which, however, can be resolved by lumbar puncture.

Bacteriological identification of *Cl. tetani* in wounds is a lengthy procedure and requires several days; treatment should never be delayed until a laboratory report is available. The morphological appearances in stained films are not sufficient to differentiate *Cl. tetani* from other terminal spored anaerobes; moreover tetanus organisms may be found in wounds without the presence of the clinical disease.

**Treatment.**

*Antitoxin.*—When the diagnosis is made 200,000 I.U. of antitoxin should be given intravenously. If the full amount is not immediately available as much as possible should be given and the balance later. Intravenous administration is the method of choice; if for any reason it cannot be used intramuscular administration is the next best. The subcutaneous route should not be employed since by this method the antitoxin in the blood does not reach its maximum until about the third day after administration. Intrathecal administration of antitoxin, once keenly advocated, is now condemned as dangerous. Lumbar puncture is not advised unless it is required as an aid to differential diagnosis. After the initial 200,000 units of antitoxin, a further 50,000 units intravenously should be given at intervals until the reflex spasms subside. Another dose is necessary before any subsequent operation on the wound during the course of the disease. Doses of 3,000 I.U. of antitoxin intramuscularly may have to be continued at weekly intervals to prevent relapses after the acute stage of the disease is over so long as the wound remains one in which the conditions favour development of tetanus organisms. With the new refined antitoxin, anaphylactic reactions may almost be discounted. They should be treated, if they occur, by intravenous or intramuscular injection of a few minims of sterile 1–1,000 adrenalin followed by 1 c.c. of pituitrin subcutaneously.

*Local measures.*—Different opinions have been expressed as to whether the wound should be treated surgically or left alone once tetanus has developed. The recommendation is to give the dose of 200,000 I.U. antitoxin intravenously and *one hour later* to aim at converting the anaerobic into an aerobic wound by thorough drainage, evacuation of pus and removal of foreign bodies and necrotic or infected tissue. Thereafter oxygenation of the area may be assisted by four-hourly irrigations with hydrogen peroxide. In this way it is hoped to remove the source of infection and prevent further production of toxin. It should be noted that the wound is not disturbed until an hour after the full dose of antitoxin has been given intravenously. Thus the danger from absorption of large amounts of toxin through disturbing the wound is overcome. The

role of sulphonamides in preventing and treating tetanus is difficult to assess in the light of the evidence so far available. It is probable that their main value is in restraining the ordinary pyogenic bacteria whose growth may favour the development of anaerobic conditions in a wound. Tetanus has resulted from applications of sulphanilamide powder contaminated by tetanus spores; hence the importance of sterilizing sulphonamide powders for local application.

*Anaesthetics and Sedatives.*—If convulsions have not begun when the disease is recognised large doses of bromide should be given. If convulsions come on within four days of the first symptom their control by anaesthetics or sedatives is indicated. For this purpose bromethal (avertin) or paraldehyde may be chosen according to circumstances. Bromethal should be given by the rectum in doses of 0.07 to 0.1 c.c. per kilo of estimated body weight. Paraldehyde is also given by the rectum, in a dose up to 8 drachms as for basal anaesthesia. Two or more doses per day may be required. Along with bromethal or paraldehyde oxygen may be given by B.L.B. mask or nasal tubes to prevent cyanosis. Atropine may be useful in preventing excessive bronchial secretion but should be withheld if the lungs are already moist. For the control of very severe and prolonged spasms which often develop suddenly and cause difficulties of respiration, general anaesthetics such as chloroform or ether may be required but, like morphine, should be used sparingly. Pentothal sodium is sometimes useful but may be difficult to administer during spasms.

Should spasms not appear for four days or later after the first symptoms, and if they are not severe, treatment with bromethal or paraldehyde is not indicated, but the drugs should be held in readiness to be used if the spasms become severe.

*General measures.*—Good nursing in a quiet darkened room kept at as even a temperature as possible can do much to lessen spasms. The patient should not be moved during this phase if it can be avoided; as far as possible enemas, wound dressings, hypodermic injections and the like should be given when the patient is most under the influence of sedatives. Adequate nutritive fluid is required frequently in small quantities and may have to be given by stomach tube. Hyperpyrexia requires treatment by tepid sponging.

When recovery begins sedatives are carefully reduced according to the number and intensity of the spasms, tonic rigidity which may be present during this phase is not dangerous and will pass off.

## SECTION VII

## ANAESTHETICS

Since the last war, the problem of anaesthesia in the Field has been simplified by the introduction of new drugs and improved methods of administration of the older agents. Chief among these innovations are the development of the intravenous route consequent upon the discovery of the various barbiturates, the use of such agents as Cyclopropane and Trilene, and the invention of a most useful machine for giving definite percentages of ether and air known as the Oxford Vaporiser Number 1.

Considerable advances have also been made in the technique of local analgesia and though its use in war surgery is chiefly to re-enforce general

anaesthesia, local blocks, *e.g.*, brachial block, are useful in severe injuries of the hand, and intercostal block combined with bilateral splanchnic block is occasionally used for an abdominal injury.

Spinal analgesia has a very small place in the surgery of the wounded man.

All cases should have adequate premedication. Many of them will have been heavily morphinised as part of first aid. These should be given Atropine intravenously when time is short. When little or no Morphia has been given Omnopon and Scopolamine should be employed, again intravenously if necessary.

From the point of view of anaesthesia the wounded may be divided into three main classes :—

I. The lightly wounded.

II. Those suffering from severe wounds with shock and haemorrhage.

III. Those suffering from severe sepsis, especially anaerobic infection.

## I. THE LIGHTLY WOUNDED

These patients are on the whole good subjects for anaesthesia, though often tired and exhausted. The chief desiderata for the anaesthetic are safety, speed, comfort and convenience ; recovery should be rapid and after effects few so that the patient may be fit for early evacaution.

Most of these requirements are met by the use of intravenous pentothal sodium. Pentothal saves time, it can be prepared in bulk before a rush of casualties, it can be given to the patient on his stretcher enabling splints and clothing to be removed painlessly and after effects are absent. Should a longer anaesthesia be required further small doses may be injected or the anaesthetic supplemented by nitrous oxide and oxygen.

If, for any reason, pentothal and nitrous oxide are not available, a satisfactory alternative is ether preceded by ethyl chloride.

## II. THE SEVERELY WOUNDED

With the severely wounded the chief consideration is safety. The anaesthetic chosen must be not harmful to a patient suffering from shock and should leave few after-effects. In some cases it must, in addition, give adequate muscular relaxation.

General anaesthesia should be employed in almost all cases, though it may be re-enforced by local. Local analgesia alone is not entirely satisfactory. It is time consuming and many patients become restless during operations under local.

Spinal analgesia should not be used in the surgery of the severely wounded.

## III. THOSE SUFFERING FROM SEVERE SEPSIS

In anaesthesia for these cases the more toxic agents such as ether and chloroform should be avoided. This is especially so in cases of anaerobic infection. The best technique is to carry out induction with a small dose of pentothal and to maintain the anaesthesia with nitrous oxide and oxygen. Care must be taken to keep the percentage of oxygen in the mixture high, as even a slight degree of anoxia will bring about deterioration in the patient's condition.

If available, cyclopropane and oxygen is useful in these cases.

## ANAESTHESIA IN RELATION TO SHOCK

However urgently operation is required it should not be undertaken in a patient suffering from shock until measures have been taken to improve his condition. The only exception to this is a patient suffering from active haemorrhage.

The resuscitation will generally be carried out in the resuscitation ward and the officer in charge will decide when the optimum time for operation has arrived.

The chief restorative measures are warmth, morphia (which can be given intravenously in small doses) and the administration of fluids. Fluid may be given by the mouth (except in abdominal injuries) by the rectum or intravenously in the form of blood or plasma. Care should be taken not to overdo warmth and morphia as excess of either may have a harmful effect, but used with care both are of considerable value. The restorative measures should be continued during operation and an anaesthetic employed which, as far as possible, does not increase shock.

Continuous pentothal in very small amounts injected along with saline blood or plasma drip will give the best results in cases not requiring muscular relaxation. Nitrous oxide and oxygen may also be used, ether being added to the mixture where relaxation is required as in abdominal cases ether may be given alone by the Vaporiser following an induction with pentothal.

## RISK OF EXPLOSION FROM ETHER

When ether is in use in an operating room or tent in which naked lights are exposed, the risk of fire or explosion should never be overlooked. Unless ventilation is satisfactory it will be wiser to employ intravenous methods or gas and oxygen.

## ANAESTHESIA IN RELATION TO SPECIFIC WOUNDS

The choice and method of anaesthesia is also influenced by the site of the operation.

### Wounds of the Head.

Local analgesia may be used alone but has not proved entirely satisfactory. Many patients become restless and a long period in one position is trying to a conscious patient. Also he may have wounds elsewhere requiring operation unsuitable for local analgesia.

The best anaesthetic both in forward areas and at the base is pentothal sodium. This may be used alone or combined with local. Anaesthesia is induced with 0.5 g. in 5 per cent. solution and maintained by intravenous drip using 1 per cent. solution in normal saline. With this method induction is quick, breathing quiet during the operation, the brain does not bulge and post anaesthetic vomiting is rare. There is no risk from explosion if diathermy is used.

Pentothal, if used with care, is a safe anaesthetic in head cases. Carelessly used it is extremely dangerous. Special care is needed in stuporous patients and in those with depressed respiration.

The initial injection should be given very slowly. As soon as the patient is unconscious an oral airway is inserted, or if this is not tolerated, a Magill tube size 7 or 8 cut to a length of 5½ inches, is passed down one nostril and its end transfixed with a safety pin to prevent it disappearing

into the nose. Oxygen should always be at hand and if breathing becomes shallow a bag containing oxygen should be placed over the face and the lungs rhythmically inflated. Breathing will soon be re-established. Cyanosis must never be allowed to persist. If at any time during the operation the surgeon notices the colour of the blood is not perfect, he should warn the anaesthetist who should attend to the airway and at once administer oxygen.

As an alternative to pentothal, nitrous oxide and oxygen re-enforced by small amounts of trilene or chloroform may be employed. Ether should be avoided as it causes congestion of the brain and there is as well a risk of explosion. If the site of the injury necessitates the patient being placed on the table in a position which might hamper respiratory movement the anaesthetist should, by the use of pillows and sandbags, make certain that no impediment to free respiration is allowed to persist.

Endotracheal intubation need not be used unless there is some special indication. Such indications are :—

(i) Cases involving operation on the air passages such as injuries to the frontal sinus. These should be intubated to prevent the aspiration of blood or debris.

(ii) Cases requiring to be operated on in the prone position. Difficulty is often experienced in maintaining a clear airway in this position and vomiting is apt to occur when the patient is turned over.

The larynx should be cocainized and intubation carried out under pentothal anaesthesia by direct laryngoscopy, the throat packed off and anaesthesia maintained with nitrous oxide and oxygen with the addition, if necessary, of small amounts of trilene or chloroform.

**Maxillo-Facial Wounds.**

These are among the most difficult cases the anaesthetist may meet. A wrong choice or a fault in technique may bring about a sudden fatal result. Many of these cases have compound and frequently comminuted fractures of the jaw with floating tongue. The most important factor is to maintain a clear airway before, during and after anaesthesia. Some cases after an apparently successful operation have died in bed from neglect of this precaution.

During induction of anaesthesia every effort must be made to avoid struggling. Care must be taken to prevent the entry of blood into the air passages. If there is bleeding into the mouth or nose the patient should be placed on his side and his mouth cleared of blood and a gauze pack placed on the bleeding surface. The induction is carried out with pentothal with the patient still on his side ; as soon as anaesthesia is established he is turned on his back and quickly intubated either through the nose or mouth, the pharynx packed with gauze soaked in saline or paraffin, anaesthesia being maintained with ether from the Oxford Vaporiser and kept at the lightest possible level. As long as the endotracheal tube is in place the patient is safe from respiratory obstruction. At the end of the operation, and when all bleeding is arrested, he is once more placed on his side, the pack and tube removed, a naso-pharyngeal tube passed and fixed with adhesive plaster. Such a tube is far more comfortable and better tolerated than an oral airway.

Should intubation prove impossible or when haemorrhage has only been controlled by packing, a tracheotomy should be performed, the pharynx

packed, and anaesthesia maintained through the tracheotomy tube. It must be remembered that in a badly shocked patient a slight degree of laryngeal obstruction can cause death.

The anaesthetist must exercise great care in using a gag, as a sudden movement may convert a simple into a compound fracture.

If the patient is wearing dentures, these should be carefully preserved as they may be of the greatest use to the dental surgeon in the subsequent treatment of the case.

**Wounds of the Chest.**

In forward areas the present tendency is to reduce operations on chest cases to a minimum. They are chiefly undertaken for closure of an open pneumothorax, aspiration of haemothorax, and arrest of haemorrhage. For these cases a small dose of pentothal will prove adequate. Cyanosis must be avoided, oxygen being given along with the pentothal.

For more extensive operations at the base and at special chest units, local analgesia is sometimes used, but in most cases a general anesthetic is to be preferred.

In most chest units cyclopropane is available and, provided there is no danger of explosion from diathermy or naked lights, is the method of choice. Induction is carried out with pentothal and maintained with cyclopropane and oxygen using the closed circuit technique.

If cyclopropane is not available nitrous oxide and oxygen with small amounts of trilene can be used, keeping the oxygen content of the mixture high. Here again the induction should be carried out with pentothal.

At the end of the operation oxygen is given by means of a B.L.B. mask and continued during the journey back to and on arrival in bed.

**Abdominal Wounds.**

For these cases complete muscular relaxation is required. Unless this is obtained the surgeon's work will be hampered, made more traumatic, and the time of operation prolonged. Although the most perfect muscular relaxation can be obtained with spinal analgesia, this method should never be employed for an abdominal operation on a wounded man. Local analgesia by means of intercostal and splanchnic blocks has been recommended as the ideal for these cases, but it is too time-consuming in a rush of casualties and unless the patient is heavily dosed with morphia it places a considerable strain upon him.

For general anaesthesia a small dose of pentothal followed by nitrous oxide, oxygen and ether will prove satisfactory especially if a closed circuit machine is available but almost equally good results may be obtained with the Oxford Vaporiser. If the operation is likely to be a long one or when trouble is anticipated with the airway an endotracheal tube should be passed. Where this is done anaesthesia can be maintained at a somewhat lighter plane. If the surgeon infiltrates the line of the incision and each layer of the abdominal wall with 1 per cent. novocain and adrenalin solution, muscular relaxation may be obtained with a lighter degree of anaesthesia. Surgeons should make long incisions and speed and gentleness on their part has great influence on the future progress of the case.

Abdominal cases should be handled with great care after operation and not turned over. Should the patient have a wound of his back or buttock as well as an abdominal wound, these should be dealt with before the abdomen is opened.

**Burns.**

In severe burns the choice of the anaesthetic is important. Patients with recent extensive burns suffer from severe shock and local treatment should not be undertaken until this has been overcome by transfusion. Plasma should be given before, during, and if necessary after, the local treatment. During the first thirty-six hours after injury a small dose of pentothal given with the transfusion will be satisfactory. Cases of burns appear to be very susceptible to pentothal so the injection should be made slowly and the smallest possible dose given. Oxygen should be administered along with the pentothal.

In cases treated more than thirty-six hours after injury the liver may have suffered from the effects of the burn, so pentothal is better avoided. In these cases a small dose of morphia given intravenously followed by general anaesthesia with nitrous oxide and oxygen will give good results provided anoxia is avoided.

## SECTION VIII

# HAEMORRHAGE AND INJURIES OF THE LARGE VESSELS

### HAEMORRHAGE

In the Field, bleeding from large vessels into the thoracic or abdominal cavities is responsible for a large proportion of immediate deaths. However, if the main artery of one of the extremities is cut or torn across completely there may be no immediate progressive bleeding to threaten life. If, on the other hand, the wound of the vessel is incomplete—and this applies equally to arteries of modest calibre—bleeding will continue till the subject faints and it may recur when he recovers from this state. First aid for such conditions should include some method of haemostasis. It has been customary to rely on the tourniquet for this purpose and orderlies are trained to use it. Many surgeons have noted the difficulty experienced by the partly trained in differentiating arterial, venous and capillary bleeding. This difficulty often leads to the unnecessary application of the instrument. In fact, most surgeons are of the opinion that its use has been productive of more harm than good. The manifest shortcomings of the tourniquet in the zone in question arise from the following considerations :—

(1) The instrument is sometimes applied so as to obstruct the venous circulation without completely checking the arterial—serious venous and capillary oozing resulting.

(2) It may be applied so harshly that the main nerve trunks are damaged —this has been observed most often in the upper extremity.

(3) The rush of evacuation may lead to a tourniquet being left *in situ* for many hours. This will cause serious changes in the limb such as infection, ischaemic paralysis or gangrene.

The danger of such effects can be reduced by NOT warming the damaged limb. Indeed, if the limb is allowed to cool down to air temperature, this reduces metabolism and may delay infection. Tissues are thus likely to remain viable for a longer time, when there is a minimal amount of oxygen available for their use.

Temperatures as low as 5° C. will do no material harm to ischaemic tissue and there is evidence that amputation or other surgical procedures can be carried out with success after twelve hours or longer after a limb has been kept cooled to this extent. Any temperature of 4° C. or less is harmful and will cause serious damage.

The routine use of the tourniquet is therefore NOT recommended in first aid work. As a rule haemostasis will be sufficiently effected if direct pressure is exerted on the wound. This may, in the first place, be by direct digital pressure, and should be followed by the firm bandaging of an adequate dry gauze dressing which has been pressed into the wound. If a rubber bandage is used for this purpose it is liable to cause considerable venous congestion.

**At the R.A.P. or A.D.S.**

When there are light and reasonable operative facilities wounds showing signs of progressive haemorrhage should be inspected.

If recognised, bleeding points should be ligatured or underrun. Sometimes it may be necessary to leave pressure forceps *in situ*, stabilising them by a suitable dressing. If these measures fail, tight plugging held in place by suture is the remaining resource. A man so treated should be put on the priority list for evacuation to a surgical centre.

**At the C.C.S.**

After the commencement of resuscitation any wounded who are still bleeding or in whom reactionary haemorrhage is a possibility are submitted to operation. The wound should be freely opened by longitudinal incision, clot is cleared and dead tissue excised. Haemostasis is then effected on normal surgical lines. If it is necessary to ligature a major vessel, the procedure and after treatment should be as detailed below.

Access to the bleeding point will usually be through the wound track ; when the wound is small the classical routes will sometimes be taken. In exposing the posterior tibial in the calf the most effective approach is by direct incision in line with the vessel through the substance of the calf muscle and not that described in the older books.

In the control of bleeding from the face or fauces, a determined attempt at direct ligature should be made. If this fails, as is most often the case in secondary haemorrhage, ligature of the external carotid is often ineffective and the common carotid should then be tied just below its bifurcation. The risk of cerebral complications in a young man with healthy vessels is not great and must be accepted.

The control of bleeding from the scalp or sinuses is considered in Section XVII, p. 103 ; concealed haemorrhage into the thoracic or abdominal cavities, in Sections XIX and XX, p. 115 and p. 123.

It may be noted here that a healthy man can recover from a primary loss of blood of up to two litres ; if he should subsequently bleed again, a comparatively small loss may bring him to death's door.

## SECONDARY HAEMORRHAGE

Secondary haemorrhage occurs only in the presence of active sepsis. It generally occurs from an artery which has been damaged at the time of the primary wound or from one which has been cut across and ligatured at an amputation. It sometimes results from the erosion of an intact

exposed vessel by an inflammatory process or may be associated with the friction or pressure of a sharp bony fragment on the vessel wall.

**Time of Onset.**

This type of haemorrhage is not seen till some days after the primary wound and is rare until the second week. So long as sepsis is active in a wound it remains a possibility. Warning of an impending serious haemorrhage is usually given a day or two before it occurs by the appearance of blood streaks or a slight trickle of blood in the wound discharge.

**Treatment.**

This should, if possible, be undertaken before a major haemorrhage has forced matters. The principles of action are the same as for primary bleeding. Control is effected by direct pressure, or if necessary, by the application of a tourniquet till the patient is on the table and under anaesthesia. The bleeding point should then be sought for and the vessel doubly tied with catgut above it at the nearest level at which it is firm enough to stand ligature. A ligature below as well may sometimes be necessary. Proximal ligature at the site of election is unsatisfactory and should only be employed as a last resort; this will most often be the case in a gluteal haemorrhage not accessible to direct control. In such an instance ligature of the appropriate internal iliac should be carried out. Occasionally haemostasis can only be effected by leaving pressure forceps *in situ*.

In dealing with bleeding from an amputation stump, if the tissues are oedematous and fragile from inflammation, it may be well to make an incision through fresh tissue just above the level of the amputation. The vessel is found and ligatured a short distance from the leak with stout catgut. The new wound made for this purpose should not be sutured.

**Transfusion.**

Should be commenced early, preferably with whole blood.

When haemostasis has been effected, free exposure of the infected tissues should be obtained by incision of fascia or excision of muscle. The cavity should be dressed with vaseline sulphonamide gauze and left widely open.

**Amputation.**

In recurrent cases or rarely in a patient in a toxic state following prolonged suppuration about a fracture, amputation may be a life-saving procedure.

## DELAYED HAEMORRHAGE

This type of bleeding is sometimes referred to as secondary, but as infection is not present, such nomenclature is misleading. It is observed after injury to the spleen or liver when haemostasis has apparently taken place spontaneously.

A few days later—from three to ten days—bleeding starts again and may be sufficient to give unequivocal signs of internal haemorrhage. The cause is presumed to be the rupture of an arterial haematoma by intestinal movements or a rise in the blood pressure.

The condition has been most often recorded in relation to injuries of the spleen but it is also met with after non-fatal ruptures of the liver. Clearly such instances will be observed when prompt surgery has not been available, or has been withheld, after the primary injury.

**Signs.**

Will be those of internal haemorrhage. They may be preceded by some pain and abdominal rigidity. If the bleeding is from the spleen, pain in the left shoulder may be present.

**Treatment.**

Laparotomy through a long upper paramedian incision while transfusion is carried out. When the spleen is involved it should be removed. In the case of the liver, thick catgut sutures passed on a large round bodied needle may be effective. Occasionally a dry gauze pack must be employed.

## ARTERIAL HAEMATOMA

This is most frequently seen in a dangerous form in the axilla or popliteal space. If the condition localises without producing undue pressure on the surrounding vessels or nerves, a conservative attitude may be adopted.

**Treatment.**

If the condition is progressive or if there is a risk or evidence of infection, operation should be undertaken. The vessel above the haematoma is controlled by tourniquet or if this is not feasible by temporary occlusion of the main vessel by digital pressure or with a rubber tube loop. The haematoma is then fully exposed, the clot turned out and the damaged vessel sought for and ligatured above and below the tear after its complete division.

## LIGATURE OF MAIN VESSELS

If a main artery is divided clean across by a missile, retraction and spasm often result in only a slight loss of blood. If the vessel is only partly divided bleeding will not stop and ligature is necessary. Attempts to suture vessels after injury have been carried out with occasional success with and without the use of heparin, but this procedure has no place in field surgery. The risk of gangrene, however, of varying degree is considerable, especially if the popliteal artery is involved. It has been customary to advise ligature of the main vein at the same time as the artery with a view to increasing the venous capillary pressure and so assisting in the establishment of the secondary circulation. The evidence in favour of this procedure is not convincing, and there is no doubt that it is sometimes followed by a heavy venous limb.

**Assisting the Collateral Circulation.**

One observer has reported thirty-two cases of ligature of main vessels for various causes. In nine of these the popliteal artery was involved. In every instance a suitable sympathectomy was carried out before or at the time of ligature. In no instance was there any anxiety as to the subsequent viability of the limb. This evidence that arterial spasm is the cause of the failure to develop an adequate collateral circulation after ligature of the main vessel is important. However, in field surgery, application of the principle will be inadvisable as a routine.

Spasm of the arterial system should be guarded against so far as possible by gentle handling of the vessel before ligature and by its complete division.

After ligature, the part affected by the procedure should be kept cool

so that metabolism in the part is at a low level. This can be effected by avoiding heavy dressings and exposing the limb to the air. The body and unaffected extremities should be kept warm (up to 45° C.) as this leads to a reflex dilatation of the vessels in the cooled limb.

**Arterio-Venous Aneurism.**

This condition is of gradual development and does not call for immediate action. The same is true of aneurismal varices. Any question of radical treatment should be deferred for some months.

## SECTION IX

## THE TREATMENT OF WOUNDS AT THE BASE

Most wounded patients admitted to the base hospital will already have been operated upon, and in respect of these the surgeon's duties will be devoted to the prevention or treatment of infection and other complications (*e.g.* crush syndrome), and to the encouraging of wound healing.

He will doubtless admit, however, a number of untreated wounded, in whom there has been a considerable lapse of time since the wound was suffered. The operative treatment of such late cases does not differ in principle from that of early cases. Much confusion of thought has been caused by the unwise attempt to lay down a time limit within which it is safe to practice wound excision. The term "wound excision" is, of course, open to wide limits of interpretation. Experience so far in this war has shown that the literal interpretation of exision—the removal of every part of a wound so that a wound consisting of entirely new tissue results—bespeaks an operation which is not only needlessly ruthless but which may be in itself a cause of surgical illness. The operative treatment is best limited to the essentials of removing devitalised tissue and providing free drainage, and this technique is sound at whatever stage the wounded man reaches the surgeon. The greater the time interval between wounding and operation, the more conservative the operation required, and after forty-eight hours or more, when a natural protective barrier has formed, all that may be needed is to remove all obvious foreign bodies or sloughs, and to leave the wound widely open, after thorough irrigation. The most difficult period for operation, and one which will most exercise the surgeon's judgment, is between twenty-four to forty-eight hours. The wound may by this time be heavily infected, and as yet no protective barriers formed. Except when gas gangrene has developed (*see* Section V) the operative treatment should be as conservative as possible compatible with the removal of obvious dead tissue and foreign material. It goes without saying that for a through and through wound of the soft parts by a high velocity bullet, in which there has been no vascular damage, or severe damage to bone, an expectant policy should be adopted. Many such cases heal satisfactorily without surgical assistance.

There have been two outstanding changes in wound treatment since the 1914–1918 war; the plaster cast for wounds of the extremity, and prophylactic chemotherapy.

### PLASTER OF PARIS

Most of the limb wounds will have been operated upon in a forward area, and encased in plaster of Paris. The chief concern of the base surgeon is to decide which among the cases should remain untouched, and

which should be subjected to re-dressing and change of plaster. It is not always an easy decision to make—many plasters have been changed unnecessarily, and, no doubt, many left on unduly long. It would be of assistance to the base surgeon if the forward surgeon noted whether the plaster was applied for transport only, or whether his primary operation was of sufficient thoroughness. The need for removal must largely be determined by the presence or absence of pain, or fever : or the presence or absence of swelling of the fingers or toes, or of blueness : or the adequacy and condition of the plaster itself : or malposition of a fracture.

## PROPHYLACTIC CHEMOTHERAPY

It is generally agreed that the use of chemotherapy from the time of wounding to the time of arrival at the base has played a large part in reducing the incidence of severe infection, and the base surgeon should make it a routine to continue the course of sulpha therapy started before the patient has reached him. It cannot be said too often, however, that chemotherapy in no way obviates the need for free drainage.

In most cases, therefore, the base surgeon's task is to maintain continuity of the primary surgical treatment, playing an active role only in those in which forward surgery has been inadequate or ineffective. His main tasks therefore lie in the promotion of healing and the treatment of chronic infection.

## REMOVAL OF FOREIGN BODIES

It is difficult to give a categorical answer to the question of whether a buried missile should be removed, for the decision depends on many factors. Though from every standpoint a foreign body is better outside the body than in, no operation attended with the smallest risk should be undertaken merely to produce a trophy. The optimum time to remove a missile is at the primary operation, for its retention will undoubtedly increase the danger of primary wound infection. This applies more particularly to large and jagged pieces of metal than to small fragments —though these may also be a potential source of danger. But the risk of removal must be weighed against the danger of retention, and the surgeon is well advised to err on the side of conservatism. The presence of a large number of foreign bodies often makes an attempt at removal of all impracticable. It would be ill-judged surgery to prolong, for example, an urgent abdominal operation, and to add to shock by manipulation, by conducting a methodical search for the missile responsible for the injury.

Indications for the removal of foreign bodies from different areas of the body will be given in the appropriate sections. It suffices to say here that, in general terms, if a wound is in the process of healing the immediate removal of a missile should be undertaken only if it is a source of suppuration, or if it is causing pain. Removal should be performed, if possible, through the original wound track with a minimum of disturbance.

## INFECTION

Pulvertaft has shown that, despite the closed plaster technique and the use of sulpha drugs, war wounds are infected just as frequently as in the 1914–1918 war, though it is probable that the results of infection are less severe. To date, both gas gangrene and tetanus have been uncommon, but this is due chiefly to the nature of the terrain of battle. The common-

est infection is staphylococcal, though streptococcal infection also abounds. Infection by gram negative bacilli is also frequent, particularly the *B. Proteus*, *B. Pyocyneus* and *B. Coli*. *Clostridia* are often found in wounds in the absence of clinical evidence of gas gangrene, and the same is true of *B. Tetanus* and clinical signs of tetanus. *Diphtheroid* organisms may also be found, and may prove an unsuspected cause of delayed healing.

When a wound is persistently discharging pus, the *laissez-faire* method of enclosure in plaster of Paris should be abandoned in favour of more active treatment. Suppuration must be regarded as a symptom, and not as a disease in itself, and the first duty is to determine its cause. It should first be ensured that drainage is free, and that no foreign body or sequestrum lies dormant in the depths of the wound. In superficial wounds the cause may be adherence of the wound edges to underlying bone, and these may best be treated by skin graft (*q.v.*). Once full drainage has been established, or re-established, a set policy of future treatment should be determined upon. For grossly infected large wounds, some will favour the irrigation technique of Carrell, and others treatment with the Bunyan-Stannard irrigation envelope. Either method may be valuable in selected cases.

## ANTISEPTICS

Since war began, there has been a return to antiseptic methods of wound treatment, largely as a result of the achievements of systemic chemotherapy, an account of which appears elsewhere. It has been more fully realised in recent years that next to the choice of an antiseptic, the method of applying it is the most important factor. Most antiseptics suitable for application to wounds act slowly. They do not kill bacteria outright but over a period measured in hours, or merely inhibit their growth. This effect is achieved with sulphonamides by applying them as a solid, which undergoes slow solution. In sulphonamide-resistant infections, two useful alternatives are proflavine and propamidine. Proflavine may be introduced into wounds in the solid form in doses from 0.5 to 2.0 grammes, and may cause a dramatic improvement even though previous treatment by sulpha drugs has failed. Proflavine in the powdered form has, however, a destructive action upon the tissues which makes it undesirable for use as a prophylactic in recent wounds.

Propamidine may be used in a concentration of 0.1 per cent. in a jelly consisting of 4.5 per cent. methyl cellulose in water. After toilet, the wound is filled with the jelly, taking precautions to protect the skin edges from the irritant action of the drug. The treatment may be repeated every two days for about ten days, after which time maximum benefit is to be expected. Propamidine is not recommended as a prophylactic against infection.

## PENICILLIN

Overshadowing these two examples of local antiseptics, and perhaps also the sulpha drugs themselves, comes penicillin, the value of which as a prophylactic and therapeutic agent in the treatment of infection has in recent months been the subject of concentrated research. Though penicillin is not yet in free enough supply for general use, there is reason to hope that this shortage will be soon remedied.

Two salts of penicillin are at present in use—the sodium salt for injection or local application, and the calcium salt for local application only. The

drug has also been used successfully in solution or as a powder, either alone or mixed with sulphonamide : it has also been applied locally in an ointment base. It must be carefully handled to maintain its potency, for it is destroyed by acids and alkalis and oxidising agents, boiling, and some bacterial enzymes and heavy metals such as copper and lead.

Penicillin is active against the staphylococcus aureus, the streptococcus pyogenes, the gonococcus, the meningococcus, the bacillus anthracis, clostridia, and actinomyces. Its effects are extremely variable with different strains of pneumococci, anaerobic streptococci and streptococcus viridans. It is ineffective against the bacillus coli, the bacillus pyocyaneus and the bacillus proteus, but the continued presence of the gram negative organisms after clearance of the pyogenic cocci does not appear to cause delay in wound healing.

Penicillin is not given by mouth, but either applied locally, or administered parenterally or by intramuscular injections. It does not cause any toxic symptoms, and is effective even though pus is present. Ideally, and especially when stocks remain low, penicillin should be used only where facilities exist for control by laboratory tests, *e.g.* tests for the sensitivity to penicillin of the infecting organisms, determination of the concentrations of penicillin in the blood and repeated bacteriological examinations of the wound while treatment is in progress.

**Dosage and Technique.**

It is not possible at this stage to give precise instructions as to dosage or to the best technique for local application of penicillin, and the following is intended not as a guide but as some indication of the general trend of research to date.

For local application the Ca salt has been used in fluid form (250 units per c.c.) and in powdered form, with or without an admixture of sulphonilamide powder, the penicillin strength of which varied between 500 and 2,000 units per gram. For prophylaxis in recent wounds, amounts varying from 3 c.cs. to 10 c.cs. of the fluid were injected into the wound at eight or twelve hourly intervals for three to five days. The powder as a daily application has been used for surface wounds, particularly burns.

In chronic sepsis, the dosage required for local application is necessarily much greater, and it still remains to be decided whether the results, which are not uniformly satisfactory, justify the use of the enormous amount of penicillin entailed. Gas gangrene is, on the whole, unsuited to treatment by local application.

**Parenteral Administration.**

The most practicable method is intramuscular injection, at three to four hourly intervals, of 15,000 units of the sodium salt. The method is painful, however, and it is probable, when more is known of the correct dosage, that the intravenous route will become the one of choice.

## DELAYED PRIMARY SUTURE

A delayed suture is often theoretically possible on the third or fourth day after the primary operation in wounds which have survived the hazard of severe infection. Under war conditions, however, it will rarely be practical, and in any case is suitable only for the more superficial type of wound, and perhaps for amputations, which, of course, come under the same heading. The feasibility will depend to a large extent upon the area of

skin loss—a loss which may be unnecessarily heavy as a result of injudicious skin removal at the primary operation. If delayed primary suture is to be attempted, local sulphonamide or penicillin should be used, and provision left for drainage.

## SECONDARY SUTURE

Secondary suture may be performed when the reaction of repair is over, the dead tissues removed, and the surface clean and granulating, that is, in fourteen to twenty-one days. In fact if, after three weeks, a wound is not sufficiently healthy, the surgeon should be exercised concerning it. The object of secondary suture is to reduce the size of the wound, and no attempt should be made to gain accurate approximation of the skin edges. Undue tension must be avoided, for it may cause the wound to break down again and a painful scar may result. If the skin loss is such that it is thought that little can be gained by secondary suture, the application of skin grafts will be an infinitely better choice of treatment. As with skin grafting (*q.v.*) the wound should be prepared before secondary suture is attempted by a course of local sulpha therapy. Deep sutures are passed beneath the granulating area and tied over rubber tubing under moderate tension, no attempt being made to freshen the wound edges.

## SKIN GRAFTING

The best dressing for a wound is skin, and the early grafting of suitable granulating areas will reduce enormously the time spent in hospital, and all surgeons should acquaint themselves with the indications and technique of simple skin grafting. Treatment by this method should not be delayed too long, and can in general be carried out two to three weeks after the injury. Moderate infection of the wound need not be a deterrent. It is often worth while attempting a graft even if conditions appear to be unfavourable, for though some of the graft may be lost, a valuable proportion of it may take.

The best form of graft for general use is the split-skin graft, though pinch grafts, which give a less favourable cosmetic result, may be of the greatest use if the granulation surface appears to be unfavourable for the reception of split skin, for they will take on what appears to be the most unfertile soil. The more experienced the surgeon becomes with " sheet " grafting, however, the less will he use pinch grafts. Sheet grafts do not take well on tendon and bone, and pinch grafts are likely to be more successful in such situations.

The streptococcus is the organism most inimical to success, and its elimination from the wound should be attempted by a forty-eight hours preparation with sulphonamide powder and saline dressings. Rest, elevation of the part, and firm pressure are helpful preparatory steps, and any greasy substance should be carefully expunged from the wound surface and skin edges ; sloughs must be removed by saline baths, or by the use of an irrigation envelope.

Grafts may be placed directly on the wounds if the granulations are bright red, flat, firm and not oedematous. In the latter event, the surface should be curetted or excised, or, alternatively, pinch grafts used.

The essential of after treatment is a pressure dressing—a pad of wool soaked in paraffin or flavine for flat surfaces or a moulded film of dental stent for a cavity—firmly held in place by a crepe bandage, and the

bandage further secured with elastoplast. A splint may be necessary according to the situation of the wound. The dressing should not be disturbed for at least seven to ten days.

After a successful graft, a saline dressing may first be applied, followed later by a tulle gras dressing for a few days. When the graft is firm, light massage should be commenced.

It is important to avoid infection in the donor area and a dressing of tulle gras or its equivalent should be immediately applied, and should remain for seven to ten days. Should an accidental full thickness incision be made when cutting the graft it should be repaired at once by suture.

## GENERAL FACTORS IN THE HEALING OF WOUNDS

The maintenance of the general health of the patient is of the utmost importance. The surgeon should satisfy himself that there is no anaemia. The haemoglobin should be kept at a minimum of 80 per cent., and blood transfusions used to this end if needed. When a wound discharges pus, it pours out proteins, and protein deficiency (hypoproteinaemia) retards wound healing, just as a high protein diet accelerates it. An invalid diet is thus useless for this type of case, and a liberal high protein diet, *e.g.* eggs and steaks, should be given if available. If the patient is unable to take a full diet of this kind, the deficiency of protein must be restored by intravenous plasma. Vitamin C deficiency also prolongs healing time, and fresh fruit and vegetables are therefore an essential part of the dietary. Adequate rest, fresh air, and mental " food " such as diversional therapy can provide all contribute towards the desired end.

## THE CRUSH SYNDROME AND ARTERIAL SPASM

Interest in the effect of crush injuries upon renal function was revived by the large number of such injuries sustained during the city blitzes. The exact cause of the renal effect is unknown, but there is much evidence that it is due to liberation of a toxic substance from the damaged tissues. The clinical picture is that of a patient with a very swollen limb, which may be pulseless and discoloured, and partly anaesthetic, with whealing and blister formation, and associated with increasing oliguria. The urine contains the pigment myo-haemoglobin, and microscopic examination reveals pigmented casts and granules, the condition to the naked eye resembling that of haematuria. The blood urea rises, while haemoconcentration may reach a high level, even if little blood has been lost; if bleeding has been marked, haemoconcentration may be masked by haemodilution.

The essentials of the treatment of the renal condition are the early promotion of diuresis, and alkalinisation. A continuous infusion of 3½ per cent. sodium citrate, in normal saline or in 5 per cent. glucose saline, should be started at once, together with sodium bicarbonate by mouth, if practicable, in doses of 2 grms. hourly.

The decision to be taken as regards the treatment of the limb itself is one of great difficulty. Compression by firm bandages to limit the further loss of fluid; high application of an Esmarch's bandage to prevent absorption of toxic products; linear incisions through skin and fascia to reduce the tension in the muscles; all have been suggested, including amputation. Much will depend upon the condition of the limb, but radical surgery

should, in the main, be avoided, and attention focussed chiefly upon the maintenance of the renal function.

Closely allied is the acute swelling of a limb that may follow severe injuries, other than those of the crush type. The most common are severe fractures, often simple, of both bones of the leg in their upper third. It may also follow prolonged application of a tourniquet. The condition may be due to intense arterial spasm, and if it persists, pathological changes similar to those of crush injury occur in the muscle. It is probable, indeed, that the two conditions, though varying in degree, may be identical in etiology, for it is likely that arterial spasm plays some part in bringing about the local changes characteristic of the crush injury.

It is wise, therefore, in such cases to anticipate possible renal damage by alkalinisation of the urine by oral administration of sodium bicarbonate in the doses described above.

## SECTION X

## AMPUTATIONS

Amputations are of two kinds: provisional and final. A provisional amputation is only a stage in treatment and foreshadows another amputation in the future. A final amputation, as the name implies, is intended to be the last operation performed on the patient. A final amputation should not be done unless the surgeon is reasonably sure that the wound will heal per primam; if he is in any doubt he should do a provisional amputation. Nearly all front-line amputations fall into the category of provisional amputations.

### PROVISIONAL AMPUTATION

**When to Amputate.**

(i) For recent injuries (first twenty-four hours). *In the upper extremity* only when part of the limb is mangled and devitalised and it is judged that damage to the soft parts is such that there is no chance of the recovery of function of any part of the hand.

*In the lower extremity* after a recent injury, when the limb is mangled and grossly contaminated or when the main nerve and blood supply have been interrupted. Loss of bone without concomitant nerve and vessel injury does not justify it.

(ii) In the presence of infection :—

(*a*) For clostridial gangrenous myositis of the segmental type.
(*b*) For vascular gangrene.
(*c*) For continued sepsis associated with severe nerve damage.

The decision to amputate both for primary and infected injuries must often be difficult and a source of anxiety, and in any case it depends on the judgment of the surgeon on the spot. When in doubt, get a second opinion if it is available.

**Where to Amputate.**

The surgeon must rely on his own judgment in each particular case, but a guiding principle can be laid down. He should amputate at the lowest level at which the tissues are alive. He need not go above the infection because an amputation ensures that the infected tissues are adequately drained.

**How to Amputate.**

The technique should be the same as that for a final amputation with two exceptions : the deep fascia should not be sewn, and the skin should not be closed. The shape and size of the skin flaps are the same as in a final amputation. When the lesion for which the amputation is being done is of long standing, *e.g.* chronic sepsis, it is permissible to draw the skin edges together in the centre by two stitches in order to cover the end of the bone; when the lesion is recent, as in a battle casualty, *no stitches at all* should be inserted. If the wound remains relatively clean the skin edges can be drawn together at the end of a week by adhesive strapping or by secondary suture.

A provisional amputation is followed at a later date by a final amputation, and it is often difficult to decide when to reamputate. Bearing in mind that a final amputation ought not to be done unless healing by first intention can be guaranteed, it is better to delay until the provisional amputation has healed, but this is not always possible on account of an inveterate ulcer at the end of the stump.

## FINAL AMPUTATION

The advice of the limb-fitting surgeons should be followed, both as regards the site of the amputation and the technique of the operation.

**Where to Amputate.**

Four sites of election are approved by the limb-fitting surgeons at Roehampton ; two in the lower limb, one below the knee and one above the knee ; and two in the upper limb, one below the elbow and one above the elbow.

*Below-knee amputation.*—The stump should measure 5½ inches from the line of the knee joint to the end of the tibia. Actually 4 inches is enough, but it is wiser to aim at a length of 5½ inches because a below-knee amputation is prone to give trouble in healing ; the skin edges not infrequently pull apart or slough, and a terminal ulcer is left which takes many months to heal. Should this happen in a 5½-inch stump, one can, by sacrificing an inch of bone, excise the ulcer and bring the skin edges together without tension.

The minimum length of tibia to which a below-knee limb can be fitted depends on the thickness of the subcutaneous tissues and the prominence of the hamstring tendons. Probably 2 inches is the limit.

*Above-knee amputation.*—The stump should measure 11 inches from the top of the trochanter to the end of the femur. (NOTE.—This is exactly double the length of the below-knee stump.)

As much as possible of the femur up to 11 inches should be preserved because a short femoral stump is deficient in adductor power, and strong adductors are needed to counteract the tendency for the prosthesis to swing outwards during walking.

When the stump measures less than 4 inches the patient has to be fitted with a tilting-table limb. The limb maker does not like a disarticulation at the hip ; and 4 inches of femur, measured from the trochanter, or as much as possible if less, should be left because it enables the socket to be more firmly secured to the pelvis.

*Syme's amputation.*—A Syme's amputation should not be done except by a surgeon with great experience of the operation ; for unless a Syme's stump is perfect it does not stand up to weight-bearing.

*Below-elbow amputation.*—The site of election is 3 inches above the wrist. As regards the minimum length, there must be at least 1 inch of ulna beyond the prominence of the biceps tendon when the elbow is flexed, otherwise the stump will not remain in the socket.

*Above-elbow amputation.*—The site of election is 3 inches above the elbow. The minimum length is 1 inch of humerus beyond the anterior fold of the axilla. Any less length should be left for cosmetic reasons.

**How to Amputate.**

Almost the same technique can be used for all four amputations.

*Skin.*—The flaps should be antero-posterior, and equal: this gives approximately a transverse terminal scar. The flaps should be of such a length that the skin edges naturally come into contact, and they should be semi-circular in shape.

*Deep fascia.*—It is important to sew together the two layers of deep fascia in order to secure a mobile scar. With this end in view, the deep fascia is cut through at the same level as the skin, and the skin and deep fascia reflected back as a single layer. Then at the end of the amputation the deep fascia is identified in much the same way as the peritoneum is in closing the abdomen, and accurately sutured.

*Muscles.*—The muscles should be cut through transversely at a level half an inch below the proposed site of section of the bone. They should not be sewn over the end of the bone.

*Nerves.*—These are cut through with the muscles. They should not be crushed or bullied in any way. If a nerve bleeds it may be ligatured; otherwise it should be left alone.

*Periosteum.*—In the below-knee amputation the deep fascia is absent over the subcutaneous surface of the tibia. The periosteum on the surface of the tibia should be cut through at the same level as the skin, and reflected up as a layer in line with the deep fascia medial and lateral to it. In all other amputations the periosteum is left undisturbed and is divided at the sawing of the bone.

*Bone.*—The bone is sawn through flush with the retracted muscles. In the forearm the two bones are cut at the same level. In the below-knee amputation the fibula should be cut 1 inch shorter than the tibia, and the sharp anterior angle of the tibia should be bevelled.

*Haemostasis.*—All bleeding points must be secured. When the skin is being sewn there should be no leakage of blood; if there is, haemostasis has not been satisfactory and the wound should be reopened. Drainage is of doubtful value; usually a drain lets infection in and does not let blood out.

## AFTER-TREATMENT

This is important. It consists of (1) Reshaping the stump, *i.e.* converting a wide cylinder into a narrow cone. This is done by firm bandaging, which is commenced as soon as the wound is healed. (2) Preserving or regaining full movement at the joint above the amputation. The amputee is encouraged to move his stump as early as he will. (3) Strengthening the muscles, by weight and pulley exercises. (4) Connecting the brain to the stump: a matter of importance, because the patient will not otherwise use the muscles of the stump to control his prosthesis.

# SECTION XI

## FRACTURES

### THE TREATMENT OF FRACTURES DUE TO G.S. WOUNDS AT THE FRONT

All fractures caused by gunshot wounds are liable to be complicated by severe laceration of the soft tissues, especially where the injury is caused by ragged fragments of shell which may tear away large masses of muscle and skin and bruise the tissues to a great depth from the exposed surface. Bullets also may cause such extensive tearing that the part looks as if it had been struck by a shell fragment. This is frequently the case when the fracture is due to a bullet fired at close range, and when the bone struck is a large one, such as the femur or the humerus. In such cases it is the exit wound which is so large and lacerated, and this is due to the fact that the bullet, travelling at the height of its velocity, not only smashes the bone, but also imparts its momentum to the shattered fragments and drives them in front of it; the resulting wound is caused as much by the broken fragments as by the bullet, and the wound is often said to be of the "explosive type." In others where the entrance and exit wounds of a bullet are small, there may yet be much tearing of the muscles, and as a result the limb is liable to become greatly swollen by the subsequent interstitial bleeding.

#### At the Regimental Aid Post.

The treatment of any fracture should commence as soon as the wounded man is seen by the surgeon, and the first essential is to steady the limb and temporarily fix the broken bones so that no further movement of them is permitted. In the case of the upper extremity, bandaging the arm to the side may be sufficient, but in the case of the lower extremity, some sort of emergency splint is required. If nothing can be obtained then the legs may be bandaged together till the regimental aid post is reached.

Here, or at the field ambulance, the limb should be most carefully splinted, so that no unnecessary pain or injury may be caused by the transport to the casualty clearing station. It is most important to remove the improvised splints and dressings first applied as soon as possible, and never in any circumstances to bandage the limb without first putting on a splint and a large quantity of cotton wool. Much harm is often done by bandages applied tightly over first field dressings by the comrades of the patient, and care should be taken at field ambulances and clearing stations to see that bandages have not become too tight owing to the swelling of the limb.

A triangular bandage is better than the roller applied spirally.

#### At the Forward Operating Centre.

**Time Factor.**

Experience in this war has shown that the average time of arrival at an operating centre after wounding is probably less than twenty-four hours, during a battle period. During a quiet period this time may be greatly reduced. The importance of appreciating this is great, as the treatment of wounds after this lapse of time differs in detail from the

methods suitable for the bomb wounds received in towns, when the patient reaches hospital within a short time.

**General Wound Treatment.**

This differs in no way from that employed in the case of other wounds. The shock arising from G.S. wounds causing fracture of the femur or multiple fractures must be prevented or treated if it has arisen.

**Operation.**

When the patient is seen within twenty-four hours of being wounded the operation should consist of a cleansing of the skin, excision of edges of jagged skin and trimming of muscle. Loose pieces of bone, metallic fragments and clothing should be removed, but pieces of bone anchored to the shaft, or with considerable muscular attachment, should be left. Haemostasis must be obtained as far as possible. The wound is lightly packed after dusting the surface with sulphanilamide powder. The pack should be of gauze infiltrated with vaseline. Ribbon gauze should not be used.

In the thigh, division of the fascia by extension of the wound up and down, or by transverse incision, with or without counter drainage may be advisable in forward areas. Rubber drains of all types are to be avoided in surgery of bones and joints.

The skin must not be sutured. The pack must not be inserted so firmly that it acts as a " plug."

**Splinting.**

This must fix the dressing and provide a reasonable degree of immobilisation of the fracture until the patient reaches the Base. It must be simple, easy to apply and easy to remove. It must not " rub " the patient and should require a minimum amount of attention during the patient's transit by M.A.C., ambulance train, etc.

*Upper Limb.*

*Shoulder and humerus.*—" U " plaster from nape of neck down over elbow and up to axilla, with circular turns round arm is the standard. A narrow arm sling—and sling around the elbow—is an essential part of the splinting.

Alternatively, plaster of Paris slabs up and down the arm with a narrow arm sling may be sufficient until the patient reaches the Base. Kramer wire is useful in some cases, with or without plaster, but its application generally takes longer than that of plaster.

In severe arm injuries the " U " plaster is fixed to the chest by a few turns of plaster round chest and arm. A large pad is put in the axilla and the hand is left free.

*Elbow and forearm.*—The elbow is placed at a right angle and forearm supinated. A slab is placed on the back of the arm and forearm. Circular turns cover this from the axilla to the necks of the metacarpal bones. The plaster cast is split by one long incision down the anterior and flexor surface. A large arm sling is used.

*Hand.*—At this stage the splinting is to provide rest and comfort. A plaster slab is applied to the flexor surface of the forearm and over the palm of the hand, the wrist being dorsiflexed and fingers somewhat flexed at the metacarpo-phalangeal joints. The fingers must not be forced straight. This slab is bandaged into place by a cotton bandage, and the limb put in a large arm sling.

*Lower Limb.*

*Femur and knee joint.*—At R.A.P. Thomas' splint with or without the addition of small splints should be used if facilities allow. Extension *via* the boot should be by metal clip or clove hitch. The boot lace should be loosened and a small pad placed under the tongue of the boot.

In the field ambulance, Thomas' splint should be applied or adjusted if it has been put on at R.A.P. Clove hitch extension should *invariably* be removed and extension made by adhesive strapping applied to the leg. The best type available is termed—Bandage, plaster extension for treatment of fractures. This is an elastoplast which can be stretched around the limb, but not in length. Prolonged extension by clove hitch or any method of traction through the boot or a "spat" causes pressure sores around the ankle and over the heel.

In a field ambulance, having no F.S.U., plaster of Paris should not be used as an adjunct to Thomas' splint in cases of G.S. wound of thigh, knee or leg, complicated by fracture or joint injury, although its value after operation is known. If it is applied in simple fracture, only a few turns around splint and thigh should be employed. Some padding above the knee in front and below the tuber ischii behind is necessary. It must be appreciated that the thigh may swell before the patient reaches the F.S.U.

In C.C.S. and F.S.Us., the use of plaster of Paris with Thomas' splint has proved a great success, from the point of view of efficiency and comfort. A plaster spica should not be used when the patient must be transported soon after being wounded and operated on. Its application increases shock at this time and during transit friction is inevitable and almost invariably causes pressure sores.

*Splint—Type A.*—Apply plaster extension for treatment of fractures (*see* above) to leg and thigh if wound allows. The skin above the malleoli requires protection, preferably by adhesive felt. Cover the dressing and limb from groin to metatarsal necks with plaster of Paris bandages keeping the knee flexed ten degrees and the foot at a right angle with the leg (Figs. 1, 2 and 3). Before this plaster is dry, the limb and cast are placed on slings attached to a Thomas' splint. The cast is split from end to end down the front of the limb and three bands of cotton bandage are tied round the cast (Fig. 4).

NOTE 1.—*A simple method of opening the cast is by placing a length of rubber tubing down the front of the limb before the plaster is applied. Alternatively any length of pliable metal, folded in paper will suffice if rubber tubing is not available. Such metal strips can be got from waste dumps. The tubing is removed and a space left, into which the cutting edge portion of the plaster shears can be easily placed, immediately or at any stage of a journey.*

NOTE 2.—*The extension bands must be placed direct on to the limb; a common mistake has been to place these between the layers of plaster of Paris. Traction on such an arrangement causes the plaster cast to press on to the foot so that sores arise.*

*Type B.*—Strapping extension is applied to the limb. The limb is placed in a Thomas' splint and the extension bands tied. One pad is placed above the knee in front and another behind the thigh below the tuber ischii; plaster of Paris circular turns are taken around the thigh and splint. A cuff can be placed round the calf and splint after adequate padding, if desired.

*Leg.*—After the operation, plaster is applied from mid thigh or above to the metatarsal necks. The knee is flexed ten degrees and the foot is placed at right angle ; the plaster can be rested on slings and Thomas' splint.

NOTE.—At the R.A.P. a large dressing and wool are used and the limb is elevated on the stretcher.

After operation, plaster of Paris is applied from below the knee to the metatarsal necks.

As suggested in the section of this handbook on Plaster of Paris Splinting, opinions vary as to the relative virtues of the non-padded and padded plaster casts. If the surgeon prefers to pad the limb before applying the plaster, this modification in technique should be added to the above description of the " Tobruk plaster."

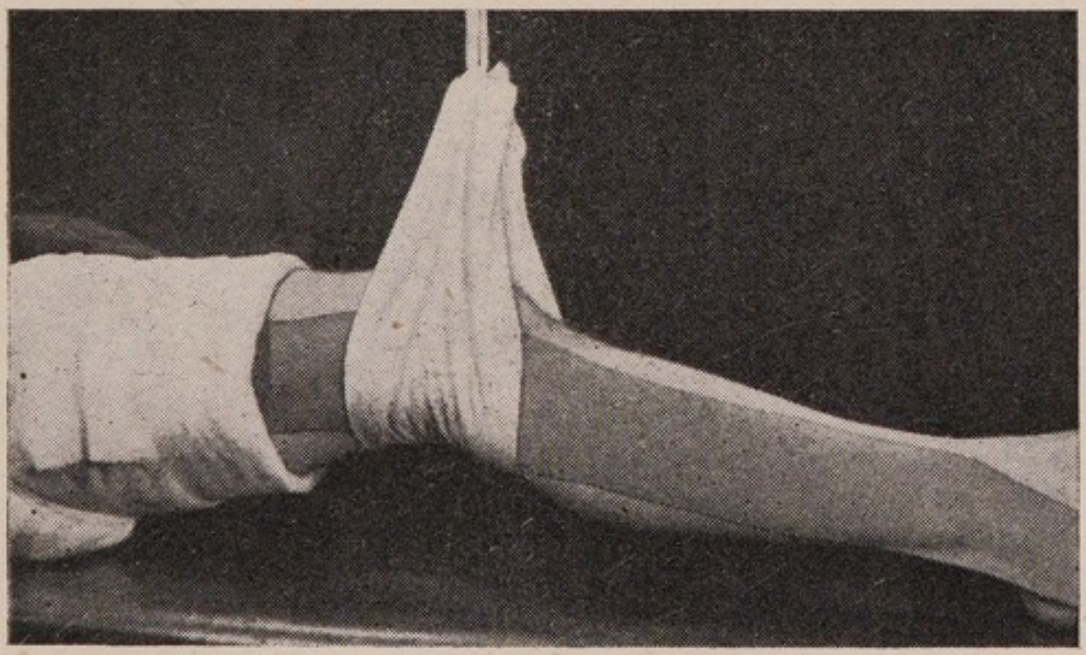

FIG. 1
Extension bands and suspension bandage for knee are shown.
(Padding around ankle is not shown.)

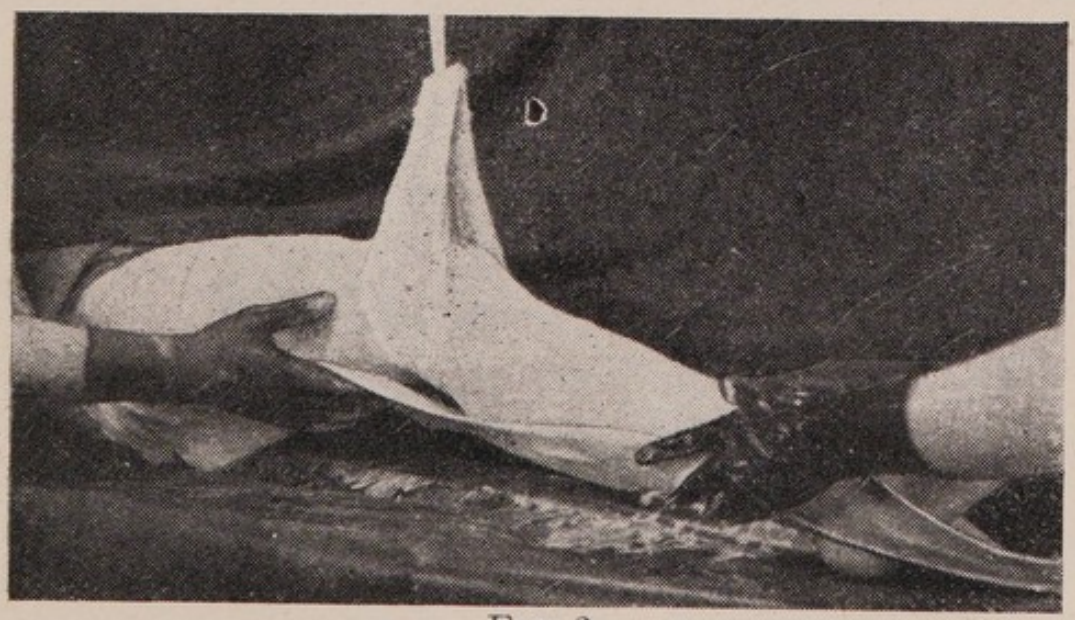

FIG. 2
Plaster applied. Slab is being added to back of cast.

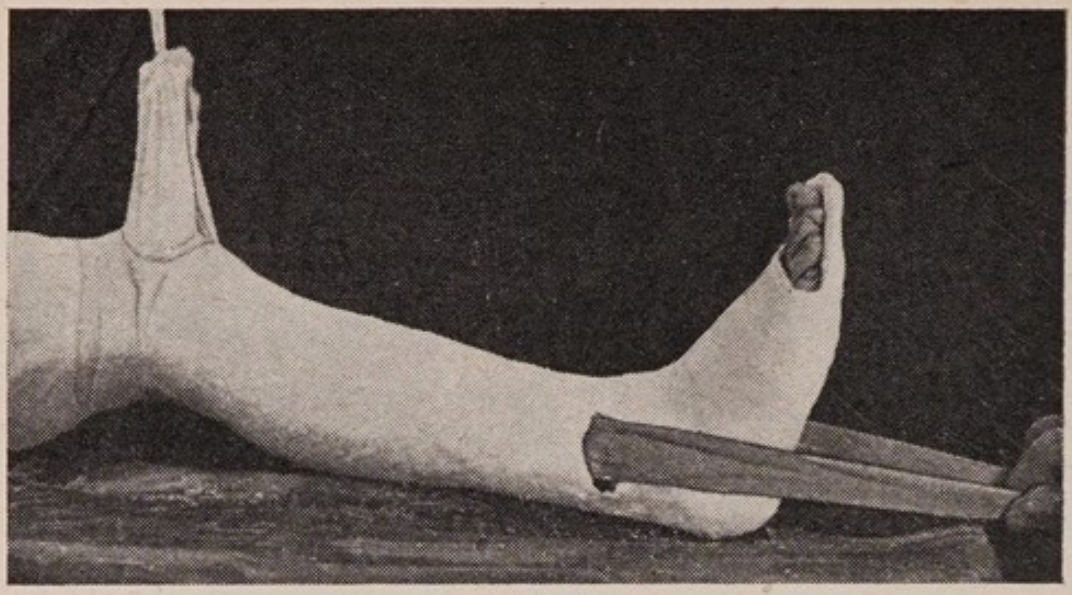

FIG. 3
Plaster completed. Extension bands with adequate opening above ankle shown.

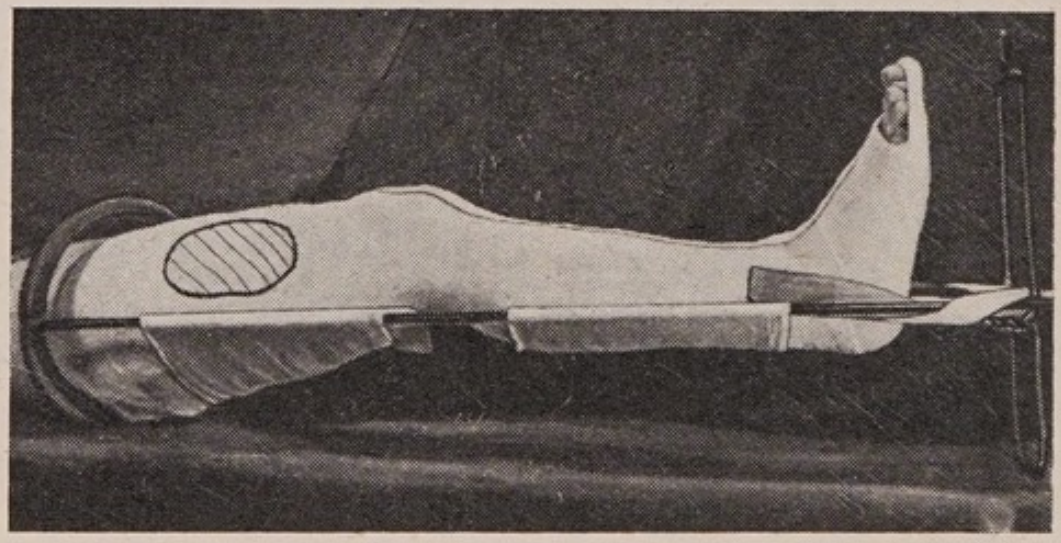

FIG. 4
Cast and limb on Thomas' splint. Note split down front of cast. A pad between great trochanter and the ring, and a bandage across the upper end of the leg (to prevent cast rising from the splint) are to be added.

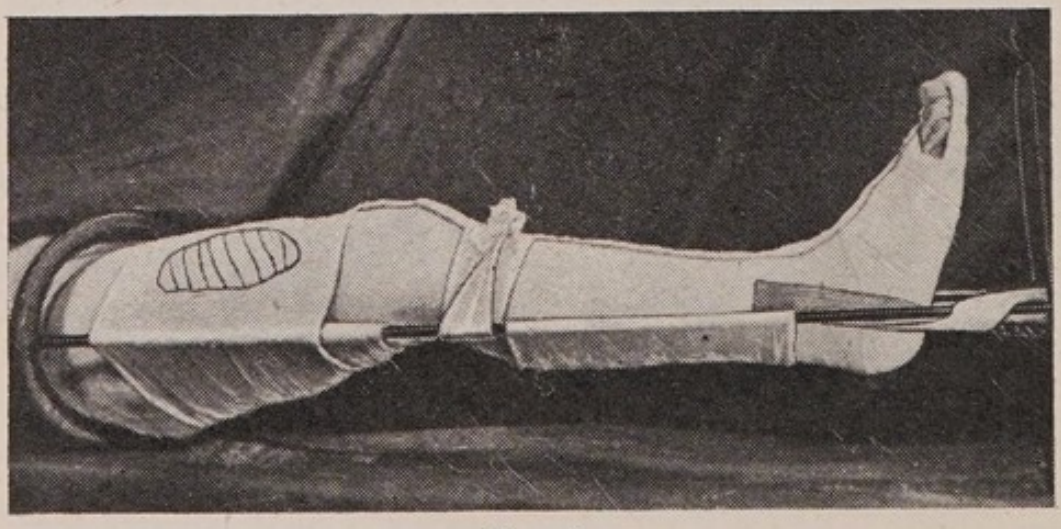

FIG. 5
The Tobruk plaster fixed to a Thomas' splint by circular cuff of plaster around the cast and the bars of the splint. This partial combination of the Tobruk and double-cuff plaster is a popular and efficient modification.

## In Base Areas.

### Time Factor.

The time taken for the patients to reach this area must necessarily depend upon the distance from the battlefield and the means of transport.

It has been found that patients seldom arrive at a Base in a condition of shock, but they are "travel tired."

### Investigation.

After study of the notes and examination of the patient it is advisable to consider into which of three groups each patient falls :—

(*a*) Those requiring immediate treatment for shock, haemorrhage, etc.
(*b*) Those who have not been operated on.
(*c*) Those who have had an operation and are splinted.

*Group* (*b*) is practically non-existent except in battle periods. The type of operation to be employed is the enlargement of the wound and counter-drainage in some cases. Excision of the wound is not advisable. In other respects the treatment is similar to that recommended in forward areas.

*Group* (*c*).—After one or more nights' rest radiography is employed to discover foreign bodies and the nature of the fracture.

### Operating Theatre.

When an operation and splinting has been carried out in forward areas there is seldom any urgency for taking the patient to the operating theatre. A few patients require attention in twelve hours but many can be left for a week or longer. The deciding factors are temperature, pain or discomfort and the amount of discharge.

The plaster of Paris is removed, the limb is cleansed. The dressing is then removed and skin around the wound cleansed. Surgical experience and judgement enable the operator to decide whether the wound should be enlarged, foreign body removed or counter-drainage made. Large foreign bodies must be removed. As a general rule it is unwise to search for small ones as the opening up of tissue planes is undesirable and may be dangerous, but division of fascia transversely is useful. Sulphanilamide powder is dusted over the wound and vaseline gauze pack inserted. The limb is then splinted.

*N.B.*—For cases arriving late at the Base eusol irrigation or packs of gauze soaked in eusol or acriflavine are often preferable to closed plaster treatment. Although these methods are suitable for large and dirty wounds, it is not suggested that they should be the standard treatment. The combination of eusol and sulphanilamide locally is valueless.

### Splinting.

*Principles.*

In the selection of method the following points should be taken into consideration :—

(*a*) The type chosen should be applicable for treatment until the fracture has united.

(*b*) As anatomical alignment is desirable the splinting must fix the whole length of the bone and in the lower limb extension with support of the fracture is generally necessary. Fixation of the shoulder joint or hip joint is not necessary when extension is applied to the limb.

(*c*) In grossly comminuted and infected fractures due to G.S. wounds, extension should not be employed to produce a limb of equal length to the other. Should this be accomplished a central abscess cavity with sequestra is formed. Hence a degree of telescoping is desirable.

*Lower Limb.*

*Femur, mid-shaft and lower half.*—Skeletal traction by means of a pin or wire through the tibia at the level of the tubercle provides the best method of extension. The limb is placed in a Thomas' splint to which are attached a leg extension piece and foot piece. This is suspended from a Balkan beam or similar overhead apparatus.

*Upper third.*—Fractures of this area are always difficult to treat when due to G.S. wounds. A posterior wound adds to the difficulty and in many instances may be very large, or there may be a pelvic complication. Skeletal traction from the tibia should be used. There is usually advantage in placing strapping on the leg as well, so that extension is achieved both through the leg and thigh. Surgical judgment must decide whether it is sufficient to support the fracture by slings round the thigh suspended by pulleys from a Balkan beam, or whether a Hodges or Thomas' splint should be used as a support.

This fracture requires extension and support by a pull in two directions ; complicated apparatus should not be used. A spica plaster is sometimes indicated, but if there is a constant flow of discharge from the top of the plaster on to the perineal area, secondary infection of the wound is inevitable. There is ample evidence that the organisms of the perineum cause secondary infection of these wounds.

Braun's splint is used by some surgeons and they state that it is easy to use, but experience shows that the patients are uncomfortable and the femur tends to unite with a varus deformity. There are exceptions, as many fractures of the lower third of the femur are well treated on this splint. However, the use of a Thomas' splint is preferable in the hands of the majority of surgeons.

The weight to be employed in the case of fractured femur is learnt by experience and radiographic check assists the surgeon. Distraction is to be avoided as it is an important cause of delay or non-union.

Many fractures of the femur are adequately controlled by skin traction throughout treatment—indeed, the surgeon will be wise to use the method in which he has been trained and in which he is experienced. Skin traction and skeletal traction both have their champions—so long as length is retained and distraction avoided, either method will suffice correctly used.

*Leg.*—Plaster of Paris is used from groin to metatarsal necks. A small amount of padding is advisable above the malleoli and the inexperienced should cover the anterior border of the tibia. Adhesive felt if available is suitable. The plaster is usually applied by a posterior slab followed by circular turns.

It is not always advisable to employ traction in treating G.S. wounds of the leg, with fracture of the tibia, for fear of separating the fragments. When traction is necessary, a pin through the heel is effective.

*Upper Limb.*

*Humerus.*—" U " plaster as described for use in forward areas, is used with the addition of a narrow arm sling.

A shoulder spica is sometimes required, particularly when the head of the humerus and glenoid cavity are comminuted. This splint is uncom-

fortable in bed and when travelling, and the plaster spica with the arm abducted only thirty degrees has no advantages over the " U " plaster. It is less comfortable and takes longer to apply.

*Elbow and forearm.*—The same splinting is used as is advised for use in forward areas.

**Movement of Joints.**

Early active movement of toe and finger joints is advocated. A masseur should assist with frequent movement. He should move the patella after the first day or two for a patient with a fractured femur. The patient should be taught and assisted if necessary to move the toes or fingers, and told to move them himself every hour.

In most cases of fracture of the femur, not involving the knee joint, it is safe for the patient to move this joint three or four weeks after treatment has commenced ; pain, if severe, is a contra-indication to movement.

The " leg extension piece " which can be fixed to a Thomas' splint is an invaluable addition to the splinting. By fixing a cord to the end and taking it over pulleys to the head of the bed, the patient can move his leg at the knee joint.

It should be appreciated that after union of the femur, the patient is generally faced with some degree of limitation of movement of the knee joint. The success of regaining full movement requires all the skill of surgeon and patient. When there is suppuration in the thigh, early movement is followed by a greater range than if no movement is commenced until the fracture is united. Pain may prevent such movement, during the acute stage, but to wait until the wound is healed before attempting to get movement is bad policy and likely to result in a very limited range of movement of the knee.

At a later stage active exercises, such as using a treadle and riding a bicycle are indicated.

**Foot Support.**

This is carried out by a variety of methods. The simplest is to place strapping on the sole of the foot and attach this by cord to a light-weight. It is important to place this strapping correctly and to place the pulley over which the cord passes, so that the toes are not hyperextended. There must be adequate support for the big toe and the four outer toes must not be over-extended. Failure to attend to these details may cause the complication of hallux flexus and hyperextension of the four outer toes at the metatarso-phalangeal joints. This is serious as it prevents the patient putting on his shoe and takes a long time to correct.

**Dressings and Infection of Wounds.**

If a wound complicated by fracture does not appear to improve when under treatment with vaseline pack and plaster of Paris the condition frequently benefits after a few days irrigation and daily dressing through a window. This treatment is not advocated until *three weeks* after wounding. Infection is most noticeable in large wounds (such as the thigh) when primary operation cannot be planned to remove the greater part of tissue which was virtually infected. Infection spreads up fascial and intermuscular planes. Irrigation may be helpful before resorting to further incision.

When a large wound is insufficiently drained a gravitation abscess is liable to occur when infection is not severe ; serious infection of muscle and muscle planes may arise and may be complicated by secondary

haemorrhage. As so many methods of treating an infected wound are being used with equally good results no one method can be advocated.

Stress is laid on the preventive treatment of infection by carefully planned primary operation followed by limitation of dressing.

There is no evidence of the value of oral chemotherapy after the first week's prophylactic course for G.S. wounds complicated by fracture. The local use of sulphanilamide powder is probably of value.

Amputation may be required for :—

Gangrene.
Extension of infection to neighbouring joint.
Septicaemia.
Recurrent secondary haemorrhage.
Progressive emaciation with delayed union.

## SECTION XII

## GUNSHOT WOUNDS OF JOINTS

The gravity of the wound penetrating or perforating a joint is due to the fact that if suppurative arthritis arises it may be followed by :—

(*a*) Fibrous ankylosis which is generally painful and tends to leave the joint in a position not the most serviceable for function ; or
(*b*) Bony ankylosis.

During the healing process the patient is exposed to the danger of septicaemia during which time limb and life are endangered.

Suppurative arthritis is very serious if the patient has other wounds of moderate severity.

Certain common types of injury may be summarised :—

(*a*) Cases of effusion without lodgment of the projectile in the joint ; (i) in which the missile may have traversed the synovial cavity or only bruised the synovial membrane. It should be borne in mind that with a fracture of the femur and intact knee joint effusion into a joint is common ; (ii) in which there has been a penetrating wound of the synovial cavity ; (iii) in which the missile has perforated one of the bones, entering into the articulation without causing severe comminution.

(*b*) Cases in which the missile has lodged within the synovial cavity or in one of the articular ends of the bones.

### KNEE JOINT

The joint should be immobilised by traction and the Thomas' splint as soon as it is recognised that there is a joint injury.

**At the Forward Operating Centre.**

(*a*) The treatment in a forward area should be that of the wound. Surgical judgement must decide whether the synovial membrane should be closed and skin left open or whether the joint should be entirely left open. When in doubt no sutures should be used. If traction has not already been applied this is carried out by strapping. Plaster of Paris over the thigh and leg, and strapping extension is satisfactory ; the limb and cast are placed on a Thomas' splint and extension tied to the end of the splint.

When the injury is a perforating wound caused by a machine gun bullet, no attempt at wound excision should be made unless an explosive exit has grossly exposed the synovial membrane.

(*b*) *Amputation.*—If the main vessels are injured so that the foot is already cold, amputation is indicated. The amputation should be supra-condylar if the wound is likely to remain clean, but can be through the joint, if the condyles of the femur are undamaged, in the presence of sepsis.

(*c*) *Removal of patella.*—This is indicated when the bone is communited by a missile, with the femur and tibia uninjured.

(*d*) Primary excision of the joint is not advised at forward operating centres.

**At the Base.**

(*a*) Aspiration is most valuable in the sterile or mildly infected joint. This may be repeated at intervals of a few days.

(*b*) Strapping extension and splinting with the knee 10 degrees short of full extension should be employed until it is quite certain that all activity has ceased. Plaster of Paris is applied and the limb and cast are rested in a Thomas' splint.

(*c*) Removal of foreign bodies from the joint cavity and when protruding into articular cartilage is advisable. If this has not been done in forward areas, it should be carried out at the base when the wound is infected. If aspiration shows that the joint is sterile it is advisable to wait two or more weeks before removing a piece of metal from the joint. When a foreign body, the size of a large pea is embedded in a condyle (not an uncommon occurrence), there is no urgency about its removal from a sterile knee.

(*d*) The infected joint is best drained by long lateral incisions extending into the supra-patellar pouch above and as far back as possible below.

Irrigation is not advocated except at the time when the incisions are made. Posterior drainage seldom proves satisfactory and should only be employed to drain an abscess.

(*e*) When there is prolonged suppuration, sequestra lying in a cavity communicating with the joint should be removed. It is uneconomical to remove sequestra from the patella when this bone is infected and sequestrated. Under these circumstances the patella should be removed.

(*f*) Early movement of the joint in the non-suppurative case is encouraged. The date of commencement and extent of movement is controlled by the pain arising.

(*g*) When ankylosis is expected, the knee should be kept straight, but not hyperextended.

(*h*) Injection of chemical fluids and irrigation of the joint are not recommended.

(*i*) No drainage tube should be placed in the joint. If the synovial membrane is closed at operation, a vaseline gauze dressing is placed over this and skin left unsutured.

(*j*) Amputation is indicated :—

(i) to save life, when there is a secondary haemorrhage in a patient who is ill, in most cases of septicaemia, with organisms in the blood stream and in the gravely ill patient (in spite of a negative blood culture, when the temperature is persistently high and pulse rapid).

(ii) when local complications, such as suppurative arthritis with persistent tracking of pus, are affecting the patient's general condition, as may be shown by increasing anaemia, loss of appetite and sleep.

## SPECIAL REMARKS ABOUT OTHER JOINTS

**General.**

(*a*) Infection of the hip and shoulder joint are liable to be overlooked.

(*b*) Prevention of suppurative arthritis should be aimed at by a well planned primary operation. Removal of comminuted bone in and around the joint is indicated, but large pieces with attached muscular tissue are left *in situ*.

(*c*) If this has not been carried out, better drainage is obtained by removal of shattered bone than by incision alone. Rubber drainage tubes are not used.

(*d*) Immobilisation is of great importance soon after the injury and while active infection is present.

**Shoulder Joint.**

If the head of the humerus is shattered, it is removed if the wound is severely infected, but should the wounds be small and relatively clean, such a procedure should be delayed.

At the forward operating centre, the upper limb is fixed to the chest with plaster of Paris. At the base a shoulder spica should be applied, with the arm abducted 70°, with the elbow 30 degrees in front of the body plane, and arm 30° externally rotated.

**Elbow Joint.**

It should be noted that peripheral nerve injury is present in over 25 per cent. of cases.

If all the articular surfaces are comminuted and infection is a probability, the loose pieces of bone should be removed. If the olecranon alone be shattered, the fragments are taken away, but no more bone cut from the ulna. Good drainage is provided by this procedure.

If there is a dislocation of the upper end of the radius in association with loss of bone from the ulna or humerus, the dislocation must be reduced and the elbow fixed in semi-flexion.

Splinting is by plaster of Paris from the axilla to metacarpal necks. The forearm is fully supinated and the elbow is placed at a right angle with the arm.

If ankylosis is expected, the angle can be enlarged and a midposition of forearm adopted in a subsequent plaster.

Primary excision of the joint is rarely indicated. Amputation in the upper extremity should never be advised excepting as a life-saving measure.

# SECTION XIII

# PLASTER OF PARIS SPLINTING

## PLASTER ROOM

Plaster work should be done as far as possible in a plaster room. If this adjoins the operating theatre, the patient can be passed through after the operation is completed. This enables the theatre to prepare for the next operation and limits the cleaning.

In some hospitals it will be convenient to have another room for plaster work, for up-patients and out-patients.

When working in field hospitals the obstruction of waste pipes by plaster can be prevented by the use of a trap below the sink and " open drainage " of the waste pipe.

## MATERIALS AND INSTRUMENTS

(*a*) (i) Plaster of Paris and muslin, Book No. 14 ; or (ii) Cellona bandages and slabs are issued to forward units, when available.

(*b*) Padding of adhesive and plain white felt ; suitable wadding can be made by " dressing " wool with soap.

(*c*) Kramer wire, malleable iron wire 10–20 s.w.g. and flat strips of malleable iron 2 feet long, $\frac{3}{8}$ inch wide, $\frac{1}{8}$ inch thick, will be found useful. A board 36 inches by 24 inches is required for making " slabs " or " plaques."

(*d*) Instruments which are essential are plaster shears ; large and small scissors ; plaster knives ; strong scalpel (not Bard Parker) ; wire cutters ; pails ; bowls ; a pint measure ; tape measure and indelible pencils.

If " fabric plaques " are employed, a trough or large flat bath is necessary.

## CARE OF APPARATUS

Plaster table, Bohler's traction apparatus, the blades of knives and joints of shears and scissors used for plaster work should be kept well greased.

## PLASTER BANDAGE MAKING

The outer three threads should be drawn from each side of the muslin bandage which should be then rolled loosely. The transference of this into a plaster bandage requires practice. It can be done by special machines or on a smooth-topped table, or on a board (2 feet by 1 foot) sloping into a box in which there is loose plaster. Twelve to eighteen inches of the bandage is unrolled and powdered plaster rubbed into it. No more of the bandage than this should be exposed at one time, and the plaster bandage must be rolled evenly. Experience alone will show the correct amount of plaster which should be rubbed into and held in the mesh or left as an even layer on the muslin. If the bandage is rolled too tightly—the usual fault—water cannot soak into it ; if too loosely plaster is lost before, during and after soaking, and the bandage falls into a long tail during application.

The plaster bandages and loose plaster should be kept in containers as airtight as possible and in a dry place.

## APPLICATION

**Soaking.**

(*a*) For cellona use cold water.

(*b*) For hand made bandage use warm water, in a bucket half full or bowl 6 inches deep. Put out on a tray the number of bandages probably required so that a wet hand is not put into the stock. Lower the bandage to the bottom of the bucket and leave until all bubbling has stopped. Put both hands into the bucket and gently grasp each end of the bandage, raising it in a horizontal position, and squeezing it gently in a concertina-like movement of both hands. This will get rid of the excess of water with the minimum disturbance of plaster in the bandage, but the bandage

should still be dripping wet. " Wringing out " the bandage will ruin it. The nursing sister or O.R.A. should then unroll 4 inches of the bandage and hand it to the surgeon.

**" Slabs " or " Plaques."**

These are made by running the soaked plaster bandage to and fro on a smooth board. The process is speeded up if the assistant puts an index finger at each corner of the slab each time that a turn is made. Six layers of bandage generally make an efficient slab. Unwinding dry hand made bandages to make slab fails, as the plaster falls out, but this method works admirably when " cellona " bandages are used.

**Creamed-fabric Method.**

Sheets of cellona or muslin or flannelette are used. With either of the latter one piece is wrapped around the sound limb and the size marked in pencil. Ten per cent. is added, and then a number of layers cut to the required shape. It is necessary to know the number of layers required for each part of the body. Three layers of muslin equal one of flannelette. The layers are placed to form a " pack " and put into plaster cream, which should be made in the proportion of four pounds plaster to two pints water.

**Skin tight and padded Plaster Casts.**

The popularity of the skin-tight and the padded plaster has varied—correctly applied, either suffices. If the skin-tight non-padded cast is used, bony points must be protected by a layer of wool or piece of felt. It should be appreciated that many " plaster sores " arise from too loosely fitting a plaster, so that a rub occurs. Other causes of " plaster sores " are irregularity of the first turns of bandage applied, so that ridges are formed ; and application of plaster to the limb in a faulty position and correction of this position whilst the plaster is still wet, causing a ridge. The commoner sites of the sores are heel, dorsum of foot, base of little toe, sacrum and lumbar spine and anterior superior iliac spines.

**Windows and Bridges.**

The former are undesirable in the early stages of treatment, as swelling tends to occur through the window and the normal circulation is impeded. If windows are cut for the removal of stitches, they can be replaced after the dressing is completed. Bridges made from plaster rope are useful for strengthening plaster casts and for joining the thighs together, when using a spica.

## AFTER TREATMENT

**Immediate splitting of Casts.**

Every transportation plaster must be split, and care must be exercised that no circular bandage or dressing encircles the limb under the plaster.

The ideal policy, that patients with plaster casts should remain for forty-eight hours at the hospital where the cast is applied, is not always possible. In forward units it is essential that a linear cut should be made through the whole thickness of the cast, just before it is dry. This should be on the front of the leg and foot ; and on the flexor surface of the forearm and elbow. This will facilitate the opening of the cast during transport or at a subsequent hospital, particularly if plaster shears are not available. Bivalving is not advocated.

**Elevation of the Limb.**

The leg encased in plaster should be raised a foot above the level of the buttock. The upper limb should be propped up on pillows or similarly suspended to obviate reactionary swelling.

Early movement of fingers or toes is to be encouraged when limbs are immobilized in plaster.

**Soiling and Smell.**

Discharge coming from the top or bottom of a cast is an indication for the change of the cast. Staining of the cast over an open wound is inevitable. Painting of the outside with iodine may be of value. Of the methods of preventing offensive smell, two are of some help :—

(*a*) *Deodorant.*—Powdered naphthalene (a handful) is scattered around the wound area on the cast before the last turn of plaster is applied.

(*b*) *Concealment.*—A pillow case type of bag of thick canvas or thin felt with a tape around the top is used to enclose the cast. The black felt-like impregnated material supplied to base hospitals is of value if available.

The employment of urea and other substances are advocated, but receive no general recommendation.

## SPECIAL PLASTERS

**Hip Spica.**

The hip spica is condemned by many surgeons but remains popular with some. There is a great tendency for plaster sores to form across the sacrum—and ill patients travel badly in spicas. A well fitting spica is difficult to apply and generally a Thomas' splint and traction is preferable.

**Arm-abduction.**

This plaster is of value in certain cases ; but should not be applied at forward units. The patients cannot travel in ambulances and other conveyances in any comfort ; the cast generally has to be removed on arrival at the base. The use of an axillary pad and fixing the arm to the side by plaster or bandages is satisfactory. Equally useful is a slab from the nape of the neck over the arm and around the elbow up to the axilla. This is fixed by a few turns round the arm with a plaster bandage. A narrow arm sling is used.

**Leg Plasters.**

These should extend from the upper third of the thigh, or in some cases from below the knee, to the base of the toes. The foot should be at a right-angle to the leg, and not in equinus. The foot must be plantar grade, neither valgus nor varus. Great attention to the position of the foot is necessary and medical officers are warned that much delay in convalescence is caused by immobilisation of the foot in faulty position

Both the equinus and varus deformity are met with far too commonly.

**Elbow Plasters.**

These should extend from the upper third of the arm to the metacarpal necks. The elbow should be fixed at a right-angle in forearm injuries and an open angle in most injuries of the joint. The application of a slab, applied to the posterior surface of leg or arm and forearm, followed by the use of circular turns of plaster bandages is a good technique. The slab should be made to fit snugly around elbow and ankle by making lateral slits and interleafing the two cut edges.

**Compound Fractures.**

Compound fractures of the spine that have to be evacuated should be placed on plaster beds when such is possible.

## SECTION XIV

## INJURIES OF THE KNEE JOINT

The knee joint is very susceptible to injury, but because a knee is injured, it does not necessarily follow that the semilunar cartilage is displaced or fractured.

There are four main ways in which the knee is damaged :—

*Abduction Strain.*—Resulting in a tear or partial rupture of the femoral attachment of the internal lateral ligament.

*Rotation Strain.*—Caused by twisting of the knee. If weight is being borne on the flexed knee with the foot firmly anchored to the ground, the force of the injury may either stretch or tear the coronary ligaments or cause a split or fracture of the semilunar cartilage. When no weight is borne, or if the foot is not held, the semilunar may escape. The modern football boot, with good studs to prevent slipping, often gives just that fixation which causes damage to the cartilage, whilst a rotation sprain when wearing an army boot, allowing the foot to slip, more often causes tearing of the ligaments, and allows the cartilage to escape.

*Hyper-extension Strain.*—Results in a tear or rupture of the anterior crucial ligament. This injury may be further complicated by an avulsion of the spine of the tibia ; in other words, the bony attachment yields rather than the ligament.

*Adduction Strain.*—Is a rare injury which when the force is powerful tears the lateral capsule, the external lateral ligament and may avulse the fibular styloid. This serious joint injury is sometimes complicated by a traction lesion of the external popliteal nerve.

A severe crush may result in a combination of these injuries.

### INTERNAL DERANGEMENT

If a cartilage is torn, the line of cleavage is in the substance of the cartilage, which is avascular and so incapable of repair, except at the extreme periphery. Tears of the coronary ligament repair by fibrous tissue.

The injury which results in a damaged cartilage, in the first instance, is usually a rotation sprain or twist, with the knee flexed and the weight transmitted, the semilunar caught between the femur and tibia is compressed and splits longitudinally, by this direct compressing force. If the split involves the main body of the cartilage, the central portion may be displaced across the joint giving rise to the so-called " bucket-handled " lesion which blocks movement. If the split is localised in the middle third, the symptoms and physical signs may be those of a sprained knee, that is, there will be no true " locking " of the joint. If, however, the tear involves either the anterior or posterior thirds, with a free end, the tongue-like process passing across between the femur and tibia, interferes with joint movement and gives rise to the so-called " locking."

**Differential Diagnosis.**

It is impossible to overstate the value of an accurate history, and the full appreciation of the details of the accident and the after happenings. This takes time but is time well spent, and is an indispensable prelude to the clinical examination.

## PRIMARY INJURY OF A SEMILUNAR CARTILAGE

The diagnosis of the primary injury is more difficult than that of a recurrent derangement, and it may be doubtful whether the lesion is a severe rotation sprain of the coronary attachment, or whether the cartilage itself is torn. Pain and tenderness on palpation over the joint line is suggestive of cartilage injury. When uncertain, it is wise to regard the injury as a sprain and treat it accordingly ; and to wait for a recurrence of symptoms, before advising operation.

If, following injury the normal knee becomes locked, that is, fails to extend fully to 180 degrees, and if when manipulated is immediately restored to normal, perhaps with an audible snap, we may confidently diagnose an internal derangement, either a torn cartilage, or a loose body. The value of the clinical sign of unlocking, that is, restoration of the lame knee to normal by manipulation rather than the story of locking, should be emphasised. A strained knee will often fail to extend being held semi-flexed by muscle spasm. Under anaesthesia such a knee straightens, but the spasm returns as the effect of the anaesthetic passes off. With a displaced cartilage when reduction is accomplished, the knee retains the power of extension to 180 degrees.

**Recurrent Displacement.**

There is little difficulty in arriving at a correct diagnosis of recurrent displacement when a patient states that his knee was injured and since that time has given way on some four or five definite occasions ; that he fell because the knee gave way and not because he slipped ; that the knee would not straighten and that he was assisted off the field limping, with his toe, but not his heel, on the ground ; that someone pulled his leg straight, he felt something move in the joint and was then able to straighten and bend his leg ; and that his knee swelled the same evening. From such a history, the diagnosis of recurrent displacement of a torn cartilage is simple. In practice, it is only necessary to exclude a loose body.

Some surgeons attach considerable importance in diagnosis to eliciting a click in the knee joint in flexion with rotation, and consider this to be an essential point in the diagnosis of a cartilage lesion. Some go even further and mobilise the knee under anaesthesia as a preliminary procedure and as part of diagnosis, in order to elicit this click and regard it as essential.

**Loose Body.**

The patient with a loose body gives a history and describes symptoms similar to those given by a patient with a torn and displaced semilunar cartilage. The X-ray examination is the deciding factor, unless the loose body can be felt by the patient or the surgeon. Frequency of locking, with ease of unlocking, is suggestive of loose body.

*X-ray films should always be taken of any injured joint before finally arriving at a diagnosis.*

**Abduction Sprain.**

Can be diagnosed with certainty by the site of maximum tenderness on palpation and by pain on forced abduction. As already stated, there may be limitation of extension in a severe sprain.

**Rotation Sprain.**

This may easily be mistaken for a true internal derangement, and provides a real and practical difficulty. It may well be impossible to make sure whether such a sprain is complicated by a torn cartilage or not. It is best to treat the sprain, and await evidence of recurrence of the cartilage displacement, as otherwise many knees will be needlessly submitted to operation.

A severe rotation strain without weight on the leg is liable to damage the attachments of the cartilages towards the front of the joint and about the fat pad. There is pain, fluid in the joint, and movement is limited by spasm. The range is small. The knee will neither fully flex nor extend, but has perhaps some 30 degrees to 40 degrees of movement through an intermediate arc. The joint line is tender on palpation, and there may be oedema localized over the inner side of the knee.

Under anaesthesia, knees of this type straighten and bend. The protective spasm is abolished, but, if a few weeks have elapsed since the accident, there is a feeling of spring, as if the full 180 degrees extension were not quite maintained. Any forced manipulation makes the condition worse and operation is useless. The great factor in recovery is time, together with early rest and physical treatment. If the rest is complete—*e.g.* in a plaster cast—the inflammation will subside more quickly, but adhesions will form. The effusion and haemorrhage into the loose cellular tissue and the fibrosis—all processes of repair tend to cause limited movement. When these adhesions are put on the stretch, the patient experiences a feeling of weakness, pain and insecurity. Early mobilisation ends in disaster. The knee gets stiffer and the spasm returns. Many patients are incapacitated for months, but gradually improve with time. These are knees which repay forced manipulation later on and do not require operation for removal of cartilage.

**" Over-use Arthritis."**

The knee joint feels weak, swells, may give way under strain, and generally feels insecure. Such knees are seen in patients from thirty-five to fifty, generally after performing more active exercise than is their usual habit. The knee sustains some slight and indefinite twist, it fills with fluid and extension is painful and limited by a few degrees. The inner joint line is tender. The X-ray may show some slight lipping but no gross change at this stage. Support, building up of the quadriceps, and counter-irritation, together with a return to a more sedentary occupation, the avoidance of P.T., assault courses and long marches, will usually be followed by recovery—so long as the joint is not again subjected to the same undue strain. Such men should be down-graded.

**Torn or Stretched Crucial Ligaments.**

Allow of hyper-extension and give a feeling of weakness and insecurity, with recurrent attacks of synovitis, or any strain or over use. Careful examination of the passive joint range compared with the sound limb will reveal the A.P. glide of the tibia on the femur.

**Avulsion Fracture of Tibial Spine and Fracture of the Patella without separation.**

Must be borne in mind. The X-ray, which forms part of the routine clinical examination of every joint, will show the fracture.

**Osteo-Chondritis Dessicans.**

In the young soldier this condition is always a possibility. The symptoms complained of are usually a weakness of the knee, a giving way and a general feeling of insecurity in the joint. Mild swelling is common. In the early stages, before separation of the body, X-ray examination confirms diagnosis. When a loose body is formed and free, there is no difficulty in reaching a correct appreciation of affairs.

**Recurrent Dislocation of Patella.**

Is more common than is generally supposed, and must be remembered by the surgeon. Clinical examination will reveal the extra mobility of the patella, and the ease with which it can be pushed over to the outer side ; indeed, sometimes the dislocation can be produced at will.

## TREATMENT

When the diagnosis of the primary injury is in doubt, as at times it must be, it is wiser to wait than to advise operation. The knee should be treated symptomatically, then tried out with use and free standing gymnastic work. If the knee holds up, well and good. If it gives way and exhibits the syndrome of a recurrent displacement, an operation should be performed. If it recovers up to a point, but then exhibits the syndrome of capsular adhesions—pain and limitation of movement on forced flexion with rotation—it should be mobilized.

If one can be reasonably sure that a cartilage is torn and displaced, it is safer and better to remove it. Treatment by manipulation is indicated if the disability is due to adhesions which are the results of sprain.

As has been stated, the difficulty lies in arriving at a certain diagnosis following the primary injury, and so it is wise to temporize. What has happened cannot be seen unless the joint is explored, so it is obvious that any statistics as to cures by manipulation must be fallacious. If the correct treatment of the primary injury, whether by rest, by manipulation or by operation, be a matter of opinion, there can be no doubt that operation is required for a recurring derangement. A knee which has been subjected to repeated internal trauma is likely to be the site of osteo-arthritis.

Again, the physical danger of the unstable joint, which may throw the patient down at any time and in any place, is a factor to be considered.

**Manipulative Treatment.**

Should be undertaken when dealing with the effects of injury to the knee, resulting in adhesions. It should be borne in mind when in doubt about the accuracy of diagnosis and with a normal X-ray that manipulation is well worth a trial. Adhesions about the periphery of the cartilages, at the coronary attachments, will commonly follow a strain, unless the original injury has been treated by active movements, or manipulation at an early stage. Such adhesions, when put on the stretch by a sudden twist during active movement, as in playing a game, give rise to a sudden feeling of pain and weakness, and mimic a true internal derangement.

The manipulation is carried out under anaesthesia and the patient should, on recovery from the anaesthetic, immediately walk and put the joint through its full range several times.

The manipulation may be repeated with advantage, if the result on the first attempt is partially but not completely successful.

## OPERATION

Operation on the knee joint should only be undertaken by those surgeons who are specially experienced in the treatment of joint injuries, and further, this operation is never an emergency one and should only be performed when the conditions permit of perfect asepsis, and the employment of the ancillary methods needed in post-operative care. It cannot be stressed too strongly or too often that this is not an operation which should be undertaken lightly in the serving soldier.

A difficulty arises in dealing with soldiers with a combined lesion, viz. a torn cartilage and a lax crucial ligament. Although in civil life it may be wise to remove a cartilage which is giving trouble in a patient with a lax and unstable knee, this operation has no place in the treatment of the serving soldier. He should either be down-graded or discharged from the service.

## PRE- AND POST-OPERATIVE TREATMENT

Both pre- and post-operative treatment are of the utmost importance, although naturally the details of treatment will vary in the practice of different surgeons. The strength of the quadriceps should be toned up before operation is undertaken and after operation. The patient is encouraged to put the muscle into action the day following operation, and should raise his leg from the bed in a few days. He gets up, with a small supporting bandage on the tenth to fourteenth day, and his early efforts at walking are watched by the masseuse, who insists on symmetry of stride, balance and so forth, and teaches him to avoid the tendency to limp. No passive movement is required—movement is regained by the patient's voluntary effort, but the masseuse assists with rotation of the knee through all degrees of flexion. Towards the end of the treatment period, it is necessary that she should make sure that full outward and inward rotation is regained, to avoid the formation of adhesions about the attachment of the coronary ligaments. Some swelling of the joint is not uncommon in the early stages, but may be disregarded, and is controlled by a small crepe bandage, which does not extend up the thigh beyond the limits of the joint.

Non-weight bearing exercises of the quadriceps by weight and pulley slide, in the sitting position, restores muscle power, and the patient passes on to class work exercises with weight, and thence to the hardening process of the convalescent depot.

The length of time which this rehabilitation programme takes from the date of operation to return to unit varies considerably. With a simple tear of the cartilage, about eight weeks will be the average time for the man to return to his unit. If the knee was weak before operation was undertaken and if the musculature was not built up by pre-operative treatment, then it is not unusual to find twelve weeks is the period required before a man is back on duty. Further, in certain of the knee injuries, it is wise to down-grade for a period in order to let the knee accommodate to the new conditions.

Modern training is extremely strenuous and there is great strain, particularly on the knee joint and many knees will react poorly to too strenuous or too hastened a convalescence. The man will present himself with swelling and will complain of pain. The surgeon who is controlling the after-treatment must be on his guard that too enthusiastic and too strenuous a course of rehabilitation does not jeopardise the result of his operation or delay the patient's return to full active use.

### CYSTS OF THE SEMILUNAR CARTILAGE

Cystic formation is more frequent in the external than in the internal cartilage. A rounded, sometimes tender swelling about the lateral ligament, prominent on extension and usually disappearing on flexing the knee, suffices for diagnosis. The condition may or may not be painless.

**Treatment.**

Operation should be reserved for those patients with symptoms and not performed merely to remove a swelling. The post-operative convalescent period is longer than that after removal of a torn cartilage. In a series of sixty-four cases (sixty-two cysts of the external semilunar cartilage), forty-six remained in Category " A " and sixteen in Category " B."

### SUMMARY

1. No examination of the knee is complete without an X-ray examination.

2. No single sign or symptom is pathognomonic of cartilage lesions.

3. No diagnosis is reliable that fails to consider all the evidence obtainable ; historical, clinical and radiological.

4. Operation following the first injury should be exceptional.

5. Pre-operative exercise—rehabilitation—under the care of the same surgeon is to be aimed at.

6. The advantage of post-operative immobilisation of the knee is a matter of opinion, a successful end result may be achieved with or without this.

## SECTION XV

## FOOT DISABILITY IN THE SOLDIER

The problem must be approached with realism. The question is not how to make feet with gross deformities fit for the Army, but how to keep men with good or reasonably good feet free of symptoms.

The perfect foot is a rarity ; suppleness, adequate musculature, absence of gross deformity, and freedom from pain are all that can be expected. Hence, mild degrees of hallux valgus, hallux rigidus, planus, cavus, claw toes, etc., are to be found in the A.1. category. Such feet are vulnerable, demanding intelligent supervision, but under certain circumstances almost all these deformities can arise in a foot which previously had appeared normal.

Pain is the greatest safeguard to the life of the foot, and early recognition of the cause of the pain will prevent irreparable harm.

When symptoms arise, the primary aim should be to relieve them and not necessarily to correct deformity. Every effort should be made to retain the soldier in the medical category in which he was placed prior to the onset of symptoms. Co-operation between medical officer and specialist is essential, and down-grading should seldom be recommended by the latter without a report from the regimental medical officer.

The term " flat foot " is given to those feet in which there has been a lowering of the arch of the foot from the height, considered normal, for such a person. It does not follow that any discomfort or symptoms need arise. In fact, 24 per cent. of an Infantry Brigade examined in 1942 had some anatomical deformity of the foot producing no symptoms even after long route marches with full equipment.

## FOOT STRAIN (Acute Flat Foot)

The prime cause of disability is strain—an acute condition of sudden onset. The greater part of the foot is swollen, tender and painful. Rest is required and not exercise or physical treatment, and by rest is meant rest in bed with the feet elevated, in the acute stage.

The prevention of footstrain, which so often results from the severity of modern infantry training, must be constantly borne in mind and the following points noted :—

1. *The soldier must be placed in his correct category, and periodically surveyed to see if his condition has deteriorated or improved.*
   This calls for accurate assessment of foot disability in the recruit. Distinction must be made between normal discomfort of initial training and real disability. " A.1." men should not be expected to remain " A.1." if employed continuously on sedentary duty.
2. *Categories must be respected in relation to training and duty.*
   Care in categorisation is wasted if low category men are asked to do duty beyond their capabilities. It is impossible for the regimental medical officer to watch all duties in relation to categories, but it can usually be determined whether those reporting sick have been subjected to overstrain. An abnormal number of men reporting sick through overstrain calls for action on the part of the commanding officer.
3. *Inspections must be held to ensure that the foot is working under optimum conditions.*
   Many minor casualties are caused by boot friction or pressure, and the fit and condition of socks often leaves much to be desired. An adequate foot toilet has become more important now that all boots are dressed with dubbin. Dubbin excludes water but reduces ventilation considerably.
4. *Warning signs of footstrain must not be ignored.*
   This calls for early treatment and this means, as already stated, REST and not physical treatment. These patients will lose their symptoms if treated early, but if the condition has been ill-treated, or neglected, the pain will persist for a long time. The advice given in paragraphs 1, 2 and 3, must be remembered. It is of no use to cure the present attack and return the patient to the exact conditions which caused it, as this will inevitably cause a relapse. Modern training is too strenuous for many recruits, and the conditions and speed of training

must be modified for certain men, to prevent complete breakdown and loss of man power.

Fatigue of the muscles controlling and supporting the foot allows abnormal strain to fall on the ligaments, producing pain and swelling. Intrinsic muscles are most liable to fatigue and as they co-ordinate the action of the long flexors and extensors of the toes, an abnormal action of the foot follows when they cease to act. The toes become clawed and fail to take their proper share of the weight. More stress is thrown on the metatarsal heads and anterior transverse arch, and so the condition rapidly progresses; the whole foot aches, muscles are incordinated and balance is bad.

*The treatment of footstrain* is rest, as complete as possible. Following rest, non-weight bearing exercises should be given to develop the intrinsic foot muscles. When training is started again the exercises should be continued to develop the small muscles equally with the muscles of the calf. These exercises should be supervised by a masseuse or a sergeant instructor A.P.T.C.

*Recommended Exercises.*

1. Dorsiflexion of foot with plantar flexion of toes, and plantar flexion of foot with dorsiflexion of toes.

(This exercise is impossible to do in a case of acute footstrain and is therefore found useful in diagnosis.)

2. Stroking the opposite shin up and down with the curled toes.

3. Plantar flexion at the metatarso-phalangeal joints with the inter-phalangeal joints extended (done standing—develops lumbricals and interossei). This exercise is best taught first with the patient sitting.

When the exercises are well performed and the general balance is good, training may be stepped up gradually with every hope of success. If the exercises cannot be performed properly after a period of rest and balance remains bad, down-grading should be carried out.

*Pressure of bony prominences* is shown by skin irritation if the foot is inspected after exercise. It is necessary to check boot fit and condition of boots and socks and to see that boots are softened properly.

In the case of gross defect, down-grade, but delay the issue of light boots unless it is obvious that the foot cannot be fitted from stock.

## CLAW FOOT (Pes Cavus)

In the soldier this has been present before enlistment or acquired as a result of a paralytic condition. It was seen in its typical form after trench foot during the last war. Except in an advanced state, it is usually symptomless, but causes trouble by the formation of corns and hard skin. Most men can be retained in the category in which they entered the service if they receive attention from the chiropodist or foot orderly. Operative treatment to correct deformity is not advisable in the serving soldier.

**Mobility of the Toes and Tarsal Joints.**

With either flat foot or pes cavus, a stiff foot is unlikely to have normal function, whereas many deformed feet which are supple are efficient.

It is essential for medical officers to be constantly on the watch in order to prevent stiffness of the toes and tarsal joints. Careful attention to boots and socks should be stressed. Short boots and shrunken socks prevent mobility of the toes and induce clawing. After resting a patient

with acute foot strain, and as soon as inflammatory reaction subsides, physical treatment to maintain or restore mobility must be commenced—contrast bathing—massage—friction and like measures will help and the man must be made to understand the necessity for keeping his toe joints and feet supple.

## HALLUX VALGUS AND RIGIDUS

Mild examples can be helped by placing a bar across the sole behind the metatarsal heads. If symptoms persist, it may be necessary to down-grade. Operative treatment is seldom indicated in a serving soldier, as experience has shown that he is seldom restored to a high category and he can usually serve in the lower categories without operation. Light boots may be necessary and the sole must be stiffened, but the standard army boot should be worn, if possible. Slitting the tongue down on each side will make the boot easier to put on.

## HAMMER TOE

By itself is often of no significance. An effort should be made to keep the man in a high category by refitting with the standard boot. Operative treatment by arthrodesis of the interphalangeal joint with excision of the corn and not by amputating, is often successful in preventing ultimate down-grading and should be considered ; three months down-grading will, however, be necessary immediately after operation. The services of a chiropodist will be found helpful.

## SHORT TENDO ACHILLIS

This is a common condition and one which is often missed. The foot cannot be dorsiflexed above a right angle except in the valgus position, and the heel tends to evert, leading to footstrain and an abducted foot.

These men should be treated by the addition of a quarter of an inch to the heels of their boots. Recruits suffering from this condition should be treated at once, or otherwise their feet will soon deteriorate. Boots should be worn for all P.T. work, and flat heeled shoes or plimsoles forbidden.

## ADHESIONS

Adhesions should be suspected if there is a sudden onset of pain, which has become chronic in a previously normal foot following footstrain. The foot lacks mobility and is painful when manipulated. These patients should be admitted to hospital for manipulation under anaesthesia to be followed by a course of exercises.

## ABDUCTED LITTLE TOE

The disability is usually entirely due to friction and can be helped considerably by refitting these men with larger boots and an extra pair of socks if necessary. Operation is sometimes advisable with a good type of patient. An effort should be made to prevent down-grading.

## INGROWING TOE NAIL

This may result from faulty cutting of the nail or from wearing too short socks. Toe nails should be cut straight across at right angles to their long axis. The sides should not be cut away, but in the big toe nail, the surface of the whole nail should be thinned in the centre by flaking off the surface of the nail with one blade of the scissors. The pain caused by an ingrowing toe nail is due to inflammation, where the nail is cutting into the underlying soft tissue, and frequently suppuration follows. The chiropodist may be able to affect a cure, failing which, operation should be considered.

## BOOT ALTERATIONS

**Light Boots.**

Should be ordered for men in categories " B.7 " or " C " and rarely for men in category " A." Shoes are not authorised except for rare cases, and then only on the recommendation of an orthopaedic specialist.

**Surgical Boots.**

Cannot be ordered except on the recommendation of an orthopaedic specialist. The man who requires a specially made boot is usually unfit for further military service.

**Alterations.**

Should never be made to the standard boot with the exception of wedging the inner side of the heel, applying a transverse bar, raising the heel for a short tendo achillis, and slitting the sides of the tongue for a hallus rigidus. Therefore the following suggestions apply in the main to light boots :—

1. *Metatarsal Bars.*—These are very often found placed too far forward. They must be placed *behind* the metatarsal heads. Three-eighths of an inch is the usual thickness.
2. *Crooked and Elevated Heels.*—These are heels elongated and wedged one-sixth of an inch on the inner side. The sole of the boot should never be wedged.
3. *Felt Metatarsal Pads.*—Anterior arch supports or inner platform. These should be ordered for early conditions of footstrain with pain in the metatarsal arch, and are also useful for men suffering from prominence of the metatarsal heads with callosities. At intervals these pads and arch supports will require renewal.
4. *Felt Padding of Tongue of Boot.*—Three-sixteenths of an inch of adhesive felt, should be used, cut to the size of the tongue and the adhesive side applied to the inside of the tongue. Padded tongues are useful for cases of high arch suffering from pressure on the base of the first and second metatarsals.

Points which the R.M.O. should bear in mind. Confusion arises from such facts as the following :—

" A.2 " has no value as a foot category. Men classed " A.2 " are usually expected to march and train with " A.1 " men.

" B.2 " is not a foot category but it does allow for defects of locomotion, and it is reasonable to place a man in this category who cannot march more than ten miles.

" B.7 " is the principal foot category, and allows for no other defects. Men in this category should be able to march two to three miles, but the fact must be faced that the majority of " B.7 " men cannot march this distance in good order. A man who can march properly for three miles can be trained to march much further. The " B.7 " man cannot march properly at all, but he can usually cover the distance if allowed to do it in his own way.

" C.1 " are fit for duty within the limits of their disability. It is not a lower foot grade than " B.7." Example : A hallux rigidus which prevents a man doing duty in " B.7 " usually renders him unfit for military service.

" C.2 " are fit for more or less sedentary duties on home service.

"C" category, both 1 and 2, should be used almost exclusively for trade-tested men.

### OPINION OF THE SPECIALIST

Far too much value is attached to the importance of a specialist's opinion where feet are concerned. From the methods of assessing disability already given, it will be seen that the regimental medical officer has full access to the information required, and will, after a little practice, dispose of most patients without having to call for a specialist's opinion. The opinion of a specialist is not required to lower a man's category or for the supply of light boots.

### MARCH FRACTURE

March fractures can occur without any history of direct or indirect trauma and may give rise to only slight symptoms—some aching of the foot after a long march, for example. Or the soldier may complain of severe pain in the foot during or after a long march, and have an obvious limp. The local signs are variable. In some no abnormality is apparent on inspection but there is tenderness on pressure on the dorsum of the foot over the site of the fracture. In others the foot is swollen with marked oedema over the dorsum but without bruising of the sole, which is common in ordinary fractures of the metatarsal caused by injury.

In all suspected cases an X-ray examination should be made. Little may be seen at first, but at re-examination the fracture may be seen as a crack or solution of continuity without displacement and a small bracket of ensheathing callus appears on either side in the antero-posterior view.

**Treatment.**

Immobilisation of the foot in plaster is not only unnecessary, but tends to prolong disability and retard recovery as a result of the ensuing stiffness. "March fractures" show no tendency to mal-union and it suffices to support the foot with a turn of strapping. Enough splintage is provided by the neighbouring metatarsals together with the wearing of an army boot. If the foot is swollen to any extent, the patient will require a day or two in bed until the swelling has gone down sufficiently to let him wear his boot. If there is neither swelling nor excessive pain he should remain up and about.

The decision on whether or not to send a man to hospital depends on the degree of pain and amount of swelling. Medical officers must use their own judgment, but in cases of doubt the man should be sent to hospital. He is, in any event, excused marching and any form of physical training for some weeks. It is important to realise that the degree of disability commonly seen is as often the result of treatment as of the injury. It is important to avoid plaster fixation and the resulting stiffness of the foot.

## SECTION XVI

## INJURIES OF THE PERIPHERAL NERVES

Injuries of peripheral nerves, either alone or complicating a fracture are common and are liable to be overlooked.

## 1. IMMEDIATE TREATMENT

When a recent wound first reaches the surgeon, no prolonged attempt is made to ascertain whether or no a main nerve is divided. The preliminary examination may reveal evidence of nerve injury or a divided nerve may be discovered when the wound is dealt with at the F.S.U. If a main nerve is found divided, most surgeons will approximate the ends with a fixation stitch. It is doubtful if nerves retract, but they may be displaced, and the fixation stitch will render the secondary operation easier. Burying of foreign material in a wound is to be avoided, but the single fixation stitch can do but little harm and is generally recommended. No attempt at meticulous end to end suture should be attempted in the forward areas, there will be no time and the appropriate instruments and suture material will not be available. In any event, if sepsis supervenes the procedure is useless.

*It is essential that the surgeon makes a note on the field card if a nerve is seen to be divided and also if he has attempted to fix the ends or to suture.*

**Nerves exposed to Local Sulphonamides.**

It has been shown experimentally, that the local application of sulphonamide in too great concentration will damage a peripheral nerve, even if the sheath is intact. Sulphonamide applied locally must be used with discretion and not poured into a wound in bulk. Applied by an insufflator, or dusted in, it is harmless—poured in or ladled in with a spoon, it may and has caused irreparable damage to the nerve. The same attitude should be adopted towards the use of propamidine.

## 2. TREATMENT AT THE BASE

**Pre- and Post-operative Treatment.**

The aim of treatment is to maintain nutrition and mobility in joints and in the paralysed muscles whilst awaiting the return of conduction in the damaged nerve and the restoration of function. Fixed deformity is caused by the pull of the non-paralysed opponents of the paralysed muscle groups, the action of gravity, or the contraction of scar. In the present war, too much fixed deformity has arisen from prolonged and ill-judged splintage. A nerve injury is usually complicated by damage to soft parts and sometimes by fracture, *e.g.* a large proportion of G.S.W. humerus are complicated by injury to the musculo-spiral (radial) nerve. Splints are used to relax paralysed muscles and so hasten recovery, or to prevent contractures. The fingers must never be kept rigidly splinted and for this reason no splint is allowed to impinge on the palm distal to the proximal palmar skin crease. The thumb must be prevented from falling back into line with the fingers, for if it gets fixed in this position, the power of adduction is lost, and is difficult to get back again. It is essential to conserve mobility in joints and especially in the hand and fingers.

Splints should be simple : a small cock-up with elastic extensors replacing the paralysed finger and thumb extensors—the musculo-spiral glove, or some modification of this suffices for the radial nerve. For ulnar paralysis, small finger splints improvised of metal should prevent clawing —*i.e.* hyper-extension of the metacarpo-phalangeal joints of the little and ring fingers. The common deformity of fixed abduction of the little finger can be prevented by a garter or loop of bandage holding the little finger to the middle and ring. For the median, a piece of adhesive to hold the

thumb in opposition for part of the day and at night is all that is required. With an injury of the sciatic, the foot must be kept at a right angle to prevent foot drop, and a right angle splint applied at night or when the patient is in bed.

The more elaborate splinting sometimes seen will interfere with movement and therefore with blood supply. The patient must be encouraged to keep the fingers and hand moving, passively if active movement is not possible, and to maintain free range for the toes and tarsal joints in the case of the lower limb. Once this acquired stiffness has occurred, it may take many months of intensive physical treatment to overcome.

### 3. OPERATION

The differential diagnosis between anatomical and physiological division of a peripheral nerve can only be made with certainty by viewing the exposed nerve at operation. There may be complete division, with end bulb formation requiring suture, or there may be a lesion in continuity, or there may be an incomplete division.

The working rule is to explore, as early as possible, as part of diagnosis, if a missile has passed in the vicinity of the known course of a nerve and there is loss of conduction. If there be no wound, *e.g.* a nerve injury complicating a closed fracture, a period to allow time for signs of commencing recovery to appear is advised and operation is delayed.

There is evidence that the earlier the suture of a divided nerve is carried out, the better the chances of recovery. Therefore exploration should be performed as soon as it is thought the sepsis has subsided sufficiently. The number of weeks which should elapse will vary with the severity of the sepsis. A clean bullet wound may be explored as soon as the wound has healed, whilst it is wiser to wait two to three months after healing if there has been much sepsis.

It is when dealing with a lesion in continuity that experience is required. The problem which faces the surgeon is, should he be content to remove scar tissue and replace the nerve in as good a muscle bed as he can, or should he resect and resuture. The answer depends on evaluating several points. How long is it since the injury, and is the nerve undergoing spontaneous recovery? If the lesion is incomplete shall he sacrifice what is retained in the hope of a more complete recovery of function with resection and suture?

The answer can only be given after full neurological investigation of the patient, a consideration of the history, and a knowledge of what degree of functional recovery is likely to follow a suture of the particular nerve involved at the particular level.

## SECTION XVII

## INJURIES OF THE HEAD

### 1. GUNSHOT WOUNDS OF THE HEAD

Gunshot wounds of the head are divided into (*a*) *penetrating wounds*, in which the dura is pierced; and (*b*) *non-penetrating wounds*, in which the breach of tissue is limited to the scalp alone or to the scalp and skull.

When a missile produces severe damage, particularly to the brain stem, the soldier usually dies on the battlefield, or after a few hours or days, during which he remains in deep coma. Less severe brain damage is usually not attended by loss of consciousness, but there are frequently focal signs, depending on the part injured. Thus, a missile in the parietal region may produce loss of power and sensibility in the opposite arm and leg, and a mid-parietal wound in the region of the sagittal sinus may produce paralysis of both legs; an occipital wound usually results in blindness of the opposite half fields of vision, and if the occipital wound is near the middle line blindness may be complete. These focal signs may follow non-penetrating as well as penetrating wounds. They show a strong tendency to spontaneous recovery within a few hours or days.

There are two important complications of head wounds—infection, and massive intracranial haemorrhage. *Massive intracranial haemorrhage* may be intracerebral, subdural or extradural, and may follow non-penetrating as well as penetrating head wounds. The accumulation of blood clot within the cranium is accompanied by progressive increase of unconsciousness or of focal signs. It is not common, but when it does occur the patient's life depends on prompt recognition and removal of the clot. Hence, in head injury patients it is important, at all staging posts from the R.A.P. backwards, to record on the field medical card the state of consciousness and the presence or absence of gross focal neurological signs. Most patients with head wounds arriving at the C.C.S. in deep coma which has been present since the moment of injury should have a low surgical priority, for their coma is due to gross brain damage, and a considerable proportion will die whatever is done for them; but if from the medical notes it is clear that the onset of unconsciousness is more recent than the wound, then the patient should have a high surgical priority. Early evacuation of the blood clot will save his life. It must be emphasised that cases of massive intracranial haemorrhage after wounds of the head are relatively rare.

*Infection* is the common complication. Virtually all head wounds are contaminated with a mixed bacterial flora. The infection which develops in the wound is due usually to staphylococcus aureus, less commonly to streptococcus pyogenes, and rarely to pneumococcus, *B. tetani*, or other organisms. Gram-negative organisms are also often present, also anaerobes. Gas gangrene of the brain was not seen in North Africa, but has been encountered in Europe.

In simple scalp wounds the infection is rarely serious, though failure to treat it adequately will delay the soldier's return to duty. In fractures of the skull the bone easily becomes infected, and then the scalp wound will not heal until all the infected bone has been removed. In brain wounds infection is followed by brain abscess, ventriculitis, or meningitis.

Whenever there is an open wound of the dura and overlying parts, the brain tends to protrude as a fungus, and the size of this fungus increases if intracranial tension is raised by the development of a brain abscess or meningitis. Protrusion of the brain through the wound produces irreparable damage, not only of the fungating part of the brain, but also of the underlying brain tissue. One aim of surgical treatment of brain wounds is to protect the brain from fungating by firm closure of the scalp in two layers. The operation of decompression has no place in the treatment of head wounds.

*First Aid.*—The hair is cut away around the wound and sulphanilamide powder is dusted on. A shell dressing is then applied and secured firmly by bandage or strapping. Morphia is contra-indicated at this stage. Treatment against tetanus will be the same as for other wounds. The following entries should be made on the field medical card :—

1. Date and time of wounding.
2. Date and time of examination.
3. Site of wound.
4. State of consciousness (alert, drowsy, comatose).
5. Presence or absence of weakness or paralysis of the limbs.
6. Pulse rate.

At the various staging posts on the way to the C.C.S., entries should be made whenever possible on the points 2, 4, 5 and 6 above.

**Treatment at the C.C.S. or Field Surgical Unit.**

(*a*) *Examination of the Patient.*

The hair is close-clipped all over ; unsuspected multiple injuries may be disclosed by this procedure. After examination of the central nervous system and assessment of the patient's condition, the findings are compared with those previously recorded on the field medical card.

(*b*) *Resuscitation.*

Shock is not common in uncomplicated head injuries. Transfusion is rarely necessary, except to replace blood lost at operation. Morphia *in small doses* (gr. 1/6) can be used effectively to allay anxiety and restlessness ; in large doses it depresses respiration and so raises intracranial venous pressure.

(*c*) *Disposal.*

(i) *Immediate Evacuation.*—In most cases the patient is evacuated to a neurosurgical unit for operation, for brain wounds cannot be treated satisfactorily without the aid of preliminary X-ray examination to reveal the whereabouts and extent of indriven bone fragments, and it is necessary also to have certain apparatus, such as suction and diathermy, without which it is difficult to do a satisfactory debridement of the wound. Head casualties travel well and are given priority in air evacuation.

In cases for immediate evacuation 1–2 gm. of a sulphonamide, or, if it is available, penicillin-sulphonamide powder are placed in the wound and a firm dressing applied. Three gm. of sulphadiazine should be given by mouth, and this dose should be repeated twice daily on the line of evacuation. Sulphadiazine may be given intravenously if the oral route is impossible.

(ii) *Operation.*—When the military situation prohibits evacuation to a neurosurgical centre for some days, or when other injuries, such as an abdominal wound, demand immediate treatment and retention of the patient for some days, operation must be undertaken.

Before operating on head wounds the surgeon should give careful consideration to the following points :—

(*a*) The main aim of a *complete operation* is to convert an open wound into a clean closed wound. This may be quite difficult to carry out in the forward area with limited equipment. In such circumstances it is recommended that the surgeon should carry out *open toilet of the wound* (*see* below).

(*b*) Apparently trivial scalp wounds may turn out to be serious penetrating wounds of the brain. The diagnosis as between penetrating and non-penetrating head wounds can only be made at operation, except in those cases in which preliminary X-ray examination in two planes has shown indriven fragments of bone or metal.

(*c*) Incision and excision of the scalp is attended by severe and dangerous blood loss, unless performed by the standard technique (*see* below). Thorough inspection and cleaning of the subcutaneous and deeper layers of the wound cannot be carried out without haemostasis.

(*d*) Dislodgment of indriven bone fragments in the region of the sagittal sinus may be attended by disastrous bleeding.

(*e*) Rough handling of the brain, as in " blind " exploration for foreign bodies, either with sinus forceps or with the finger, may produce irreparable functional damage, resulting in such disabilities as permanent hemiplegia.

(*f*) It is no part of the operation on a brain wound to provide decompression, either by removing large areas of undamaged bone or by opening the dura.

(*g*) Head wounds should not be packed or plugged with gauze.

(*h*) Surgeons who are unfamiliar with the technique of cranial operations are recommended to seek the opportunity in quiet times of spending some days with a neurosurgical unit, if such is available.

*Premedication.*

Morphia gr. $\frac{1}{4}$ should be given unless the patient is unconscious.

*Anaesthetic.*

Regional block anaesthesia with 1 per cent. novotox is satisfactory, except when the wound extends into the region of the eye, face or ear, or the patient is uncontrollable. In such cases intravenous pentothal, with or without a general anaesthetic through an intratracheal tube, may be used. Ether causes congestion of the brain and should be used sparingly.

*Preparation of the Scalp.*

The whole scalp should be shaved. It is then thoroughly cleaned with 1 per cent. cetavlon, or, if that is not available, with soap and water. No further antiseptic is necessary.

## A. **Complete Excision and Suture.**

*The Scalp.*

The wound is opened and if necessary prolonged, or two separate wounds are joined, to facilitate exposure of the deeper parts. Blood loss is prevented by finger pressure on the wound edges till the galea aponeurotica can be picked up with light artery forceps placed at intervals of 1 cm. Until it is definitely decided whether to undertake the complete operation or open toilet the edges of the wound should not be excised. The subgaleal plane should be thoroughly explored for dirt, hair, bone chips and missiles, which sometimes lodge at a considerable distance from the wound edge.

*The Skull.*

In *fissured fractures* the skull need not as a rule be opened. But if there is visible dirt in the crack it should be guttered till clean. Contaminated periosteum should be removed, but as sparingly as possible.

In *depressed fractures* all contaminated bone and periosteum must be removed. This includes depressed and loose fragments and a narrow excision of the edges of the defect. If the dura is penetrated, bone should be nibbled away so as to expose a healthy margin of dura about ¼ inch wide. If the dura is intact it should be left unopened. (In rare instances where there are indications of intra-dural clot—a blue tense dura, absence of pulsation, and clinical signs of compression—an incision to evacuate the clot may be made in the dura.)

*The Dura.*

The tear in the dura should not be enlarged or trimmed. It is wise as a rule to remove enough bone to expose the whole dural tear, otherwise uncontrollable bleeding may occur under the bone edge and indriven fragments will be missed. It is seldom advisable to close the dural rent.

*The Brain.*

Laceration and pulping should be treated conservatively and no attempt must be made to excise damaged tissues. Pulped brain may be removed by gentle suction and irrigation ; it is harmful to wipe away debris with gauze. All readily accessible indriven bone chips should be removed, and this is facilitated by irrigation of the track with normal saline or Ringer's solution, and gentle suction, which brings them towards the surface. It is harmful to search blindly for indriven fragments. When they cannot be easily exposed they are better left alone.

*Closure of the Scalp.*

A sulphonamide powder or penicillin-sulphonamide powder is insufflated over the wound generously, care being taken to ensure that it is not washed away by bleeding during closure of the scalp. Whatever the depth of the wound, whether it is non-penetrating or penetrating, accurate and complete suture of the wound without tension is a most important step in the operation and is worth taking trouble with. No attempt must be made to pull the skin edges together under tension when closure is difficult, and flaps must be undercut, and relieving incisions should be made, until the skin edges come together readily. This can best be achieved by turning the wound into a small flap or extending it in a triangular or Isle of Man fashion. When the materials are available, closure of the scalp in two layers with fine silk is ideal ; the deep layer in the galea holds the edges together and controls the bleeding and the skin stitches are then placed loosely and superficially and can be removed early (in two to four days). Closure in one layer with silk, thread, or fine steel wire is, however, quite satisfactory, providing that the stitches are placed at the correct tension through all layers (*i.e.*, only tight enough to approximate the skin edges). In this case they must be left in longer (six days). It is usually advisable to insert a small stab drain clear of the incision. At the end of the operation any pent-up blood is evacuated along this track and a firm pressure dressing applied. Drains inserted through the wound itself tend to interfere with primary healing.

B. **Open Toilet of the Wound.**

If facilities for the complete operation are lacking, or if a case already embarked on proves technically too difficult to complete, the surgeon

should perform open toilet of the wound. After preparation of the scalp in the manner described above, the surgeon should inspect the wound by separating its edges. If the exposure is inadequate the wound may be appropriately extended with due precautions to achieve haemostasis in the manner already described. The superficial layers of the wound should then be cleaned. Missiles, dirt, hair, blood clot, and bone chips should be thoroughly removed from all layers of the wound down to the dura. Blood clot and fragments of bone presenting in the dural opening should be gently removed without incision or excision of the dura, but the brain wound should otherwise be left alone. The wound is liberally dusted with a sulphonamide, or penicillin-sulphonamide powder. If disturbance of depressed fragments of bone seems to be about to provoke haemorrhage, these should be left alone. Where the scalp has been incised it should be closed, but the wound itself should be left open or loosely approximated without tension and its edges should not be trimmed, this being left for the neurosurgeon at the base to whom the patient should be sent at the earliest opportunity.

*Dressing.*

With confused and restless patients it is necessary to secure the dressing carefully. The wound is covered with one layer of tulle gras or vaseline gauze, followed by gauze and a thin layer of cotton wool. A 6 inch plaster bandage is then applied so as to cover the scalp evenly and is moulded to form a skull cap. If the patient is very restless and confused, careful moulding of the cap around the occiput and a loose padded strap under the chin helps to prevent it being torn off. The position and size of the wound, the presence of a drain and the date of the operation are then marked on the plaster in blue pencil.

*Post-operative Treatment.*

Restlessness after operation is best controlled with paraldehyde (2–3 drachms orally or 6–8 drachms P.R.), or phenobarbitone (3 gr. orally or in the soluble form intramuscularly). Stitches are left two to three days if there is a deep layer, or six days if there is only the one. The wound is then exposed to the air.

The fluid intake is important, particularly in patients who remain unconscious or semi-conscious for some days after operation, for unless special measures are taken these patients soon become seriously dehydrated. The fluid intake should be measured ; it should be 70 to 100 ozs. in twenty-four hours. If the patient cannot swallow, a stomach catheter should be passed through the nose into the stomach and should be fixed by strapping to the cheek. Fluids should be given down this tube at frequent intervals.

Special care is also necessary to ensure that unconscious patients do not develop bedsores. Any patient who is incapable of moving himself should have his position changed every two hours. Even slight changes of position will suffice, but there is no reason why head injury patients should not be freely turned from side to side.

Lumbar puncture is the best indication of latent intracranial infection ; it also allows the surgeon to measure the intracranial pressure and to reduce it if necessary, and to determine, by bacteriological examination and white cell count of the cerebro spinal fluid, the course of an infection. Repeated lumbar punctures are useful in the treatment of brain fungus.

In cases of penetrating wound one of the sulphonamide drugs should be administered until the usual course is complete, or the patient's condition warrants its cessation. Sulphadiazine is the best drug for the purpose, and stocks will be reserved for head cases while it is in short supply.

As soon as the patient has recovered from the immediate effects of operation he should be evacuated to the nearest head centre. Notwithstanding statements to the contrary, experience of this war has shown that head injury patients travel well after operation.

## II. BLUNT HEAD INJURY

The treatment of accidental head injuries should be on conservative lines unless there is a scalp wound or unless the patient is developing a massive intracranial haemorrhage. Open wounds should be dealt with in the same way as gunshot wounds. There are, of course, no missiles to be removed, though there may be dirt, cement, etc., driven into the subaponeurotic layer. Indriven bone fragments are also rare. In these cases the risk of infection of the wound should be small, smaller than in gunshot wounds, if the treatment of excision and closure of the wound is thorough.

In blunt head injury careful examination and record of the clinical findings is just as important as in gunshot wound, and should be carried out on the same lines. The general plan of treatment of unconsciousness is also the same: (1) the maintenance of an adequate fluid intake, due care being taken—if necessary, by passage of a stomach tube—to ensure that fluids do not pass into the lung; (2) frequent alteration of the patient's position to prevent pressure sores; (3) sedatives for restlessness, chloral hydrate gr. 20–30, or morphia in doses not larger than gr. 1/6, to be repeated as often as return of restlessness may make this necessary. If there is risk of intracranial infection, as after fractures of the base with discharge of cerebrospinal fluid from the nose or ears, or after an open wound of the vault with a tear of the dura, prophylactic doses of sulphonamides should be given parenterally. The most effective of these is sulphadiazine, 2 gm. intravenously, followed by 1 gm. six-hourly for five to six days.

Massive intracranial haemorrhage after blunt head injury may cause extradural or subdural haematoma. The outstanding symptom of either variety of haematoma is progressive deepening of coma, sometimes preceded by great restlessness and often associated with dilatation of the pupil on the same side as the clot, and sometimes, though by no means always, with progressive hemiplegia on the opposite side of the body. This condition is not common, but when it does occur immediate removal of the clot through a small opening may become a life-saving measure at any time from a few hours to several days after the injury. It is a justifiable procedure in most cases of progressive unconsciousness after closed head injury to undertake an immediate exploration. The exceptions are those cases with gross evidence of fractured base, *e.g.*, continued epistaxis, blood and brain tissue escaping from the ear, and rapidly progressive bilateral proptosis. A burr-hole above the ear at the temporal crest will usually suffice, but the surgeon must always be prepared to explore on both sides because the lateralising signs can be capricious. Occasionally in extradural haemorrhage the upper limit of the clot lies nearer the base of the skull than the incision described. If no extradural clot is found

the dura should be opened. Both extradural and subdural clot can be easily removed by enlarging the burr-hole. Decompression operations for lacerations of the brain are often dangerous procedures and are rarely indicated.

Cases of blunt head injury should be evacuated as soon as possible to the head injury centre.

## III. METHODS OF HAEMOSTASIS IN BRAIN SURGERY

Haemostasis must be much more carefully carried out in operations on the head than in those on other parts. The scalp, dura and brain cortex are extremely vascular, and patients with head injury tolerate blood loss badly. An accumulation of clot within the skull after operation can be rapidly fatal. The general principle that to stop bleeding the surgical exposure must be adequate applies as much in the head as elsewhere.

**Scalp.**

The line of incision should first be marked by scalpel and then assistants should compress the scalp digitally on each side of this line until artery forceps are applied. It is impracticable to catch individual scalp vessels; complete haemostasis can be obtained by applying light artery forceps to the galea aponeurotica at intervals of about 1 cm. When these are removed at the end of the operation no ligatures need be applied, for the closing suture should effectively stop all bleeding, especially if the scalp is closed with fine silk in two layers as recommended above.

**Bone.**

Bleeding from the cut edge of the bone may sometimes be considerable and is always persistent. It is effectively stopped by Horsley's wax.

**Dura Mater.**

The middle meningeal artery may be stopped by Cushing's silver clips or by ligature. Bleeding from the surface of the dura near the bone edge can be stopped by stitching the dura to the pericranium or by muscle "stamps." Take a small piece of temporal muscle, or muscle from the anterior compartment of the leg, hammer it out flat and lay it gently on the bleeding point, covering it for the time being with a piece of an old rubber glove, through which it can be firmly pressed into place. It adheres in a few minutes and the sheet rubber can then be removed without dislodging it.

**Venous Sinuses.**

Bleeding from the superior longitudinal or other sinuses may be fierce, and difficult to control. If the sinus is merely nicked a curved clamp will usually control it for the time being, and then a muscle graft can be prepared and applied. With gross injuries of the sinus the first step is to control the bleeding temporarily by pledgets of cotton wool wrung out in Ringer's solution or normal saline, and then, if the operating table allows, and the patient is not exsanguinated, he should be gradually sat up. This lowers the pressure in the sinus, sometimes to such an extent that there may be risk of air being sucked into it. The gaping edges of the vessel can then be approximated by silver clips or by silk suture. Gauze packing should hardly ever be necessary, though if operating facilities are poor it may be left in for twenty-four to forty-eight hours.

**Brain.**

The large cerebral vessels are on the surface of the brain and bleeding from the white matter is usually slight, and can be stopped by temporary

application of wool pledgets. Surface vessels are best stopped by diathermy, or, in the case of the larger arteries, by the use of Cushing's silver clips. Small muscle grafts are sometimes useful. It should never be necessary to leave a gauze pack against the brain, and ribbon gauze should never be used for drainage.

## SECTION XVIII

# THE EARLY TREATMENT OF INJURIES OF THE SPINAL CORD AND CAUDA EQUINA

The spinal cord may be injured by gunshot wounds, or by fractures and dislocations, such as occur in civil life. In gunshot wounds the missile may score a direct hit on the theca, or may pass nearby with little damage to the spinal column. In the latter case spontaneous recovery from paraplegia may occur; if it is to be sufficient to be useful, the recovery of function will usually be evident within the first week, and this statement also applies to injuries of the spinal cord resulting from fractures and dislocations. The symptoms which result from gunshot wound of the lumbar and sacral vertebrae are for the most part due to injury of the spinal roots of the cauda equina, and in these cases a large amount of recovery, especially motor recovery, is to be expected, but it may not begin for several weeks after the injury.

In injuries of the spinal cord death is most commonly due to urinary infection or to septic bedsores. In incomplete lesions spontaneous recovery of spinal cord functions may be seriously interfered with by these complications. It is on the treatment given in the first few days that the severity of these complications largely depends.

### TRANSPORT

The patient may be transported on his back. In fractures and dislocations the injured part of the spine should be kept so far as possible in the hyperextended position. In gunshot wounds, since the spine has not lost the support of the vertebral bodies the position of the patient is not of the same significance as in fractures and dislocations of the vertebral bodies.

### PRESSURE SORES

These tend to develop rapidly in anaesthetic and paralysed parts, *e.g.*, over the sacrum, the great trochanters, the head of each fibula on the heels, or, when the legs are tied together or in close contact with one another, over the internal malleoli. These sores usually become infected and may produce fatal septicaemia. To prevent pressure sores it is necessary to avoid undue or prolonged pressure on any part of the insensitive skin. *Therefore it is of the utmost importance to ensure that the paraplegic patient has the position of his legs and pelvis changed at frequent intervals.* This rule should apply not only in hospital but particularly when the patient is being evacuated. Special steps should be taken to ensure that the paraplegic patient who is being sent down the line, either by land, sea or air, should have his position on the stretcher changed slightly at one- to two-hourly intervals. If possible he should be lying on an air-ring.

When the skin is accessible it should be washed twice daily with soap and water. Special care should be taken to avoid wetting of the skin with urine.

## PRESSURE PALSY OF THE LATERAL POPLITEAL NERVE

It is important also to protect the head of each fibula from pressure against the edge of the stretcher, thereby preventing pressure palsy of the lateral popliteal nerve, onset of which in incomplete lesions of the spinal cord and cauda equina may ruin the chances of a good functional recovery of the legs. A pad and bandage should be placed over the head of each fibula.

## THE BLADDER

All complete, and most incomplete, injuries of the spinal cord or cauda equina cause paralysis of the bladder and retention of urine. In these cases infection of the bladder which spreads to the kidneys, is the commonest cause of death. Recent work has shown that treatment of retention by means of in-dwelling or intermittent catheterisation does not prevent urinary infection. The most satisfactory treatment for incomplete, as well as complete, lesions of the spinal cord is suprapubic cystotomy: this will prevent serious infection if done not later than the fourth day. To be watertight the opening must be made high, and the incision in the bladder wall should be only large enough to admit a large self-retaining catheter.

If there are no facilities for carrying out a suprapubic cystotomy, and retention must be relieved, the bladder may be emptied by catheterisation under aseptic conditions. This is only a temporary measure and should be followed as soon as possible by suprapubic cystotomy. Severe constipation is common and should be treated by enemata, and, if necessary, digital-evacuation of fæces from the rectum.

## THE WOUND

In many cases a missile which damages the spine produces also a penetrating wound of the chest or peritoneal cavity. In such cases operation on the spinal wound is usually out of the question. In other cases, if the condition of the patient permits, the wound should, as a rule, be surgically cleaned in the usual manner to diminish the liability to infection. The spinal cord should not be interfered with, and usually no search should be made for missiles or bone fragments, nor should the spinal cord be decompressed, for the damage to the spinal cord is almost invariably due to the violence of impact, rather than to continued pressure of a missile or displaced bone. If there is a leak of cerebrospinal fluid the skin around the wound should be cleaned with especial care with cetavlon (1 per cent.) or soap and water, and a voluminous firm dressing should be applied. Sulphadiazine should be given by mouth, as a prophylactic against meningitis.

In some cases wounded by rifle and machine-gun bullets there is a small clean wound of entry and little apparent damage to the soft parts. Some such wounds may be treated expectantly in the hope that they will not suppurate. But if suppuration then ensues, they must be freely laid open and drained.

# SECTION XIX

## WOUNDS OF THE CHEST AND ABDOMINO-THORACIC INJURIES

### A. WOUNDS OF THE CHEST IN THE FORWARD AREAS

Estimation of the relative frequency of wounds of the chest to other parts of the body has been based largely on figures obtained during the war 1914–18. They vary very considerably, depending on the locus at which the studies were carried out, *e.g.* examination of the dead on the battlefield show that 30 per cent. to 40 per cent. of the total had sustained wounds of the chest, while studies carried out at the casualty clearing station showed that 2 per cent. of the wounded admitted suffered from these injuries. It is therefore obvious that chest wounds are relatively common and that the immediate mortality is high. A large proportion do not live long enough to reach surgical aid. Our first line of attack must therefore be the perfection and extension of first aid treatment on the field of battle.

(*a*) **First Aid Treatment of Chest Wounds on the Field.**

Small perforating wounds should be left untouched. The patient should be made to lie down in a sheltered spot and the usual methods taken to keep him warm and calm. If he coughs up some bloodstained mucus it is very necessary to assure him that such a symptom is *not* of serious import. The application of a dressing should be postponed until he reaches a field dressing station, thus preventing loss of heat from exposure. Evacuation of this type of injury is not urgent—in fact, a short rest before moving is beneficial.

Sucking chest wounds, interfering as they do with both circulatory and respiratory functions, are rapidly fatal. *The wound must be made air tight.* This can often be accomplished by tight strapping or bandaging over a large dressing, but if this fails an attempt should be made to close the wound by through and through stitches. Rapid evacuation of such a case is essential, and a note of the procedure should be made if this is possible. A similar method of treatment by suture should be carried out if brisk haemorrhage from a divided intercostal artery is seen.

(*b*) **Evacuation.**

The patient should be evacuated on a stretcher in the position which is most comfortable. This will often be the semi-recumbent position, but no hard and fast rule should be followed. If shock is marked it is advisable to have the head low, while if there is much coughing or spitting of blood-stained mucus a lateral position may be advantageous. Morphia is not contraindicated, and should be given in a single dose of gr. $\frac{1}{2}$ and not repeated for fear of unduly depressing the respiratory centre.

### B. AT THE REGIMENTAL AID POST OR FIELD DRESSING STATION

Here the wounds can be more calmly examined and dressed, shock treated where necessary, and the patient passed on to a surgical centre. Again it should be remembered that it is only the urgent cases suffering from haemorrhage or from large lacerated wounds which require rapid evacuation.

## C. CHEST WOUNDS AT FIELD SURGICAL UNITS, OR CASUALTY CLEARING STATIONS

A certain number of cases arrive at these centres so badly wounded that surgery is unavailing. It is important, especially during periods of rush, to recognise that this is so, thereby using the available surgical resources to the best possible advantage.

### Examination of the Patient.

If the patient shows symptoms of shock on arrival he should be put to bed and no attempt made to remove clothing until there is some recovery. When this has occurred a survey of the whole body and of all wounds should be made. Injury to intra-thoracic organs may result from entrance wounds situated in the neck, shoulder, or even pelvis. Evidence of haemothorax, pneumothorax or collapse of the lung, should be sought for ; the most helpful single sign being displacement of the apex beat.

If possible X-ray films, antero-posterior and lateral, should be taken to give information concerning the position and size of the missile, the existence and extent of haemothorax or pneumothorax and the condition of the opposite lung.

Chest injuries may be divided into two classes : (1) Non-penetrating, and (2) Penetrating.

(1) *Non-penetrating Injuries of the Chest Wall.*

In this war owing to mechanisation and increase in explosive power of missiles (blast), non-penetrating injuries have assumed a much greater significance than in the last war. Such injuries vary in degree from simple contusion and fractured ribs to the " stove-in " chest, traumatic asphyxia and blast injuries. Their importance depends not on the local injury of the chest wall, but on the accompanying damage to and interference with the functions of the intra-thoracic organs. Evidence of an intra-thoracic lesion should, therefore, always be looked for even if the subjective symptoms are few or absent.

(*a*) *Simple contusions* are treated on orthodox lines.

(*b*) *Fractured ribs* are to be supported by strapping or firm bandage—the latter is preferable until confirmatory X-ray films can be taken.

(*c*) *" Stove-in " chest.*—This condition results from a relatively localised direct injury, with anterior and posterior fractures of several ribs. The segment involved shows paradoxical movement being sucked in during inspiration and blown out during expiration. The effect is somewhat similar to a large open pneumothorax and causes the same cardio-respiratory embarrassment and considerable shock. It is usually associated with intra-thoracic damage such as contusion of the lung, haemothorax, pneumothorax, and localised or widespread surgical emphysema. Immobilisation of the affected side of the chest by overlapping layers of adhesive strapping rapidly improves the grave condition, and the administration of high concentrations of oxygen by the B.L.B. mask is invaluable.

(*d*) *Traumatic asphyxia* occasionally results from sudden compression of the chest. It is characterised by dark blue discolouration of the skin of the face, neck, shoulders and upper chest. Sub-conjunctival haemorrhages are common, and occasionally retinal haemorrhages are present. There is no specific treatment and the condition usually clears up gradually.

*Intra-thoracic injuries.*—Contusion of the lung with haematomata of widely varying sizes frequently result from the above types of injury.

Haemoptysis may therefore occur, but is usually of no serious import. Large haematomata may be visualised by radiography, but smaller lesions cannot be seen. They are of importance in that they may be the cause of future trouble such as pneumonia and pulmonary suppuration. Surgical emphysema is common, and tension pneumothorax may occur.

Damage to the cardiac muscle, difficult or impossible to recognise soon after the injury, but giving rise to symptoms later on, may occur. The possibility of the development of a crippling haemopericardium should be kept in mind and treated by aspiration should it occur.

(*e*) *Blast injuries.*—Although reference was made to deaths of soldiers on the battlefield in the 1914–18 war associated with bloody mucus in the mouth and nose and without obvious injury to the chest wall, the pathology was not recognised. The increased number of such cases due to longer and more devastating bombing has led to much greater interest in the aetiology and pathology. The condition is believed to be a contusion of one or both lungs caused by the driving inwards of the chest wall by the blast of a nearby explosion. The lesion may be so extensive as to cause instantaneous death, but less severe cases survive. There is generally no external evidence of injury, but the patient shows signs of shock, restlessness, dyspnoea and chest pain. Cyanosis in greater or lesser degree is a constant feature, and haemoptysis often occurs. Some cases show marked boarding of the abdominal muscles, and this is important as an intra-abdominal lesion may be suspected. The radiological signs are multiple shadows or mottling throughout one or both lungs, and appear early. Some cases in the early stages show practically no signs of lung injury or, if present, they are masked by wounds or injuries to other parts of the body. Some hours later such signs as pain, upper abdominal rigidity or haemoptysis may call attention to the pulmonary lesion.

Treatment consists of rest, warmth, morphia and oxygen. The patient should be evacuated as a lying case. A general anaesthetic should be avoided if possible. If operation is necessary for the treatment of concomitant wounds, pentothal, gas and oxygen or local anaesthesia should be chosen. Spinal anaesthesia is not advised on account of the danger of shock. The value of blood and plasma transfusion is debatable and may be harmful; some observers have advised venesection (*see* Section III, p. 31).

(2) *Penetrating Wounds of the Chest.*

Wounds in which penetration of the pleural cavity results, produce great variation in symptoms. Thus perforation of the chest by a bullet which does not involve bone often gives rise to little or no disturbance. The superficial wounds heal rapidly without suppuration and in some cases lung injury may consist of a small haematoma along the track of the missile in the lung, with or without a small haemothorax. In other cases, particularly those with wounds caused by shell or bomb fragments or where there has been much splintering of ribs, widespread laceration occurs, amounting to loss of chest wall with a large opening permitting communication between the pleural cavity and the external air. The majority of such cases die on the field, but a proportion survive to reach hospital.

**Tension Pneumothorax.**

This condition arises from the escape of air into the pleural cavity from the respiratory tract secondary to lacerations of the larger or smaller

bronchioles and in the absence of an open pneumothorax. It occurs during inspiration and as the air is unable to pass back on expiration, the result is a gradual accumulation of air in the pleural cavity which first collapses the lung and later displaces the mediastinum with its contained structures. When the air escapes into the chest wall surgical emphysema may be extensive and progressive. Tension pneumothorax causes increasing dyspnoea, cyanosis and restlessness. The physical signs are hyper-resonance, absence of breath sounds and displacement of the trachea in the suprasternal notch and of the cardiac apex beat towards the unaffected side. Although not a frequent complication of chest wounds, it is a rapidly fatal one, but can be remedied by prompt treatment. Treatment consists in the insertion of a large-bore serum needle into the second intercostal space in front and aspirating or permitting air to escape through a connecting tube to a " water-seal " bottle. In order that the needle may be held in position for some time it should be passed through a small piece of rubber cut from the side of a drainage tube before it is introduced into the chest. This will act as a flange and can be fixed to the skin by strapping. In the exceptional resistant case an intercostal catheter may be necessary.

**The Question of Primary Operations.**

The decision to undertake primary operations will depend on such varying circumstances as the facilities for operating on and for the post-operative care of such cases, the experience of the surgeon, the nature of the terrain over which fighting has been taking place, and the probability or otherwise of being able to evacuate the case to more advantageous environment in the rear.

(1) Cases which do not require primary operation. These form the great majority of all cases and include :—

(*a*) Small clean wounds without evidence of serious intra-thoracic injury other than haemothorax.

(*b*) Cases in which a missile is retained which is only of small size.

(*c*) Cases in which a retained missile, though of large size, is in a position which is difficult of access.

(*d*) Cases of uninfected haemothorax.

(2) Cases in which primary operation is indicated :—

(*a*) A ragged wound of soft parts.

(*b*) Compound fracture of ribs.

(*c*) Bleeding from the parietal wound and intercostal artery.

(*d*) Severe pain (often the result of in-driven splinters of rib scratching the pleura with each respiratory movement).

(*e*) An open wound of the thorax through which air is pumped in and out of the pleural cavity.

(*f*) Retention of a large foreign body in an accessible position.

(3) Cases in which primary operation is contra-indicated :—

(*a*) Shock and collapse, such as would be contra-indications for any surgical procedure.

(*b*) Collapse of the opposite lung as indicated by inspiratory retraction of the chest wall. In this condition the administration of an anaesthetic and the opening of the chest may be fatal.

**Treatment by Operation.**

*Time to Operate.*

Operation, if necessary, should be undertaken as soon as possible after the initial shock has passed off and before sepsis has become established. The " débridement " of wounds of the thoracic wall does not differ from that of wounds in other parts of the body, namely a minimal removal of skin and enlargement of the skin wound so as to explore the underlying lacerated muscles and splintered ribs. All dead muscle is excised, splinters of bone removed and jagged ends of ribs cut cleanly off. Examination of the wound may reveal a bleeding or contused intercostal artery, which should be doubly ligated, or a large hole leading into the chest. A finger should be introduced into the pleural cavity and a search made for splinters of bone free or sticking into the lung. These should be removed as they play an important part in the production and maintenance of infection. If it is decided not to open the chest further, the blood should be evacuated by suction or by rolling the patient on to the side, and then the thoracic wall should be closed in layers after " frosting " with sulphonamide powder. Closure of the pleura is frequently impossible, but this is not important. Every attempt should be made to close the muscle layer and skin should be brought over the gap even if a flap has to be cut. The chest *must* be closed. The value of temporary airtight drainage of the chest after thoracotomy is generally recognised. A separate intercostal opening in the lower chest posteriorly is advocated, through which closer drainage is established.

**Retention of large Foreign Body.**

There can be no doubt that healing is as good and infection in the pleural cavity not appreciably increased if small foreign bodies up to the size of a pea as seen radiologically are left without operation, and a large proportion of foreign bodies of larger size can be left for late operation with little or no increase in the risks of infection if the haemothorax is adequately treated. The presence of an irregular shell or bomb fragment 1 inch by ½ inch or larger, accompanied as a rule with splinters of in-driven ribs and clothing, is likely to be a focus of infection and if apparently accessible calls for attempt at removal.

**Anaesthetics.**

These patients bear operation well, and take a general anaesthetic satisfactorily, provided that there is no damage to or collapse of the contralateral lung. Local anaesthesia may be employed for the chest wall, but if an intra-thoracic operation is to be performed, a general anaesthetic should be administered. Pentothal should be used with care and by the controlled slow intravenous drip method owing to the danger of anoxaemia. Gas and oxygen, given by a well fitting facepiece, is probably the best anaesthetic to use.

**Operation of Thoracotomy.**

The choice of route depends on the position of the foreign body relative to the wound of entry. Where possible thoracotomy through the wound is to be preferred, and follows the rules already detailed except that instead of removal of the broken ends of ribs only, a resection of rib 4 inches in length will be necessary to give adequate exposure.

If the entrance wound is situated in the upper part of the chest, thoracot-

omy by a fresh incision may be necessary. This is done by resection of 4 to 6 inches of rib or by intercostal incision. The fifth rib in the mid or anterior axillary line, or the seventh rib posteriorly, gives good access. A rib retractor is inserted and good exposure obtained. Fluid blood and blood clot are removed by suction and swabbing, and the foreign body sought and removed, particular care being taken to remove any pieces of bone and clothing. Readily accessible wounds of the lung should be cleansed by wiping with gauze, and fragments of bone, etc., removed. The wound should be closed by catgut suture because, if left open, organisms may pass from the lung to the pleural cavity, where they will give rise to empyema. The lung is capable of dealing satisfactorily with a very considerable amount of infection enclosed in its own tissues. A haematoma in the lung should be left untouched. It is very rarely necessary to perform lobectomy or lung resection.

**Post-Operative Treatment.**

Blood or plasma transfusion given slowly and as indicated by the condition of the patient—not as a routine—is a valuable post-operative form of treatment. It may be commenced during or immediately after the operation and continued for twenty-four to forty-eight hours. Care must be taken not to overload the already embarrassed right heart by giving the fluid too quickly or in too large quantities. The semi-recumbent position will generally be the best, but circumstances may indicate a lowering of the head or even a lateral position. Morphia should be given in doses sufficient to relieve pain and distress, and soon after the drug is given the patient should be encouraged to cough up any mucus or blood which has collected in the air passages. Support of the lower chest by the attendant's hands is helpful and encouraging to the patient. Oxygen in high concentration, given by B.L.B. mask or intranasal catheters, should be commenced immediately after operation, and not delayed until signs of anoxaemia develop. The administration should be continued intermittently for two to three days, the periods being controlled by the condition of the patient. In order to control the almost inevitable sepsis a full course of sulphonamide treatment should be given by mouth, commencing as soon as possible after operation.

**Haemothorax.**

An accumulation of blood and effused serous fluid in the pleural cavity is the most frequent complication of chest injuries. It follows in non-penetrating wounds, closed or open penetrating wounds, and after thoracotomy. Haemorrhage takes place from the lung or from the vessels in the chest wall, but in the larger haemorrhages, bleeding from the latter is probably largely responsible. The blood usually remains fluid, although clots may be found in the costo-phrenic angle.

Even in cases of sterile haemothorax the whole of the fluid in the chest is not defibrinated blood. This is shown by two facts: first the cell content of the fluid is different from that of defibrinated blood in that an increased number of lymphocytes may be present together with endothelial cells, eosinophile cells sometimes in considerable numbers and marrow cells; secondly, the quantity of fluid is sometimes very large, that is, four to five pints, and even then the patient may not show any gross or obvious signs of anaemia. Hence it is evident that there is some pleural exudate as a sequel to and a result of the presence of the blood in the

pleural cavity. In some cases further evidence of the presence of pleura exudate is afforded by the occurrence of a slight and peculiar clotting in the fluid removed from the chest by paracentesis. This clotting resembles that seen in the fluid of ordinary pleural effusions but differs from it in that the coagulum contains abundant red corpuscles. This clot, although containing red corpuscles, is often scanty, and generally gelatinous in consistence and hence quite different from the clot formed from entire blood.

The diagnosis of haemothorax is usually obvious from the well-recognised signs of pleural effusion and the ground glass appearance of the radiograph.

*Treatment.*

The treatment consists of early aspiration, preferably within the first forty-eight hours after wounding. The objects are :—

(*a*) The relief of intrapleural pressure.
(*b*) Early re-expansion of the lung, thereby limiting the area of infection should such supervene.
(*c*) The removal of the excellent culture medium for organisms.
(*d*) The prevention of massive clotting.
(*e*) Shortening of the period of invalidism.

It can be carried out by a two-way syringe with the usual surgical precautions and after local infiltration of the needle track with local anaesthetic. The advantages and disadvantages of air replacement of haemothorax fluid have been widely discussed. The fear of reactionary haemorrhage from the expanding lung has been the main indication. This risk has been much overstressed as in almost all cases bleeding from the lung would probably cease by haematoma formation after twenty-four hours. On the other hand, the introduction of sufficient air to permit of full aspiration of the effusion without discomfort to the patient, would appear to have advantages at the *first* aspiration. The maintenance of a large pneumothorax will lead to a considerable empyema cavity should infection supervene. Air replacement is condemned by surgeons in charge of chest units in the Middle East. Aspiration should be repeated every second day until re-accumulation ceases. If there is extensive clotting which interferes with aspiration, it may be necessary to make a small intercostal incision, turn out the clot, close the wound and regularly aspirate the secondary effusion.

**Infection of a Haemothorax.**

This usually becomes evident between the fourth and seventh day. Clinically two types are seen :—

(*a*) The acute fulminating anaerobic type, and
(*b*) the slower pyogenic type.

It is to be remembered that during the first few days an uninfected haemothorax is usually associated with some pyrexia often as high as 101 degrees F., but under favourable circumstances both temperature and pulse rate gradually fall. A sudden rise of pulse rate should lead the surgeon to suspect infection.

(*a*) *The anaerobic type.*

The patient suddenly becomes acutely ill. Face sometimes pallid, sometimes unhealthily flushed, temperature and pulse rise. There are now signs of pneumothorax with displacement of the heart to the sound side

and probably a hyper-resonant percussion note on the affected side. Exploration of the chest will usually reveal a stinking fluid, but on the other hand it is not infrequent for the exploring syringe to draw off a sample which is sterile, though septic infection has taken place in another part—a blood clot or separate loculus. It is therefore necessary, if clinical signs suggest infection, to explore at several different places before being satisfied that the fluid is sterile. At other times blood or fibrinous clot may block the needle and no fluid will be drawn into the syringe although present in the pleural cavity in large amounts. If the aspirated fluid has a foul smell, or if the froth be of a purple crimson colour, anaeorbic infection is certain, and bacteriological examination unnecessary before treatment is undertaken.

*Treatment.*—Experience in the war 1914–18 showed that "resection should always be performed in cases where the effusion is foul or the clinical symptoms point to severe infection." With improvement in treatment, by aspiration and sulphonamides, infection may be so modified that repeated aspiration may be carried out until the case can be treated as in the pyogenic type. If resection is carried out the surgeon must remember the possibility of a raised diaphragm and make his incision correspondingly high. A small opening into the pleural cavity should be made and the escape of fluid controlled by the surgeon's finger to minimise the danger of sudden mediastinum shift. The last of the fluid is then sucked out, and blood clot and easily found foreign bodies removed. Airtight drainage is established through a rubber tube around which the muscles and skin are stitched. The condition is a serious one and the prognosis grave. The use of blood transfusion, sulphonamides and anti-gas gangrene sera may help to reduce the high mortality.

(*b*) *The slower Pyogenic Infections.*

In this type of case operation is not urgently called for. Repeated aspiration, until the pus becomes thick and creamy and until the surgeon is sure that the mediastinum is fixed, should be carried out. All patients with chest wounds have courses of sulphonamide by mouth, and organisms frequently fail to grow on artificial media from specimens of pus obtained by aspiration. In order to minimise the risk of a virulent infection of the chest wall at the sites of punctures a small incision is made down to the rib at the selected site, and the wound is packed. Within a day or two a protective layer of granulation tissue forms, and by removal of the pack repeated aspiration can be carried out through the wound without the risk of spreading infection. Some surgeons prefer the insertion of an intercostal Malecot's tube to repeated aspiration, but whichever method is adopted in the early stages adequate drainage by rib resection must be carried out later in order to avoid a chronic empyema. About 1 to 2 inches of the eighth or ninth rib behind the scapular line should be excised, the empyema cavity cleared by suction and removal of clots by swab-holding forceps, and airtight drainage established. The tube ought not to be removed until the empyema cavity is obliterated. This is judged by X-ray films taken after the injection of a radio opaque substance such as Lipiodol, or a Barium suspension. This will take several weeks or months, as in infected cases the expansion of the lung is slow. Too early removal of the drainage tube is a frequent cause of chronic empyema.

**Condition of the Lung on the unwounded side.**

*Pneumonia.*

It is not uncommon for pneumonia, probably due to inhalation of septic material from the wounded side, to arise in the opposite lung.

Collapse of a lobe, usually the lower, or even the whole lung, may occur in the contralateral lung. Unless collapse is extensive recovery usually takes place, but the patient requires very careful nursing and should on no account be evacuated. Complications affecting the uninjured lung are important as they are easily missed and may be the cause of an unexplained rise of temperature or pulse, or attacks of dyspnoea or cyanosis when the patient is moved.

**Haemopericardium.**

Haemopericardium causing cardiac tamponade, although a very rare condition in war wounds, may occasionally be encountered as the result of a stab wound by knife or bayonet. The position of the wound, the venous distension and cyanosis of the head, neck and upper limbs, diminution in the volume of the heart sounds, lowered arterial pressure and raised venous pressure and the cardiac shadow on X-ray examination, will help to make the diagnosis clear.

Aspiration through the xiphisterno-costal angle, the needle being directed upwards and backwards, should first be tried. If relief is not obtained operation is called for. A direct attack, if possible incising the track of the missile, is the best approach. Parts of the left third and fourth costal cartilages may, if necessary, be excised to give adequate exposure. Blood and clots are evacuated and the site of haemorrhage sought. If the wound is in the wall of the heart bleeding is temporarily controlled by the finger. Catgut sutures should be quickly inserted on each side of the wound and by bringing together the upper and lower ends *across* the wound, haemorrhage will be controlled. The wound may then be sutured by transverse interrupted sutures. A " stay " suture inserted into the apex of the left ventricle is useful to steady the organ during these manoeuvres if difficulty in stitching the cardiac wound is experienced. The pericardium should be left open to allow of the escape of exudate into the pleural cavity, from which it can be removed by aspiration. The muscles and skin should be closed, and this can be done with impunity as the danger from sepsis in a recent wound caused by a sharp cutting instrument is minimal.

## CHEST WOUNDS AT THE BASE HOSPITAL

Patients with chest wounds will arrive at varying times and at various stages of treatment, depending on the military situation, means of transport, etc. For those who arrive within one to four days the treatment will be similar to that in the forward areas, with the advantage that better facilities in regard to equipment, surgical, X-ray and anaesthetic, and for pre- and post-operative care will be available. In cases which have been delayed for several days the treatment instituted in the forward areas will be continued. In non-septic haemothorax cases attempts to expand the lung by repeated aspiration and by the commencement of special breathing exercises, will be instituted. Breathing exercises carried out under the supervision of a specially trained attendant have proved of the greatest benefit, not only in non-septic but also in septic cases, and should be begun as soon as the patient is able to co-operate.

In septic cases the first care is to see that drainage is adequate, and where it is not further rib resection in a more dependant region should be carried out as soon as possible. Plastic operation for obliteration of a chronic empyema should not be undertaken *until* adequate drainage combined with pleural lavage with an antiseptic such as Eusol—*if a broncho-pleural fistula is absent*—has been tried over a prolonged period.

**Late removal of Foreign Bodies.**

In view of the late complications such as lung abscess, bronchiectasis, haemoptysis, etc., which experience of the last war tells us may occur, foreign bodies should be removed at the optimum time after healing. If sepsis has supervened the pleural sinus may lead down to the foreign body and healing will not occur until its removal has been effected. Operation in such cases should be delayed over a period of weeks until the empyema cavity fails to diminish in size, unless such emergencies as secondary haemorrhage necessitate earlier operation. When healing has resulted without sepsis, the fifth or sixth week after wounding appears to be the optimum time for removal of the foreign body. Small foreign bodies which are not giving rise to symptoms may be left *in situ*, but the patient should be kept under observation for some years.

## ABDOMINO-THORACIC WOUNDS

Wounds involving the cavities of both the thorax and abdomen are probably rapidly fatal in a large proportion of cases. Of the number of patients who live to arrive at a casualty clearing station, those with abdomino-thoracic injuries form about 9 per cent. of all penetrating chest wounds. The size of the diaphragmatic wound is important. When the missile is small or when a bullet makes clean wounds of entrance and exit, the damage is of no great importance. If, on the other hand, the missile is large or has passed obliquely, the wound in the diaphragm may be very extensive. Even if there is no injury to abdominal viscera a large wound of the diaphragm is in itself very dangerous to life. It is dangerous, at once because of the difficulty of respiration and because the blood from the wounded lung is not confined to the pleural cavity, and so does not cause the natural arrest of bleeding by producing a condition of collapse and cessation of movement. It becomes more dangerous later because of the hernial protrusion of abdominal viscera through the torn diaphragm into the pleural cavity. This danger is more pronounced on the left than on the right side, because on the right side the liver blocks the aperture. On the left side the suction action of the thorax tends to draw in the abdominal viscera, the most frequent being the colon, stomach and spleen. Under such circumstances the hole in the diaphragm tends to become larger.

**Diagnosis of Abdominal Injuries when the Lung is injured.**

In many cases it is very difficult to know whether an abdominal viscus has or has not been injured because any injury to the lung, especially in the diaphragmatic region, is liable to cause abdominal pain and rigidity. If the examining hand is kept moderately firmly applied to the abdominal wall a distinct lessening of the rigidity will be appreciated at the end of expiration in purely thoracic injuries. If the patient is placed in the sitting position for twenty minutes, the rigidity of thoracic injury will greatly relax. In some cases, however, exploration of the abdomen will be necessary to make certain. In cases where the missile is retained,

examination by X-rays is of the greatest value, as its position will often decide at once whether the missile has or has not entered the peritoneal cavity.

**Treatment.**

The following views of Gordon Taylor on abdomino-thoracic wounds will be found helpful :—

" (1) In many traversing (through and through) abdomino-thoracic wounds of the right side produced by a small bomb fragment or bullet no immediate active surgical treatment is required provided that (*a*) no gross damage has been inflicted upon the thoracic or abdominal wall—fractured ribs, explosive effect, etc. ; (*b*) the direction of the track of the missile does not appear to compromise the general peritoneal cavity or suggests the desirability of its exploration ; the signs of abdominal haemorrhage or of injury to a hollow viscus are clearly absent.

(2) In cases of right sided abdomino-thoracic wounds in which a small fragment is retained in an inaccessible position in the substance of the liver, an expectant line of treatment is the correct procedure ; accessible fragments unless small, should be sought and removed.

(3) When there is an open, blowing thoracic wound or an associated " stove-in " chest, the chest injury must, of course, assume chronological priority in treatment.

(4) If the position of the wound of entry and exit in a left sided abdomino-thoracic wound adumbrates a track implicating that fatal left subphrenic area of the abdomen, or if a radiograph demonstrates a fragment of metal retained in this region, the thorax should be dealt with first and access to the upper abdomen obtained through the diaphragm.

(5) When the thoracic injury appears insignificant but there is evidence of severe widespread intra-peritoneal damage, especially involving hollow viscera, the abdomen should be explored through an appropriately placed laparotomy incision. This instruction applies to wounds of thorax and abdomen produced by the same or by separate missiles.

(6) When the thoracic injury seems slight, and when the evidence of a radiograph or the direction of a missile track in a through and through wound suggests an intra-peritoneal course of a small fragment, such an abdomino-thoracic injury may be left alone. If in such cases there is evidence of injury to the kidney the parietal wound down to the kidney should be the organ investigated and any foreign body removed.

(7) In cases in which the thoracic wound is situated low down on the lateral or antero-lateral aspect of the chest access to both supra-diaphragmatic and infra-diaphragmatic areas may be obtained by cutting through the costal arch ; this method of access is indubitably severe.

(8) If an abdomino-thoracic injury has been approached from the abdominal aspect, it is important not to waste time trying to complete a difficult suture of the diaphragm in a critically ill patient, unless the aperture in the midriff is so large that immediate or early herniation of the abdominal contents is certain to occur."

When the approach is through the chest wound a wide exposure is necessary as a small wound of the diaphragm is easily missed. Crushing of the phrenic nerve as it courses over the pericardium facilitates manipulation and closure of the diaphragmatic wound. If, after exploration of the abdominal cavity through the diaphragm a doubt as to further abdominal injury remains, after closure of the thoracic wound the patient should be turned slowly on his back and further exploration carried out through a pararectal abdominal incision. The prognosis in abdomino-thoracic wounds with injury to lungs and hollow viscera is exceedingly grave. In a few small series of cases in the war 1914–18 only 20 per cent. to 30 per cent. recovered. Operation adds to the already severe shock of wounding and to combat this, blood transfusion, given at first rapidly, should be commenced at the beginning of the operation and continued more slowly when the patient returns to bed. Other means of resuscitation, especially oxygen, morphia, etc., will also be found of value.

# SECTION XX

# ABDOMINAL WOUNDS

## I. INTRODUCTION

Wounds of the abdomen cause such damage to vessels and viscera within, that only surgical intervention can save the victim. To be successful, surgery must be applied quickly, skilfully and under suitable conditions. Without surgery the mortality is probably over 90 per cent. ; with surgery it is from 30 to 50 per cent. When operation is performed within six hours of wounding the chances of recovery are good : after this interval of time the mortality rises rapidly. Time is the great factor.

The matter of suitable conditions is important, for if cases cannot be held for five or more days, or the skilled nursing necessary for continuous intravenous drip and gastric suction cannot be organised, the most dextrous surgery is likely to fail. The keenness of the modern surgical unit should not allow its excellent equipment and great mobility to tempt it to open up so far forward that conditions prove incompatible with safe surgery ; and field ambulances, and divisional F.D.Ss. should realise that their comprehensive sets of surgical instruments are meant for immediate life-saving operations, such as tying a bleeding artery or closing an open pneumothorax, and not for abdominal work. Only in the exceptional event of a field ambulance or divisional F.D.S. becoming isolated and unable to evacuate its casualties would it be justifiable to contemplate abdominal surgery at such a level, and then only if an experienced surgeon were available—otherwise expectant treatment should be applied.

The urgent need and constant aim always must be to evacuate all abdominal wounds to an established surgical centre with the utmost speed possible.

## II. WOUNDING AGENTS

1. Rifle and machine-gun bullets.
2. Jagged fragments of shell, bomb, mortar and mine, accounting for 70 to 80 per cent. of all wounds.
3. Minute fragments and razor-blade-like flakes of metal.
4. Bayonet, dagger and knife.

5. Blast—air, water.
6. Crushes, blows, falls from a height.

1. Bullets, being of high velocity, are likely to pass right through the body, from front to back, from side to side, or obliquely, depending upon the line of fire and the position of the man. They cause small entry and larger exit wounds and usually produce multiple injuries within.

2. Fragments from shell, bomb, mortar and mine are of lower velocity and tend to become embedded in muscle, bone, solid viscus, or to lie free within the abdominal cavity or some hollow viscus like the bladder. The wound of entry is larger than that of the bullet, and irregular in outline. A man may be hit by several such pieces and sustain generalised wounds.

3. Minute fragments and thin flakes of metal are important because they may leave no more than what appears to be a mere scratch or abrasion on the surface, yet the internal injury may be severe and multiple. It stresses the need to examine the whole of the body surface, and to keep any such case complaining of symptoms under observation.

4. The wounds caused by these sharp cutting weapons speak for themselves.

5. The blast of bombs, etc., bursting in air, and depth-charges in water, may inflict severe intra-abdominal injuries in men nearby without there being any external signs.

6. Crushes from falling debris, being buried by collapsing earth-works, or falling from a height as from a parachute wrongly manoeuvred, may all result in injuries to intra-abdominal organs, and such cases should be kept under observation.

## III. RELATION OF NATURE OF WOUNDING AGENT AND SITE OF WOUND TO LESIONS CAUSED

Anatomical knowledge coupled with an appreciation of the track of the missile gives the clue to the probable injuries sustained. In through-and-through wounds this is relatively straightforward ; but where the F.B. is retained, although X-rays will help greatly in estimating its probable path, diagnosis is bound to be less certain, especially when the entry wound lies at a distance, as for instance in the axilla. Even in through-and-through bullet wounds the bizarre sometimes happens, as when the bullet is deflected from its line by bone and thence follows a circumferential course round the body cavity. As a rule one may say that where the entry and exit wounds lie between the two lineae semilunares the peritoneum has not been penetrated, but there may, nevertheless, be considerable bruising of the intestine, with consequent bleeding.

As examples the following may be given. A midline antero-posterior through-and-through bullet wound is likely to injure the great vessels and spine. Such wounds are rarely encountered as most of them die in the field. An antero-posterior wound of the right hypochondrium will damage the liver and probably the colon and right kidney too. A side to side wound at the level of the umbilicus will perforate or tear the small intestine in several places, and if slightly oblique, though still in the horizontal plane, one or other of the vertical colons. In like manner it can be roughly worked out for obliquely directed missiles in any plane, remembering

particularly that the wound of entry may be at a distance, as for instance, in the axilla, or supraclavicular space, in the buttock, perineum or upper thigh, and yet the metal comes to rest in some part of the abdominal cavity. The importance of wounds in the region of the buttocks cannot be overstressed for they are often accompanied by injury to the rectum, bladder, pelvic peritoneum and pelvic vessels, and are therefore dangerous.

It has to be remembered too that viscera may be wounded by pieces of indriven bone from the lower ribs or from the pelvis.

**Actual lesions caused.**

*Blood-vessels.*

As elsewhere in the body arteries torn right across bleed less (and some not at all) than when there is a lateral hole.

The deep epigastric arteries have been known to be the source of internal haemorrhage, having been involved in the parietal wound.

Wounds of the aorta and of the vena-cava are usually fatal, though cases are recorded of lateral tears in the latter being controlled by clamp, muscle graft, stitches or packing.

The vessels most commonly damaged are those of the mesentery, meso-colon, meso-sigmoid, greater and lesser omenta (gastro-colic and gastro-hepatic), and pelvis, but tears of the small bowel (when the visceral peritoneum is torn too), may give rise to considerable haemorrhage and threaten life. Injured solid viscera may also, but not necessarily, be the source of much haemorrhage.

*Solid Viscera.*

*The liver*, being the largest, is the one most commonly damaged. This happens in about one in five cases of abdominal wounds. Because of its position under the right cupola of the diaphragm it is particularly vulnerable in right-sided abdomino-thoracic wounds. Bullets may pass through it leaving no more than an oozing cored-out track which heals spontaneously. On the other hand a bullet has been known to break it into pieces. Pieces of bomb or mortar may lodge in it causing ragged bleeding tears. Crushes or blast may crack its surface or split its substance in several places.

*The spleen* may be similarly affected, its smaller size rendering it less vulnerable to missiles, but its friability and greater vascularity making it more susceptible to blows, crushes and blast. It may even be torn clean off its pedicle. However, it is damaged in only about 10 per cent. of cases of abdominal injury.

Injuries of *the kidney* take several forms. It may be transfixed, cracked, split into parts, torn from its pedicle, or a piece of metal may come to rest within it. Depending upon the damage to the pedicle the resulting haemorrhage will be severe or of no consequence. The kidneys are damaged less frequently than the spleen. Unlike civil injuries, intra-peritoneal haemorrhage is very frequent.

Wounds of *the pancreas* are not often met with, either because accompanying vascular injury leads to death in the field, or because minor ones are masked by retro-peritoneal haematoma.

*Hollow Viscera.*

*The stomach* is wounded in about one in eight cases—sometimes alone, sometimes the transverse colon, jejunum, liver and left kidney being damaged too. Wounds of stomach may be small or large perforations,

sometimes both anterior and posterior walls being penetrated. On other occasions linear tears are produced, and cases are recorded of large fragments having almost completely torn across the antral portion. It is especially important to remember the possibility of a posterior perforation being the only one present. The mucous membrane does not protrude in the smaller perforations but does so in linear ones much as it does during a formal gastro-enterostomy operation.

*Small intestine.*—The small bowel is injured in at least a third of the cases, and almost invariably in several places. These may be close together or widely separated, and the perforations are circular or oval. Occasionally a fragment or bullet passes through opposite walls, continuity being maintained by two strips of wall only. In all but the most minute punctures, the mucous membrane pouts out like circular or oval rosettes, and for several hours this may effectively prevent leakage of contents. Sometimes the bowel is completely torn across, or nothing but a mesenteric strip is left to maintain continuity. The bowel may be torn away from its mesentery, anything over an inch jeopardising its blood supply. Non-penetrating wounds of the abdominal wall often cause subperitoneal and intra-mural haemorrhage of the small intestine, and these are liable to cause ileus.

*Large intestine.*—This is affected less frequently than the small bowel—perhaps in about one fifth of all cases. The actual lesions are much the same as those of the small gut but less often multiple, or if multiple, less numerous. The larger size also makes it less liable to trans-section. One of the most important of abdominal wounds, because dangerous, is perforation or tear of the posterior bare surface of the ascending and descending colon, and this may be caused not only by missiles but by indriven bone. Wounds in the loin are particularly likely to damage the bare areas of the colon. Whenever signs, symptoms and the probable track of the missile focus suspicion on the vertical parts of the colon these posterior perforations should be sought for. Spreading cellulitis, especially if of gas gangrene infection, is one of the killing complications of abdominal wounds.

*Rectum.*—The commonest wounds involving the rectum are those of the buttocks, upper thighs and perineum. The wound may be a wide open laceration of the buttock extending up into the ischio-rectal fossa and tearing the wall of the rectum above the sphincter : the anal canal may be torn open : the peritoneum of the pelvic cavity may be penetrated. A smaller wound may nevertheless allow a missile to pass through the sacro-sciatic notch into the pelvis and tear the sigmoid and upper rectum, the sciatic nerve being severed in the process.

Any of these wounds may shatter the bone as well. These compound fractures, associated with perforations and tears of the rectum or sigmoid are some of the most difficult and dangerous problems with which base hospitals have to deal.

*Bladder.*—The bladder is not as often injured as might be expected, and in half the cases it is the only viscus damaged. In the remaining half the small intestine is most commonly involved, but the sigmoid and rectum are rarely affected. The pelvis, however, is often fractured at the same time, and this is a serious combination. It is not unusual for sharp pieces of bone to be the tearing agent. The lesion is in the form of round or

oval perforations, or linear tears, and these may be intra- or extra-peritoneal or both. On occasions a fragment of metal or piece of bone may be found within the bladder, either at the primary operation or at subsequent cystoscopy.

**Blast Injuries of the Abdomen.**

In these days of amphibious operations the effects produced by under-water explosions, as of depth-charges, mines, torpedoes and bursting boilers, become of importance to the military surgeon. The injuries caused by these pressure waves are greater than those following exposure to air blast, and consist of submucous, subserous and retroperitoneal petechial haemorrhages, the latter sometimes being large, and rupture of hollow organs, often multiple. The large intestine is affected more commonly than the small, the caecum being the most constant site, but the stomach too has been found ruptured. The solid organs are not immune, there being subserous and interstitial haemorrhages, and the substance of the liver sometimes being cracked and fissured. As the legs and thorax are almost always immersed too the effects on them must be mentioned. Patients often say their legs have been completely paralysed and benumbed for from one to two hours, this being due presumably to some passing vascular or neuronal phenomenon in the cord. Subcapsular and capsular haemorrhages of the testicle may be found. The effect on the lungs is to cause subserous and interstitial haemorrhage and to rupture some of the alveoli.

**Protrusion of Omentum and Viscera.**

Any wounds, however caused, but especially by knife or dagger, may rip open the abdominal wall sufficiently to allow omentum, small intestine or transverse colon to protrude. This can occur in the loin or through the chest-wall just as through the belly-wall.

**Acute Dilatation of the Stomach.**

This complication may occur after crushes, falls or exposure to blast when no actual major internal damage has been caused. Collapse and copious vomiting following such an injury should suggest this possibility.

## IV. CAUSES OF DEATH

1. Haemorrhage.
2. Peritonitis with ileus.
3. Retro-peritoneal cellulitis and suppuration.
4. Osteomyelitis of fractured pelvis associated with tears and perforations of the rectum and bladder.

Haemorrhage is the commonest cause of death, and deaths occurring within twelve hours of wounding are the direct result of bleeding rather than of any concomitant injury. The possibility of severe haemorrhage in any abdominal wound places it second only to open pneumothorax on the priority list for operation. The transfusion organisation has made it possible to render men fit for life-saving operations who would otherwise have been beyond surgical aid, and has enabled surgeons to carry out more thorough procedures than they would otherwise have dared.

## V. TREATMENT IN FORWARD AREAS

Treatment is essentially surgical, and this as soon as possible, and the aim of forward units must be to get the man back to an established surgical

centre without delay. Action in front of the advanced Surgical Centre must be directed towards the treatment and prevention of shock, and will therefore follow the ordinary rules of applying warmth, dressing wounds, splinting fractures, and moving from R.A.P. to A.D.S. forthwith. Morphia should be given even in the absence of pain, for pain and distress are very likely to be initiated by an ambulance journey over rough roads. Moreover, it lessens excitement and fear. On reaching the A.D.S. he will be " triaged " and if fairly fit should be sent to the advanced Surgical Centre at once. Anything that relaxes the abdominal muscles, such as a pad under the knees, or a raised pillow under the head, will make the journey easier. If badly shocked the question of transfusion at the F.D.S. will arise.

Abdominal cases travel badly by air.

**The Question of Transfusion in front of the advanced Surgical Centre.**

It is quite easy to send a shocked patient to the F.D.S. for resuscitation, and for wounds of other parts this would be the correct procedure, but with abdominal cases the following points have to be considered. The commonest cause of death is haemorrhage—might not plasma or blood increase the bleeding? Shocked abdominal patients resuscitated by plasma or blood tend to relapse within three to four hours, *i.e.* just at the time when operation would be contemplated. A second lot of plasma and blood does not revive them as well as the first, and indeed may fail to render them fit for anything but a hurried operation, and perhaps not even for that. If the evacuation from A.D.S. to advanced Surgical Centre is not long—say less than two hours—it is better as a rule to refrain from transfusion until reaching the advanced Surgical Centre. If, on the other hand, it is felt that a patient might collapse *en route* it is better to start a transfusion and to continue it during the ambulance journey. In actual fact many abdominal wounds are not shocked at all and travel quite well. There have even been instances of cases not only walking unaided into a collecting-post, but giving help to a wounded comrade.

## VI. EXPECTANT TREATMENT

There are undoubtedly cases of traumatic perforations of small, and even large, bowel having recovered spontaneously on expectant treatment, evidence having been revealed at a subsequent operation for some new condition. They are rare—probably less than 10 per cent.—but the knowledge is useful in showing that it is better than nothing, and worth trying, if circumstances make active surgery impossible. It consists of the Fowler position, rest, warmth and morphia, intra-venous drip of glucose-saline (three to four pints daily), nothing by mouth, and gastric suction. If no intravenous apparatus is available, rectal salines can be given, either as a drip or intermittently, half a pint four-hourly.

## VII. SIGNS AND SYMPTOMS

These are variable. As already mentioned, an abdominal case with perforation may walk unaided into a R.A.P. or C.C.P., apparently unshocked, and even helping another wounded man. Such is the heat of battle that he may not realise more than vaguely that he has been wounded somewhere. As a rule, however, generalised pain, often intense, is experienced from the beginning, and the picture may not be unlike that

of a perforated gastric or duodenal ulcer. Collapse may be transient or persistent, but shock, rigidity and rapid pulse may all be absent in the early stages. The actual perforation of a hollow viscus has no signs or symptoms : these are caused by the resulting peritonitis and haemorrhage. In the case of the small bowel there may be no leakage for many hours, and therefore no early peritonitis, but where the colon or rectum is concerned leakage is early and highly infective, and peritoneal signs and symptoms develop more rapidly. Haemorrhage alone, whether intra-peritoneal or retro-peritoneal, causes peritoneal irritation, and when free blood is in contact with the diaphragm shoulder pain is a common feature. Later on the man looks ill and anxious : the pulse-rate rises ; there may be signs of internal haemorrhage : pain, rigidity and tenderness are present. An early rapid pulse is usually the result of bleeding : later on it may be due to peritonitis. Vomiting is common, and in stomach perforation almost invariable. Injuries of the stomach, and especially submucous haemorrhages into the upper reaches of the bowel, resulting from exposure to blast in water frequently cause haematemesis. Haemorrhage into the substance of any part of the gut is followed some hours or days later by melaena ; and loose stools may continue for several weeks after such an experience.

The rigidity present in some thoracic wounds may give difficulty in diagnosis but it can usually be differentiated by the fact that it relaxes somewhat when respiratory movement changes from expiration to inspiration, whereas in intra-abdominal injury it is persistent.

## VIII. DIAGNOSIS

The warning to examine the whole body surface is here repeated : the importance of the small scratch or abrasion that may be the only external evidence of entry of a flake or minute fragment of metal, is again emphasised.

Diagnosis depends on :—

1. A brief history to elicit, if possible, the nature of the wounding agent.
2. An examination of the body-surface to discover the site of the wounds, and from this to estimate the probable track of the missile. In the case of a retained F.B. an X-ray examination will be of great help. X-ray investigation will demonstrate the position of foreign bodies, pneumo-peritoneum and any associated lesion of the chest or extra-peritoneal injury. But if this is not readily available laparotomy should not be unduly delayed.
3. The signs and symptoms.

The diagnosis should also include an estimate of the general condition of the patient and his fitness or otherwise to undergo operation. This will depend mainly on pulse-rate, pulse-volume, blood-pressure, temperature, general appearance and condition of the skin. An early rising pulse points to haemorrhage ; a later rising pulse to peritonitis. A pulse of over 120 indicates urgency. Blood-pressure is the important thing. However much you may possess the mysterious " clinical instinct " the only safe estimate of a patient's condition and progress is by observations of the blood pressure by sphygmomanometer. The critical B.P. is 80 mm. Hg. systolic, and is an indication for immediate transfusion. It is risky to embark on laparotomy with a systolic B.P. below 100 mm. Hg.

Patients will fall into four groups :—

1. A few that show no evidence of intra-abdominal injury—no shock, pain, rigidity or vomiting. These should be kept under observation, remembering that small intestine perforations may not leak for many hours.
2. Cases with evidence of intra-abdominal injuries but fit for immediate operation.
3. Cases with evidence of intra-abdominal injuries but unfit for operation because of rapid pulse (say 130), low B.P. (say 85/65), and cold. Such cases require immediate transfusion of plasma and blood in the proportions of three to one. In severely shocked cases it may be necessary to start this off at positive pressure (applied to the air-inlet tube of the bottle) and to run in the first two pints quickly. As soon as fit for operation as judged by blood-pressure he should be taken to the theatre with the transfusion still running.

   Cases arriving from forward areas with a transfusion already started will probably require a short period in the resuscitation-ward before operation, but some can be taken to the theatre forthwith.
4. Cases in a moribund state from multiple wounds (*e.g.* head, abdomen, femur). This group will also contain cases whose evacuation has been long delayed and in whom peritonitis is advanced, the typical picture being cold, clammy, blue hands with failing peripheral circulation. The pulse is thready and running, yet they are mentally clear and alert, but restless from discomfort. Such cases do not recover.

## IX. OPERATION

Most of the work entailed in the previous two sections will have been done by the sorting-out officer and the resuscitation team, but the surgeon should from time to time between operations go into these two departments to help decide which of certain patients shall take priority.

The following principles are worthy of note :—

1. As haemorrhage is the commonest cause of death it is worth while taking risks that would not be justified in cases where the haemorrhage could be controlled by temporary measures.
2. The aim of operation is to find and repair the sources of haemorrhage, peritonitis and retro-peritoneal cellulitis. Do not use an elaborate method where a simpler, and therefore quicker, one will suffice. Speed combined with reasonable care is an important factor.
3. Use a generous incision—it allows of examination of all viscera without having to eviscerate fully.
4. Whenever it is necessary to perform two operations, one anteriorly and one posteriorly, it is important to do the latter first, for experience shows that great shock is caused by turning a patient into the prone position after laparotomy has been performed. This is probably because the presence of air in the abdomen resulting from laparotomy allows the whole intestine to fall forwards when the patient is subsequently turned into the prone position, thus pulling on the mesentery, a well known cause of shock.

5. Excision of bowel has a much higher mortality than suture.
6. In all but the very fit it is wise to start an intravenous drip of plasma and blood (depending on the amount of internal haemorrhage that appears to have taken place) for the operation. This will usually be done in the resuscitation ward, and often will have been started at a F.D.S.
7. When in doubt, operate.

**Incision.**

The ideal incision is one overlying the lesion, but as this is usually multiple and not accurately predictable, the right or left paramedian incision is the most generally useful. It allows of good wide exploration, and can be extended right or left by further incision across the rectus muscle. Moreover, no nerves are damaged, and it gives a good scar. When possible it should be made to embrace the wounds of the missile, but as a rule these must be excised separately. Where the track of the missile is well to the side a flank incision may be used, and where the F.B. has entered and come to rest in the loin, a loin incision will be chosen. For most cases however one or other paramedian incision is best.

**Exploration.**

Usually the first thing met with is free blood, and this should be mopped out from the kidney pouches and pelvis and its sources found, and controlled, remembering that the mesenteries, omenta, solid organs and tears in the small intestine are the common ones. Severe bleeding from a torn liver can be lessened temporarily by compressing the hepatic artery and portal vein in the free edge of the small omentum with the finger and thumb. Whilst controlling bleeding from mesenteries an estimate should be made of how much—if any—bowel has been deprived of its blood supply.

Then examine the small intestine from caecum to duodeno-jejunal junction, getting an assistant to hold each damaged portion with a mop. Note will be made of the numbers of perforations or tears and how close together they are. Where the mesentery has been severed from the bowel the length involved should be noted.

The large intestine should be similarly inspected, and any such findings as retro-peritoneal haemorrhage or emphysema in the region of the ascending or descending colon, or signs of the wound track being in their vicinity, should lead to a most careful search for any perforation of the bare areas. It may be necessary to mobilise the colon by incising the parietal peritoneum lateral to either vertical colon and stripping it medially in order to expose the posterior surface. When examining the stomach the posterior wall must be remembered and, where under suspicion, must be exposed by opening the two posterior layers of the great omentum. The duodenum will naturally be inspected at the same time as the stomach ; this, like the colon, has a bare area that may have been injured.

Then examine the liver, spleen and kidneys.

Finally, the pelvis should be examined for injuries to the rectum or bladder, and where the lesion in the latter is large enough to admit the finger its cavity should be so explored for any F.B., since fragments and bullets have been discovered therein on a number of occasions. At the same time damage to the base can be assessed and dealt with.

**Repair of Organs.**

No hard and fast rules can be laid down, but the following principles have been proved by experience.

Suture is better than resection, since it carries less risk. So far as the small intestine is concerned, this applies even to multiple perforations and only if they are so close together that their suture would narrow and distort a length of bowel, should resection be considered. Resection will also have to be practised where the blood-supply is cut off, as when the gut has been torn from its mesentery over a distance of more than one inch, or where the feeding arteries to main arcades in the mesentery have been ligated for haemorrhage. Small perforations can be closed by purse-string suture, larger ones and tears by an inverting stitch—one layer sufficing.

Where resection is inevitable, end-to-end anastomosis is better than side-to-side.

Perforations, tears and bruising of the large intestine are dangerous and exteriorisation of the affected part has proved a life-saving measure. Under the following circumstances it should be used without exception :—

1. Where there is a jagged tear with bruised edges.
2. Where there are two or three perforations within a short segment.
3. Where there is considerable bruising of the walls of the colon.
4. Where the blood supply of a segment is in doubt.
5. Where, in spite of a perforation being small and solitary, considerable soiling of the peritoneum has occurred.
6. Where the condition of the patient demands speed.

Some experienced surgeons make an exception of the small, solitary perforation without soiling, and are suturing them instead of employing exteriorisation, and with satisfactory results. However, the safe rule is —when in doubt exteriorise.

The surgeon performing the colostomy or exteriorisation is rarely the one who subsequently has to close it, and he should bear in mind certain principles if he is to avoid bequeathing to his colleague at base a difficult if not dangerous task. Whichever part of the colon is used a generous loop with proximal and distal limbs lying parallel and in contact should be arranged. In the case of the fixed portions of the colon, and of its flexures, considerable mobilisation will be necessary. This must be carried out purposefully and often needs a longish incision through the peritoneum lateral to the ascending or descending colon so that it can be stripped medially and so brought through a separate skin incision without tension and with limbs parallel and in contact, this latter being maintained by two or three stitches through the visceral peritoneum. This eliminates the risk of a piece of gut or omentum being nipped by the enterotome during subsequent closure. When the site of the colostomy is not dictated by large gut trauma but can be chosen, as in rectal wounds, the best ones are the left iliac fossa, or the two hypochondria, as shown in the diagram.

Wounds of the rectum are dangerous, even when the rent can be exposed and sutured, and the best results have been obtained by performing a colostomy. If the sigmoid is long this can be used, but the quickest, easiest and therefore safest, is the transverse colon. Use a generous loop, fixing it with a glass rod or by stitching the skin edges beneath it, and open it forthwith. Colostomy is even more important for the extra-peritoneal tear of the rectum associated with wounds of the buttock and perineum.

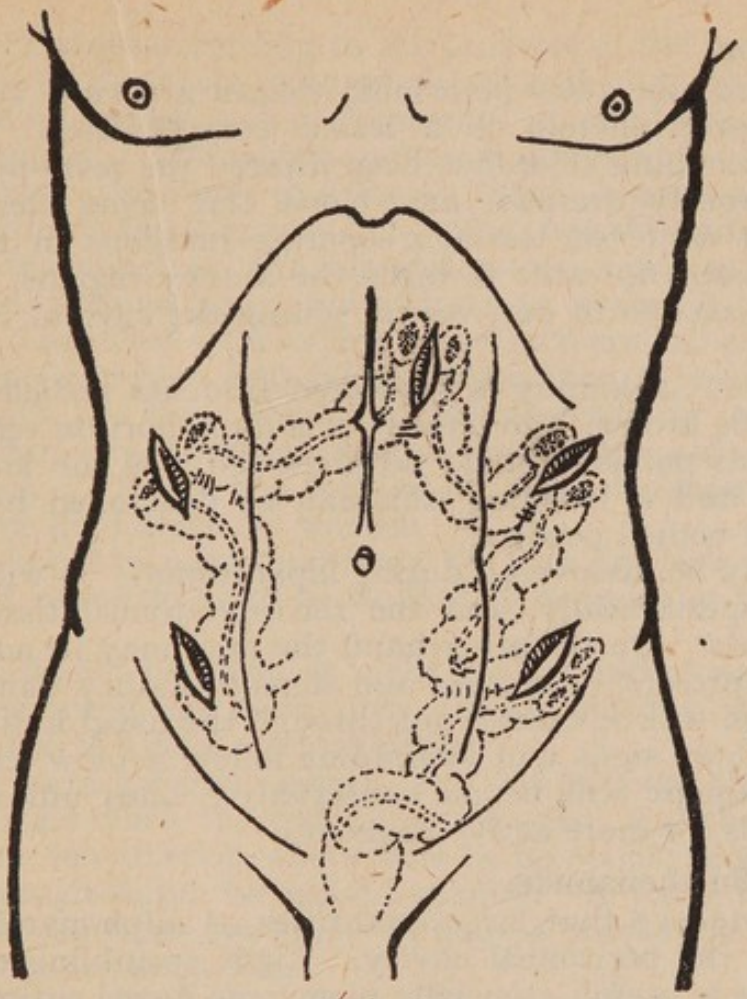

FIG. 1

Sites of election for colostomies in war injuries.

Perforations and tears of the stomach afford little difficulty.

Intra-peritoneal tears of the bladder are repaired with an inverting stitch and without drainage, and the same applies to those into the cave of Retzius, but where the tear is extra-peritoneal and postero-inferiorly situated repair is best achieved from within the bladder, and a suprapubic drain should then be used.

If the spleen is torn it is better removed.

Tears of the liver have often ceased to bleed by the time laparotomy is performed. Massive blood clot should be removed, otherwise it may become septic. Any large F.B. in the liver substance should, also, if easily accessible, be removed. Bleeding may be controlled by several sutures on large curved round-bodied needles, taking large bites.

**The Question of Drainage.**

1. *Peritoneal.*

Once perforations of the stomach and small intestine have been closed, the peritoneum can look after itself, and unless there has been gross soiling, as from a large tear in a full stomach, there is no need to drain. Where soiling has been extensive, or operation has been delayed—more than eight hours after wounding—a pelvic drain through a supra-pubic stab wound is a good safety-valve.

In cases of intra-peritoneal colon injury where suture has been performed without exteriorisation of the bowel, it is wise to use a small drainage tube passing from a separate wound in the flank down to near the site of repair.

2. *Retro-peritoneal.*

As already said, the retro-peritoneal tissues are very vulnerable, and cellulitis developing therein is a lethal complication. Wherever the ascending or descending colon has been injured the retro-peritoneal space should be generously drained, any blood clot being cleared out first. Drainage is best achieved through separate incisions in the flank, and tubes can be passed upwards towards the kidney regions, and medially. If there is any question of peri-vesical soiling the cave of Retzius should also be drained.

*The Kidneys.*—If a kidney is separated from its pedicle it should be removed. If it be broken into pieces yet a large portion remain attached to its pedicle, this portion should be preserved. If the kidney is found merely fissured, and is bleeding, this can be controlled by deep catgut sutures on round-bodied needles.

The injury may be discovered during laparotomy. It will then best be dealt with transperitoneally, and the retro-peritoneal tissues should be drained afterwards. On the other hand the man may be admitted with a loin wound and present symptoms and signs of kidney damage, in which case the operation will be carried out through the usual kidney incision.

Where the kidney signs and symptoms follow a blow, crush, burying, blast, etc., treatment will be on conservative lines unless evidence of haemorrhage calls for more active measures.

**The Question of Sulphonamide.**

There is no evidence that large quantities of sulphonamide powder do any good inside the peritoneal cavity. Light sprinkling over suture or anastomotic lines is useful, especially over large bowel suture lines.

It is valuable in the treacherous retro-peritoneal spaces.

Sulphadiazine should not be used.

## X. AFTER-CARE

The importance of after-care cannot be exaggerated, for upon it depends the life of the patient. The essence of sound after-care is to foresee all the various complications and then to do everything possible to prevent their development.

It is essential to "hold" cases for at least five days, and preferably seven or eight days, after operation—they will not stand being moved. They travel badly by air.

The most urgent early complication is paresis with distention, leading up to paralytic ileus. Bruising and multiple perforation of the bowel cause a temporary intestinal paresis; retro-peritoneal haemorrhage tends to maintain this for several days, and peritonitis aggravates the condition. With the stasis and distention that follow there is a rising blood-urea (up to as much as 100 mgms. per 100 c.c.), and a loss of chlorides leading to alkalosis. The older methods of treatment, namely pituitrin, eserine, acetyl-choline, and the various kinds of enemata, combined with starvation and rectal salines, were distressing to the patient, and often did not keep up with the distention. The best way undoubtedly of avoiding these troubles is to give the bowel complete rest. This is achieved by intravenous drip of glucose saline and gastric suction. The former rests the bowel, replenishes fluids, restores chlorides and affords calories in the form of glucose. Three to five pints daily should be given and it can be con-

tinued for several days according to the progress of the patient. In many instances it can be dispensed with on the second or third day, the indications being a falling pulse, lack of distension, an empty stomach, and satisfactory bowel action. The gastric suction is obtained by attaching any of the simple forms of syphonage to a Ryle's tube. A great advantage of the continuous suction is the economy in nursing, but the end of the tube does sometimes become blocked, and for this reason some surgeons prefer to attach a 20 c.c. syringe about every hour to draw off what may have accumulated. The Ryle's (or other) tube is removed as soon as there appears to be no secretion and regurgitation into the stomach, and this will coincide with the time when the intravenous drip is discarded. At the same time fluids by mouth are started, and a progressive diet instituted in the usual way. During the spell of no fluids by mouth the patient's mouth should be kept clean by washes.

These cases should be nursed either in the true Fowler's position (*i.e.* the head of the bed raised so as to be sloping 30 degrees) or with the patient sitting up.

Morph. gr. ¼ should be given at night for the first three or four nights, and, at the beginning, an extra dose during the day is justifiable—an important point is to assure sleep at night.

As a rule enemata are unnecessary, but if it happens that the man was wounded at a time when the rectum was loaded, and the faeces become inspissated from dehydration, there may be no spontaneous action of the bowel, even though flatus be passed readily. A patient should not be allowed to go more than two days without a reasonable stool. A soap enema will relieve the situation.

Should distention develop in spite of the intravenous and gastric-suction regime a turpentine enema, succeeded by ½ c.c. pituitrin, will probably prove effective, but if not it should be repeated in four hours' time.

If, in spite of all these measures, a true paralytic ileus develops, as indicated by the disappearance of colicky pain, and complete absence of any peristaltic sounds through an examining stethoscope, the giving of morphia to allay restlessness is called for, and little else can be done. If a stage of subacute obstruction is reached, as indicated by increasing distention, colicky pain, vomiting, and unsatisfactory bowel actions, it must be assumed that some mechanical factor is present, and the question of reopening the abdomen must be considered. During the first few days after the original operation a band is most unlikely, but sticky adhesions in the bends of mechanical kinks do, on occasions, form early, and may be the cause. Under such circumstances something must be done to relieve this mechanical factor, and if the patient is fairly fit a second laparotomy should be undertaken, for on rare occasions an internal hernia, such as bowel slipping through a tear in the omentum may be formed. If, however, nothing more than distended coils, kinked at flexures, and with sticky adhesions, be encountered, a rubber tube should be stitched into one of the most distended coils. Where the patient is too ill for a laparotomy, this drainage of distended gut can be carried out under local anaesthesia, and is sometimes a life-saving procedure.

## XI. TREATMENT AT THE BASE

This consists of treating complications.

1. **Septic Laparotomy Wound.**

This is treated along ordinary lines including secondary suture when clean.

2. **Burst Wound.**

This is usually due to imperfect suture of the peritoneum, and often takes place within an hour or so of the removal of the skin stitches. It is remarkable how little the incident, as a rule, affects the patient, and resuture brings about a satisfactory result.

3. **Intestinal Obstruction.**

This is due to bands, adhesions and openings in such structures as the mesenteries or omentum. The signs and symptoms are unmistakable, and operation is the treatment.

4. **Intra-abdominal Abscess.**

The common sites for this are any of the subphrenic regions and the pelvis. Drainage must be established.

5. **Faecal Fistula.**

After perforations and tears of the colon have been sutured a small proportion of them break down and a fistula results. Many heal spontaneously and it is always worth giving them two or three months to allow this to take place. Since exteriorisation has been generally employed for a badly torn or bruised colon these fistulae have been seen less often. The same applies to colostomy for injuries to the rectum.

It is not always possible to recognise an extra-peritoneal tear of the rectum associated with wounds in the buttock, and these latter cases sometimes arrive at the base with faeces pouring from the buttock wound. The right treatment for this is an immediate colostomy, but where the discharge of faeces is only slight and occasional the fistula may eventually heal spontaneously. For this reason, faecal fistulae discharging only small amounts of faeces should be evacuated to the U.K. without further active treatment.

6. **Urinary Fistula.**

Like faecal fistulae these are most commonly seen following extra-peritoneal tears of the bladder associated with wounds of the buttock and perineum. When accompanying fracture of the pelvis the fistula may discharge into the groin, the bladder usually having been injured by a fragment of bone. Many of these heal spontaneously and reasonable time should be allowed for this to take place. Cystoscopy should be performed, for sometimes a F.B. or fragment of bone may be revealed and should of course be removed. Some require supra-pubic drainage attached to a syphonage apparatus, but in view of the tendency to heal excepting for cases of severe cystitis, this should be postponed until evacuation to the U.K.

Urinary fistulae may come from wounds of the kidney or ureter, and there may even be an extensive extravasation in the lumbar region down into the groin and pelvis. Such a collection of urine must be drained, and once drained the fistula may become quite small and discharge little urine. These, too, tend to heal spontaneously, but it may be necessary to perform a plastic operation on the kidney, its pelvis or the ureter. Such operations should await transfer to the U.K.

7. **Secondary Haemorrhage.**

This is an alarming complication that may affect the kidney about ten to fifteen days after wounding. If it comes from the main vessels nothing but excision will suffice, but violent haemorrhage has been known to arise from a lacerated area of the organ, excision and suture of which will control the bleeding and save a functioning part.

## SECTION XXI

## MAXILLO-FACIAL INJURIES IN THE FIELD

Past experience has proved that ignorance or disregard of the limitations of general surgery as applied to these injuries has been responsible, not only for unnecessary delay and suffering, but also for creating difficulties later to be overcome when finally they do come under competent care.

### IN THE FIELD

Only first aid treatment is practicable. Whatever the type of injury, until the patient arrives at the main dressing station, this is directed to saving life ; the two main aims being to prevent suffocation and to control haemorrhage.

General treatment, rest, warmth and sedatives, to combat shock.

When a high-velocity missile hits a soldier in the face he often feels only a local burning sensation, but he finds blood pouring from his wounds, so profuse that it may interfere with his vision or breathing. A large shell dressing should be inserted into and over the wound, and the affected part of the face firmly bandaged, using the barrel type of bandage reinforced with " elastoplast " if available. By this means an upward and not a backward pressure is maintained which is especially important in wounds in the region of the symphysis menti with comminution of the bone and separation of the lingual attachments. Backward pressure in such cases not only increases the bony displacement but greatly interferes with swallowing and respiration. *Posture is of vital importance.* The patient should be placed on the stretcher in the prone or semi-prone position to prevent falling back of the tongue. A suture passed through the tongue from dorsum to under surface and the free ends attached outside, *e.g.* button of tunic is a valuable method of keeping it forward. If sitting, or the wounded man is able to walk, he should do so with his head bent forward and downwards.

When the palate and/or maxilla is floating and flapping on the tongue, stuff a wad of vaselined gauze in the hollow of the palate so that the patient can push his tongue against it. Do this when suitable, and when the patient can co-operate, before applying the barrel bandage.

Such measures are usually sufficient to stop the bleeding. Morphine may be administered early.

### AT THE C.C.S.

These wounds require more thorough cleansing than others because they should never be excised. They are washed or even scrubbed with soap and water, irrigated first with peroxide and then with saline or acriflavine. Foreign bodies and completely detached fragments of bone should be carefully removed. A fragment of bone attached to any soft tissue must

not be sacrificed. It will probably survive, furnishing an invaluable scaffold for repair, whereas its removal will be followed by deformity of the framework and contour of the face.

Under suitable anaesthesia and precautions (*see* Section VII) reduction and immobilisation of bony fragments by wiring can now be undertaken by the dental officer before any treatment of the soft tissues is begun. Cases which have been firmly fixed by wires usually arrive at the base in the most satisfactory condition. Dental officers of forward hospitals have a very important function in ensuring that all cases passing through have such fixation before evacuation.

If there is a perforating wound into the mouth with loss of tissue, skin sutured to mucosa round the edges of the defect lessens the contraction of scar tissue and the onset of sepsis. The temptation to draw the wound together under tension should be overcome, as it is the worst possible surgical treatment. It cannot be too strongly emphasized that the suture of a lip, for example, when the jaw or jaws are fractured should not be attempted until complete control and repositioning of the bony fragments have been obtained. Neglect of this rule causes encroachment upon the oral opening, making subsequent manipulation extremely difficult, if not impossible, without further operation to gain access into the mouth.

Reduction by leverage is usually easy in the early stages, and should be attempted (*see* Section XXIII).

All facial wounds without such loss of skin as will call for tension on the sutures or distortion of the underlying cavity, *e.g.* mouth, nose, eye, should be sutured as soon as possible with fine material and an atraumatic technique. This applies whether it lies over a fracture or not. The same applies to the mucosa. If this is not feasible the wound must be left widely open. It is important also to remember that successful plastic repair can only be assured if the foundation of contour is restored. The first thought must be for the bony framework and in the estimation of displacement or loss of tissue, first the bony framework, secondly mucosal linings, and last of all the skin covering should be considered.

## TREATMENT OF UPPER FACIAL FRACTURES

The optimum period for replacement of the nasal framework is within forty-eight hours of the injury, disimpaction being carried out under endo-tracheal anaesthesia.

More violent blows cause a circular depressed fracture of the maxillary block, the whole being separated from base of skull. Minor " dish-face " deformities can be reduced among other ways by gradual elastic traction applied to the sunken maxilla through upper dental splints by means of a headcap bearing an anterior bar. Mastication is nearly always interfered with.

The malar bone and zygomatic arch take the full weight of all blows upon the cheek, and the zygomatic, frontal, orbital and maxillary roots are commonly injured. Unless seen on the day of the injury, before the swelling of the cheek has occurred, these deformities are usually missed, but bleeding from one side of the nose, diplopia, pain or numbness in the distribution of the infra-orbital nerve, bruising of the cheek and sub-conjunctival haemorrhage are significant. The upper part of the cheek is flattened and usually a notch is palpable on the infra-orbital margin.

There may be interference with the movements of the mandible due to pressure of the displaced zygomatic arch upon the coronoid process.

### SUMMARY

A floating tongue, blood in the pharynx are the chief causes of early death. Flooding of the pharynx with blood is particularly likely to occur during induction of anaesthesia, and in the post-operative period of unconsciousness.

Proper prevention is prompt intubation, direct or indirect under pentothal, packing of the pharynx.

Cleanse the wound thoroughly with soap and water, peroxide and saline.

Immobilise fragments of bone.

Never excise a facial wound.

Save the framework of the face even if it is loose ; sacrifice a bony fragment only if it is detached from all the surrounding tissues.

If there has been any skin loss, pack the wound with sulphanilamide powder and leave it open.

If there has been no skin loss and the wound is recent, after attention to any underlying bony injury, insert fine silk stitches and remove them within three days.

In the face, never insert a few big stitches under tension ; they usually lead to serious septic complications and will always be followed by a scar, which will remain a disfigurement for life.

### POST-OPERATIVELY

A naso-pharyngeal tube should be left in position, and the patient kept under supervision until conscious. When jaw fragments have not been fixed and there is continued oozing and early evacuation is necessary, tracheotomy or laryngotomy may have to be performed. The patient should be evacuated on his face or side, the head over the edge of the stretcher, with the forehead supported on plaster bandage passed between the handles of the stretcher.

## SECTION XXII

## INJURIES TO THE EYES

### DISPOSAL OF EYE WOUNDED

1. War injuries of the eyes are a considerable source of anxiety to medical officers, among whom the fear of sympathetic ophthalmia is constantly present. The tendency, particularly among general surgeons, is therefore to play for safety and excise more eyes than is necessary. It is true that the development of sympathetic ophthalmia is a tragedy which ends frequently in complete blindness ; but it is to be remembered that sympathetic disease does not develop before ten days after trauma, and only very exceptionally indeed before three weeks. There is, therefore, usually abundance of time for the patient to come into the hands of a specialist and for the latter to give a considered opinion on the case at leisure before any drastic action need be taken. It is to be remembered, moreover, that many eyes, although they appear useless at, or soon after

the time of injury, may eventually recover sufficiently to allow of some vision ; and particularly in cases of injury to both eyes a small amount of vision may make all the difference in the patient's after life. It is a good general rule, therefore, that *no eye should be excised by the general surgeon in advanced surgical units unless the globe is completely disorganized and in addition its removal is necessary as part of the general surgical toilet of an extensive wound of the face.* Otherwise the eye should be dressed and the case referred to the most forward ophthalmic specialist. Any intra-ocular interference or attempt to excise prolapsed uveal tissue by those who have neither experience of the technique or the necessary instruments for the purpose, easily leads to a disaster that cannot usually be remedied by subsequent operations.

2. If by any chance it is decided that an eye be removed at this early stage, the technique advised in para. 11 should be followed. It is of the greatest importance, however, that the socket should never be packed subsequently, for example, with sulphonamide vaseline gauze, as has frequently been done in a misguided attempt to avoid sepsis and secure haemostasis. The first purpose can be achieved by dusting sulphanilamide powder into the socket, but this is rarely necessary ; the second, by firm bandaging over the closed lids. *Packing a socket almost invariably results in contraction,* necessitating tedious and unsatisfactory subsequent operations, or in the development of a sunken socket, making the fitting of an artificial eye difficult or impossible.

## TREATMENT BEFORE ARRIVAL AT A FORWARD OPHTHALMIC UNIT

3. If the lids are torn or split *no tissue should be excised;* the skin in this region is too precious to be sacrificed and, moreover, is remarkably viable. If the wound is recent and primary closure seems indicated, it is legitimate, provided sufficiently fine needles and silk stitches are available, to approximate the ciliary margins of the lids if this can be done with accuracy, and to sew up a wound provided this can be done without tension. Otherwise it is best simply to apply a sulphanilamide, tulle gras and saline dressing. Any attempts to close a gap after an interval or where there is loss of tissue, when big stitches only are available or where tension is thereby induced, must be resisted since it leads invariably to serious sepsis and extensive cicatrices, necessitating much more involved plastic procedures than would otherwise be required.

4. An examination should be made of the eyeball, the lids being pulled back by the fingers resting on the upper and lower bony rims of the orbit without putting any pressure on the globe itself. Loose foreign matter should be washed out of the conjunctival sac with saline and an examination made to determine whether or not a penetrating wound exists, particularly if there is a prolapse of pigmented uveal tissues or vitreous loss. If these do not exist and the eye is not painful, atropine should be instilled and the eye protected by a flap of material (such as lint) hanging from a strip of adhesive plaster from above the brow. Such patients can be evacuated as " walking wounded." It is to be remembered that when an eye is closed by a bandage for more than forty-eight hours it is usually found on removal of the bandages to be bathed in pus owing to incubation of organisms in the closed conjunctival sac. No eye should, therefore, be bandaged at this stage unless it is absolutely necessary.

5. If the eye is painful, or if there is an obvious penetrating wound, the lashes should be cut with vaselined scissors to prevent their sticking, atropine should be instilled after cleansing, the lid margins lightly smeared with vaseline, and a pad and bandage put on. If a penetrating injury has occurred, and particularly if there is vitreous loss, the patient should be evacuated lying and not treated as "walking wounded." In such cases a course of sulphonamide therapy should be started and the dosage annoted at this stage. It is essential that the cornea should be covered during transit, and if the lids are markedly torn or split a single key-suture may be necessary, catching the skin near to the lash edges of both lids so that they are approximated: such a stitch can be snipped through on arrival at an ophthalmic unit.

## EXAMINATION AND TREATMENT AT A FORWARD OPHTHALMIC UNIT

6. Arrived at a forward ophthalmic unit, a detailed specialist examination should be undertaken. Two questions immediately arise, both of which are full of pitfalls and require the utmost care in decision: (1) is the eye dangerous? (2) is there a retained foreign body? It is of the utmost importance to decide at the earliest possible date whether or not penetration has occurred. A penetrating wound may be so inconspicuous that the possibility of a small foreign body having been driven into the globe is easily overlooked. If there is penetration, or if it is thought probable or even possible, the sooner the eye is thoroughly examined and treated, the better. It should be borne in mind that penetrating injuries, especially if associated with prolapse of the uvea or lens capsule, are most liable to cause sympathetic ophthalmia and that penetrating injuries in military practice are frequently associated with retention of a foreign body in the eye. It may be said that sympathetic ophthalmia never follows a non-penetrating injury and that therefore an eye which has not sustained such an injury can be left with safety.

The examination should include a search for wounds in the surrounding areas, as the lids, temple or cheek, which may indicate the entrance of the foreign body that has passed into the globe. Proptosis may be due to panophthalmitis or to a foreign body in the orbit having caused haemorrhage or cellulitis. A minute search for small wounds in the cornea should be made and also in the sclera and a note made of any hyphemia or hypopyon in the anterior chamber. The iris should be examined to note whether the pupil is circular or regular, if the sphincter is ruptured, is torn from the periphery (iridodialysis), or if there is a hole indicating the penetration of a foreign body. The tension should be noted, but it should be remembered that although a soft eye following an injury usually suggests a rupture, this is not diagnostic, for a ruptured eye may have normal tension and a bruised globe may have reduced tension. Vision should be tested and recorded, the field taken roughly with the hand and the accuracy of the projection of light determined. After the pupil is dilated the red reflex should be examined and the condition of the lens noted with special regard for dislocation, cataract or the track of a foreign body; blood or a foreign body in the vitreous should be excluded; and the fundus searched for signs of concussion, rupture of the choroid, detachment of the retina or the presence of a foreign body. If penetration has

occurred the presence of a foreign body should be verified by X-ray localization, being affected by the McGrigor eye localiser, and its magnetic nature determined by trial with the giant magnet.

7. The examination being completed it must be decided (i) is this a useful eye, or (ii) is it a dangerous eye ?

If there is perception of light and good projection, the eye may possibly be of considerable value. A gross diminution of vision may be due to concussion changes or haemorrhage, which may clear up surprisingly in the course of time. Excision of such an eye at this stage should only be done if evacuation to the base is difficult or if the eye is giving rise to considerable pain.

An eye is dangerous in the sense that it is liable to cause sympathetic ophthalmia, if there is a rupture or penetrating wound of the globe, particularly in the ciliary region, and especially when complicated with a prolapse of the iris, ciliary body or lens capsule. Suppurating eyes rarely give rise to sympathetic disease ; it is the angry red eye or the quiet chronic inflammation resulting in a plastic iridocyclitis that is the greatest danger. It is to be remembered that although a foreign body in the globe may lead to complete disorganization through inflammation, it rarely gives rise to sympathetic disease unless accompanied by prolapse of the uvea or lens capsule.

## EXTENSIVE RUPTURES

8. If one eye only is ruptured and completely blind, it should be removed within the first ten days after injury ; however complete is its disorganization no remains should be left. When both eyes are ruptured no operation should be undertaken immediately unless they are causing great pain (this is unlikely). The operation serves no useful purpose, inflicts unnecessary shock at an unfortunate time, and is bad psychologically. Such cases should be dealt with at the base, where there is ample time to verify the hopelessness of the condition.

## PENETRATING WOUNDS WITH PROLAPSE OF THE UVEA OR LENS CAPSULE

9. If such an eye is blind and it is considered that the blindness is permanent, it should be removed. If there is any vision and the globe is not disorganized, the prolapsed iris should be removed, the tissue being pulled out so freely that, after cutting, the pillars will retract well away from the wound to avoid the irritation so frequently produced by adhesions. Ciliary body and choroid, if clean, should be replaced and the sclera sutured with eyeless needles ; if the prolapsed uveal tissue is ragged or infected, it should be drawn out and excised before suturing. In suturing the sclera, great care should be taken not to include the uvea in the stitches, and the lips of the wound should be firmly held in toothed forceps while the needle is passing, to prevent the escape of vitreous in the manipulations. An entanglement of the lens capsule is often difficult to detect in the early stages but should be drawn out and cut off or tucked back into the anterior chamber. Gaping wounds of the cornea should be covered with a conjunctival flap ; the best flap to employ, designed to last during evacuation, is a complete purse-string flap tied over the middle of the cornea obtained after complete peri-limbal circumcision of the conjunctiva and then free dissection backwards.

## FOREIGN BODIES IN THE EYE

10. Too enthusiastic attempts at the removal of a foreign body should not be made in an advanced ophthalmic unit; unfortunately in modern war a great many of these foreign bodies are not magnetic, or only feebly so, so that removal may be difficult or sometimes impossible. If the foreign body is in the anterior chamber or is obviously at or near a scleral wound, its removal by the magnet at this stage is permissible; if it is not, the case, clearly annotated, is best evacuated as rapidly as possible to the base, because in this event post-operative treatment is too lengthy for accommodation in a forward area.

Foreign bodies either of metal, powder or dirt, when deeply embedded in the cornea are frequently troublesome to remove, and if they are numerous and not causing irritation, they are much best left alone. If they are causing irritation, each one must be picked out separately by a stiff instrument, such as a Beer's knife, with the help of bright focal illumination and a binocular loupe.

Foreign bodies in the orbit are difficult to deal with; if possible, they are best left alone. Even if they set up haemorrhage or cellulitis with proptosis, the tendency in a large number of cases is for the disturbance to subside with hot fomentations and general treatment. This is safer than an attempt, which must usually be blind, to hunt for them among the orbit tissues. If cellulitis is severe, or increasing, it should be treated by incision and drainage, but attempts at removal of the fragment should not be persisted in unless it presents itself readily. In all those cases of intra-ocular operation a course of sulphonamide should be instituted at as early a stage as possible.

## EXCISION OF THE EYE

11. If there is no infection and the globe is extensively ruptured, the contents of the eye should first be scooped out thoroughly, the separate portions of the sclera picked up and made taut with pressure forceps, the muscles dissected off and the optic nerve cut through.

If there is any infection or even a suggestion of it either in the orbit or in the eye, a frill excision is much the most satisfactory operative procedure. In these circumstances complete excision of the globe involves a definite risk of meningitis, while a simple evisceration is followed by much reaction and leaves a wound which is slow in healing.

The cornea should be transfixed as for a cataract extraction, and then the lower half cut away. The contents of the globe should be completely scraped out with a large scoop, the process being completed with minute thoroughness by scrubbing out the sclera with a swab held in a pair of forceps, and the shell of the sclera thoroughly washed. The sclera is then firmly packed with a strip of gauze to give the globe consistency, the conjunctiva circumcised, and the muscles divided. The gauze packing is now removed, the sclera drawn well forwards by two or three pairs of pressure forceps and cut far back, leaving a frill round the intact optic nerve. In this way the risk of infection of the nerve sheath is avoided, as is also the shock due to cutting the optic nerve, while there is little bleeding, good drainage for any cellulitis and rapid healing. It should be noted again that the orbit should never be packed but the closed lids covered with vaseline gauze and a pad and bandage.

During subsequent evacuation to the base the eye or the socket should be washed out and dressed at least once every forty-eight hours.

## TREATMENT AT THE BASE

12. Treatment at the base involves general ophthalmological principles. This is the stage of greatest importance and anxiety so far as the decision for the excision of a potentially dangerous eye is concerned, and it is here that final operations such as the treatment of traumatic cataract, the re-position of detached retina and the removal of difficult foreign bodies must be undertaken. Unless the eye is obviously and violently irritated, or the tension is markedly raised, the discission of a traumatized lens or the removal of cataract is best left until the eye has settled down and is white. Foreign bodies present the greatest difficulties. It is to be remembered that probably more than 60 per cent. of these met with in modern war are non-magnetic, but the evidence is that many non-magnetic foreign bodies are well tolerated. Unless, therefore, a foreign body reacts to the magnet or is in a position where it can be got at very easily, it is usually best left alone. If the foreign body is in the anterior chamber or near the pupillary area, extraction by the anterior route is advisable. If it is in the vitreous, is small and actively magnetisable, it is pulled through the suspensory ligament into the posterior chamber, drawn between the iris and the lens into the pupil by changing the direction of the magnet force by moving the eye using the giant electro-magnet; once in the anterior chamber, it is extracted through a keratome section by the small magnet. If the foreign body is in the vitreous, if it is large and ragged, and if it is only feebly magnetisable, it is most easily extracted by the posterior route. After locating it radiographically or, if it is visible, by the same technique as is applied to retinal holes, a conjunctival flap is reflected from the nearest surface area, the sclera is steadied by fine silk sutures and surface diathermy applied to the region when sclera incision is proposed. A wound is then made in the sclera, the head and eye being turned so that the wound itself lies uppermost to minimise the risk of vitreous loss. The terminal of the electro-magnet is then introduced into the lips of the wound and the current turned on. If the foreign body is magnetisable and movable it will adhere to the terminal. The scleral sutures are then tied and the conjunctival flap reposed. If there is a scleral wound of entry, this should be used as a means of exit if possible. It should be remembered in all these cases that one trial with the magnet is not sufficient to determine whether a foreign body is magnetisable or not. Several attempts should be made and if the slightest movement is elicitated its removal should be attempted in the above manner. It occasionally happens that by a scleral incision it may be possible to pick up a foreign body with fine iris forceps, or even to extract it by means of a snare of wire passed through a large sized syringe needle, but such an operation is a tricky and difficult one, and should only be attempted by those who have confidence in their surgical technique. The use of diathermy combined with incision into the posterior half of the globe minimises the risk of subsequent retinal detachment and makes the ultimate prognosis of such an operation much more favourable than it used to be.

## BURNS

13. Burns in the region of the eyes should receive special attention. They should never be tanned, nor should preparations such as gentian

violet be used on the lids : a dressing of sulphonamide vaseline should be employed. The greatest danger arising from such injuries is exposure of the cornea from the extensive ectropion which frequently results from cicatrical contracture and unless measures are taken against this almost invariable tendency, an exposure keratitis with perforating ulcers and permanent loss of vision or of the eye may result in a few days. Every endeavour should thus be made to keep the cornea covered, if necessary by stitching the lid-margins or by a tarsorrhaphy, while an early graft should be applied to the raw surfaces of lids, as soon as granulations appear, to prevent scarring—even if this fails to take it can easily be repeated. If these measures are not successful, a protective contact glass is a valuable temporary measure ; and where this is not available a pedicle flap from the forehead or temple stitched right over the exposed eye is a temporary emergency expedient of great value. In any event the subsequent complete reconstruction of the lids by grafting at leisure is a successful procedure which does not give rise to anxiety so far as ultimate function and appearance is concerned provided some underlying muscle remains.

### PLASTIC SURGERY

14. Plastic surgery, of an extensive or ambitious nature, is to be deprecated in the field and should never be attempted without the help and advice of a surgeon of proved plastic ability. When an eye is still present and the lid is partially destroyed, every effort should be made to make an eyelid for protection, and, if necessary, the expedients noted in para. 13 should be resorted to. But if there is no eye, particularly if there is lid destruction as well as a contracted socket, the patient should be transferred to a plastic centre at home or the operation—or operations—postponed to the post-war period. If the patient is otherwise fit and is anxious to return to duty, the minor operation of closing the socket will meet the case. Partial reconstructions and mucous membrane grafts in sockets have not given good long-term results. The best results, and these are often disappointing, are obtained by a complete removal of the mucosa and a total skin graft. Numerous ill-devised operations are not in the military interest and merely make subsequent and permanent reconstruction more difficult or impossible. Speaking generally, few eye surgeons do good plastics.

## SECTION XXIII

## INJURIES TO THE EAR AND NOSE

### THE EXTERNAL EAR

Lacerations of the pinna and external auditory meatus require thorough cleansing and early replacement of the damaged parts. If a portion of the ear is lost, the anterior and posterior auricular skin should be sutured round the edges of the cartilage, so defining the defect. Remaining fragments of ear should not be sutured to each other out of normal position. If the external auditory meatus is torn through completely, a careful anastomosis must be made by catgut suture and the meatal passage plugged with ½ inch ribbon gauze soaked in paraffin and flavine. Neglect of these injuries may lead to stenosis of the meatus.

Haematoma of the pinna should be evacuated under strict asepsis and the ear protected with a sterile dressing.

## THE MIDDLE EAR

Injury to the membrana tympani is common and usually associated with other and frequently more serious injuries. Damage may be caused by direct penetration, fracture of the base involving the tympanic ring or sudden compression of the air in the external auditory meatus. The latter may cause small haemorrhages into the substances of the membrane, rupture of its outer fibres, a linear tear or complete disintegration. The great danger is secondary infection. Symptoms of injury to the ear may be absent or obscured. Whenever damage to the drum is suspected the ear should be examined with care and strict asepsis. If rupture has occurred, all interference must be avoided and the outer ear protected with a sterile dressing or a sterile cotton wool plug. No drops of any kind must be allowed to enter the ear and on no account will an ear be syringed if rupture of the membrane is suspected.

Wax, if present, will be left undisturbed for three to four weeks after injury unless there are special indications (*e.g.* pain or pronounced deafness) for its removal, when this should be done by an aurist with suitable sterile instruments.

When rupture of the drum head is accompanied by damage to the pinna, sufficient to require treatment, the meatus must be carefully packed with sterile cotton wool while the outer ear is cleansed.

Cases of damage to the tympanic membrane must endeavour to avoid further injury until the middle ear has healed or, when suppuration has supervened, until the condition has become chronic. These individuals should be instructed in future to wear ear protection when exposed to blast.

When the drum has been ruptured special care must be taken to avoid acute naso-pharyngeal infection. Also patients should be told to refrain from blowing the nose until the perforation has healed.

**Sulphonamides.**

The prophylactic administration of sulpha drugs by mouth is unnecessary unless the condition of the ear is such as to render infection probable. They should always be given in cases with a pre-existing otitis externa and in those cases where rupture of the tympanum accompanies a fractured base. These latter should be kept under the strictest observation as infection may spread rapidly to the meninges. Insufflation of sulphonamide powder into the external meatus is contra-indicated for cases with rupture of the membrana tympani.

**Aero-otitis or Baro-trauma.**

Sudden alterations of pressure on either side of the tympanic membrane, such as may occur in aviation or diving, cause ear changes. Blockage of the Eustachian tube is the initial factor. This is followed by extreme retraction of the drum head, oedema of the mucous membrane lining the middle ear, and in severe cases the formation of a serous exudate, which is sometimes bloodstained and often mixed with bubbles of gas, in the middle ear cleft. Pain is severe and deafness pronounced.

These cases must be treated by an otologist as soon as possible since early inflation of the Eustachian tube is followed by rapid resolution. If

treatment is delayed recovery will take three to four weeks, and some deafness may be permanent. Incision of the tympanic membrane is contra-indicated unless acute suppurative otitis media supervenes. This complication is very rare.

An inhalation of amyl nitrite will relieve some cases of aero-otitis if given soon after the blockage of the Eustachian tube takes place.

## THE INTERNAL EAR

Damage to the internal ear may be caused by continuous loud noise, blast or barotrauma, with or without evidence of middle ear injury. Patients will complain of deafness, high pitched tinnitus and sometimes vertigo. These cases must avoid further acoustic trauma for three to four weeks. Pheno-barbitone ½ to 1 grain twice daily will relieve vertigo and may also be required for cases with severe tinnitus.

## INJURIES TO THE MIDDLE THIRD OF THE FACE

War injuries involving these parts are mostly accompanied by damage to the soft tissues of the face. While the superficial damage is conspicuous the less obvious displacements of the underlying bony framework are (in most instances) the more important. The following plan of attack should be followed in all complex injuries of the face. This may entail closely co-ordinated teamwork from plastic and dental surgeon, E.N.T. and eye specialist and neuro-surgeon :—

1. Diagnosis of injury in terms of bone and soft tissue injury, loss of tissue, and involvement of nose and nasal sinuses, jaws, eyes or cranial contents.
2. Preoperative preparation of first aid splints necessary for immobilisation of fractured and displaced bones.
3. Reduction and immobilisation of fractures.
4. Surgery of bones. Extreme conservatism should be practised here, any piece of bone attached to soft tissue being preserved.
5. Surgery of soft tissues. This is the last phase of facial repair.

After receiving first aid treatment these cases must be evacuated to a suitable surgical centre.

It must be realised that facial injuries require a somewhat different procedure from wounds elsewhere. The classical débridement has no place in their treatment and packing open wounds causes unnecessary and avoidable disfigurement. The primary treatment is most important both for the future healing of the wound and for the ultimate cosmetic result.

The salient points in the treatment of facial wounds are :—

(i) Early surgical attention. The blood supply is good and primary suture is advocated up to twenty-four hours in most cases.
(ii) Thorough cleansing with very careful removal of all dirt and accessible foreign bodies.
(iii) The removal of all irreparably damaged tissue but the preservation of all healthy tissue. Partially avulsed skin of the face should be accurately replaced even if there is only a narrow pedicle.

(iv) Haemostasis is very important.
(v) Local anaesthesia is recommended wherever possible.
(vi) Careful suture of the soft parts with accurate replacement after complete restoration, if possible, of the bony framework. Any attempt to improve a patient's natural appearance must be avoided.
(vii) All sutures must be fine and close together.
(viii) Closure without tension or at least the immediate reposition of structures in a position as near normal as possible, should be followed by a pressure dressing, preferably a crepe bandage.
(ix) Special care must be taken of the mucous membrane of the mouth and lips. With through-and-through loss of the cheek the skin must be sutured to mucous membrane and the temptation to close holes avoided.
(x) Large raw surfaces should be covered with Thiersch skin grafts as primary dressings. This procedure may save months of delay in healing.
(xi) Stitches should be removed early, starting on the second day.
(xii) Formal plastic repair should be carried out when cicatricial contraction has come to an end.

**Haematoma of the Nasal Septum.**

After thorough cleansing of the anterior nares the vestibule on each side is swabbed with methylene blue and with strict asepsis a free incision is made into the lower and anterior part of the haematoma and the blood evacuated. A small roll of sterile gauze is then fixed over the nostrils and held in position by tapes tied across the back of the head. If neglected, a septal haematoma is liable to become infected with abscess formation and destruction of the median cartilage.

**Fractures of the Nose.**

(i) *Simple.*

If treated early (*i.e.* within forty-eight hours) reduction and maintenance of the fragments in position seldom present difficulties. Complete disimpaction of the fragments is essential if accurate replacement is to be achieved. An effective external splint can be made of stent or lead. If these are not available, collodion painted on about eight successive strips of broad ribbon gauze, will suffice. Badly comminuted fractures with complete collapse of the nasal bridge may need support from through-and-through silk worm gut or fine wires, tied over lateral lead plates after efficient reduction.

(ii) *Compound.*

Thorough cleansing of the wound and early reduction of the fracture are essential. If the wound is clean immediate closure may be carried out with bony fixation as above. If infection is likely to occur free drainage should be provided and the wound dusted with sulphonamide powder. A full prophylactic course of sulphadiazine by mouth should be given.

**The Maxillary Sinus.**

Simple effusions of blood into the antrum usually absorb and are best left alone. If infection is suspected, antral puncture and lavage, followed by the introduction of sulphonamide and also prophylactic oral administration, is necessary.

When the sinus contains pieces of metal or fragments of bone it must be opened by the sub-labial route, cleaned out and counter drainage provided into the inferior meatus of the nose.

In some cases of fracture, particularly when there is depression of the floor of the orbit, it may be necessary to pack the antrum for seven to twenty-one days with sulphonamide gauze in order to retain the fragments in position.

Depressions of the malar or zygomatic arch without an external wound should be elevated as soon as possible. Most can be reduced with a lever introduced between the temporal muscle and temporal fascia through an incision within the hair line over the temporal fossa. Others can be replaced by grasping the fragment through the skin with stout tenaculum forceps and manipulating with the aid of a finger in the mouth high up behind the bucco-labial sulcus.

In some, particularly late cases, a combined Caldwell-Luc and temporal approach is often required followed by a suspension by wires attached to a bracket embedded in a plaster headcap. In severe deformities with loss of bone, replacement by an iliac bone graft will be necessary.

**The Frontal Sinus.**

Injuries of the forehead involving the frontal sinus require cosmetic repair and functional restoration. An external approach is necessary. All loose fragments of bone and blood clot must be removed from the sinus which is then drained into the nose by a rubber tube surrounded by Thiersch graft. Where there is moderate destruction of the anterior bony wall the lumen of the sinus may be restored by a larger skin graft in the form of a sac, held in position by a bag of oiled silk packed with ribbon gauze.

When the posterior wall of the frontal sinus is fractured and the dura torn, repair of the dura by a fascia lata graft is necessary and the case should be transferred at once to the care of a neuro-surgeon. This is also required for fractures involving the ethmoid and followed by cerebro-spinal rhinorrhoea.

**The Ethmoidal Labyrinth.**

Operation in this region after injury should be avoided if possible. Explorations for foreign bodies should be postponed for fourteen days at least, and approach should be by the external route. Earlier surgical clearance may be necessary if infection is present. Sulphonamide therapy should be employed early. If obstruction of the fronto-nasal duct is likely a skin graft must be inserted.

**Aviation Sinusitis.**

Sudden alterations of barometric pressure produce definite changes in the paranasal sinuses. The symptoms are acute pain referred to the region of the affected sinus and sometimes syncope. Within the sinus small petechial haemorrhages may be seen in the lining, submucous haematoma may form or haemorrhage occur into the cavity of the sinus. In severe cases the mucosa may be torn from the walls of the sinus.

Treatment must be conservative. Rest, sedatives, inhalations of menthol and the instillation of 1 per cent. ephedrine in normal saline into the nose. Amyl nitrite is efficacious in some cases. Infection seldom occurs if interference is avoided. Should acute suppuration supervene a simple intranasal drainage must be performed.

## THE PHARYNX

### Injuries to the Pharynx.

These wounds are rarely encountered because they are mostly fatal. If a patient survives perforation of the pharynx the great danger is from infection of the para-pharyngeal space. Careful haemostasis is important and it is imperative to open widely any infected wound in this region.

The general management of wounds of the mouth and pharynx is described under Sections VII and XXI.

## THE LARYNX

### Indirect Effects.

Blows on the neck and certain wounds in the vicinity of the larynx may cause a laryngeal haematoma or damage to one or both vagus nerves. These patients must be kept completely at rest, preferably in a sitting posture, and in readiness for an immediate tracheotomy should one become necessary.

### Simple Direct Injuries.

Blows on the larynx may lead to fracture of the thyroid cartilage, injury to intrinsic muscles, dislocations or fracture of the cricoid. These injuries are not, of themselves, serious, but there is an immediate danger of laryngeal obstruction from oedema. Later laryngeal stenosis may develop and this is common after fracture of the cricoid. Complete rest sitting up in bed is essential. Tracheotomy must be avoided if possible but everything held in readiness for its performance. These patients must be under constant observation and distant evacuation postponed until the danger of acute laryngeal obstruction has passed.

### Compound Injuries.

These are serious on account of the added danger of infection and particularly of perichondritis. Difficulties of anaesthesia are dealt with under Section VII. A local anaesthetic should be used whenever possible.

The immediate treatment consists of keeping the lungs as free from blood as possible. Free exposure is necessary, careful haemostasis, sulphonamide powder applied, and the wound held open by loosely packing with impregnated gauze. A suction pump is most desirable, and should always be used if available. It is important that a tracheotomy tube should not remain in contact with laryngeal cartilages for more than a few hours. A correctly placed tracheotomy (*i.e.* as low as possible) should be performed as soon as practicable.

Lung complications are common and to guard against these the patient must be allowed to cough in the sitting position and morphia avoided on account of its depressant effects.

### Plastic Procedures.

Sequelae following laryngeal injuries include fixation of the cords or stenosis from the organisation of granulations or from perichondritis, immobility of the crico-arytenoid joints, recurrent laryngeal nerve paralysis, and laryngo-oesophageal fistula. Plastic operations designed to relieve these complications must be delayed until healing is complete. It must be remembered that recovery of function in the vagus nerve may occur many months (up to two years) after the initial injury.

Restoration of the lumen for the relief of laryngeal stenosis necessitates the insertion of a skin graft. The graft is best supported by a rubber tube

held in position by transfixion with a silver wire passed through the thyroid alae as described by Schmiegelow.

Closure of laryngo-oesophageal fistula can be effected by the laryngo-fissure route, with the turning in of a skin flap.

## SECTION XXIV

## LESIONS CAUSED BY EXPOSURE TO COLD

**By the Consulting Surgeon to the Norwegian Army.**

The pathological effects of exposure to cold are: (i) general, and (ii) local.

Damaging effects of exposure to cold occur more frequently in frost and wind, and when wet weather suddenly changes to frost. Even severe dry frost in calm weather is not so dangerous. In northern countries, therefore, one sees more frost injuries in the early spring than in midwinter.

Bad general condition, exhaustion, hunger, thirst, shock, lack of blood, depression, age, lack of opportunity for exercise, are predisposing factors.

### GENERAL FALL OF BODY TEMPERATURE

This occurs mainly in people who fall asleep in the snow without proper protection against the cold. In peace-time there are two main causes: drunkenness, or exhaustion in people who lose their way in the mountains.

**Symptoms.**

Feeling of weakness, loss of normal urge to struggle for life and a most dangerous overwhelming *sleepiness*, which, if not properly combated, will become *irresistible*.

If the patient falls asleep it means death, unless he is rescued very soon. Death may occur swiftly from paralysis of the heart or, more frequently, life is slowly extinguished as the body freezes stiff.

**Local Effects of Cold.**

The peripheral parts of the body (feet, hands), uncovered parts, especially where the skin is near to bone or cartilage (nose, ears, skin over the cheek-bones) are most often affected.

Predisposing factors are general fall of body temperature, interference with the circulation—standing for long periods on deck or in a trench with wet, cold feet; sitting in a lifeboat, raft, or cold damp shelter with legs pendant, without an opportunity to change position for a long time; compression of the limbs by garters, puttees, breeches, tight boots.

1. *Frostbite*

Is most frequently seen in severe, dry cold, or still more in frost with damp, fog or wind. It may occur suddenly, sometimes within ten minutes or less, for instance when in severe cold the uncovered skin comes into contact with cold metal.

*Symptoms of frostbite during exposure.*—The biting pain which the cold may cause at first, is substituted by a feeling of numbness and very soon a *dangerous anaesthesia, preventing the patient from recognizing his condition*. At the same time the frostbitten part turns wax-white, stiff and cold, difficult to move, and finally paralytic.

2. *Trench Foot.*

Most typical in soldiers who have been in cold wet trenches, especially if they have first been soaked by rain, and the weather then changes to frost.

3. *Immersion Foot.*

In this war is frequently seen in men who have been exposed on rafts or in open boats with their feet immersed in cold sea-water for periods of hours up to several days.

4. *Shelter Foot.*

Occurring in people who spend nights in cold, damp shelters with their legs pendant over a sharp edge.

5. The well known, more innocent chilblains, will not be dealt with here.

Trench foot, immersion foot and shelter foot resemble each other closely as to clinical features and pathology. The hands may be similarly affected.

The symptoms during exposure are : Numbness. Walking " as if on cotton wool." The hands feel clumsy. During period of exposure pain is unusual. The skin is in some cases wax-pale, cold ; in others, dusky red.

A swelling of the feet may be noticed some days after exposure.

**Pathology.**

The following pathological facts are important as a basis for adequate prevention and treatment.

The changes produced in the tissues by exposure to cold are direct destruction of cellular life (" true frostbite ") in areas where the so-called critical temperature (40 degrees to 47 degrees F.) is reached in the tissues. This will, however, seldom occur except in small superficial areas even in severe cold, as long as the temperature regulation of the body is maintained.

If the general body-temperature falls, true frostbite will rapidly occur. But the majority of such cases will die of general effects of the exposure to cold before they can be treated. In most patients surviving with frostbite, the area of cellular destruction—which will always lead to gangrene—is of less importance than the surrounding area where no direct cellular destruction, but a vasoneuropathy due to chilling, has occurred.

The same, or a similar, sort of neurovascular disturbance is seen in the whole diseased area in immersion foot, trench foot and shelter foot. These neurovascular changes are the cause of exudation occurring when such tissues are thawed and get warm. The result is swelling, and a tissue-hypertension, which interferes with the circulation : stasis, cyanosis, blistering and in some cases, even compression of arteries and gangrene.

*It is this vasoneuropathy with subsequent exudation which is responsible for most of the damage caused by a local exposure to cold, and for the clinical symptoms after thawing.*

Depending mainly on the exudation one sees three degrees of symptoms and damage :—

First degree : *Dermatitis congelation erythematosa.* Dusky redness or cyanosis of the skin.

Second degree : *Congelation bullosa, swelling, cyanosis, blisters.*

Third degree : *Congelation gangrenosa.*

Second and third degrees are very much disposed to infections, including tetanus. Later on neuromuscular disturbances with anhidrosis, followed by hyperhidrosis, are seen, more or less pronounced.

Such changes reduce the resistance to further exposure to cold.

**Prevention.**

Planning by the C.O. and M.O. may avoid unnecessary exposure to cold, by providing training, hardening, rest, shelter, food, adequate clothing and by inculcating individual understanding of the measures of protection against cold.

The problems to be solved are : Protection against cold, wet, wind and the predisposing factors such as exhaustion, hunger, alcohol, depression, shock, haemorrhage.

Prophylaxis consists in strengthening of general condition and power of resistance.

*Hardening procedures.*

Systematic general physical training is essential, and regular cold baths, or washing the body with cold water followed by subsequent rubbing. Animal fat, for instance whale oil, should be rubbed into the skin thoroughly until the skin is dry.

If washing of the whole body is impossible, daily washing of the feet with subsequent rubbing till the skin is dry, is most important. Excellent for hardening purposes is a Finnish " Badstue "—bath with subsequent snow bath.

*Hyperhidrosis pedis* must be treated.

Proper food should be available which, in severe winter cold should contain at least 5,000 to 6,000 calories, rich in fat and carbohydrates. During marching, skiing and fighting, the men should be provided with sugar or glucose tablets, which they can easily get at without stopping the march, and eat if they feel tired. The men should rest and eat every third hour if possible, and in trench warfare hot meals or drinks should be provided as often as possible.

*Rest.*—Exhaustion, which is the most dangerous cause of loss of resistance to cold, must be avoided as far as possible. When exposure to cold threatens, every opportunity must be used to let the men rest and eat in sheltered places, woods, depressions, snow-caves or huts of fir-tree branches. During rest, the clothing must be adjusted to weather and temperature, because rest is of little value if the men can't keep warm.

**Some " Don'ts."**

When frost is threatening during the march, don't force yourself and your men till exhaustion renders them unable to take the necessary measures against cold. It is much better to rest and eat while the general condition is still good.

Don't allow your men, if exhausted and feeling sleepy, to lie down and sleep in the snow without proper shelter and clothing. The only hope of saving a man's life, when in that condition, is to drive him on without mercy till he reaches a place where he can be protected against cold. Benzidrin may be useful.

Don't allow your men to submit to depression, and an encouraging word is a life-saving drug under such conditions.

Don't take a drop of alcohol till you are safely accommodated in a warm house where you can sleep, as even a slight dose makes the dangerous sleepiness due to general exposure irresistible. Alcohol causes vasodilation in the skin which gives a short, initial feeling of warmth and is treacherous and dangerous, because it means increased loss of body heat. Officers and men should not be allowed to carry alcohol in their field flasks in winter warfare.

## CLOTHING

The solution of this problem is different in :—

1. Winter warfare in snow and frost.
2. Trench warfare in temperature just below freezing point.
3. After shipwreck.

1. (*a*) **Marching and Skiing Troops in Winter Warfare in the Snow.**

Men should wear several light, thin suits, and nearest to the skin a "brynje-vest" providing a layer of warm, stable air between the skin and the shirt, and to a certain degree preventing the shirt from becoming damp with perspiration. Shirt and underwear should be woollen, as this absorbs more perspiration before getting damp than cotton, linen or silk. Over the battledress, a thin Burberry windproof smock and trousers provide an extra layer of insulating air.

By putting on or taking off the windproof suit and a sweater, the clothing during the march can be adjusted to changing temperatures, wind, wet and degree of exercise. Thus it will be possible to keep the man warm, without perspiring or getting damp.

An essential condition for varying the clothing during marching is a type of pack which can be taken off and put on in a minute as, for instance, the Norwegian Bergen ruck-sack.

(*b*) **Static Winter Warfare.**

In addition a greatcoat or furcoat (long) is wanted, and also for camping, a tent and sleeping bag. These items should as far as possible be transported by car or sledge, and not carried by the men.

*Boots* should be one or two sizes larger than the man's civilian shoes, of waterproof leather, and he should wear two thick pairs of socks, and have a spare pair in the ruck-sack.

Over the boots a special snow-protecting cover should be worn and in the Arctic, felt or fur boots.

*Hands* require—Thick woollen wrist mittens, and two pairs of large woollen mittens with one compartment for II–V fingers, one for the thumb, and one spare for index finger for shooting.—Two large windproof mittens for use over the woollen mittens.—All mittens must be long (about two-thirds way up the forearm).

2. **Trench Warfare.**

Greatcoats, or waterproof raincoats, should be provided instead of the windproof suits, and waterproof, if possible rubber, boots are desirable.

3. **Shipwreck.**

The best protection is whole waterproof clothing, which has been introduced in the Norwegian navy, and proved most valuable.

All clothing must be wide, comfortable and in no way interfere with the circulation (no garters, no puttees).

**Keeping Dry.**

Wet is most dangerous. Every effort must be made to keep dry and trenches must be drained and dry standing arranged.

As soon as the men get indoors or into a heated tent, they should change their underwear and socks if wet, take off their boots, and rub if possible the whole body, or at least the feet, which are the most important. They then proceed to *dry* their clothes and stuff their boots with dry hay and paper and hang them up 1–1½ metres above the stove. The leather is

spoilt if they are put near an open fire, on or too near a warm stove. Wet boots are a dangerous predisposing factor to frostbite, as they may freeze, and the boots should, at intervals of a few days, be greased with water-free animal fat, for instance seal oil to which is added 5 per cent. beeswax or wood tar. In severe cold the boots should not be greased.

In the Arctic leather boots will freeze, however well they are prepared, therefore felt boots or fur boots must be used.

Shirt, underwear, socks and mittens are hung up to dry not too near a stove, and the men put on dry underwear and socks before they go to sleep.

If the men are in sleeping bags in the open, or in a tent, they should, if possible, change underwear, shirt and socks, and rub their skin dry before they go to sleep in the bag. Wet shirt, underwear, socks, mittens and boots should be placed in the sleeping bag, where they will be dried to some extent by the heat of the body. Boots must never be left outside the sleeping bag in frost. They will freeze, and it will be impossible to get them on again.

In a severe snow or ice-storm, it is better to go with the wind which is much less exhausting and cold, until some sheltered place can be found.

**Prevention of Local Effects of Cold.**

Use all the measures suggested for preventing the general effects of cold. and in addition wash the face and, if possible, clip the beard in the evening, not before starting in the morning. Rub thoroughly into the skin of face, feet and hands, water-free animal fats, for instance, whale oil, till the skin is dry.

When out in the cold, it is well to make sure every five minutes that your toes, fingers or face do not get numb or become anaesthetic or difficult to move. Touch the nose, cheeks and ears to determine whether they are hyperaesthetic or anaesthetic. Keep an eye on your comrades' noses, cheeks and ears for the appearance of white spots.

If any of these signs appear, start active movements of the affected part and if the face is concerned rub and warm the part with your bare hand, which may be uncovered from the mitten for one to two minutes. If this does not help try to get to a house and obtain first aid treatment.

**Treatment.**

*General loss of Body Heat.*

If the temperature of the body has not sunk below 80 degrees F., and this condition has been of short duration, attempts at revival may succeed in exceptional cases. But usually the prognosis is bad.

Attempts to re-heat the body must be done gradually. Slight rubbing, cautious massage in a relatively cool room (55 degrees F. at the beginning, gradually increased up to 62 degrees) or, if available, a bath in which the temperature in the water should be raised slowly from 60 degrees F. to 95 degrees F. within a period of three hours.

During such procedures of revival, the patients often show signs of collapse which makes injections of heart stimulants (camphor, coramine, caffein), and even massage of the heart and artificial respiration, necessary.

As the patient regains his body temperature and his frozen limbs begin to thaw, he frequently suffers intense pain and requires injections of morphia. Even if the revival is successful, he may subsequently die after some days or some weeks owing to pneumonia or to the destruction of

erythrocytes caused by the cold. This eventuality may to a certain degree be prevented by blood-transfusions.

Even if the patient survives, sequelae may be in evidence, such as symptoms from the circulatory or nervous systems, as well as the effects of local frostbite.

*Treatment of Local Effects of Cold.*

The aim is to prevent or reduce the exudation and hypertension in the tissues :—

(1) The body is heated, the extremities kept cool. The patient is placed in a cool room (60 degrees F.), not too near a stove or open fire.

His wet clothes are removed. He is wrapped in blankets, hands and feet exposed. A fan may be used for air cooling of the injured part, but no rubbing or massage with snow.

(2) All clothing which might interfere with the circulation is removed. The damaged extremity should be elevated as near as possible to a vertical position.

If, in spite of this, any greater degree of pain and swelling occurs, digital compression of the main artery for fifteen minutes with intervals of fifteen minutes, for an hour or two after the thawing is completed, may be tried.

If these measures do not prevent increased swelling, and signs of hypertension threatening the circulation in the part appear, multiple incisions for draining off the exudate and decompressing the tissues should be made. The part should be kept elevated until several days after the swelling has disappeared.

If swelling starts when the extremities are lowered, or when the patient starts to walk, he should be confined to bed again for an additional period and if blistering or gangrene is present a sterile dry dressing should be used.

The danger of infection and of development of foetid gangrene is less with dry dressing than with a wet one. And a dry dressing can be left without changing much longer than a wet one.

Prophylactic tetanus antitoxin should be given.

Apart from exceptional cases with septic infection, amputation should be delayed till a clear line of demarcation is formed. Almost in every case, the gangrene is much less extensive than it appeared to be at the beginning.

If, in the months following the recovery, treatment for the results of the vasoneuropathy is necessary, sympathectomy may be considered.

## NOTE ON THE MANAGEMENT OF THE WOUNDED MAN IN SUB-ARCTIC REGIONS

The treatment of sick and wounded in this zone is an exceedingly difficult problem. Any wound induces a condition of shock. Cold increases or may even induce shock. It follows, therefore, that everything possible must be done to keep the patient warm ; warmth is the first essential—the treatment of the wound is of secondary importance. The following general principles should be adhered to :—

Replacement of lost blood and resuscitation for shock is essential before transport of wounded in the cold.

First aid dressing of the wound should not be carried out unless bleeding is profuse. The main aim is to prevent chilling by placing the patient in his sleeping bag and to arrange for his evacuation as soon as

possible. If splinting is necessary it should be applied outside the clothing. If bleeding is profuse put on a field dressing over the clothing and bandage firmly.

The application of a tourniquet will almost certainly lead to the loss of the limb from frostbite; one should therefore only be used as a last resort. Even a bandage applied at all tightly will predispose to gangrene.

While awaiting evacuation, the man should be protected from the weather by placing him on the lee side of a snow wall.

# SECTION XXV

## BURNS

**Causation and Prevention—Classification of Types—Treatment, General and Local—in Forward Areas—at Base. After Treatment.**

### BURNS.

The rapid development of mechanised warfare has caused the subject of burns and their treatment to become a major surgical problem. To date, figures suggest that the best part of 10 per cent. of army casualties are due to burns. Naturally, A.F.V. personnel, gunners and drivers of supply vehicles are the chief sufferers. Amongst tank crews during battle periods the percentage of burns may rise as high as twenty-five—and as these are often accompanied by serious wounds, as a group they must be considered as producing some of the most severe casualties.

**Prevention.**

It should be definitely borne in mind, however, that on an average for every battle casualty burn there are two accidental, and too much stress cannot be laid on the necessity of constantly instilling into troops the importance of prevention—both by instruction and stringent disciplinary measures. The possibilities of protective clothing—especially for A.F.V. personnel—are under immediate consideration.

**Economic Importance.**

The efficient treatment of burns is of vital importance from the viewpoint of saving man-power, as these cases by their severity and chronicity tend not only to occupy valuable bed-space for long periods of time, but also to throw a great strain on medical and nursing personnel. The prevalence of sepsis in war burns is obviously not without grave risk of cross-infection to other casualties treated, as they often have to be in close contact with them.

### TYPES OF BURN

Practical considerations have led to the classification of burns into two types only—superficial and deep. In the latter all the true dermis is lost, in the former at least islands of skin are preserved. Clinical differentiation of these two types is not easy—but an attempt at the earliest possible moment is essential to efficient treatment.

**Depth and Extent.**

As well as depth, extent must be considered in assessing prognosis. To date in this war four out of five burns are only moderate in extent—being

confined particularly to exposed skin surfaces—and in these the ultimate result is, generally speaking, satisfactory. The remaining 20 per cent., involving large areas are always severe, and are productive of an 80 per cent. mortality.

**Flash Burns.**

The former and larger group constitute what are now known as " flash burns "—resulting from the explosion of either petrol or ammunition. Such burns are limited by the covering of ordinary clothing. It should be noted, however, that they may involve the upper respiratory passages.

Electrical, chemical and gas burns are also occasionally met with, but perhaps not to the same extent as in other services and in civilian war work. The outstanding feature of this group is their slowness of healing.

## TREATMENT OF BURNS

This is admittedly a most controversial subject—there is to date no " cure-all " in the treatment of burns—and in the following remarks stress is laid on methods of proved practical value under service conditions, while mention is made only of alternative measures often probably just as efficient in better circumstances.

### (A) General Treatment.

*Causes of Death.*

It must always be remembered that the first consideration in the treatment of a major burn is the saving of life, and so-called general measures apply equally well in both forward and base areas. Burns cause death through shock, toxaemia and sepsis, roughly in the proportion of one of the two former to two of the last. Shock is due both to neurogenic influences and to fluid imbalance, although the age-old premise that the loss of tissue fluids from a raw, burnt surface is, in itself, detrimental, is open to considerable doubt. Providing always that intravenous infusion facilities are available, there seems a lot to be said for allowing a free flow of toxic tissue fluids in the first few hours. It has been frequently observed that this fluid loss is automatically reduced to minimal proportions within the first forty-eight hours after burning.

*Shock.*

The degree of shock is not always easy to determine. Haemoglobin estimation is probably fallacious, and a record of blood-pressure readings at short intervals is always a better guide, *i.e.* a steadily rising systolic pressure is a better indication of recovery from shock than a falling haemo-concentration.

Measures for treating shock are as follows :—

(i) *Plasma.*—Intravenous plasma is a life-saving procedure and should be given as soon as possible in all severe burns. As much as eight to ten pints are frequently required and it is important that the first two or three should be given quickly—at the rate of ten minutes per pint. Thereafter, plasma can be " dripped " in at a steadily decreasing rate until sufficient has been given to counteract the existing shock. In successful cases this will usually be achieved within the first forty-eight hours. After this period recent research has tended to show that serum given for several days has a markedly beneficial effect. If plasma is not available, an ordinary blood

transfusion is preferable to the infusion of saline or glucose saline. Fluids by mouth (and per rectum) should be pushed to the limit of the patient's tolerance as soon as possible.

(ii) *Morphia.*—An initial large dose (⅓ to ½ grain) is indicated, followed by doses of grs. ¼ when and if required. Careful record of administration must be kept to avoid overdosage.

(iii) *Oxygen.*—Inhalations repeated at short intervals, by B.L.B. mask unless the burn has involved the face to too great an extent.

(iv) *Sulphonamides.*—All war burns are potentially, if not actually, septic by the time they come under treatment. Oral sulphonamides should be exhibited in full doses in any obviously infected or very large burn. Careful watch must be kept for signs of individual susceptibility.

(v) *Rest.*—Not enough attention is often paid to this important point. Major burns travel badly and should be retained in forward units as long as is feasible, even up to a week or ten days.

(vi) *Reassurance.*—Fear of pain or disfigurement is a very potent factor and reassurance on this point from the medical officer in the early stages will often do immeasurable good.

(vii) *Heat.*—Must be used with discretion and certainly not to excess. In warm climates there is probably no necessity to use this means of combating shock.

*General Treatment in Chronic Cases.*

A few points that have been proved to be of value in the later stages should be mentioned. As full a diet as is procurable, fresh air, cheerful surroundings where possible, and the administration of iron in large doses, have all proved their worth. The chronic " toxaemia " of large burns is often dramatically improved by one or more " whole corpuscle " transfusions.

(B) **Local Treatment.**

This can best be divided into three sections, viz.: preliminary (" forward "), interval (transport), and " full " (hospital).

(*a*) **Preliminary.**

Sufficient clothing should be cut away thoroughly to expose the extent of the burn, no attempts at cleaning should be indulged in, blisters are better left alone, and an application of sulphonamide powder (if available) made, the area being covered with tulle-gras or vaseline gauze. If this dressing is not available the following are permissible—acriflavine soaks; " Cetavlon " cream; simple dry dressings (with or without previous sulphonamide powder, bearing in mind the risk of producing toxic symptoms very rapidly in a proportion of patients by this method if used extravagantly); saline soaks—which probably increase the chances of subsequent sepsis; or triple dye jelly (application of which is painful).

Tannafax, or any form of coagulant treatment is definitely contra-indicated at this stage.

(*b*) **Interval.**

*Transport of burnt cases.*—As has been previously stated severe burns travel badly, and in serious cases evacuation from forward areas to base

should be delayed as long as possible. This applies equally to air evacuation.

Great improvement in the general and local condition of extensive burn cases and in their comfort has been effected by transporting them in loosely padded, divided, light plaster of Paris casts.

(*c*) **Full** (*Hospital*).

The primary aims of local treatment are to relieve pain, to protect the burnt surface, to prevent sepsis and to accelerate healing. To achieve these, whatever the subsequent local application is going to be, a thorough and meticulous cleansing of the burnt area is essential, and in anything but really minor burns this cannot be efficiently carried out without general anaesthesia. It is only when full anaesthetic and surgical facilities are available, and when the patient is fit enough, that the " full " treatment of a burn should be attempted.

(1) Pentothal is the best *anaesthetic* for burns, given by the drip method when a long administration is likely. No bad effect on shocked cases has been reported, nor does there seem to be any contra-indication to its use in the more chronic " toxic " cases. In badly burnt cases it may be difficult to find a suitable vein for administration. A " gas-oxygen " (or gas-oxygen-ether) mixture is the best substitute for pentothal.

A general anaesthetic saves considerable time and the patient's feelings —hence reducing this shock-producing factor. But the habit of doing subsequent dressings—after the first—under general anaesthesia is one that is definitely detrimental to the patient and should be discontinued as soon as possible.

(2) *Cleaning* the burnt area should be carried out methodically and carefully, using gauze swabs soaked in saline (some use dry gauze but it is certainly more traumatising), and discarding each swab after it has been gently rubbed over one particular part of the burn. Blisters should be opened and all loose epidermis removed, except on palms of hands, soles of feet and ears. Attention must be paid to surrounding skin. Hard rubbing and nail brushes should never be employed.

(3) There are three groups of *local applications* to burns—the non-coagulants, the dyes and the coagulants. This—for war burns—is considered the order of preference :—

(i) *Non-coagulants*.—A sulphonamide and vaseline (or a sulphonamide cream) mixture is the best application. The sulphonamide—a powder containing three parts of sulphonilamide to one of sulphathiazole can be recommended—is bacteriostatic and hence helps to counteract that greatest bogey of burn treatment—sepsis (particularly from streptococci) and its attendant perils of toxaemia and scarring. But it must be admitted that although the sulphonamides limit the sepsis, they do not prevent it and practically as many septic burns are seen when this method is used as when coagulation is carried out.

Again, the possible toxic effect of these drugs when used locally must be remembered, and the powder should always be applied in measured doses with a 15 gram maximum. Co-relation to oral administration is also necessary. But even allowing for these possible disadvantages it has been amply proved in dealing with actual casualties that when compared even to the successful tan the sulphonamide cream (or vaseline) treatment is definitely more

comfortable to the patient, is conducive to relatively more rapid healing, and produces a new skin of considerably better trophic condition—hence assisting quicker return to normal function.

The effect of the oily base is probably entirely physical and many varieties of oil have been used with equally good results. Apart from ensuring an even distribution of the sulphonamides over the surface of the burn—and into all its cracks and crevices—it also prevents any rapid absorption into the blood-stream, hence producing a long-continued non-toxic but protective, blood-sulphonamide level.

The sulphonamide powder should be applied by shaking through gauze bags (containing a measured quantity) of two or more thicknesses. Tulle-gras or vaseline gauze is then gently spread over the surface and coverings of wool and bandage applied. The sulphonamide-oil mixtures (" cetavlon " ointment and cream are examples) are best applied on the smooth side of lint, which, where necessary, can be cut into the shape of a face-mask, or made into large gloves for the hands.

Re-dressings should be done as little as possible, but the patient's comfort is increased by daily moistening the lint on the outside with oil. Many superficial burns will heal under the first dressing if left undisturbed and in the deeper burns, after two to three weeks (and perhaps as many dressings) the surface should be sufficiently covered in good granulations to skin-graft.

Furunculosis of surrounding skin is not uncommon and is best treated by gentian violet.

This is a method capable of general application from forward areas to base, from time of burn to day of healing, by any reasonably skilled person and its ingredients are cheap, easily obtainable and efficacious in action.

The use of *Penicillin* is still in the experimental stage, but preliminary reports suggest that when supplies become adequate, it may have a big future.

*Saline baths* (thermostatically controlled) and irrigation three times a day for twenty minutes with hypochlorites in a *Stannard envelope* (or Bunyan bag) are both methods which produce satisfactory results, but which have only very limited practical application in a field force.

(ii) *Dyes.*—" Triple dye " (gentian violet, brilliant green and euflavine) has many supporters, but it would appear to have all the disadvantages of the tans (*q.v.*)—except the production of toxaemia—without any very positive advantages. Perhaps its greatest field of usefulness is on the face, where it is relatively easy to apply.

(iii) *Coagulants.*—In that all war burns are for all practical purposes infected, tanning methods should have small place. A comparison has already been made above between the tans and the sulphonamide-oil mixtures, in which the former (even when perfectly satisfactory) do not come out well. Further, sepsis when it does occur under a tan is difficult to deal with ; pressure on a tan (often very hard to avoid) softens and ruins it ; and tannic acid itself has recently been shown to be a liver poison—and hence probably to some extent

it may be directly responsible for cases of burn toxaemia. This last consideration does not apply to the silver nitrate tans.

It is not denied that there is a place for coagulant methods given carefully selected cases, adequate surgical facilities and considerable surgical skill and experience, but these desiderata are so hard to come by—together—in the field that it is felt not only that the tans have a very small practical application, but also, that they constitute an actual danger.

### (C) After Treatment.

*Centres.*

There is much to be said in favour of segregating the more serious burns cases in a special centre, but it should be understood that even where this is feasible it in no way absolves every medical officer from understanding the rudimentary principles and being able to carry out the essential treatment of burns. Only a relatively small proportion of burns should require segregation and this should be carried out in such a manner and at such a time that it does not adversely affect the patient's condition.

In such a centre it would be possible to obtain :—

(*a*) *Special nursing.*—There is no more arduous case to nurse than the severe burn, and not only the patient's comfort but his actual chance of survival very often depends on the constant care and meticulous attention to detail of a specially trained nursing staff.

(*b*) *Special equipment*, as, for example, saline baths and a superficial X-ray therapy set for the treatment of early keloids.

(*c*) *Special diets.*

*Rehabilitation.*

It cannot, however, be too strongly stressed that rehabilitation should constitute an essential part of burn treatment from the moment the case comes under medical care. Movements should be encouraged from the time of application of the first dressing, long periods in bed should be avoided wherever possible, and gentle massage of the new skin (with a simple oil or, if available, lanolin) should be practised.

*Skin-grafting*

Finally, must be mentioned one of the greatest advances in recent war surgery—early skin-grafting. This is a procedure which can be carried out by any surgeon and the saving in " hospital days " effected by this means is enormous, to say nothing of the avoidance of scarring and deformity and the improvement of function. A burn which does not appear likely to heal by itself after two weeks' treatment, should be viewed as a possible field for grafting. The presence of sepsis does not vitiate the results, though streptococci particularly will account for some failures. Where frank pus is still present some form of " pinch " graft should be used; but if the exudate has become largely serous a Thiersch graft will usually take. The presence of reasonably healthy granulations is the one essential in skin-grafting, and it is wise to dust the burn with sulphonamide powder before applying the graft. The optimum time for grafting is between two and three weeks after the injury.

If a burn has produced total skin loss, grafting is imperative if scarring is to be avoided ; in the more superficial burn, it will accelerate the healing process to a remarkable extent.

**Chemical and Electrical Burns.**

In general it can be said that a vesicant agent must be wiped off as soon as possible, and some simple dressing applied—anti-gas ointment for mustard, an acid (*e.g.* vinegar) for an alkali, and vice versa are obvious examples.

Phosphorus burns should, if possible, be washed with 2 per cent. sodium bicarbonate and treated with 2 per cent. copper sulphate—and in this instance oily dressings must be avoided.

Apart from this exception this class of burn can be, and from a practical point of view, should be, treated on exactly similar lines to the thermal burn.

## SECTION XXVI

# SURGERY IN THE TROPICS, AND TROPICAL DISEASES OF SURGICAL SIGNIFICANCE

### GENERAL POINTS

1. In malarious districts trauma, whether accidental or by designed surgery, may precipitate an attack of malaria even though suppressive quinine or mepacrin has been taken regularly. This should be kept in mind when a patient develops a disquieting temperature, pulse and malaise a day or so after an injury or operation, and therefore a blood film should be examined.

2. The exhibition of some of the quinine derivatives, especially of plasmoquin, is, on rare occasions, followed by intestinal colic so severe as to mimic intestinal obstruction, acute appendicitis and even perforated gastric or duodenal ulcer. Vomiting, collapse and rigidity may all be present, but the latter lessens or disappears on inspiration, and thereby differentiates it from that of peritonitis. Absence of distention and positive results from enemata will exclude the diagnosis of obstruction.

3. Remember the discomfort caused by overheating. Great care must be taken not to use too many bed-clothes. In semi-conscious or helpless patients this is especially important, and blankets should not be applied to the extent that the patient sweats profusely. A convalescent case during the day is often most comfortable with nothing more than pyjama trousers and a sheet. On the other hand, in some parts of the tropics the nights are very cold, and blankets should then be applied, or placed at the foot of the bed so that they can be pulled up by the patient in the early hours of the morning.

4. Patients should be given plenty to drink—six to twelve pints daily—for by unconscious perspiration they lose fluid more rapidly than in temperate climates, and bed-ridden patients develop urinary gravel and even stone very easily.

5. Because of excessive sweating in the tropics operation wounds tend to become moist and mildly infected. The following points will help to combat this difficulty :—

(*a*) Tie skin stitches with knots to the side, not along the line of incision where they cause minute points of pressure necrosis.

(*b*) Avoid wool, bandages and binders. Use small patch dressings fixed with elastoplast or adhesive, which prove no more irritating than in

temperate climates. In the absence of adhesives a cracker dressing with a second piece of gauze encircling it is an effective substitute.

(*c*) Remove alternate stitches on the second day and the remainder on the fourth or fifth—wounds heal more quickly in hot climates, probably because of the peripheral vaso-dilatation engendered by the heat.

## DISEASES

The diseases listed below are the ones most likely to concern the surgeon. A brief description accompanies those not fully treated in the text-books.

### 1. Tropical Ulcer.

The legs of most natives show scars of healed ulcers. Some of these are a manifestation of skin yaws, but 90 per cent. of them are of traumatic origin. They are most common on the lower third of the leg, usually anteriorly but also posteriorly, and on the dorsum of the foot. They are due to the unshod habits of the native, as even soldiers wear boots and puttees (or gaiters) only for work. Diet and physique play a part, but the essential cause is trauma in a hot humid climate where the scratch rapidly becomes heavily infected with a great variety of organisms. The lesion rapidly breaks down into an ulcer with flat edges surrounding a filthy, slimy, smelly, purulent centre. They vary in size from a thumb-nail to the palm of the hand, and unless they are treated with vigour they cause many months invalidism. X-ray films show osteoperiostitic and osteomyelitic appearances.

*Treatment.*

The 10 per cent. showing the specific spirochaete of yaws and a positive Kahn blood-reaction—and these two tests should be made in all cases—are treated with arsenicals and respond readily.

There are various effective treatments for the remaining 90 per cent., but all commence with two or three days cleansing with fomentation or hot saline soaks, and the following is the quickest way of returning them to duty.

Under anaesthesia scrape the ulcer bed and freshen the edges. Then apply 5 per cent. silver nitrate or 2 per cent. chromic acid solution and enclose in elastoplast or plaster of Paris.

This method was found to be the quickest in over one hundred cases, only the very large ones took more than four to five weeks to heal.

### 2. Stubbed-toes.

This is again an accident happening to the unshod native. The toe-nail is torn off, leaving a narrow basal rim and the nail bed becomes heavily infected. The vigorous treatment of scraping the nail bed, applying 5 per cent. silver nitrate solution and enclosing in elastoplast, avoids many weeks of off-duty. An essential part of the treatment is first to remove the basal rim of nail which otherwise appears to act as a foreign body, keeping up the suppuration.

### 3. Pyomyositis.

This commences as a tender, painful swelling, increasing in size, in one or other muscle, the pectorals, deltoid, thigh and calf muscles being commonly affected. A superjacent oedema and cellulitis soon develop, followed by fluctuation, and there is constitutional disturbance. The patients usually show a recently healed ulcer, and there is often a story

of a blow on the affected muscle. Sometimes the march of events is very slow, and instead of pus formation there is a fibrous tissue reaction within the muscle, converting it into scar tissue. This is often a sequel to sulphonamide therapy which, in spite of the responsible organism being the staphylococcus, sometimes leads to immediate constitutional improvement.

*Treatment.*

Before fluctuation—rest and heat and perhaps sulphonamides. After fluctuation—incision.

**4. Yaws.**

This widespread disease is encountered amongst native troops in several forms :—

(*a*) Crab-yaws of the feet.
(*b*) Involvement of tendons giving lesions like ganglia
(*c*) Skin yaws.
(*d*) Bone yaws.

(*a*) The unshod native has immensely thick plantar pads. Sometimes deep cracks appear in the soles of the feet which are very painful and quite disabling. At the bottom of each crevice is a linear ulcer from which the specific spirochaete can sometimes be isolated. The Kahn blood reaction is positive.

*Treatment* is ineffective, and it is best to discharge the man from the Service.

(*b*) Large, smooth, elastic or cystic subcutaneous swellings in the region of tendons, especially of wrist and ankle, appear. Those of the wrist are often of the compound palmar type. These swellings are partly solid and partly cystic and consist of a granulomatous mass originating in one or more tendons and largely replacing them. The solid part is of pinkish yellow colour and the cystic spaces contain yellow sticky fluid. Rest on a splint allows the latter to absorb, but the solid element remains: neither is it influenced in size by arsenicals.

*Treatment* is surgical excision combined with arsenicials. Should joint movements be markedly affected it would be wrong to do this before boarding out of the Service.

In investigating these cases the Kahn blood reaction should always be taken for the ordinary ganglion as we know it in the British Isles does occur in the native. A negative Kahn would favour the latter diagnosis.

(*c*) Multiple superficial ulcers affecting the trunk, arms, and especially the genitalia and adjacent portions of the thighs, should always make one examine for yaws. Specific treatment is rapidly effective.

(*d*) The spirochaete causes a localised periosteomyelitis. The typical story is that the patient complains of pain in an arm, hand, or leg, and limitation of function may result. At first there is little or nothing to find on examination, and no radiographic changes. The patient continues to suffer pain. By the end of three weeks it may be possible to detect some thickening of the bone but it is unusual to get any oedema or thickening of the muscle. X-ray films often show cortex erosion with little periosteal involvement, but differential diagnosis from syphilis is difficult. Several bones may be affected simultaneously. The Kahn is positive and there are usually scars of healed ulcers of skin yaws. Exhibition of arsenicals is effective in causing pain to subside and the bone change to stabilise. No surgical intervention is necessary.

5. **Subacute Staphylococcal Periosteomyelitis.**

This is not common, but from time to time one meets a case giving a history much like that of bone yaws, yet the blood-Kahn is negative and the X-ray films are vaguely different. The periosteal reaction gives a laminated appearance, and suggests a series of recurrent reactions. Therapeutic tests with arsenicals show no benefit. There is a mild leucocytosis and slight constitutional disturbance, and the pain suffered is considerable and disabling. The laminated appearance on radiographs is due to alternating layers of sub-periosteal new bone and granulation tissue from which latter the staphylococcus aureus can be grown after about forty-eight hours plating, but there is no pus formation.

*Treatment.*

Incision through the periosteum and subjacent reactionary products down to the shaft of the affected bone, with removal of any sequestrum, followed by light packing with vaseline gauze leads to rapid improvement in general comfort. A little suppuration develops but the wound soon heals by granulation tissue. It is worth giving sulphadiazine by mouth.

The ordinary form of acute osteomyelitis of childhood familiar in this country, is also encountered at the civilian native hospitals.

6. **Lymphogranuloma Inguinale (L.G.).**

It is no unusual thing for a native to suffer from several forms of V.D. at the same time. Only lymphogranuloma inguinale (L.G.), sometimes called tropical bubo, will be considered here.

L.G. is a virus disease of venereal origin occurring in the tropics. The primary lesion appears from two to five days after coitus in the form of minute pustules or ulcers, rather like herpes, on the glans, prepuce or body of the penis. It is painless and fleeting, often having disappeared within two or three weeks. The secondary—and characteristic—lesion develops from three to eight weeks after coitus and consists of swelling of the glands of the inner part of the groin. Four distinct stages can be recognised :—

(i) A solitary freely movable gland, adherent to neither skin nor deeper tissues. It may be painful and tender, but often gives no symptoms at all.

(ii) The gland becomes adherent to skin and deeper structures, and surrounding glands begin to enlarge. The skin becomes oedematous, sometimes the periadenitis causing a large, hot, plum-coloured, brawny, oedematous mass. Sometimes the external iliac glands are also enlarged and can be felt as a mass just above Poupart's ligament in the iliac fossa. There may be considerable pain and tenderness with limitation of hip-joint movements. The constitutional reaction may be considerable, and in the white races severe, with high temperature, rapid pulse, headache, vomiting, jaundice and cough. In the untreated case this stage may last many weeks.

The section of a gland at this stage is pathognomonic, being packed with minute abscesses.

(iii) Softening takes place at one or more points and fluctuation develops. The minute abscesses have coalesced, and incision reveals a cavity broken up by trabeculations of fibrous strands and filled with sterile, glairy, sticky fluid which adheres to the cutting knife.

(iv) The mass breaks down and fistulation occurs followed rapidly by secondary infection.

Treatment is essentially medical. It is true that many cases in stage (i) subside spontaneously, and indeed many never report sick, but of those who do one can never foretell how many will progress to stage (ii) if no treatment is given. It is also true that the gland can be excised and the patient be returned to duty within twenty-one days, but this needs hospitalisation.

Stage (ii) may be accompanied by such discomfort and general disturbance that the patient has to be taken into hospital. Excision, however, should not be attempted as the wound usually breaks down. Medical treatment causes the mass either to subside or rapidly to pass into stage (iii).

Never be tempted to incise the fluctuating mass of stage (iii). Secondary infection invariably follows, and the case takes many weeks to recover. These fluctuating areas should be aspirated with aseptic technique, and the process may need to be repeated two or three times. Medical treatment is applied at the same time.

If the patient first reports when in stage (iv) he must be put to bed and treated with sulphonamides, for the secondary infection is the real problem.

The condition is so common amongst natives that glands in the groin fitting in with any of the four stages described, and not associated with either sepsis in the areas drained by the glands, or enlargement of the glands elsewhere in the body, can confidently be diagnosed as lymphogranuloma. Where septic lesions are present, which may be the cause of the adenitis, Frei's intra-dermal test will differentiate.

The treatments available are :—

(*a*) Rest in bed and application of heat ; or
(*b*) Intravenous injection of antimony tartrate ; or
(*c*) Injections of triple typhoid vaccine which causes a pyrexia ; or
(*d*) Three courses, at weekly intervals, of sulphonamide, the total amounting to 100 gms. These heroic doses mean that careful watch has to be kept on the white cell count, but the treatment is very successful, and relatively inexpensive ; or
(*e*) Injections of anthiomaline (antimony) if available. This is a useful drug, for it gives little reaction and can be given by the unit medical officer in unit lines. It requires no special apparatus, being merely an intra-muscular injection. But it is expensive.

7. **Filariasis.**

There are many forms of this disease. The dramatic elephantiasis is only encountered in the Army in its very earliest stages, and once the diagnosis is established the man is boarded out of the Service. Rare forms are chyluria, chylous ascites, filarial synovitis, etc., but the three types relatively commonly met with amongst native troops are :—

(*a*) Loa-loa—Kalabar swellings.
(*b*) Onchocercus volvulus.
(*c*) Dracontiasis—Guinea-worm.

(*a*) Those serving in West Africa will meet this condition. It is only temporarily incapacitating and affects white troops as well as native. It is conveyed by the bite of certain mosquitos and the parasite gives rise to fugitive swellings in the subcutaneous tissue. These are puzzling to the uninitiated for the swellings look as if they are patches of cellulitis which

will suppurate, but whilst awaiting this event they disappear spontaneously after a few days, only to appear elsewhere. Several patches may be present at one time, and the swellings may for a while seem to be in the underlying muscle.

(*b*) Onchocercus volvulus appears as hard, painless, freely moveable, subcutaneous tumours, roughly spherical in shape, with a slightly rough surface. Common sites are in the region of the great trochanter and on the chest wall. It is transmitted by the bite of a species of sandfly or buffalo gnat. The treatment is surgical excision. The tumour consists of a thick firm fibrous capsule, with a small central cavity containing the coiled up worm in yellowish fluid.

(*c*) The guinea-worm is the most important of the filarioidea from the military point of view, since it is incapacitating.

Infestation results from drinking water containing the cyclops quadricornis, the intermediate host. Its prevention therefore is a matter of water discipline.

The full cycle and the treatment are excellently described in all the text-books.

The other conditions of interest to the surgeon are all well described in text-books, and he should study them before arriving at his destination. They are :—

8. Bilharzia—schistosomiasis.
9. Jigger-flea.
10. Tumbu-fly.

## SECTION XXVII

## MALARIA AND THE SURGEON

In malarious districts trauma, whether accidental or by designed surgery, may precipitate an attack of malaria even though suppressive quinine or mepacrin has been taken regularly. The possibility should be thought of whenever a patient develops unexplained malaise, temperature, pulse or abdominal symptoms a day or so after operation or injury.

The combination of head injury and cerebral malaria (M.T.) is a particularly dangerous one, for the uninitiated or unwary will attribute all the cerebral symptoms to the injury whereas, in fact, the parasite may be largely or even wholly responsible. Lives have been lost as a result of this error, for in the absence of correct treatment cerebral malaria is fatal.

Another pitfall is when, two or three days following trauma of the kind that might have damaged one or other kidney, the parasite (M.T.) causes massive haemolysis, heralded by the passage of dark urine (blackwater fever). An inexperienced surgeon, down the line, might think the colour of the urine could be explained by old blood, and although its examination under the microscope would immediately reveal the absence of red corpuscles, he would not think of employing it.

Always remember, malaria may occur in other than tropical countries. Always remember, trauma may precipitate an attack of malaria in any of its forms, for a fighting force nowadays contains men who have served in all parts of the world, and whose blood, therefore, may contain any of the

different types of malarial parasite. When working in a malarious district, or when dealing with a patient who has served overseas, think of the possibility of malaria whenever symptoms are not satisfactorily explained by the injury alone, and especially in cases of injuries involving the head or trunk. When there is the least doubt get a blood film examined and obtain the help of a medical specialist.

There is another aspect of malaria that concerns the surgeon. His co-operation may be sought over a case of malaria undergoing routine treatment in the medical wards (malignant tertian malaria itself). Quinine and its derivatives sometimes cause intestinal colic of such severity as to mimic obstruction, gall-stone colic, perforated peptic ulcer, or appendicitis. Vomiting, rigidity and collapse may all be present. Under such circumstances it is wise to watch the case hour by hour, taking careful note of the pulse. There is usually something in the picture that does not fit in with these diagnoses properly—the pain is too sudden and severe and the rigidity too diffuse for appendicitis; on the other hand, the onset is not sufficiently catastrophic, nor the pain correctly sited for perforation; the absence of distention and good results from enemata are against intestinal obstruction. Nevertheless, these cases are very difficult.

## SECTION XXVIII

## REHABILITATION

Rehabilitation can be defined as the restoration to health in the shortest possible time of those who have become unfit by injury or disease. In this process skilled medical and surgical treatment come first. The advantages of physical treatment are obvious, but perhaps the more important side is the psychological. The improvement in morale and the avoidance of the depression which prolonged hospitalisation tends to produce, is of incalculable benefit.

There is urgent need for rehabilitation treatment in the Army. Such treatment is desirable for every patient, and is especially necessary for those who will eventually be fit for duty, but whose disability will involve a long convalescence.

Experience has shown that a large proportion of patients after a stay in a military or E.M.S. hospital and afterwards at an auxiliary hospital, arrive at a military convalescent depot in a lowered state of morale and with impaired discipline, due to lack of planned activities for body and mind directed in a graduated way towards recovery of health and keenness as a soldier.

**Stage 1. At Military Hospitals.**

Owing to the limited number of beds and the early discharge of patients to auxiliary hospitals, the average stay in a military hospital is short, and therefore planned rehabilitation should be simple and consist of :—

(*a*) *Occupational therapy* in the wards, especially for bed patients. This is mainly diversional and should be carried out with the co-operation of the medical officer, the ward sister, personnel of the A.E.C., and visiting women handicraft workers. Basket, rug and camouflage net-making, etc., are examples of the type of work.

(*b*) *Physiotherapy*, should be carried out by masseuses holding the Chartered Society of Physiotherapy qualification. Every effort should be made to encourage and extend these departments in military hospitals. It is essential that the physician or surgeon concerned visits the department regularly to review the patients under treatment. Exercises form an important part of treatment and should be not only remedial, *e.g.* for an affected limb, but also general to maintain fitness. It is not sufficient to carry out exercises once daily for some twenty minutes. In addition, five minutes every hour should be spent doing exercises by all patients whose medical condition permits. The masseuse or P.T. instructor superintends when available. Stiff hands, stiff feet and wasted muscles can be largely avoided by these means .

**Stage 2. At Convalescent Hospitals,** usually in U.K., B.R.C.S. or Order of St. John.

These hospitals act as auxiliaries to the parent hospitals and serve the purpose of relieving beds. Patients retained in these auxiliary hospitals are those who are still in need of skilled medical or surgical supervision at regular intervals, and a proportion of these will be bed patients. This system is working satisfactorily in connection with certain military hospitals. The patients are visited regularly by the appropriate specialists from the parent hospital, although under the immediate care of the local visiting practitioner. The type of rehabilitation required is :—

(*a*) *Occupational therapy*.—For bed patients this, as at military hospitals will be mainly diversional and should be run on similar lines.

For *ambulant* patients the type of work which demands little mental or physical effort should not be encouraged. The patients should be occupied in more active and useful ways, graded according to their disabilities. A daily programme of fatigues, games and lectures is drawn up in consultation with the surgeon or appropriate specialist to include light fatigues inside and outside the hospital, gardening, wood sawing, and other work useful to the community ; organised games, marches and P.T. under supervision by an army P.T. instructor.

It is equally important to keep the patient's mind active. For this reason education in subjects of military and general interest should be stimulated by the provision of lectures by combatant and education officers, the promotion of discussions, debates, etc.

(*b*) *Physiotherapy*.—This will be on lines slimilar to those mentioned under military hospitals.

*Long-term Rehabilitation Centres.*

These centres receive patients who, although unlikely to be fit for some time, will not require frequent medical and surgical supervision and many of whom are sufficiently advanced in convalescence to be ready for a hardening programme. These centres also receive those patients who after trial have been found unable to stand up to the more vigorous regime at the military convalescent depot.

It is important that there should be as little as possible of the hospital atmosphere at these units, and that there should be a return to discipline and to a more military life.

It is equally important that daily time-tables of work, lectures, etc., should be arranged, so that the patient has a fully regimented day.

*Physiotherapy.*

The apparatus can be quite simple and much of it, *e.g.* weight and pulley machines, can be improvised. More time will be devoted to harder training, including games, drills and marches as preparation for the military convalescent depot, but individual physiotherapy will be required for some of the patients.

**Stage 3. At Military Convalescent Depots:**

This is where the final state of rehabilitation is carried out and only those patients should be admitted who are no longer in need of medical or surgical treatment. They should be able to participate in active graded P.T. and organised games, as a result of which they should be fit for full duty with their units within a period not exceeding six weeks.

It is emphasised that the proper and efficient functioning of the convalescent depots is of the greatest value in conservation of man-power.

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