A field surgery pocket book : memoranda mainly based on experience in the 1939-45 War / prepared under the direction of the Director General of Army Medical Services.

G. B. ARMY MEDICAL SERVICES.

A field surgery pocket book.

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INTRODUCTION

The first edition of this pocket book was published in January 1944. Early in 1943 it had become apparent that something of the kind was necessary if the lessons learned as the result of widening experience in the treatment of war injuries were to be disseminated throughout the Army. Unfortunately, due to causes beyond the committee's control, there was considerable delay in distribution, with the result that some surgeons in distant commands did not receive their copies until 1945.

It has become obvious that certain amendments are now required. In so far as advances in therapy can be said to have become established practice, they have been incorporated in the text. Contributions have been made by surgical consultants, advisers, specialists and others, all writing from experience in the field. Many will recognize their own work and sometimes even their own words pirated in a good cause, with this the only acknowledgement made.

Most of the introduction to the first edition remains true today. The evolution of weapons of destruction has proceeded apace and worse may be yet to come, but the same surgical problem has been repeated in every war and is likely to be the same in the next—the missile which on impact and on its onward journey bears devitalization and infection to whatever tissues may impede its passage.

It must be repeated that this pocket book is not to be regarded as a treatise on "Military Surgery." It should rather be accepted as a directive on "Surgery in the Field" both in the forward and base areas. As such, it attempts to direct the attention of army surgeons to methods which have by experience and general consent proved most likely to lead to the best results. It seeks to stimulate interest in the problems associated with surgery in the field, and to impress upon all the value of team work, all with the object of attaining and maintaining the highest possible standard of efficiency as regards traumatic surgery, throughout the army. A field surgery pocket book should advise on field surgical procedures, it should not elaborately detail those later procedures which more fittingly can be carried out by experts after evacuation to home bases. It should not appear to invite surgeons to tackle work of the latter description in the field. On occasions in this respect, this edition may appear to err, but it errs with the purpose of covering the eventuality of evacuation becoming an impossibility. There have been occasions when a Field Surgery pocket book included in a box of Red Cross stores has been the only text book on the subject available in a prisoner-of-war camp.

The early and adequate surgical treatment of the wounded or injured soldier saves lives and limbs, conserves function, and prevents suffering both early and remote. Successful intervention at the primary operation is of both military and national importance; military in that it is an important factor in keeping up to strength the army in the field, and in that its influence for good on the fighting morale of the troops is incalculable; national in that the final—and pensionable—disability is reduced, while the worker is enabled to return to fuller function in industry.

The work, particularly in the forward zones, calls for knowledge, skill, judgment, stamina, and stability, but most of all for the wisdom derived from experience in the treatment of severe wounds and of battle conditions.

Many an able surgeon with ample experience of the type of surgery met with in civil practice finds himself utterly at a loss when, for the first time at an advanced operation centre, he finds himself confronted with an overflowing pre-operation tent. It follows, therefore, that all surgeons should graduate for this forward work by stages, from the base forwards, gaining all the time in experience and resourcefulness. They will learn in the process that many of the accepted procedures and techniques of civil life will not work in the field.

There must be standardization of surgical equipment in the interests of supply. Most field surgeons doubtless will agree that the greater the experience of a surgeon in this type of work the fewer the instruments he is likely to demand or regard as essential.

So also there must be a measure of standardization of the methods of treatment. Post-operatively it may be necessary to evacuate as many as are fit to travel. Each surgeon therefore must regard himself as a single member of a team of surgeons sited from battlefield to base, and realize that ultimate success will depend on the correct integration of the surgical efforts of each member of the team.

Much is to be learned from the study of previous campaigns. The medical service of the British army has gained its experience in every climate, in the cold, wet, infected mud of Europe, in scorching deserts and tropical jungles, in mountains and veldts, in invasion and evacuation, in hurried withdrawal, in static warfare, in precipitous advance. From battlefield to hospital has sometimes been a matter of an hour or two's journey over good roads, sometimes a trek of three weeks over a roadless waste. In practically every conceivable condition and climate we have gained our experience and learned to modify surgery according to these conditions.

Many expert field surgeons are now well versed in the surgery of successful war. It should not be forgotten that when surgeons are experienced, are available in numbers adequate to deal with any influx of wounded within the recognized time limits, when all necessary facilities can be and are provided, when conditions permit far forward surgery with the certainty that the next leap will be forwards and not back, when the air above is not dominated by the enemy, under these conditions, great benefits must accrue to the wounded. There will be the possibility of full resuscitation for all requiring it, and of chemotherapy at appointed times, the ability to close 90 per cent. of wounds within a matter of days, the power to hold cases, to afford good nursing, to site special centres where best they may function.

We are sometimes accused of always being prepared for the last war. Certainly it would be unwise to neglect the problem of too many high priority cases awaiting the attention of too few surgeons, of supplies not being available according to plan, of wounded in such numbers—85 per cent. of atomic casualties are surgical—and evacuation so complicated, that resuscitation and chemotherapy plans break down and surgery is late not early.

When the military situation is unfavourable, the methods of perfection may be impossible, but good and proved alternative methods still remain available. The closed plaster, after the basic minimum of surgery, is safe for patients held in hospital and has the added advantage that the after-care of hundreds so treated can be a comparatively simple matter, for those not doing well can be recognized almost at a glance.

In the interval between wars there may be surgical innovations of great promise but they will not have been tested under all the exacting conditions

of war, so briefly mentioned above. So far as chemotherapeutic drugs are concerned, the pocket book will require amendment, antibiotics yet unknown will make their appearance, the method of administration in the future may be on quite different lines, and dosages will be more standardized.

It may be that many years will elapse before the need for a field surgery pocket book will arise. Even so, this edition should not have become obsolete. The policy of early adequate surgery was *the* lesson of the South African War, and some of the teachings of the old masters of 1917 were being rediscovered a quarter of a century later. It is the duty of those who go, to record the lessons learnt, and of those who come, to study them.

GLOSSARY

I. ABBREVIATIONS

RAP	Regimental Aid Post.
RMO	Regimental Medical Officer.
ADS	Advanced Dressing Station.
CCP	Casualty Collecting Post.
CCS	Casualty Collecting Station.
FDS	Field Dressing Station.
FST	Field Surgical Team.
FTT	Field Transfusion Team.
Gen. Hosp.	General Hospital.
L of C	Lines of Communication.
MAC	Motor Ambulance Company, R.A.S.C.
RHU	Reinforcement Holding Unit.
FM Card	Field Medical Card (A.F.W. 3118).
AFV	armoured fighting vehicle.
OC	Officer Commanding.
ORA	Operating room attendant.
WE	War Establishment.
ORs.	other ranks.
a.t.s.	antitetanic serum.
a.g.g.s.	anti gas gangrene serum.
d.p.s.	delayed primary suture.
s.s.	secondary suture.

(II) SOME DEFINITIONS OF TERMS

Team

Two or more individuals grouped and working and training together for a specific object. Teams are always attached to a parent unit for pay, discipline, rations, etc.

Surgical Team

A team concentrating on surgery, generally with a surgeon in charge. A team 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 authorized W.E. to which an individual may be posted. Equipped in accordance with the purpose for which it was authorized, it is independent and self-accounting.

Surgical Centre

A locality where a unit or group of units is situated. These units are 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 Advanced

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."

Organization of the " Surgical Service " in the Field

The reader is referred to R.A.M.C. Training Pamphlet No. 2 (1949) 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 and wounded unlikely to respond to rest, or such treatment as is available in the Divisional or Corps Areas, within twenty-four or forty-eight hours, 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 surgeons, 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 out-put—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 down, but will tend to deteriorate, either from sheer fatigue or staleness.

SECTION I

CARE OF THE WOUNDED IN THE FORWARD AREA

Every man carries on him a first field dressing and. when wounded, he or some comrade applies it to the wounded part. He makes his way, if he can, to his RAP or CCP. If more seriously wounded he is collected by stretcher bearers as soon as possible. At either of these posts larger dressings and splints are available, and all RAMC personnel should be expert in the application of the Thomas' splint.

The guiding principle in the handling of seriously wounded men in the forward zone is their rapid collection to, and by ambulance from, the CCP to an ADS.

Speed at this stage is of very great importance. It must be the aim of medical officers who collect and evacuate, that casualties will reach the next stage of their journey in better condition than when they left the previous one, but too much time should not be spent in the process of resuscitation. Time is precious and one of the treatments for shock is operation. It may be much better to give a severely shocked man a pint or two of plasma or blood, continue the process by drip transfusion in the ambulance and send him to an appropriate surgical centre.

AT THE REGIMENTAL AID POST

1. Medical officers should always bear in mind that the RAP is inevitably, from the surgical point of view, dirty. The treatment at the RAP is therefore confined to essential first aid measures. Bleeding must be stopped; an open pneumothorax hermetically sealed; a limb hopelessly damaged and attached by a thread, amputated; splints applied. When morphia is given, or a tourniquet applied to a patient, an "M" or "T" respectively is marked with grease pencil on his forehead : and details giving times are entered up on his FM Card. Clear concise particulars of the wound and its effects, details of chemotherapy, etc., are recorded on the card, all in *legible* writing, signed by the medical officer (name in print).

2. The wounded man must be made as comfortable as possible. After the necessary first aid has been applied, he is gently warmed if cold, if there be no contraindication is given hot sweet tea, food, cigarettes. An atmosphere of cheerfulness should pervade the RAP.

3. Not every minor casualty requires evacuation. Some only need a dressing, perhaps an antitetanic injection and a meal, and are then ready to return to their units for duty, or for transfer to a rest station.

4. It is seldom that a tourniquet is necessary. Its use is only justifiable when local pressure fails to control bleeding. All RAMC personnel should be aware of its dangers, and when on account of haemorrhage its application has been deemed necessary, an orderly in attendance during evacuation should be instructed to release it cautiously every 20 minutes, only re-applying it when bleeding recommences. It is repeated that when a tourniquet has been applied, the fact MUST be recorded on A.F. W 3118 and on the forehead. A forgotten tourniquet leads to certain gangrene. This is the worst preventable medical catastrophe in war. (*See also* Section XV)

5. Generally speaking, transfusion is inadvisable at the RAP, but circumstances of isolation may alter cases.

6. All AFVs carry first aid outfits including " tubunics " (1 cc. Omnopon = Morph. Tart. gr. ¼ for injection) and crushable ampoules, containing chloroform minims 40. The former are of far greater practical value than the latter. The teaching of first aid is of even greater importance to A.F.V. crews than to infantrymen.

7. Burns. An extensive sterile or clean cloth should be applied to the burn and well beyond it. This should be kept in place by bandages and reinforced by wool to prevent soaking if evacuation is delayed. A nylon derivative envelope which can be applied to the limbs or trunk would be a preferable alternative. Patients with extensive burns of the extremities, as those with tissue lacerations, are made far more comfortable, and travel better when immobilized by splinting.

8. Fractures. Thomas' splints, Gooch splinting and Kramer wire are all available but the latter is too springy for immobilizing the foot. No form of splinting, however well applied, guarantees immobilization unless checked at frequent intervals and adjusted as necessary. Knee and femur cases develop pain because extension is no longer effective. The Spanish windlass extension may require a twist at various staging posts.

9. **Wounds of the Face and Jaws**

At the instant of injury pain is seldom felt. There may be the sensation of a smack on the face, or a bruised feeling, or a temporary failure of vision. Usually the first sign noticed is blood in the mouth or running down the clothing. It is the threat to the airway which is the main risk as the danger of asphyxiation is especially high in the unconscious patient. Cases of facial injury may suffer from temporary unconsciousness or, if there is an associated head injury, unconsciousness may be profound. In this connection also, care must be taken when giving an anaesthetic particularly in the induction phase, and again in the post-operative period when the endo-tracheal tube is removed.

Airway and Posture

The unconscious patient should be placed so that the tongue falls forward and blood and saliva can run out of the mouth. He must be placed in either :

(*a*) the renal operation position.
On the side with the head in the crook of the underarm and with the underknee flexed.

(*b*) completely prone.
The head projecting beyond the canvas of the stretcher with the forehead supported by cross bandages between the handles.

The foot of the stretcher is best kept higher than the head. Care must be taken to ensure that the face is not embedded in a blanket or pillow to which it may become stuck by blood and saliva. The mouth and upper pharynx may have to be cleaned of clot, mucus, loose fragments and foreign bodies by finger or swab. If the tongue is floating a suture through it will enable forward traction to be applied.

A conscious man may think that he best knows his own position of maximum comfort and ease of respiration. There is, however, a real risk in cases of jaw injury, of anoxia if the patient is allowed to lie on his back. All cases

must be shown the proper posture. Nothing must be taken for granted and there should be very frequent checkings of airways and postures.

When posture and simple measures fail to relieve dyspnoea, and evacuation has to be undertaken in difficult circumstances, a tracheostomy may be the only way of preserving life.

The Wound

A shell dressing should be fitted snugly into the wound and extend well beyond. It should be supported by bandages reinforced by strapping. The pressure must be upwards and never backwards on the symphysis. For fractures of the symphysis a barrel bandage is a most efficient support. Semi-detached flaps should be placed in anatomical position and care taken that they are not folded on their pedicles. The shell dressing should be renewed and the wound thoroughly irrigated with saline or water every three to four hours and after each feed.

The Arrest of Haemorrhage

The firm application of a shell dressing together with manual pressure over it for five minutes is sufficient to stop haemorrhage in most cases. When major haemorrhage continues in spite of simple measures a more direct attack is necessary :—

(*a*) Retraction of the wound edges may allow one to grasp the bleeding vessel with a haemostat in which case the artery forceps may be left *in situ* until the patient reaches the C.C.S.

(*b*) The external wound may be securely sutured taking deep bites with stout silk.

(*c*) When the wound communicates with the mouth it should be packed with gauze.

(*d*) The mucous membrane may be sutured to the edge of the wound with emphasis on haemostasis.

The pack should always be removed from the wound within 24 hours. If haemorrhage recurs and the case is still in transit a pack must be reinserted.

10. Chest Wounds

(1) The perforating wound requires little direct attention ; reassurance and calmness are essential and the casualty should lie down and be kept warm. Haemoptysis is common and this should be explained to the patient ; a short rest is indicated before the patient is moved.

(2) The sucking open wound requires active treatment and the essential is immediate closure of the wound to prevent the sucking noise, and to render it air-tight ; an open sucking pneumothorax is fatal because of the effect on the respiratory and circulatory system. Paradoxical respiration is checked at once when the hole is firmly closed by tight strapping or bandaging over a large dressing. This is usually effective but occasionally a few temporary skin stitches are required.

11. Abdominal Wounds

The administration of morphia and rapid evacuation is all that is usually possible. The case which develops signs of general peritonitis early (say, 2—3 hours) with pallor and low blood pressure is bleeding internally, and should be regarded as of equal urgency to the open pneumothorax and

extensive muscle wound. If there is prolapse of omentum or gut, it should not be reduced, but should be protected by an adequate moist dressing. If circumstances prevent evacuation to a surgical centre for some hours, the best treatment is to keep the patient under the influence of morphia (gr 1/6 four hourly) to give in proper proportions intra-venous saline, glucose, or plasma, and to administer penicillin and phthalyl-sulphathiazole.

Abdominal cases do not travel well by air, but a short rapid air journey to the surgical centre may be vastly preferable to the hours of jolting which so often is the price to be paid for surface travel.

12. **Morphia**

Overdosage with morphine is a constantly recurring error. It results from giving subcutaneous injections to a shocked patient whose peripheral vessels are in such compensatory spasm, or whose blood pressure is so low, that the drug is not absorbed. Because he receives no relief from his pain, a second dose may be given which again remains unabsorbed. When finally he is resuscitated there is a comparatively rapid absorption of what may by this time be 1–1½ grains.

The intramuscular route is the most practicable. The intravenous route is the best but is not always possible in many of the circumstances of forward work.

Morphia should not be given as a routine. When pain or anxiety indicate its use, ½ gr. may be given by the first MO to see the case, the time and dose being noted on the FM Card and a letter " M " being pencilled on the forehead.

Patients wounded in the *abdomen* may be given morphia if the diagnosis of perforated gut is quite clear or it is foreseen that, because of temporary isolation, there will be prolonged delay before a surgical centre can be reached ; or to diminish the effects of a journey over rough roads and give emotional rest (*see* Section XIX).

Patients with wounds of the *chest* may be given the full dose advised above, but those wounded in the *head* should only receive small doses (1/6 gr.) to allay restlessness. A large dose raises the intracranial venous pressure and increases the liability to haemorrhage.

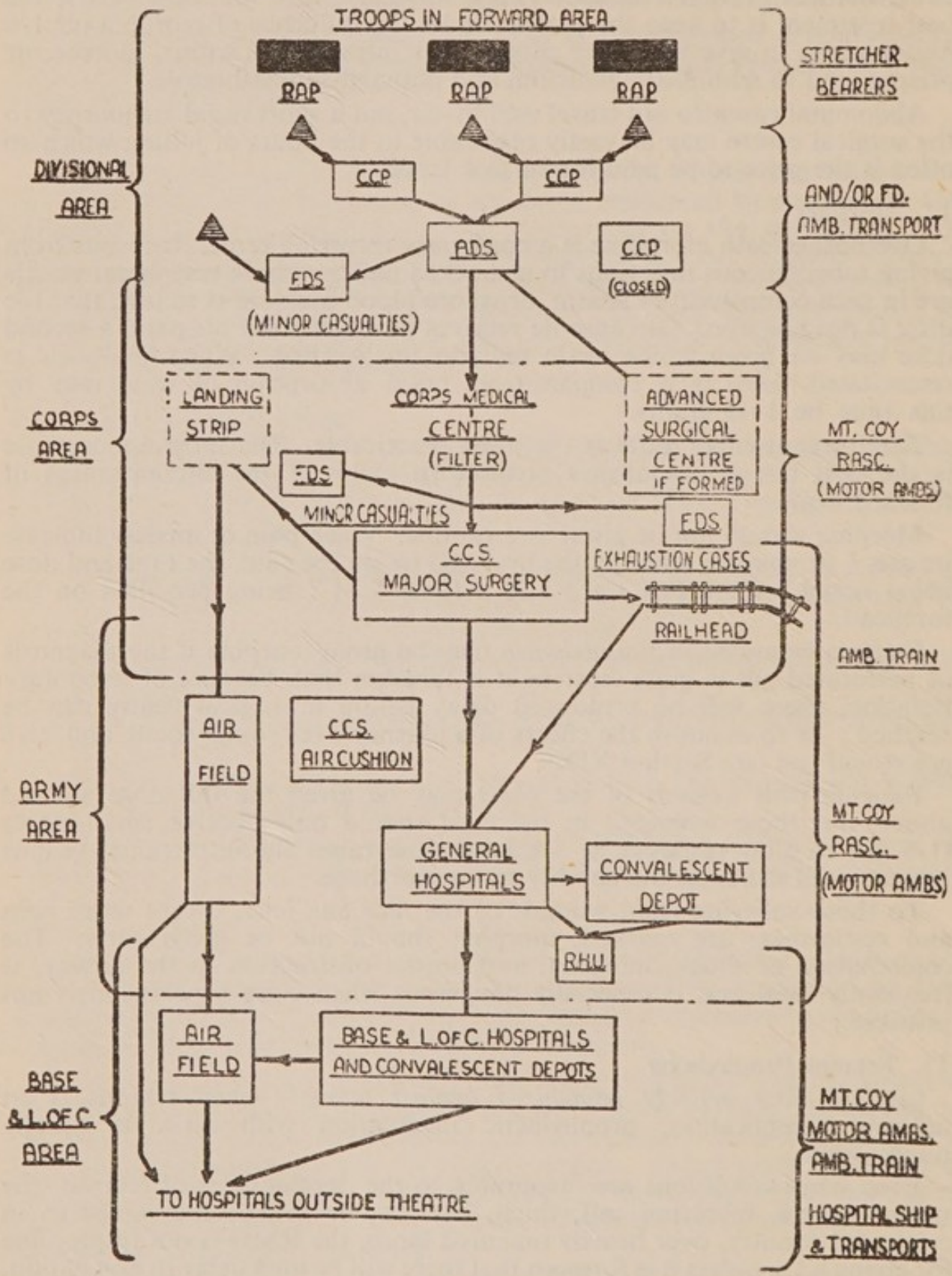
To those suffering from wounds of the *face and jaws*, except when pain and restlessness are marked, morphia should not be given early. The combination of shock, morphia, and partial obstruction to the airway, is frequently fatal and is especially dangerous when close supervision is not possible.

13. **Tetanus Prophylaxis**

(*a*) *For those actively immunized against tetanus*—when tetanus is an unlikely complication, prophylactic inoculation with a.t.s. is usually unnecessary.

Even when conditions are favourable to the development of tetanus (the wound severe, involving calf, thigh, buttock, or axilla ; the campaign in cultivated country, over heavily manured land), the RMO is not responsible for giving a.t.s. unless it is foreseen that there will be long delay in evacuation. Normally the decision to give or withhold a.t.s. is the responsibility of the surgeon who performs the primary operation.

(*b*) *To those who have not received full active immunization* the RMO must give a.t.s. (3000 international units), as previously.


TROOPS IN FORWARD AREA
RAP
RAP
RAP
STRETCHER BEARERS
DIVISIONAL AREA
CCP
CCP
AND/OR FD. AMB. TRANSPORT
ADS
CCP
(CLOSED)
FDS
(MINOR CASUALTIES)
LANDING STRIP
CORPS MEDICAL CENTRE (FILTER)
ADVANCED SURGICAL CENTRE IF FORMED
CORPS AREA
MT. COY RASC. (MOTOR AMBS)
FDS
MINOR CASUALTIES
FDS
C.C.S. MAJOR SURGERY
EXHAUSTION CASES
RAILHEAD
AMB. TRAIN
AIR FIELD
C.C.S. AIR CUSHION
ARMY AREA
MT COY RASC. (MOTOR AMBS)
GENERAL HOSPITALS
CONVALESCENT DEPOT
RHU
AIR FIELD
BASE & L. OF C. HOSPITALS AND CONVALESCENT DEPOTS
BASE & L. OF C. AREA
MT COY MOTOR AMBS. AMB. TRAIN
TO HOSPITALS OUTSIDE THEATRE
HOSPITAL SHIP & TRANSPORTS

CASUALTY COLLECTING POST

14. Casualties are cleared from a Casualty Collecting Post by motor ambulance. Frequently motor ambulances may clear direct from the Regimental Aid Post, short-circuiting the CCP. The CCP should be cleared promptly to the ADS or CCS, for it is only in a very few selected and urgent cases that transfusions will be carried out at this stage.

ADVANCED DRESSING STATION

15. This is the unit in which classification is first undertaken. 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 classification into one of the three priorities is effected preparatory to evacuation :

Priority 1.—Cases requiring resuscitation and *urgent* surgery.
Severe shock from whatever cause.
Open wounds of the chest.
Abdominal wounds.
Very extensive muscle wounds (calf, thigh, buttock, axilla).
Serious open fractures.
Severe burns.
Certain multiple wounds.

Priority 2.—Cases requiring *early* surgery and possibly resuscitation (for operation if time permits, otherwise for evacuation or rest).
Less serious open fractures.
Multiple minor wounds.
Less serious amputations.
Less serious burns.

Priority 3.—All other wounded cases.

Disposal by priority.—Priorities 1 and 2 to the CCS (or advanced surgical centre, if formed) ; priority 3—minor injuries, those who will be fit to return to duty within a few days, go to Divisional FDS ; remainder to CCS.

Classification into priorities 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, considerable discrimination may therefore be required in the proper grouping of urgent surgical cases. One surgical team cannot deal efficiently with more than 15 operation cases in 24 hours.

SECTION II

TREATMENT OF THE WOUNDED AT FORWARD SURGICAL CENTRES

1. The management of battle casualties is not only a matter of first-aid and surgical treatment, but includes every phase of the organization set up for the restoration to working fitness of the wounded, in the shortest possible time.

2. In almost no other circumstances of human activity does an injured man remain surrounded by such hazards as continued danger, delay in

receiving treatment, exposure, dehydration and the further trauma of a long ambulance journey over rough roads. Even the most experienced civilian surgeon must re-orientate himself and learn much before he can become a good surgeon in the field.

3. Weather, time and terrain are factors influencing the behaviour of wounds, and treatment may have to be varied accordingly if the best results are to be obtained. The man wounded whilst fighting in the hot sandy desert and dressed in shorts and an open shirt is a different surgical problem from the man wounded in winter whilst wearing many thicknesses of clothing soaked in the liquid mud of highly cultivated soil. In either event, the time factor—whether the wound is two or twenty hours old—is a matter of great importance.

The experience of two world wars has shown the following principles to be fundamental to the surgery of war :

(i) Every war wound is contaminated, but infection remains relatively superficial for about the first 8 hours, after which it penetrates into deeper tissues.

(ii) Some product of lacerated and devascularized muscle is absorbed into the circulation and leads to profound and prolonged depression of blood-pressure. After about 3 hours it is impossible to restore the blood-pressure until the damaged muscle has been removed.

(iii) Pieces of indriven clothing and equipment are dangerous sources of infection, more so than are metallic fragments. It has always been agreed that X-ray examination is advisable in chest, abdominal, and abdomino-thoracic wounds. Whenever possible it should also be a preliminary to operation on wounded limbs, not from the point of view of showing up a fracture, but to indicate the site of a foreign body. Where a foreign body lies, there are likely to be pieces of indriven clothing.

(iv) Gas gangrene is a specific infection of devitalized muscle, and anything that embarrasses the circulation of the limb, such as tight bandaging or badly applied splints, will encourage its development.

(v) Shock results from loss of blood but also from pain, exposure, dehydration and the absorption of the products of dead muscle.

(vi) The adequate treatment of a wound consists in the removal of all devitalized tissues—frayed skin, tags of fat and fascia, all muscle that does not bleed or contract when cut with knife or scissors, and indriven pieces of clothing or equipment. Sulphonamides and penicillin are valuable adjuncts but no substitute for good surgery.

(vii) The time factor is all-important ; if a wound needs operation at all, it needs it at the earliest moment possible.

(viii) Frequent inspection of wounds at staging posts is meddlesome and inevitably leads to super-imposed infection. Unless the patient's temperature, pulse and general comfort are unsatisfactory, the wound should not be exposed until the occasion of the delayed primary suture.

(ix) Abdominal casualties do badly in noise, whether due to enemy shelling or to our own guns. Even though it postpones operation 1–2 hours, it is almost always better to evacuate them to a surgical centre in quiet surroundings. Following operation they also travel badly ; they should never be evacuated in under 7–10 days.

(x) The treatment of a war wound is a two-stage operation : the first, performed by the surgeon at the forward surgical centre, is concerned with the saving of life and limb but also prepares the wound for the second stage. The latter—the closure of the wound—is carried out after evacuation, at a centre on L of C or Base, where the patient can be held. The more universally this policy can be adopted, the better will be the results.

It is necessary that the surgeon should have some 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*) *Corps Medical Centre.*—This is normally a group of one or more CCSs and one FDS situated as far forward in the corps area as is practicable, depending on the tactical situation and the availability of roads and buildings. Two FSTs and one FTT will normally be attached to each CCS ; the CCS is responsible for their administration.

(*b*) *Advanced Surgical Centre.*—This is established *only when circumstances do not permit moving forward a CCS.* It is formed by attaching two or more FSTs and one or more FTTs to one of the Corps FDSs together with four nursing officers from a CCS. The OC FDS administers the centre. It will be established as far forward in the Corps area as is practicable, and is intended for use as a stop-gap only until such time as the CCS can be moved up.

Personnel and Duties

FST (2 officers and 8 ORs).

Surgeon (Specialist)	1
Anaesthetist (Graded)	1
Operating Room Assistants (1 Sgt) ..	2
Clerk, clinical	1
Nursing Orderlies	2
General Duty Orderlies and Drivers ..	3

FTT (1 Officer and 3 ORs).

FDS (7 Officers and 115 ORs).

This unit is not designed for major surgery but it can hold and nurse patients either before or after operation until they are fit for evacuation

One or more FSTs must be attached to enable it to function as a surgical centre.

CCS (16 Officers, 131 ORs, 22 Nursing Officers).

This is a unit capable of holding 200 sick or wounded (120 on beds, 80 on stretchers). It includes two surgical teams, and can cope with major surgical cases.

Equipment

The FDS carries 40, and the CCS 120 light beds for serious cases. They should prepare in advance, stocks of dressings sufficient for approximately 100 operations. Sterile vaseline gauze squares 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 includes overalls with detachable sleeves, caps, masks, and boots,

rubber or linen, but the surgeon should be prepared, in emergency, to work in a clean mackintosh overall, and if necessary without gloves.

The Situation and Administration of Forward Surgical Units

This question can be answered only by the administrative staff. The decision in any particular set of circumstances must be left to it. Both the siting and administration of these units will depend on a variety of factors—whether the warfare is static or one of movement ; whether the fighting is desultory or active ; on terrain, whether desert, open fertile country, or mountainous ; and finally whether in advance or retreat. The medical objective, however, is to bring surgical aid to battle casualties as nearly as possible in accordance with the ten fundamental principles enunciated above. This will not always be easy. The tactical situation, enemy shell fire, temporary road blocks, etc. may complicate the problem of evacuation. The consulting surgeon on his visits to the various surgical centres observing the state of the wounded as they arrive at ADSs, FDSs and surgical centres, by collecting reports from the surgeons and resuscitation officers particularly with regard to the time lag after wounding, can do much by constant co-operation with the administration, to obtain the best results in difficult situations.

There are certain general principles. 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 not economical, are difficult to control, to service, and to clear. From the administrative point of view, the fewer the centres the better. A large medical unit makes a good centre because accommodation is good, nursing more adequate and the equipment available is on a more lavish scale. A centre at a CCS, for instance, will have the advantage of electric light throughout, X-ray service, more ample sterilizing and laundry facilities, etc., and here in most circumstances skilled nursing is provided by officers Q.A.R.A.N.C. Whenever possible a corps FDS is sited alongside a CCS to act as a filter for minor cases. Grouped CCSs 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 wound-time-lag rising beyond the accepted limits of surgical safety. Again it must be remembered that the CCS has another function to perform, that of dealing with the more lightly wounded. Surgery is just as important for these cases, and indeed from the point of view of saving man-power, even more so.

Special Centres—orthopaedic—for femoral and complicated fractures, neuro-surgical, maxillo-facial, thoracic, vascular injuries, peripheral nerve injuries.

When conditions permit, cases of these types are best segregated in special centres at the Base, sufficiently far back to draw cases from several routes, and in hospitals large enough to hold them for some considerable time. Sometimes it may be of value to site the light sections of neuro-surgical and maxillo-facial units on L of C in Army Area, to screen off the relatively trivial cases—provided that they can be held for the few days until stitches can be removed.

Types of Wound—(sites)

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.

Reception of Wounded

In static warfare surgical centres have the opportunity of becoming "settled in and well established," and can deal with convoys of wounded without difficulty, but in a war of movement and this was usually the case during World War II, a surgical centre may be called upon to close down, move at short notice, and open up on arrival at a site some 10-20 miles distant. Less commonly, during a rapid advance, single surgical teams may have to leapfrog each other, working for 2-3 days and then moving on again ; on very rare occasions, as when a temporary road-block can be foreseen, a single team may be sent forward to work at an ADS for the specific purpose of dealing with casualties in whose case a delay of 1-2 hours may make the difference between life and death—the uncontrolled pneumothorax, the major muscle wound (particularly buttock and thigh) and the abdominal wound with internal haemorrhage.

The principles of classification into priorities have already been explained, more from the point of view of evacuation and disposal. At the surgical centre casualties must be arranged in the order they are to be sent to the operating room. In the main, this order depends on the severity of the wounds, but actual fitness for operation must also be taken into account. For instance, a particular chest wound patient may be more seriously ill than a particular abdominal case, yet because the latter has responded earlier to resuscitation he is fit for operation first.

The reception of patients should be in the hands of an experienced officer who should possess not only sound clinical judgment, but also an appreciation of the general situation and a knowledge of the medical units behind and in front of his own, since it is upon these facts that decisions regarding disposal, depend. In larger centres this duty is often performed by the transfusion officer, a highly satisfactory arrangement. At an advanced centre all except priority 1 cases, after simple resuscitation, must be sent on. The temptation to retain less serious cases must be overcome for the fresh arrival of more priority 1 cases inevitably leads to postponement of treatment until long after it could have been given at a less busy centre further down the line.

When it appears likely that the unit will have to move, even some priority 1 cases should be evacuated if it is moderately certain that a further journey lasting 1-1½ hours will not involve serious risk. This applies particularly to abdominal wounds as it is these patients who embarrass a unit about to move, orderlies having to be left behind to look after them.

On the other hand, during quiet periods an opportunity is given to operate when the surgical time-factor is ideal, and even priority 2 cases can be dealt with at forward centres. There is always one best time to operate, once past, it never returns.

It should be borne in mind that the majority of the wounded have probably had an exhausting time and a very rough journey before reaching the centre, most are mildly and many are severely dehydrated, most will require rest, fluids and gentle warmth—not overheating which will increase dehydration. Cases should not be rushed to the table unless there is free bleeding, but it should be remembered that after 3-4 hours those suffering from major muscle wounds are unlikely to respond to any form of resuscitation until the dead muscle has been removed by local excision or amputation. A priority list is started to which amendments can be made as worse cases arrive. Pre-operative blood transfusions are given as required. In many cases it is an advantage to start an infusion of saline or glucose, continuing it during operation. Some anaesthetists set up a drip in nearly every case so that the tubing can be used for the injection of more pentothal, a.g.g.s., and various other forms of therapy.

Treatment of the Wound

The average time taken for a priority 1 case is one hour, and no one team can be expected to deal with more than 12-16 heavy cases in 24 hours. Experience shows that when more is undertaken, judgment is liable to fail and the standard of work falls—exhaustion and sound work are incompatible. The Hercules surgeon must remember that the other members of his team are unlikely to possess similar stamina.

Delayed Primary Suture

The great lesson of World War II was that if wounds are treated properly 90 per cent of them can be stitched up about five days later with an excellent prospect of primary union in over 90 per cent of cases. This means that the formation of massive scar-tissue is eliminated, that compound fractures can be converted into simple ones, that persistent sinus formation is prevented, that prolonged invalidism is avoided, and that men are restored to fighting fitness in the minimum of time.

The General Principles of Wound Treatment

Every primary operation is in preparation for delayed suture about five days later, and for any subsequent reconstruction work that may be necessary. It has the following three 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 ligate where possible, any torn or damaged larger blood vessel.

(*c*) To relieve local tension by incising fascial compartments thereby permitting the escape of blood clot, at the same time designing the operation in such a way that free drainage is established. Counter incisions may be required.

Technique of Wound Excision

A wide area of skin surrounding the wound is washed with soap and water or C.T.A.B. and shaved. The frayed edge of skin is removed, but no more than this, since not only is skin remarkably viable, but every particle

conserved is of vital importance five days later when the wound is closed. Skin is the best " dressing," encouraging healing without scar formation. The wound is extended sufficiently to allow retractors to be inserted to its full depth, so that a full inspection can be carried out. This necessitates generous longitudinal incisions into the deep fascia, these decompress the oedematous and congested tissues : with the same object in view it is sometimes desirable to incise the deep fascia transversely also. Tags of fat and fascia are removed, and all muscle that does not bleed or contract when cut with knife or scissors must be excised. This latter is the most important part of the operation, since incomplete removal of dead muscle carries with it the risk of gas gangrene and the certainty of sepsis which will nullify the general policy of delayed suture. The inspection should include a search for pieces of indriven clothing or equipment, as also for any readily accessible fragments ofmetal. All nooks and crannies that might form pockets of pus should be laid open. Under the influence of penicillin, clean pieces of bone detached from periosteum may be retained, since they become incorporated in callus. At the end of the operation penicillin-sulphonamide powder is insufflated into the wound. Under no circumstances is packing employed, and only in those cases certain to be detained at the Centre for 7-10 days, e.g., abdomens and abdominothoracic cases, are wounds stitched. When a general policy of delayed suture of wounds is practicable, and the first dressing will be under anaesthesia, dry dressings are best, but when circumstances make this impossible, a dressing of gauze impregnated with vaseline containing 5 per cent suphanilamide has been found preferable. For major muscle wounds treatment with antibiotics should be carried out.

Relatively superficial through-and-through wounds may be dealt with by laying open the track by cutting across the bridge of tissue, but if deep, it is better to treat each wound separately, as above indicated.

Adequate splinting is essential. Quite apart from fractures, every extensive wound of muscle should be so splinted as to include the joints above and below, otherwise they travel in discomfort : penetrating wounds of knee-joint, put up in Thomas' knee splint with extension, will become uncomfortable unless effective extension is maintained by the occasional tightening of the Spanish windlass at different staging posts. Fingers and toes must be left free in order to avoid stiffness. Toes must be protected from the weight of blankets by some such device as a ring of wire or plaster (" kettle-handle ") in the plane of the sole. It is a fundamental rule of the surgery of war that when plaster cases are applied they must be split before evacuation.

In the absence of pain or toxaemia following operation, no inspection of the wound should be made until in the theatre of the hospital at which the delayed suture is to be carried out.

These principles apply equally to all soft tissue wounds, whether of limbs (with or without fractures), chest-wall, back, axilla or trunk. Once it was appreciated during World War II, that in penetrating chest wounds the chest-wall required this same " excision " technique, followed at once by closure of the muscles to produce a hermetic seal, the empyema rate fell from over 30 per cent to below 5 per cent. When, for medical reasons, it is essential to hold certain cases for 7-10 days at a Forward Centre—*e.g.*, abdominal wounds—primary suture may usually be employed. This is not breaking the rule of never applying primary suture to war wounds since there is no intention of evacuating them until after stitches are due to be

removed : the fundamental fact is that " stitches and ambulance journeys are incompatible."

Tetanus Prophylaxis

For those actively immunized, serum prophylaxis is unnecessary when tetanus is an unlikely complication. When from the nature of the terrain and the site of the wound, tetanus is to be feared, it is advisable normally to give a single dose of 3,000 units of anti-tetanic serum. On occasions when it is considered that there is grave risk, this dose may be repeated at weekly intervals. To those not actively immunized, the preliminary 3,000 units should have been given at the RAP. This dose is repeated at weekly intervals.

Records

Clear, concise notes should be written 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.) He must state :—

1. Missile (whether removed).
2. Time after wounding when operated on.
3. Resuscitation given.
4. Operative findings and techique (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."

Some Don'ts

1. Do not excise any skin unnecessarily.
2. Do not incise the constricting fascia inadequately.
3. Do not waste time searching for foreign bodies except in vital situations, especially in the absence of X-rays.
4. Do not insert rubber drains or wicks. A gauze drain soaked in discharges swells and in time acts as cork.
5. Do not suture the wound (exceptions : certain head wounds, abdominal wall, open pneumothorax) except by d.p.s. when case can be held till healed.
6. 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. Avoid the use of safety pins.
7. Do not omit to split plaster cases before evacuation.
8. Do not be guilty of not being ruthless enough when dealing with gas gangrene, nor of being too ruthless when dealing with anaerobic cellulitis (q.v.).

Treatment during Transit to Base

During the journey from forward area to base, the patient has his creature comforts attended to, is given food, drinks, morphia if necessary, continues his travelling transfusion, receives antibiotics as ordered. His dressings are not undone unless haemorrhage or gas gangrene make it essential. It may

be justifiable to replace the *outer* dressing, and his splints may require adjusting. The position of the inert patient must be changed at one or two hourly intervals, day and night.

AIR TRANSPORTATION

When air evacuation was in its infancy certain types of surgical cases were considered suitable for transportation by air and in the following priority :—

1. Maxillo-facial injuries.
2. Burns, especially of the hands and face (after shock had been overcome).
3. Perforating wounds of the globe of the eye.
4. Limbs and joints (if suitably splinted so as to be transportable).
5. Heads.
6. Spines, etc.

Very soon patients suffering from eye injuries complicated by prolapse of the iris were given the highest priority. Head injuries were raised then lowered in the list, the conclusion having been reached that their best disposal was to a neuro-surgical centre even if it took up to three days to arrive there.

Listed as unsuitable were the following :—

1. Those shocked or likely to develop shock (given 24-36 hours' treatment before air evacuation).
2. Abdominal and thoracic wounds.
3. Recurrent and severe haemorrhages.
4. Acute abdomens.
5. Gas gangrene before treatment.

Several of these obviously are unsuitable for high altitude flying, and obviously require preliminary treatment, but there can be no hard-and-fast rules. A rapid air journey lasting minutes may spare a very ill patient several hours of lethal jolting by surface route. As so often occurs in war, the correct treatment and disposal may be a counsel of perfection and so often the lesser of two evils has to be chosen, the ideal being ruled out. By the end of World War II, it was accepted that the only type of patient who did not travel reasonably well by air was the wounded abdominal who had had an adequate surgical operation.

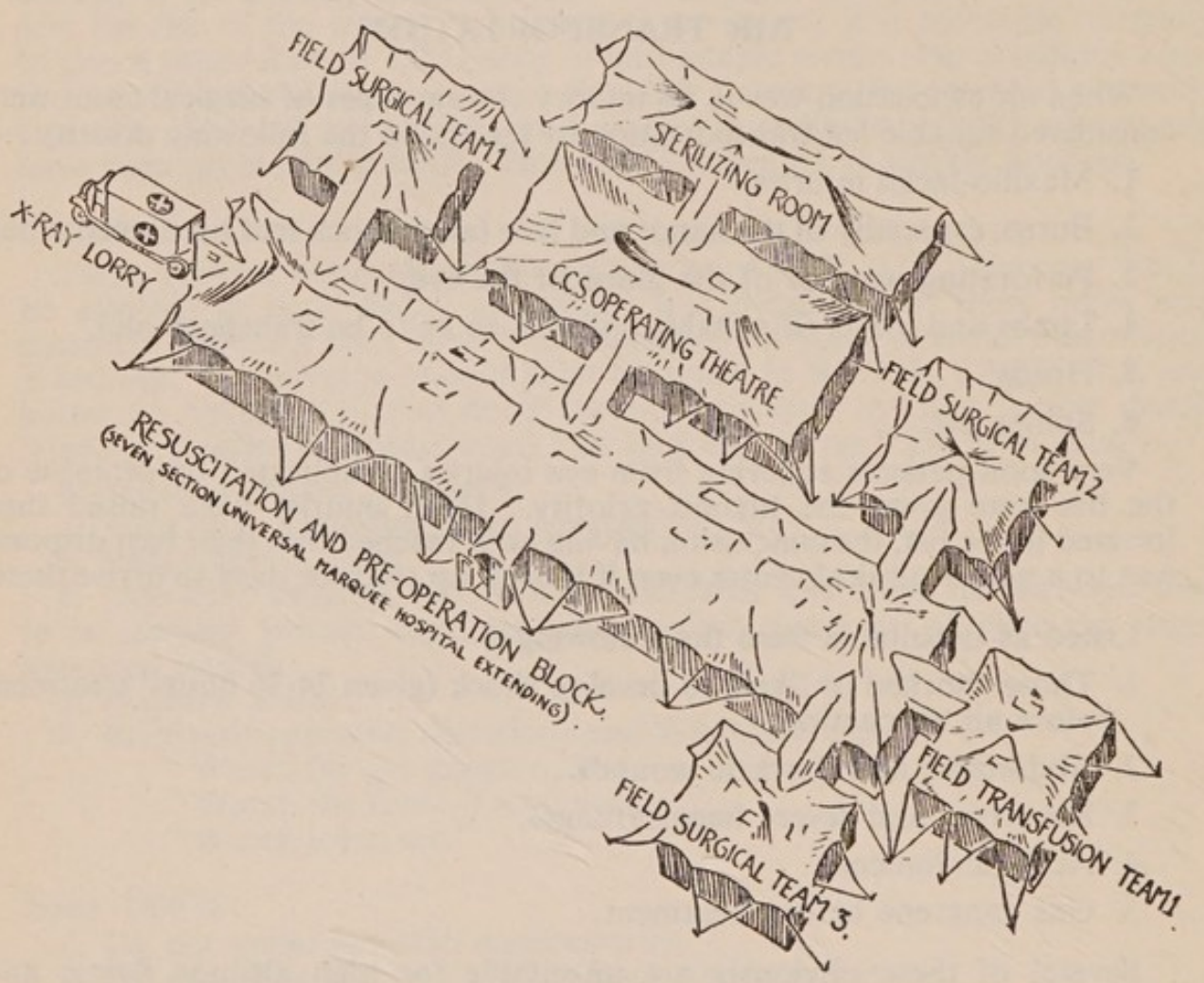
Evacuation by Helicopter

Westland-Sikorsky helicopters, modified for the evacuation of casualties, are available in Malaya, and have been used successfully under operational conditions.

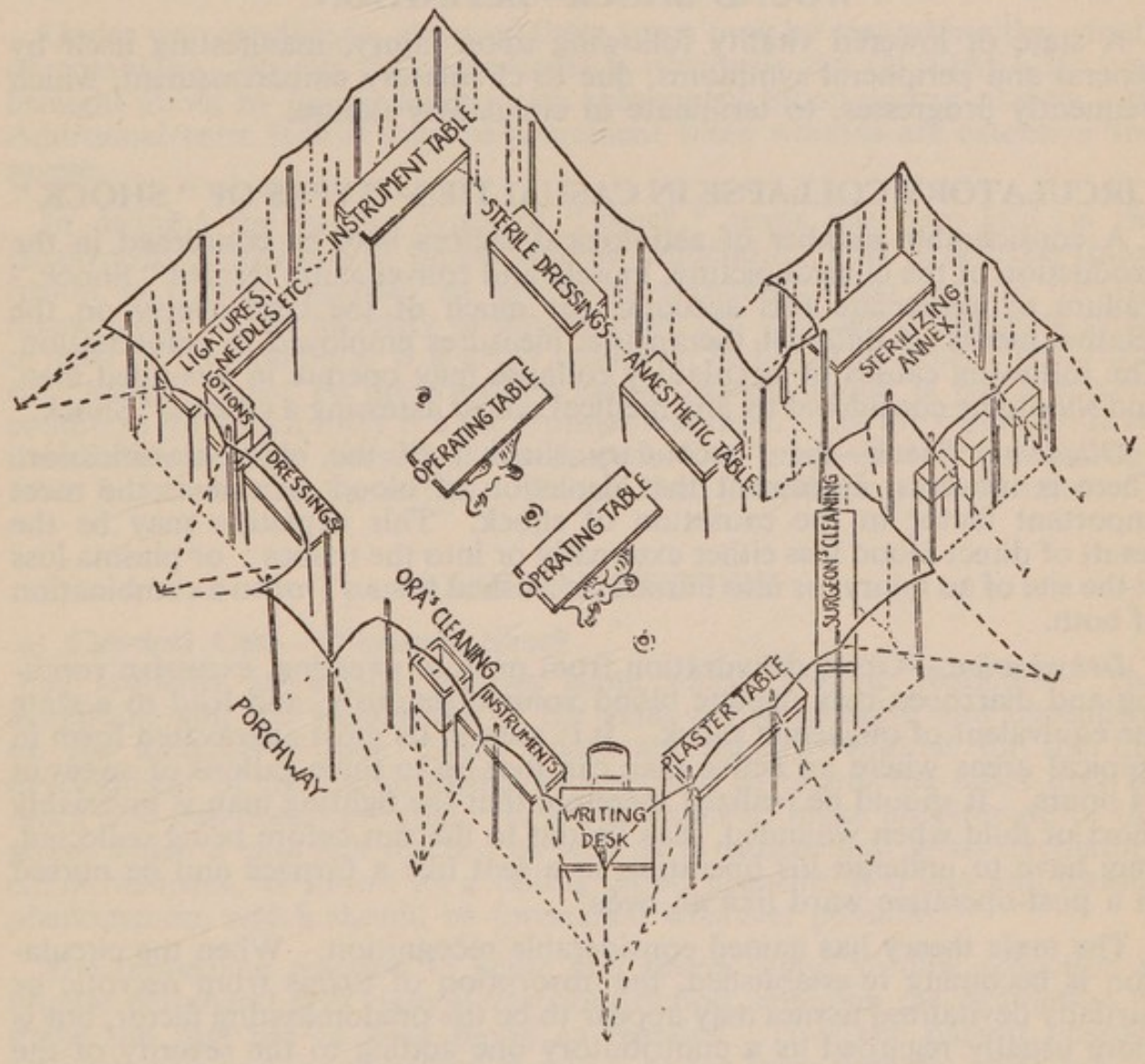
Experiments are also taking place on other types of helicopter with suitable modifications.

A full appreciation of the limitations of these aircraft by both medical and combatant officers and the closest co-operation with the Royal Air Force are essential.

SUGGESTED LAYOUT OF SURGICAL BLOCK OF C.C.S.



SUGGESTED LAYOUT FOR AN OPERATING THEATRE



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."

Oligaemic Shock—the " secondary shock " of the older classification. There is universal agreement that depletion of blood volume is the most important factor in the causation of shock. This depletion may be the result of direct blood loss either externally or into the tissues ; or plasma loss at the site of an injury, or into burned or crushed tissues ; or to a combination of both.

Dehydration.—Gross dehydration from profuse sweating, excessive vomiting and diarrhoea may deplete blood volume seriously, and lead to a state the equivalent of oligaemic shock. It is seen in its most aggravated form in tropical areas where an active man can lose up to three gallons of sweat in 24 hours. It should be realized therefore that the fighting man is invariably short of fluid when wounded, may lie out in the sun before being collected, may have to undergo his operation in a tent like a furnace and be nursed in a post-operative ward like an oven.

The **toxic theory** has gained considerable recognition. When the circulation is becoming re-established, the absorption of toxins from necrotic or partially devitalized tissues may appear to be the predominating factor, but is more usually regarded as a contributory one adding to the severity of the condition.

Examples quoted as evidence in favour of the theory are the deterioration in the patient's condition which follows the removal before operation of a tourniquet worn for some time, and the renal failure which may cause a fatal ending to a severe crush injury. The presence of these " tissue " toxins may account to some extent for " traumatic " fever, for the increase in protein breakdown with nitrogen loss, and for the anaemia which so frequently occurs in patients recovering from severe injuries.

Carbon monoxide poisoning may occur under war conditions in casualties injured in a confined space to which coal gas or explosive gases have access, or in a burning building, and give rise to symptoms of shock from toxic action on the vital centres and from pulmonary oedema.

Neurogenic Shock—the primary shock of the older classification. This is now more generally regarded as vaso-vagal collapse due to emotional distress

or to pain, not necessarily severe. There is no reduction in blood volume. Shock following extensive damage to the brain or spinal cord is in large part neurogenic not oligaemic.

Symptoms comparable to those of shock may occur in other conditions—in fat embolism and thoracic injuries, including blast effects—from mechanical interference with the circulation and not from reduction in blood volume.

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 when wounds are extensive and severe.

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, catechize 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 emphasised 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 ($\frac{1}{8}$–$\frac{1}{6}$ 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 cc. 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 which may be intolerable if blood loss has been severe. The administration of fluid not only gives physical relief but is also of first importance in assisting the natural restoration of blood volume spontaneously. 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 RAPs and casualty collecting posts along the chain of evacuation including motor ambulances. The weak and helpless who complain of thirst must be helped and encouraged to drink. 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 the 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.

Contraindications to the Oral Route.–Unconscious patients and those suffering from abdominal wounds or penetrating wounds which may have damaged the oesophagus are not given fluids by the mouth. All others who complain of thirst should be given drinks freely. Those who are nauseated or have been vomiting are more likely to keep down small drinks (2 oz. every 15 mins.). Large drinks should not be given to anyone likely to be operated upon within two hours, nor should drinks in large quantities be forced on those severely shocked following serious haemorrhage and those suffering from severe chest wounds who are in some danger of developing acute dilatation of the stomach or intestine.

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 99 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. It can be given with the patient on a raised stretcher using a broomstick as an improvised transfusion stand. 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.

Transfusion during an ambulance journey has 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. 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 (ambulance transfusion illustration, page 36).

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 blood, although theoretically necessary, 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. The use of plasma is not devoid of all danger. It is a potentially dangerous fluid which requires discrimination in its use. It may contain the icterogenic agents of infective hepatitis or of homologous serum jaundice. The danger of transfusion jaundice is much greater than after the use of whole blood as the possibility of inclusion of icterogenic agents in a " pool " is much greater than in a single blood. Following the administration of plasma contaminated in this way the number of persons affected may not be large but there have been quite considerable outbreaks with the mortality rate reaching 12 per cent. Until a practicable method of killing the virus is discovered, this risk, in war, must be accepted. There is some prospect that the Swedish product Dextran may be modified in time to prove acceptable as a plasma substitute. Blood should be reserved for selected cases, as described below.

As a general rule, all transfusions should be begun with plasma. If three pints suffice, plasma alone may be given, but when the quantity required is greater and especially if it exceeds five pints, 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. When blood is not available, plasma must replace it in the full amount required, but if the best results are to be obtained, the aim and object of the transfusion service should be to provide stored blood for " forward " use.

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 conditions 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 vaso-dilatation 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 recrudescence 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*.

CONTRAINDICATIONS 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 contraindication 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.

Drugs

There is no 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 effective.

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 must be used to correct severe dehydration when a rapid result is needed, when vomiting or other features prohibit the oral route ; in abdominal cases in which this route of administration is the only

practical and satisfactory way of giving fluid, and in the immediate post-operative period to replace the considerable loss of fluid which may occur during operation.

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 administering fluid 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.

In severe tropical conditions the administration of fluids must become a ritual from the earliest possible moment after wounding and when enough fluid cannot be given by the mouth, it must be administered parenterally. Depletion of the fluid reserves invariably complicates the clinical picture of severe haemorrhage and shock in tropical battle surgery and even when the general condition of the wounded man appears to call for urgent blood transfusion, a pint or two of saline rapidly given as a prelude, may effect a miracle.

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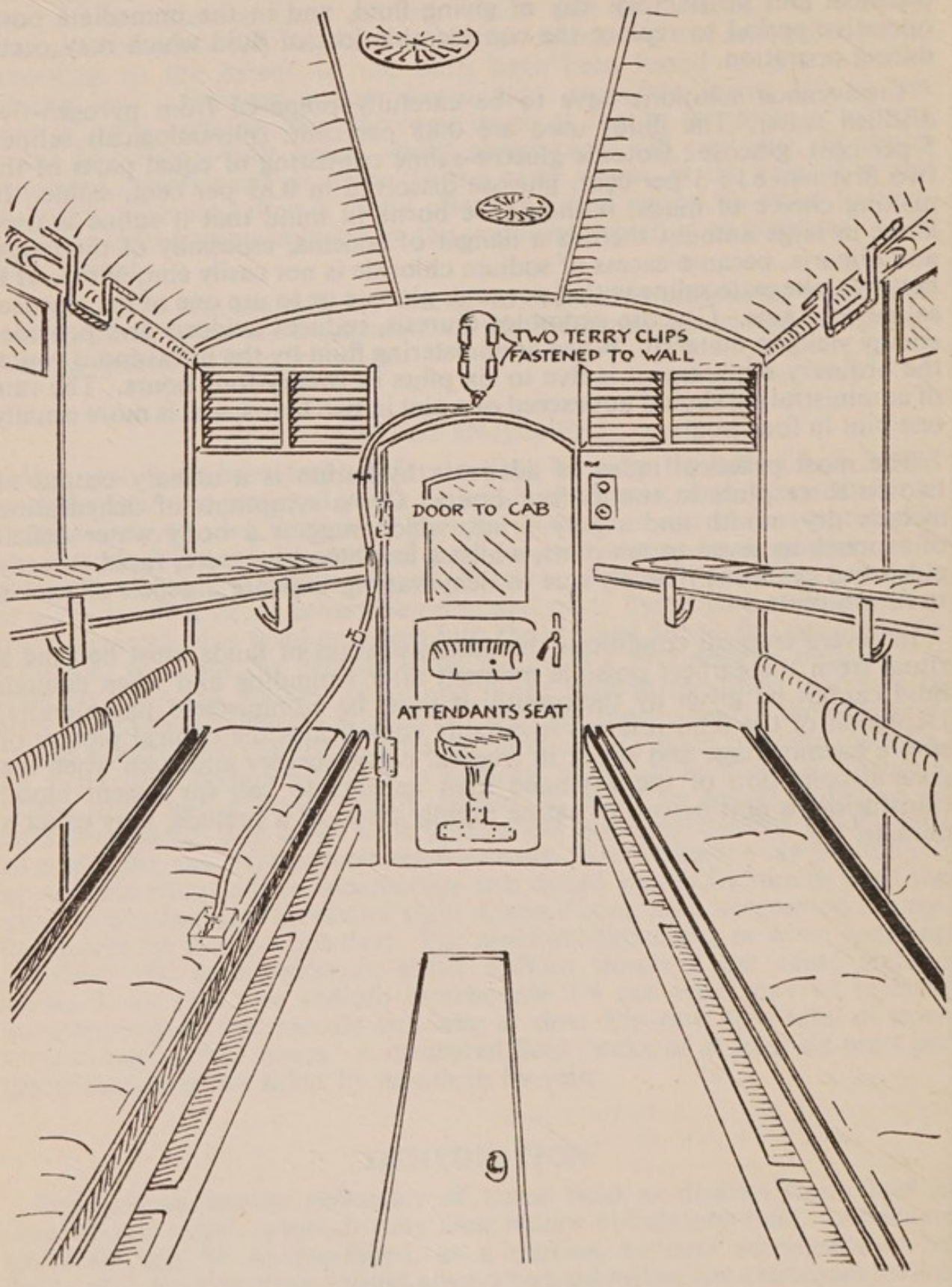

TWO TERRY CLIPS
FASTENED TO WALL
DOOR TO CAB
ATTENDANTS SEAT

SECTION IV

THE CHEMOTHERAPY OF BATTLE WOUNDS

During the period that has elapsed since the publication of the last edition of this pocket book there has been greater progress in the control of infections than has ever taken place before in medical history. The sulphonamides have been largely overshadowed by the rapid establishment of penicillin. Important new antibiotics have been discovered in America and fresh publications continue to appear giving additional proof of their usefulness in a wide variety of infections. Meanwhile, the search is continuing and doubtless further discoveries will be made. Thus in this small section the most that can be attempted is to outline the present trends in chemotherapy.

THE SULPHONAMIDES

Compared with penicillin even the most potent sulphonamides have only a slight action against staphylococci. Given by mouth or applied locally they are of value in controlling local infection by susceptible organisms in superficial wounds. The sulphonamides are antagonized by the presence of pus, and so in the case of deep wounds may be ineffective. However, they will prevent the systemic spread of streptococcal infection from local foci such as wounds or burns. During the North African campaigns it was found that the sulphonamides were no substitute for early forward surgery. At that time the vogue was for excision with drainage followed by immobilization in padded and split plaster casts. When sulphonamides are used the risk of renal damage must be borne in mind, especially when the patient is dehydrated. Sufficient fluid must be given to ensure a daily output of 1,500 c.c. for an average adult, and the urine must be kept alkaline. *Succinylsulphathiazole* and *phthalylsulphathiazole* are exceptions to this rule, for only extremely small amounts of these drugs are absorbed from the gastro-intestinal tract. They are both extremely useful in colonic surgery, suppressing the coliform organisms in the bowel. Daily dosage : Succinylsulphathiazole, 20 gm., phthalylsulphathiazole, 10 gm., given in 4 or 6 divided doses. Both drugs are also being used with great success in the control of Bact. coli infections of the genito-urinary tract.

PENICILLIN

At the present time, penicillin is the most important drug in the treatment of wounds, and its prompt use is advocated for the prophylaxis and treatment of infection in battle wounds and burns. It is effective against a wider range of gram-positive bacteria than the sulphonamides, including most strains of staphylococci, and is not antagonized by the presence of pus. In the treatment of wounds it in no way replaces surgery but aids it in rendering wounds of all degrees of severity safe for delayed primary or secondary closure. Whereas the use of sulphonamides carries a risk of renal damage, especially in dehydrated patients, penicillin is non-toxic. Its main disadvantage compared with the sulphonamides lies in the fact that it cannot economically be given by the mouth. Neither penicillin nor the sulphonamides are effective against the gram-negative bacteria which may infect wounds or burns at a relatively late stage—the stage of sloughing; here the use of one of the newer antibiotics is indicated.

Osteomyelitis.—It is interesting to look back on the early days of penicillin during the last war when small quantities were sent out to the Middle East for trial during the North African campaign. The results were almost unbelievable, limbs being saved when apparently hopeless cases of osteomyelitis were treated by local irrigation with saline containing minute amounts of the antibiotic. Penicillin has completely altered the prognosis of acute and chronic osteomyelitis and of compound fractures. In acute osteomyelitis when adequate treatment is started within the first 2 or 3 days, surgery is usually unnecessary and abscess formation is rare. Chronic osteomyelitis requires both penicillin and surgery. Determination of the sensitivity of the infecting organism—usually *Staphylococcus aureus*—is advisable, and this may indicate the combination of penicillin therapy with sulphadiazine or other antibiotic.

Abdominal Wounds.—Several large series of cases of traumatic abdominal infection and of peritonitis due to appendicitis have been published which indicate the value of penicillin in such cases, both with and without sulphadiazine, and the present tendency is to give penicillin prophylactically and post-operatively to every laparotomy case where infection is likely to occur. Reports of trials during the Italian campaign were not so optimistic. The present position is summed up in the section dealing with abdominal wounds where it is advised that there should be a light sprinkling of sulphonamide (sulphathiazole suspension (Micraform) is the preparation at present issued for this purpose) at the site of intestinal repair, especially when the wound involves the colon; and that penicillin and a soluble sulphonamide should be given for as long as there is danger of peritonitis. It should be remembered that sulphonamides must not be added to blood.

Dosage and Administration.—The dosage of penicillin naturally depends upon the type, situation, and severity of the infection and upon the sensitivity of the infecting organism to the drug. The determination of the latter should be done as a routine in the laboratory where the pathogen is isolated and cultured. The aim in treatment must be to give sufficient of the antibiotic to control the infection rapidly, for inadequate dosage may lead to the development of pencillin-resistant organisms.

Crystalline penicillin is usually given by the intramuscular route at 3-hourly intervals, and the minimal requirement for the control of serious infections is 240,000 units per 24 hours. This dose should be doubled in osteomyelitis. In fulminating infections much larger doses are given combined with intravenous drip. *Empyema.* Following aspiration, infected chest wounds should be given penicillin locally in addition to parenterally —100,000 units being instilled daily into the pleural cavity.

Intracranial Wounds.—Parenteral penicillin does not always penetrate the subarachnoid space in appreciable amounts, so that it is also necessary to inject penicillin intrathecally by lumbar, cisternal, or ventricular puncture —10,000 or 20,000 units daily in 10 c.c. of normal saline after a slightly greater volume of C.S.F. has been withdrawn. It is the present practice in these cases to combine sulphonamide therapy with penicillin and as will be seen in the section on Head Wounds, sulphadiazine orally and sulphamezathine locally are the sulphonamides used.

Advances in Pencillin Therapy.—These consist of measures taken to combat the necessity for frequent painful intramuscular injections, and to slow up the excretion of penicillin through the renal tubules. The suspension

of penicillin in oil and beeswax resulted in slow absorption of the injection but the wax caused considerable pain at the site of the injection. More recently, *procaine penicillin* has been developed. This is a crystalline complex which results from the chemical combination of procaine and penicillin. The crystals are of large particle size and of low solubility, and this results in a slow rate of absorption of the injection, over as long as 48 hours or more. Also, as the result of the procaine in the combination, the injection is comparatively painless. There are reports of cases of lobar pneumonia cured by a single injection of procaine penicillin. At present oily suspensions of procaine penicillin are marketed which contain 300,000 units per c.c. An average dosage is one daily injection of 2 c.c. intramuscularly.

Aerosol penicillin has been popular in America for the treatment of pulmonary conditions. This is being superseded by the inhalation of micropulverized penicillin as a smoke or dust from a small insufflator. The "micronized" powder has a minute particle size of about 1 μ, and appears to diffuse readily through the communicating respiratory passages and assayable levels of penicillin appear promptly in the blood, indicating rapid absorption. One of the most interesting developments in penicillin therapy has been the introduction of *Caronamide*. This substance blocks the passage of penicillin through the renal tubules and maintains high blood concentrations of the drug—ordinarily 80 per cent. of penicillin given intramuscularly can be recovered from the urine. Caronamide is given by the mouth, usually 4 gm. every 4 hours, and is useful in relatively resistant infections which call for higher dosages of penicillin.

Toxicity.—No harmful effect on the liver, kidneys, or haematopoietic system has been observed following the use of penicillin. A small percentage of individuals are sensitive to the drug, exhibiting contact sensitivity, urticaria, malaise with fever, erythematous rashes, or episodes resembling serum sickness occurring up to some 2 weeks after the start of treatment. These sensitivity reactions can usually be controlled by antihistaminic drugs. In patients, however, with a history of sensitivity to penicillin the drug must be given very cautiously and when reactions are severe its use must be abandoned. Fortunately there are now other antibiotics which can be substituted for penicillin in such cases.

Bacterial Resistance.—Ordinarily susceptible organisms can be made penicillin-resistant *in vitro* by exposure to sublethal doses, and in the body inadequate dosage of penicillin may have the same result. Here again another antibiotic may have to be used.

OTHER ANTIBIOTICS

Tyrothricin

This was the first antibiotic to gain an established place in medicine. It was isolated in 1939, after a brilliant piece of research by Dubos, from an aerobic spore forming soil bacillus, *B. brevis*, and it consists of two crystalline polypeptides, gramicidin and tyrocidine. Its range of antibacterial activity is similar to that of penicillin but it is toxic when used parenterally and it cannot be administered in any way to be effective against systemic infections. It is active only when in direct contact with bacteria and it must be used by direct topical application to infected areas. Here it exerts prolonged contact as it is relatively stable and not readily absorbed. Tyrothricin thus has a

place in the local treatment of wounds infected with gram-positive bacteria which are found to be penicillin-resistant, but is likely to be superseded by newer antibiotics.

Streptomycin

Being potent against most gram-negative bacilli, streptomycin is likely to have a definite place in the treatment of infections with *E. coli*, *H. influenzae*, *K. pneumonia* (Friedlander), *B. proteus*, *Ps. pyocyanea*. Some workers consider that streptomycin is the most valuable drug so far developed for the treatment of coliform infections of the urinary tract, in which a short course of treatment—1 gm. t.d.s. intramuscularly for 5 days—has proved effective. Dihydrostreptomycin, which is far less toxic, should be used in cases requiring prolonged treatment. Streptomycin is not absorbed from the gastrointestinal tract and thus it is very useful in the preparation of colonic cases for surgery. In this field it is likely to replace succinyl and phthalylsulphathiazole. A single dose of 1 gm. daily by mouth for 3 days prior to operation and continued for 3 days post-operatively is usually adequate. The drug has also been used with success in the local treatment of wounds infected with susceptible organisms. Unfortunately, streptomycin, like penicillin, tends to give rise to resistant strains of bacteria.

The Polymyxins

Polymyxin and aerosporin are closely similar polypeptides and there are at least four closely related types. Polymyxin is active against gram-negative organisms and does not give rise to resistant strains. It appears to be from 5 to 10 times more effective than streptomycin against Friedlander's bacillus and *H. influenzae*. It is also the most effective antibiotic so far against *Ps. pyocyanea*. It has to be given parenterally and the dosage so far has been 3 to 6 mgm. per kilo. body weight daily, split into 6 equal doses 4-hourly. Unfortunately, polymyxin is nephrotoxic and causes tubular damage. However, in severe systemic infections the danger of the disease may outweigh the danger of temporary renal damage.

Bacitracin

This antibiotic has produced striking results in the treatment of many local surgical infections. Its range of activity is similar to that of penicillin. Unfortunately, it is nephrotoxic when given parenterally and it must only be administered topically or by local infiltration. Its main usefulness lies in the fact that it is often effective against cocci which are penicillin-resistant.

Aureomycin and Chloromycetin (Chloramphenicol)

These new antibiotics have a wide antibacterial range in addition to their action against rickettsiae and some viruses. They both have the great advantage over other antibiotics of exerting a satisfactory systemic action when given by mouth, and they are non-toxic. Against gram-negative bacteria they exert a comparable effect but *aureomycin* is superior against gram-positive organisms and thus is the most versatile antibiotic which we possess at the present time. Resistance to it has been produced in some organisms only with difficulty *in vitro*. Already it has proved life saving in cases of staphylococceal septicaemia which had not responded to penicillin, and it has been found effective in systemic infections with *Strep. faecalis*. Aureomycin, which was discovered in 1948, thus promises to be of great value in the chemotherapy of surgical infections and the results of wide-scale trials are awaited with great interest.

Note

The question of chemotherapy for battle casualties was submitted to the Medical Research Council in November, 1948. The opinions expressed were strongly against the giving of sulphonamides prophylactically by the mouth and equally strongly in favour of an application of a penicillin-sulphathiazole powder locally, or even better a combination of penicillin, sulphamerazine, sulphathiazole, and sulphadiazine.

There still exists a considerable weight of surgical opinion in favour of giving sulphanilamide prophylactically by the mouth as in World War II. Admittedly its action is on the streptococcus which is not the important infecting organism at the time of wounding. There is no guarantee, however, that in a future war there may not be such numbers of casualties, both wounded and burned, as will completely swamp first aid teams and surgeons, and that streptococcal infection may not again become formidable, and more so than that due to the staphylococcus which is neither so invasive nor so deadly.

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. Even in heavily infected terrain, if there is a sufficient number of skilled surgeons to give early and adequate operative treatment to the wounded, the incidence of infection may be as low as 1 per cent., and mortality not much greater than 10 per cent. If surgery, for one reason or another, is neither early nor adequate, conditions resembling the worst days of World War I (with an incidence of infection of 5 per cent. and a mortality rate of 50 per cent.) can be expected. 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 localized " 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, in fact the fundamental factor in the disease is damage to the 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 skin may appear normal however, even when lying over massive gangrene. 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.

Of great importance also is the intense necrosis that results in the liver and kidney cells, and this accounts for the common terminal symptom of scanty blood-stained urine or even anuria.

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 most striking feature is a rapid change for the worse in a wounded man until then progressing satisfactorily. In the course of a few hours he becomes anxious, frightened or euphoric, but remains mentally alert till near the end, although sometimes quite unaware of the seriousness of his condition. The face is pale or livid. Pain in the limb was regarded formerly as a constant feature, but in cases occurring in 1943–45, only some discomfort as a rule was noted. The temperature may be slightly raised but is often sub-normal. A rising pulse in a wounded man who has recovered from shock, and is not suffering from continued haemorrhage, is highly suggestive, it quickly becomes feeble, dicrotic, and running. The blood pressure is low and it may be impossible to record it. Vomiting may be a feature in severe cases. Unless heroic surgical measures are undertaken without delay, the case goes on to a

condition of utter prostration rapidly fatal. The so-called characteristic smell is not pathognomonic of established gas gangrene, many malodorous wounds contaminated with clostridia do not go on to the profound toxaemic state described. The smell may be absent, especially when the infection is due to *Cl. oedematiens*. The presence of gas is also variable in its significance ; until the later stages it may not be apparent clinically ; its presence may be due merely to mechanical introduction at the time of wounding ; it may be palpated subcutaneously in cases of localized anaerobic cellulitis. Gas bubbles may be seen in an X-ray film of the affected part—if an X-ray apparatus should be available.

TREATMENT

Prophylaxis

Every wound of muscle is a potential case of gas gangrene; prophylaxis therefore is of supreme importance and commences with first aid which must be applied correctly. Splints and bandages must give adequate support without constriction, the rules regarding the use of tourniquets must be strictly adhered to, as must also the other rules relating to the care and handling—application of warmth, relief of pain, etc. At the dressing station all gas gangrene-prone cases (extensive muscle wounds involving calf, thigh, buttock, axilla) should be given antitoxin, sufficient of whichever brand is available, to contain 9000 units of *Cl. Welchii*. If there should be a likelihood of delay in evacuation, it may be wise to arrange for the giving of antitoxin at the regimental aid post. The greatest need of the patient in danger of gas gangrene, is for surgery : resuscitation if vital to survival must be with that end in view, and not at the expense of valuable time. These measures and the early adequate surgical treatment of wounds as described elsewhere in this handbook are the best insurance against gas gangrene. Experimental work is at present being done on the possibility of producing gas gangrene toxoids and of combining these with tetanus toxoid.

Treatment of the established case

Severe muscle wounds have suffered severe blood loss. Clostridial toxins and those absorbed from damaged muscle prevent a good response to blood transfusion until damaged muscle has been removed. Preliminary transfusion should therefore be rapid—two pints in half an hour, and a drip kept running in the theatre.

Following rapid transfusion—rapid surgery, all discoloured muscle, and any that does not bleed or contract when cut must be excised. This may mean removing a whole muscle from origin to insertion, partial resection of a large muscle, complete removal of a whole group such as the gluteals, or amputation may be the only hope of saving life when a limb is disorganized by injury and infection. Mottled discolouration of the skin does not influence the level of amputation. The wound is then heavily frosted with penicillin and treatment is completed on ordinary lines. Polyvalent gas gangrene antitoxin (100,000 units intraveneously) and penicillin or whatever antibiotic may be proved most efficacious are given for at least three days, at the same time ensuring that an adequate supply of intravenous fluid is kept up for four or five days. It is possible that one of the newer antibiotics will in time replace serum therapy altogether.

The post-operative period is likely to be stormy ; dehydration, delirium, vomiting, jaundice and anuria may persist or develop.

Streptococcal Myositis

This condition which can only be proved by a careful bacteriological examination should be a rare complication of wounds if surgical and chemotherapeutic treatment has been adequate. The odour, swelling and pain may resemble gas gangrene closely, and there may be gas formation but the condition develops relatively late, eight–ten days after wounding and the characteristic toxaemia of clostridial infection is wanting. A limb severely affected in this way is in danger of amputation by the inexperienced field surgeon. The treatment is by vigorous local surgery to give free drainage and relieve tension, and by chemotherapy.

SECTION VI

TETANUS

Tetanus, or lockjaw, is due to the action of the toxin *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 lightly cultivated soil of France and Flanders over which so much of the war of 1914–18 was fought, provided infinitely greater opportunities for contamination. Other sources of tetanus spores—imperfectly sterilized catgut, cotton wool, talcum powder, gauze packs and sulphonamide powders—have accounted for the occurrence of cases of tetanus in hospitals ; the importance of proper sterilization of all dressings applied to wounds cannot be too strongly emphasized. 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 devitalized tissues and pieces of clothing, the arrest of haemorrhage, the relief of tension, 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 immunization 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 immunization was insufficient to save the life of the patient.

Immunization

Since the war of 1914–18 *active immunization* against tetanus has been developed and the evidence shows that this is a procedure of the greatest value. Active immunization 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 antitoxin 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 methods practised in the British Army of producing active immunity against tetanus were modified in 1949 and the technical details are now as follows :—

(*a*) *Primary immunization.*—Two subcutaneous injections of tetanus toxoid, spaced by an interval of not less than six weeks, are followed by a third, given some time between six months and a year subsequently. Immunity following these injections will last for a period of five years.

(*b*) *Re-immunizing doses.*—Under normal conditions one subcutaneous injection is given every five years to maintain immunity. In addition, prior to departure for *active service*, a re-immunizing dose of toxoid is given except when *documentary* evidence is produced that an individual has been immunized within the two months prior to proceeding on active service.

Dosage.—Whether for primary or re-immunization—1 cc. given subcutaneously.

Reactions after the injection of tetanus toxoid are rare and usually mild. Patients with a history of asthma or hayfever may be more liable than others to an allergic reaction. Such cases should be given a reduced dose, *e.g.*, 0.1 cc. followed some hours later, or next day, by the ordinary dose of 1 cc. if no symptoms have occurred. A subcutaneous injection of 0.5 cc. of 1 : 1000 adrenalin or other antihistamine drug repeated if necessary, controls the allergic reaction.

Without entering into detail it may be said that experience has fully justified active immunization with tetanus toxoid. But there is a limit to the amount of toxin which can be neutralized 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 does not rely entirely on active immunization as described above. It is combined with passive immunization when the nature of the terrain and of the wound is favourable to the development of tetanus, but the administration of anti-tetanic serum routinely to each and every wound as practised in the past is no longer considered necessary.

Passive immunization is conferred by administration of antitoxic serum. In this way antitoxin is immediately available to neutralize 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 the war of 1939–45 the procedure in the British Army was to give each wounded man, as soon as possible after wounding, an intramuscular injection of 3,000 international units (IU) of tetanus antitoxin. This was intended to cover any gaps in the protection afforded by active immunization. It covered the danger-period of several days before the " shadow factory " set up by active immunization began to produce antitoxin in quantity. It had the additional advantage that it covered any men who might have refused or escaped active immunization ; such men need two extra doses of 3,000 units at weekly intervals to make them safe and 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.

These rules still hold good for non-toxoid protected individuals, but for those actively immunized against tetanus the following rules have been accepted :—

(1) When tetanus is an unlikely complication of a wound, serum prophylaxis is unnecessary.

(2) When, from the nature of the terrain and from the site of the wound, tetanus is to be feared, it is advisable normally to give a single dose

of 3,000 units a.t.s. On occasions when it is considered that there is grave risk, this dose may be repeated at weekly intervals. Larger doses are not indicated, massive doses may delay the production of active immunity in the recently immunized.

Note.—Tetanus terrain : The presence of tetanus spores in the soil is largely a question of the degree of contamination with the dung of animals, spores being numerous in highly-cultivated and well-manured ground, and rare in desert or uncultivated land.

The tetanus-prone wound is pre-eminently that which involves the calf, thigh, buttock or axilla.

(3) In the intermediate or doubtful case the decision as to whether or not to give a.t.s. to an actively immunized individual should be left to the surgeon responsible for the primary surgical treatment. The medical officer giving first aid treatment should normally be exonerated from this responsibility. The responsibility will be his only when it is foreseen that the primary surgical treatment of a tetanus-prone patient will be inordinately long delayed, and when he deals with patients not actively immunized.

ESTABLISHED TETANUS

Application of the best surgical and immunization 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

Immunization 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 immunization. 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 neutralized by circulating antitoxin. But movement, especially if sudden, may release a flood of toxin too great to be neutralized 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 generalized 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 generalized 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.—As soon as the diagnosis is made or is reasonably probable, 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 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 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 chemotherapeutic drugs 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 recognized 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

ANAESTHESIA IN WAR SURGERY

During the Second World War the lesson of the 1914-18 war, namely, that deep etherization carries a high post-operative mortality and morbidity was again emphasized, and the necessity of applying modern methods of anaesthesia to wounded men was realized. Furthermore, it was shown that even in the most isolated forward areas, modern techniques could be available. It was also demonstrated that it was essential to carry out pre-operative resuscitation by intravenous blood, plasma or saline. The principal innovations applied in anaesthesia were (1) the use of intravenous thiobarbiturate (Thiopentone sol. B.P.), (2) the Oxford vaporizer, with which constantly accurate low concentrations of ether in air could be administered regardless of climate ; (3) the availability, even in the most forward areas, of up-to-date apparatus with the anaesthetic gases ; and (4) the reinforcement of light inhalation anaesthesia by intravenous thiopentone or by nerve blocks or local infiltration. (*Note.*—The Oxford vaporizer is not at present in production.)

PREPARATION OF PATIENTS

No matter what anaesthetic technique is to be employed, every effort must be made to restore the volume of fluid in the circulatory system before the operation is commenced. The pre-operative administration of morphia will be helpful to the anaesthesia but is not essential ; the administration of Atropin gr. 1/100 or Scopolamine gr. 1/150, however, is essential especially if ether or trichlorethylene are to be used. The drug should be injected hypodermically or intra muscularly at least half an hour before the anaesthetic is commenced ; when time does not permit this, the same dose is effective if injected intravenously five minutes before commencement of the anaesthetic.

From the point of view of anaesthesia, the wounded may be divided into three main classes : (1) the lightly wounded, (2) those suffering from severe wounds with shock and/or haemorrhage, (3) those suffering from severe sepsis, especially anaerobic infections.

One grave danger common to all three classes is a full stomach. Quite rightly, troops are, whenever possible, fed before going into battle and under conditions of excitement or stress, the emptying time of the stomach is greatly increased so that a high percentage of those wounded early in an engagement, on arrival at a forward operating centre, have a stomach full of undigested food which is frequently vomited during the induction of anaesthesia. This vomiting is especially marked when intravenous thiopentone is being administered. Obstruction of the respiratory passages may occur in a few seconds and will prove fatal unless adequate suction apparatus is available.

1. THE LIGHTLY WOUNDED

These patients are, on the whole, good subjects for anaesthesia although 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 evacuation. Most of these requirements are met by the use of intravenous thiopentone for short

surgical procedures. This method saves time, a solution of the drug can be prepared in bulk before a rush of casualties, and it can be given to the patient on his stretcher enabling splints and clothes to be removed painlessly, and after-effects are absent. In order to decrease the recovery time, the amount of thiopentone administered should be reduced to a minimum. This may be achieved by following the intravenous induction with an inhalation anaesthetic of nitrous oxide and oxygen or cyclopropane and oxygen, reinforcing the anaesthetic if necessary during the operation by further intermittent intravenous injections of 1 or 2 mls. of 5 per cent. solution of thiopentone. If nitrous oxide or cyclopropane are not available, 1 per cent. ether and air from an Oxford vaporizer may be substituted. In this way very small quantities of thiopentone are administered and the recovery time is remarkably short.

2. SEVERELY WOUNDED

The problem in these cases is that of producing anaesthesia, and often abdominal relaxation in patients suffering from severe shock and/or haemorrhage. Every effort should be made pre-operatively to restore so far as possible the volume of fluid in the circulatory system, but when the haemorrhage is severe and cannot be arrested except by surgical procedure demanding anaesthesia, then blood must be rapidly introduced into the circulation during the induction and maintenance of the anaesthetic. This may be done by attaching a Higginson's syringe to the air inlet tube of the transfusion bottle and creating a positive pressure in the bottle. In very severe cases, the patient should be transfused into two or even three limbs simultaneously. Peripheral circulatory failure leads to generalized tissue anoxia, decreased venous return to the heart, increased heat loss, and decrease in renal function. It is, therefore, essential that these cases should (*a*) have a high oxygen intake—these patients will not tolerate even short periods of cyanosis ; (*b*) be kept inclined head down—turning or rolling, especially if done quickly, may lead to sudden death in severe cases ; (*c*) be kept warm but not sweating ; (*d*) have sufficient fluid intake to encourage renal function. All the inhalation anaesthetics in blood concentrations producing anaesthesia produce a peripheral vaso-dilatation, especially ether and chloroform. With these two drugs, vaso-dilatation may persist for some hours after the administration. Inhalation anaesthetics in these cases, therefore, should only be used in extremely low concentrations, the deeper levels of anaesthesia being obtained by intermittent administration of small doses of thiopentone, intravenously.

Thiopentone is a valuable anaesthetic in these cases, provided the following points are kept in mind : (1) The slower venous return correspondingly delays the onset of the signs of anaesthesia, (2) Because of the anoxia and general depression less anaesthetic is required and more slowly is it destroyed by the body. It has been shown that, with care, there is no case which cannot be safely anaesthetized by intravenous thiopentone. Local analgesia may be used to supplement a light general anaesthetic with advantage, but should not be used as the only means of anaesthesia, for to operate under local analgesia may considerably slow down the surgical procedure and exhaust the patient because of the mental strain and hinder the surgeon by restlessness.

Spinal anaesthesia has no place in the treatment of the severely wounded for this administration necessitates turning the patient, causing increased

risk and pain and distress also there is a very marked vaso-dilatation in the anaesthetized area, producing a further fall in blood pressure.

As already mentioned, turning or rolling these patients is fraught with danger. It is, therefore, wise if there is a wound in the back as well as other wounds, to deal with the back as the first part of the operation. It must be remembered that, due to sluggish peripheral circulation previous injections of morphia may fail to be effectively absorbed until circulation is restored by resuscitation. If more than one dose of morphia has been administered it may be found to have been an excessive dose in the patient when resuscitated.

3. THOSE SUFFERING FROM SEVERE SEPSIS

These cases present a clinical picture similar to that of severe shock and may be easily mistaken for a case of shock if the site of the infected lesion is not obvious (*e.g.* anaeroboic infection of a wound of the back complicated by other obvious wounds). The peripheral circulatory failure due to circulating toxins does not respond readily to intravenous therapy and anaesthesia may have to be undertaken in the presence of severe hypotension. Every effort, therefore, should be made to avoid the volatile inhalation anaesthetics. Cyclopropane is undoubtedly the anaesthetic of choice in such cases since the generalized toxic state seems to delay the destruction of thiopentone. This drug can, however, be used in these cases but even greater caution is required than in simple cases of shock or haemorrhage.

SPECIAL CONDITIONS AFFECTING ANAESTHESIA

Climate.—Owing to the low boiling points of the volatile anaesthetics it may not be possible to use them properly in very hot climates. The Oxford vaporizer overcomes this difficulty and makes possible the accurate use of ether in air or oxygen regardless of extreme temperatures. Serious disturbance of the fluid balance is very soon produced by sweating, large quantities not only of water but also of sodium chloride being lost. This serious disturbance of physiology is too often disregarded before the administration of an anaesthetic which will still further disturb the fluid balance. The administration of water alone in cases where the chloride loss is severe will only make the patient's condition worse. Adequate administration of normal saline is, therefore, called for pre-operatively. It can be given by mouth if time for absorption can be allowed before the anaesthetic is commenced, or intravenously. It should be remembered that atropin and scopolamine tend to diminish sweating so that following their administration, unless careful observations are kept and appropriate measures taken, serious hyperpyrexia may occur.

In hot dry climates, static electricity tends to develop rapidly and may be the cause of fire or explosion (*see* below).

Explosions.—Ether vapour and cyclopropane are highly inflammable even in low concentrations especially if mixed with oxygen. Combustible concentrations are soon reached especially at floor level in badly ventilated operating rooms and tents. Attention should, therefore, be paid to causing an occasional draught through the operating room, especially at floor level, if naked lights or electric motors are in use. It may sometimes be impossible in a forward area to ensure some sort of ventilation, and in these conditions

intravenous anaesthetics should be employed, if necessary in combination with nitrous oxide and oxygen, reinforced when necessary by low concentrations of trichlorethylene (the vapour of which is not combustible). The development of static electrical charges by the passage of gases through an apparatus or the friction of blankets on the operating table and on the trolleys used for transporting patients is a very real danger in dry climates. In such climates, it is essential to see that all operating room furniture is properly earthed, if not constantly, then at very frequent intervals.

Wounds of the Head

These cases require only the very lightest level of anaesthesia, the problem for the anaesthetist being to maintain a free airway in spite of the position of the patient required by the surgeon, and to ensure that the intracranial pressure is not raised either by the patient "straining" or coughing, by any slight obstruction to expiration, by the gradual accumulation of carbon dioxide due to partial re-breathing, or by the dilatation of the intracranial vessels by the anaesthetic.

These cases succumb rapidly to a slight degree of anoxia so that high concentrations of oxygen should be administered during and after the anaesthetic. To ensure a free airway it is wiser always to pass an endotracheal tube and to ensure that the expiratory valve is quite free.

An adequate flow (at least 10 litres per minute for an ordinary adult) of nitrous oxide and oxygen with a trace of ether or trichlorethylene, reinforced perhaps in the early stages by intermittent intravenous thiopentone, is the ideal anaesthetic for all head cases.

If the prone position is required, the patient's body must be supported by pillows, folded blankets, or sand bags at the pelvis and shoulders so that the lower coastal frame may move freely during respiration, otherwise each respiration will necessitate the patient lifting his own weight off the table. This will lead to marked respiratory embarrassment and, in long cases, to severe exhaustion.

It is wise to have an intravenous drip running throughout operation. This facilitates immediate deepening of the anaesthetic by intravenous thiopentone and the immediate control of blood pressure by rapid infusion of blood, plasma or pressor drug. Great care must be exercised to avoid increased bleeding at the site of operation caused by overloading the circulation. The drip, therefore, should be kept running just fast enough to keep the intravenous needle patent unless an emergency arises.

Maxillo-facial Wounds

These cases present the anaesthetist with some of the most difficult and critical problems. The greatest difficulty is the obstruction of respiration by blood, clot, and in cases of severe injury to the mandible, by a "floating tongue." The patient should be kept lying face downwards until the anaesthetist is satisfied that he has at hand (1) a sucker, working, (2) a laryngoscope with faultless illumination, (3) an endotracheal tube with mount, ready to connect to the anaesthetic apparatus, and (4) an apparatus with a bag which can be compressed to artificially respire the patient. As much clot and debris as possible should then be removed from the mouth, while the patient is still conscious and in the prone position.

Intravenous thiopentone should then be administered gradually until respiration is just abolished, thus eliminating the danger of inspiring any blood, etc. The patient is then quickly turned on to his back and, with the aid of the laryngoscope, an endotracheal tube inserted into the trachea, vision being assisted by the sucker when necessary. The endotracheal tube is then connected to the anaesthetic apparatus and artificial respiration by rhythmic pressing and release of the bag on the apparatus is carried out until the patient resumes normal respiration (usually only a minute or so). It is essential, of course, that these respired gases should have a high oxygen content. All this time, the sucker must be used to prevent accumulation of blood in the pharynx. Cuffed endotracheal tubes are preferable, but if not available, then a secure packing of gauze should be inserted round the larynx. This is inserted under direct vision through the laryngoscope. In cases where haemorrhage is severe and can only be controlled by packing, or the injury to the soft tissues is such that it is not practical to pass an endotracheal tube, then tracheotomy should be performed and the anaesthetic administered through the tracheotomy tube.

The greatest care must be exercised when using a gag, for a simple fracture may easily be converted into a compound one. When the operation is completed, a piece of rubber tubing, approximately the size of a No. 6 Magill tube 7 inches long and cut obliquely at one end, will be required. This should be lubricated and the oblique end inserted into one nostril and passed into the pharynx until such a position is reached that it provides a perfectly clear airway. When this position is arrived at, a safety pin should be passed through the tube at the level of the anterior nares so that the tube cannot be pushed further into the nose, and the pin secured by adhesive strapping so that the tube cannot move out of the nose. This device is more easily tolerated than an oral airway and can be left in position even in a conscious patient.

Before these cases leave the supervision of the anaesthetist, they must be turned on to their side and strict instructions given that they be kept in that position until they are fully conscious. This lateral position should be such that the patient would roll on to his face if he were not prevented from so doing by extreme flexion of the uppermost hip and knee and the placing of a small pillow or folded blanket at the level of the chest. In this position, any blood which may ooze post-operatively or any collection of saliva will run out of the mouth. Having put the patient into this position, it is again necessary to check that the artificial airway is satisfactory. The level of anaesthesia throughout the operation should be such that immediately the anaesthetic is discontinued, the patient has a good cough reflex. If any dentures were found in the mouth, they should be most carefully preserved as they may be the key to future remodelling of the jaw.

Wounds of the Chest

In forward areas, the present tendency is to reduce operation 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, light anaesthesia by means of intravenous thiopentone will usually prove adequate. In cases where one pleural cavity has been opened, the patient is not only suffering from shock and/or haemorrhage but from oxygen lack and carbon dioxide accumulation resulting from disturbance of respiratory mechanism. Due to the loss of the intrapleural negative pressure on the injured side, inspiratory movement will allow gases from the

lung on the injured side to pass into the lung on the sound side. During the expiration, some of the gases from the lung on the sound side will inflate the lung on the injured side. Therefore, the sound lung will not be receiving gases containing adequate oxygen, nor getting rid of carbon dioxide (paradoxical respiration). This state can be corrected by connecting the patient to an anaesthetic apparatus with a firmly fitting face piece or cuffed endotrachael tube and applying pressure to the bag on the apparatus during the inspiratory phase. Before the pleura is closed, a rubber catheter should be inserted into the pleural cavity so that, if the wound is tightly closed, the lung may be fully inflated by increasing the pressure on inspiration and maintaining some positive pressure during expiration. By then connecting the catheter from the chest to a " water seal " a permanent negative pressure can be maintained in the pleural cavity on the injured side. The " water seal " may be constructed simply by putting 2 or 3 inches of water into an ordinary blood transfusion bottle, and connecting by rubber tubing the catheter from the patient's chest to that glass tube in the cork of the transfusion bottle which runs nearly to the bottom of the bottle. To the short glass tube in the cork of the transfusion bottle the intake end of a Higginson's syringe should be attached. Two or three compressions of the bulb of the Higginson's syringe will now create a negative pressure in the transfusion bottle, and it will be seen that the air in the pleural cavity will be extracted and bubble out through the water in the transfusion bottle. The negative pressure thus transferred to the pleural cavity will cause the column of water to rise in the long tube within the bottle, the height of this column of water rising and falling with respiration. Such a device is as easy to manage during transportation as a blood transfusion and an attendant can see at a glance that intrapleural negative pressure is being maintained. This procedure is not complicated but results in the patient's general condition rapidly improving and remaining good during evacuation. In order to ensure adequate oxygenization post-operatively, oxygen should be administered in the wards or during evacuation through the BLB mask.

Abdominal Wounds

For these cases, complete muscular relaxation of the abdominal wall is essential. Unless this is obtained, the surgeon's work will be hindered, made more dramatic, and the time of operation prolonged. Although the most perfect muscular relaxation can be obtained with spinal anaesthesia, this method should never be employed for an abdominal operation on a wounded man. General anaesthesia should always be employed but, for the reason dealt with under the heading of " severely wounded " the lightest possible level should be maintained, and relaxation of the abdominal wall obtained, either by blocking the intercostal nerves or by a field block of the abdominal wall with a local analgesic, or by the intravenous injection of one of the " relaxant drugs " (alkaloids of curare or similarly acting synthetic compounds). The intercostal block is performed by injection of 5 to 10 c.c. of a local analgesic drug round the last six thoracic nerves and the first lumbar nerve as they lie between the muscular layers in the axillary line. Great care must be taken when making these injections not to cause a pneumothorax. If carefully performed, two hours of good muscular relaxation can be obtained in this way. Very profound muscular relaxation follows the intravenous injection of the " relaxant " drugs. The muscles of respiration, however, are at the same time paralysed so that it is essential to ensure

adequate respiratory exchange by respiring the patient or assisting respiration by pressure on the anaesthetic bag. The doses of these drugs required varies considerably with individual patients as does the duration of their action, which may vary from 25 to 40 minutes. Repeated injections of the drug may be made but subsequent doses required to produce relaxation are much smaller than the initial dose. Since their action takes place in two minutes, it is wiser to give small doses and add to these until the required effect is produced. The anaesthetist must be quite sure that before the patient leaves his supervision adequate natural respiratory exchange has resumed. Abdominal cases should be handled with great care after operation. Remember that should the patient have a wound of the back or buttock as well as an abdominal injury, the former should be dealt with before the abdomen is opened.

Burns

In severe burns, the choice of 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. It should be remembered that these patients have a haemoconcentration due to loss of body fluid from the burned area. They should, therefore, not be given blood intravenously (unless there has been a haemorrhage as well) but plasma. This should be given before, during, and, if necessary, after the local treatment is completed. It is a good plan to give one pint of normal saline with every two pints of plasma, thus ensuring not only replacement of circulatory fluid but restoration of osmotic balance in the tissues and encouragement of renal function.

Thiopentone is a very satisfactory anaesthetic in these cases, provided the points mentioned under the heading "severely wounded" are fully appreciated. Only a very light plane of anaesthesia is required for the local treatment of burns. If more than a few minutes' anaesthesia is required then it is better, having induced with intravenous thiopentone, to maintain anaesthesia with nitrous oxide and oxygen (ensuring good oxygenization) or cyclopropane. For subsequent dressings $\frac{1}{8}$ or $\frac{1}{4}$ gr. morphia given intravenously five minutes before the dressing often suffices.

Local Analgesia

This method has little or no place in war surgery except for ophthalmic or dental work unless combined with general anaesthesia, when it is of the greatest value. The most suitable drugs to employ are Procaine 1 to 2 per cent., Nupercaine 1:1500 or Xylocaine 2 per cent. Procaine has the disadvantage of a very brief action (twenty minutes). By the addition of 1 cc. of 1:1000 adrenalin hydrochloride to every eight ounces of 1 per cent. Procaine, the action may be considerably prolonged. Nupercaine, whilst having an action of approximately two hours, has the disadvantage of producing little or no muscular relaxation for approximately thirty minutes. Xylocaine, on the other hand, acts very rapidly and if 1 cc. adrenalin 1:1000 is added to 500 cc. of the 2 per cent. solution, anaesthesia will last for well over the two hours. A further advantage of Xylocaine is that it is stable when mixed with adrenalin, which Procaine is not, and so mixtures of Xylocaine and adrenalin may be prepared well in advance.

Note.—Xylocaine, manufactured in Sweden, may not be available.

Analeptics

It may be necessary to overcome a sudden circulatory failure. Extensive pharmacological research has shown that of all the drugs for which claims are made, the only two at present known to be of any use in these emergencies are adrenalin and desoxyephedrine (Methedrine). Adrenalin is a powerful cardiovascular stimulant. Its action is brief, approximately ten to twenty minutes, the dose required being 1 to 3 mls. of 1:1000 solution of adrenalin hydrochloride, administered intravenously. Three mls. should not be exceeded because the heart rate may be so increased that the diastolic period is not sufficient to allow of adequate filling of the auricles. The result is a decreased cardiac output which enhances peripheral circulatory failure. The drug should never be employed if cyclopropane or chloroform are being administered as ventricular fibrillation may result.

Desoxyephedrine has an action which is similar but lasts much longer (two to three hours). It is best administered by injecting 10 to 20 mgs. intravenously and at the same time 10 to 20 mgs. intramuscularly, thus producing a more rapid onset of action which will be prolonged. It should, of course, be remembered that drugs alone are of no avail in these emergencies. Adequate oxygenization and restoration of the volume of the circulation are at all times essential. Cases of severe depression due to an overdose of one of the barbiturates are best dealt with by the intravenous injection of 1 to 5 mls. of a 25 per cent. solution of Nikethamide (Coramine). Care must be taken before subsequent injections of this drug are made as convulsions may easily be produced. Perhaps a better, although slightly slower acting stimulant for these cases is 1 to 3 mls. of an 0.3 per cent. solution of Picrotoxin injected intravenously every fifteen minutes until an effect is produced. The severe respiratory depression associated with barbituric poisoning must, of course, be met with by an increased percentage of oxygen in the inspired air and, if necessary, artificial respiration.

SECTION VIII

THE TREATMENT OF WOUNDS AT THE BASE

Most casualties admitted to the base hospital will already have been operated upon. Wounds will have been thoroughly dealt with surgically, adequately decompressed, left extensively open during this period while the body is mobilizing its forces against invasion, limbs will have been well immobilized and the patients should be responding to the chemotherapeutic measures employed. When campaigns are progressing smoothly casualties should be arriving at the base hospital where they can be held, on the 2nd–4th day. In desert and jungle campaigns the journey may take a week longer but that delay should be lessened whenever aerial evacuation is possible. They should be ready for the next stage of treatment—closure of the wound—on the 3rd–5th day—at the time when the natural process of healing is beginning. In favourable circumstances the great bulk of the work at the base hospital is concerned with the closure of wounds. When circumstances are less favourable numbers of untreated wounded may be admitted long after the infliction of the wound. When the time lag has been much over 12 hours, major interference is likely to do more harm than good, it will

spread potential sepsis and in such cases the basic minimum of surgery—the removal of dead tissues and the relief of tension only—will be advisable. Wounds so treated, trimmed rather than excised, require further treatment before closure. For delayed primary suture to be a success, the primary operation must be a complete one.

Delayed Primary Suture. (d.p.s.)

Unless on admission there is an indication for immediate surgery, there should be no interference for 24 hours. If indication there be, there must be no inspection of the wound except in the operating theatre. During this period of 24 hours the patient rests, his blood picture is investigated (erythrocyte count, haemoglobin, haemotocrit index, plasma proteins). He is transfused and X-rayed if necessary.

Next day in the operating theatre, with aseptic precautions the dressings are removed, a swab is placed over the wound, and the surrounding parts are shaved if necessary and are widely and scrupulously cleansed with soap and water and painted with spirit, etc. If the condition of the wound appears satisfactory the patient is anaesthetized with pentothal. The wound is disturbed as little as possible, the edges are separated, any blood clot is carefully removed, or the wound may be gently irrigated with saline. Any tag which has been missed is excised. Since haematoma formation will ruin the prospects of success, any bleeding point must be dealt with, avoiding ligatures if possible. All parts of the wound are thoroughly dusted with penicillin/sulphathiazole which can be gently rubbed into the deeper tissues.

In deeper wounds the track should be explored in case anything has been missed at the primary operation. No deep sutures are inserted. Drainage is avoided. But it may be considered wise to drain the angle of an amputation stump.

The skin edges which have been freshened are undermined if necessary. Undermining of skin and subcutaneous fat to a depth of 1 cm., by which cover is provided without tension on the sutured edges, is safe in most areas up to 6–8 cms. Care must be taken over haemostasis. Dead space should be obliterated and the suture line should be lax and not under tension. There was in 1945 a tendency to consider that a certain amount of tension was permissible, the skin edges were brought together just as closely as appeared wise, and the operation was completed in the theatre five days later.

Any tension, however, militates against a 100 per cent successful closure and if dead space cannot be obliterated and the suture line kept lax, an alternative method should be used (flap or free graft). The edges are brought together by interrupted sutures of nylon or serum proof silk, inserted so as to give accurate apposition with eversion of the lips.

Few defects of more than 8–10 cms. across can be closed by approximation however extensive the undermining. Much smaller wounds on forearm and hand, and of leg below the calf, need tissue from a distance for a stable cover.

In doubtful wounds with a tendency to tenting and pocketing it was still occasionally considered advisable in 1945 to insert fine tubes through separate stab-incisions for the instillation of penicillin (3-5 c.c. ; 500 units per c.c.) twice daily for 5–8 days.

A pressure dressing of gauze-wool is applied and the limb is again put at rest in a padded split plaster-of-paris splint and is not disturbed for 10–12 days (deep wounds should be inspected in the theatre after 5 days) and patients treated in this way must be held until the stitches are removed. They are better nursed in separate wards away from open wounds. Multiple and severe wounds are given penicillin parenterally and transfusions if necessary during the immediate post-operative period.

The stitches are removed in the theatre on the 10th–12th day (12th if there has been any tension). Exercises are commenced next day and in the ordinary uncomplicated case the patient should be fit for transfer to the Convalescent Depot 7–10 days later.

Dirtier Wounds

Mildly infected superficial wounds can have a single dusting of Penicillin/Sulphathiazole and can safely be closed.

Larger deeper wounds without signs of serious or spreading infection can also be closed at once.

More heavily infected wounds should be examined bacteriologically and treated for two–three days with antibiotics locally and parenterally, and transfusions if indicated.

If culture shows the infecting organism to be penicillin sensitive, rapid improvement on this treatment can be expected and the wound can be closed. Even insensitive organisms are rarely highly pathogenic and seldom delay healing.

Patients showing pyrexia, toxaemia, signs of pocketing, evidences of inadequate primary operation, gas bubbles, obviously require treatment on appropriate different lines.

Secondary Suture (S.S.)

With treatment reasonably early and on modern lines, long delayed wound closure should be infrequent. When there has been spreading infection due to resistant organismal infection but dead tissues have been got rid of, when the surrounding tissues no longer show signs of induration, and healing by healthy granulation has commenced, a somewhat different technique of closure is necessary. There is no hard and fast rule as to when a late suture should be considered "secondary" rather than "delayed primary", but the stage above described may well be reached during the second ten days from the time of wounding.

When the tissues have lost their pliability and there is an edge of ingrowing epithelium which has a minimal blood supply, any attempt at direct closure will not be successful. The new epithelium should be excised, the skin margins undercut, the granulation tissue gently scraped off the surface of the wound. This should be done under pneumatic tourniquet when possible—the tourniquet is then released and haemostasis secured before wound closure. In still older wounds (over three weeks) it will be necessary to excise all scar tissue in the skin and subcutaneous layers until healthy fascial planes are fully exposed. If there is any undue skin tension flaps must be fashioned or raw areas covered with split skin grafts.

Foreword to section on "Plastic Methods of Wound Closure."

Many wounds can only be closed satisfactorily by plastic methods, and elaborate work of this nature should normally be the responsibility of skilled

plastic surgeons. In the paragraphs which follow, these procedures are described in full not as an invitation to general surgeons to practise them, but because the closure of wounds is one of the most important developments of modern war surgery and on it may well depend the whole future of a wounded man. Plastic surgeons in war may not be available, evacuation of patients may not always be possible.

PLASTIC METHODS OF WOUND CLOSURE

Most missile wounds of parietes and limbs are closed by delayed primary suture. The methods described here must be used when the tissue loss is too great for closure of the skin by approximation of the edges without extensive undermining. They are of special value, too, (1) as primary methods in certain sites such as the hand and the foot ; (2) when the wound has exposed bone or tendon, which should be given a primary cover of viable skin and fat ; (3) when simple approximations have been tried and failed. Experience and judgment will determine choice of method in individual cases, but great care should always be taken to see that the skin closure over a fracture site should not be under tension, and that dead space is obliterated—by the use of flaps and a layered closure when necessary. *These plastic methods of wound closure are reserved for conditions when the patient can be held for at least ten days, and for units which have the necessary equipment and experience to do them.*

A wound may be closed by :

1. **Approximation.**—With undermining as already described.

2. **Free Grafts.**—(i) Continuous—a sheet of split skin over the whole defect.

(ii) Discontinuous—patch grafts of split skin spread over the defect.

3. **Flaps.**—(i) Local Flaps—generally with free graft to the secondary defect. Z Plastics.

(ii) Distant Flaps—cross-limb, or tube pedicle.

The above methods may be used primarily or when primary excision has been done two to four days earlier.

CLOSURE BY FREE GRAFTS

When a free graft is used a continuous cover is best for most wounds—this means a sheet of split skin is spread over the whole raw area. Grafts are lost by (1) infection ; (2) inadequate fixation ; (3) haematoma. Discontinuous grafts (such as patch grafts) are technically easy to cut, and need a lower standard of fixation, haemostasis, and control of infection for success. But the healing time in patch grafts is slower and the end result inferior to a successful complete sheet graft cover. In some cases of difficulty, however, especially where the experience of the operator is limited, patch grafts may be chosen as a more certain method than a complete cover by a sheet of split skin.

The best takes in free grafts are seen on soft recipient sites, such as on muscle or subcutaneous fat. When the recipient bed is comprised largely of bone or tendon a flap of skin and fat on a pedicle, not a free graft, should be used for such part of the wound ; but small areas of tendon in a large recipient site of muscle and fat may be covered by a free graft with a good prospect of take. Primary free grafts are best in most sites ; that is the graft is applied at the time, or within three to four days, of wound excision.

Grafts may of course be applied to granulations, even those of several months in age, and take : but granulations of more than eight to ten weeks are better excised together with their fibrous base before the free graft is applied. Grafting should be delayed until a haemolytic streptococcal infection has been controlled by antibiotics. Whatever the organism present if pus formation is excessive it should be controlled by preliminary abrasion of the granulations with removal of slough or sequestra, or by a few days intensive dressings with compression and elevation of the part.

Graft Cutting

Either a Blair blade (hand cut skin) or the Padgett dermatome may be used. Hand cut skin is thinner and takes more readily on difficult surfaces. It is also quicker to cut. But dermatome cut skin is thicker and gives a more stable repair to most defects. The dermatome too makes the abdomen and other trunk areas available as donor sites. Less practice is needed with the dermatome to cut large grafts consistently than is the case with the Blair blade.

Blair Blade.—For hand cut skin a sharp blade and a flat surface are essential. Outer or inner sites of thigh are the donor sites of choice. A flat donor surface is given by contra-lateral pressure on the thigh by both hands of the assistant. A uniform movement (back and forth motion by the operator's right hand with his arm held into his side, with his index finger along the upper surface of the handle of the Blair blade—and with tension on the skin provided by the board held in his left hand ½ in. in front of the cutting edge) results in the cutting of a uniform layer of skin. It should be thin enough for the blue colour of the blade to be apparent through the graft.

These thin sheets of split skin are best spread upon tulle gras and sutured into position over the defect, where they are further fixed by strips of elastoplast placed over dry gauze moulded and pressed over the defect. When the split skin graft is applied as patches it is cut the same way, but then spread on greased paper which is cut into strips 1 cm. wide. These strips of paper and graft are cut into 1 cm. squares which are spread, fairly closely packed, over the raw area, covered with tulle gras and dry gauze pressure.

Dermatome.—For most grafts the blade of the dermatome should be set to cut thin (10 to 12/1000 in.) rather than thick (over 20/1000 in.), as it is possible to remove the full thickness of skin if care is not taken. Proper use of the cement is the key to the use of the dermatome. If too viscid it should be diluted with ether until it is the consistency of thick cream. The cement should then be evenly and thinly spread—without bubbles—on donor site and drum. It should be allowed to dry completely. This may take three to five minutes. The drum is then pressed firmly on to the donor site, a fold of skin elevated in front and the graft cut by a uniform back and forth motion of the blade in the right hand, while the left rolls the drum back. When the graft is cut the cement is neutralized by spreading the graft on vaseline gauze or tulle gras. The graft, which is thick enough to hold a suture securely, may then be taken by itself and sutured over the defect. Sutures at .5 to 1 cm. intervals transfixing the graft, base of defect and skin edge are taken—the more the better. For most wound closures the graft need not be an accurate pattern, and the excess may be allowed to overlap the edges. Dry gauze, inner layers cut and moulded to wound size and shape, and with outer layers extending well beyond the wound, is applied and fixed with strips of elastoplast reinforced with benzo-mastiche to the skin.

CLOSURE BY FLAPS

As a method of wound closure the outstanding indication for the use of a flap is the presence in the wound of a structure such as a tendon, bone, or joint capsule, which needs cover by a vascularized flap of skin and fat if it is to live and retain full function.

(i) Local Flaps

Except in areas where skin is scarce, *e.g.*, over wrist and hand, and in the leg below the calf muscles, cover for the vital structure—and preferably for the whole wound—may be provided by a *Rotation Flap.* That is, a flap of skin and fat is cut, hinged on a pedicle, and sutured over the defect. These flaps are best hinged proximally, their bases (or pedicles) should be at least as great as their length. The total area of the flap in most cases is best double that of the defect to be covered, *e.g.*, a flap with a base of 12 cms. and 10 cms. length to cover the defect 8 cms. by 6 cms. A rotation flap should not be cut from over tendon and bone. The secondary defect should in most cases be covered by a free graft ; if these secondary defects are closed by approximation, tension with subsequent separation or necrosis may be caused in the primary flap.

The other local flap closure of wide value is the *Double Pedicle (or Strap) Flap.* This flap retains its attachment at both ends. For safety its total length should not be much more than the combined length of proximal and distal (or both lateral) bases. The bi-pedicle flap of skin and fat is displaced over the bone or tendons in the wound, and a free skin graft applied to the secondary defect. The method has particular application for the repair of bed sores in the sacral and trochanteric regions.

"*Z*" *Plastic.*—This most valuable procedure breaks the vertical pull of a scar and increases the length of a part at expense of breadth. The flaps are cut with equal sides and with apices of 60 degrees. After elevation of the flaps the apices are interposed and sutured in their new positions. The method has particular application for scars and wounds which cross hand, finger, flexor or neck creases vertically.

(ii) Distant Flaps

These are long term procedures and best undertaken only at plastic centres or hospitals where special plastic services exist. Distant flaps—cross limb, belly-arm, or tube pedicles—are the method of choice for even relatively small defects exposing tendons, bone, or joints, in certain sites where local tissue is scarce, *e.g.*, below calf and upper limbs below forearm, and some defect in limbs, or head and neck, in which a free graft gives an unsuitable final repair.

Cross-Leg Flaps

These are of great value for the repair of defects in lower leg, heel and foot. They are cut to a pattern planned pre-operatively, should be hinged on the donor calf proximally, or be " delayed " ; and should be cut from over the calf muscles and not expose shin or Tendo Achilles in the secondary defect, which is repaired by a free graft. Plaster-of-paris fixation of the legs may be used, but great care must be taken to pad well all subcutaneous bony parts of both legs. Depending on the extent of the area of attachment of the flap its pedicle is divided in two weeks, or in stages between two to four weeks.

Belly Arm and Cross-Arm Flaps (see Hand Wounds)

Broad flaps from the abdomen based either superiorly or inferiorly are available for large defects in arm, elbow, forearm or hand. These should be cut thin particularly for the hand. Free grafts cover the secondary defects and extend over the raw base of the flap. Zinc oxide strapping fixation of the arm to the trunk is used. The base of these flaps is divided at two to three weeks after attachment.

Cross-arm flaps, because of the lack of bulk in the subcutaneous tissues, are very suitable for certain digital and palmar wounds. They are cut on the same principles as cross-leg flaps, after careful pre-operative planning.

Tube Pedicles

This method of repair is best reserved for plastic centres. It is the only method by which large amounts of tissue can be transported over large distances in the body safely. It is too the only method of repair possible in certain facial and digital reconstructions. The abdomen is the most common donor site for the construction of a tube pedicle; but neck and upper thorax are available and often used for facial repairs by this method.

The bi-pedicle flap is generally cut obliquely from the groin upwards. It is safest not to cut it much longer than double its width (*i.e.*, 6 in. x 3 in. or 8 in. x 4 in.). Extensions in length can be made at two-week intervals. The secondary defect on the abdomen may often be closed by approximation after undermining, but a free graft is generally preferable and may be essential in some of the broader tube pedicles. When the pedicle has to be taken to a distant site, *e.g.*, leg or face, the arm is used as a vehicle. The upper end of the tube pedicle is divided and attached to the vehicle arm just above the wrist. A broad attachment is essential—one 3 in. to 4 in. in diameter for most cases.

Time of attachment before division of the lower abdominal end of the tube pedicle varies. Slowness makes for safety. Tube pedicles elevated in stages should be left attached to the abdomen at both ends for two to three months before attachment of one end to the arm, and the lower abdominal attachment should be left three to six months before it is divided, the tube pedicle opened out and sutured over the defect. The tube pedicle is then divided from the wrist two to six weeks later, depending on the size of the tube pedicle. An excess of tissue is always left in the region of the defect. At later operations the tube pedicle tissue may be thinned, excess removed, and such adjustment of the margins done as may be necessary for the best function and appearance.

Avulsion Flaps

In vehicle accidents, particularly those involving the lower limbs, it is not uncommon to find that the skin and fat have been separated from the underlying fascia and bone for considerable extents. Skin with some subcutaneous tissue may lie as a partially detached loose flap, or may form a loose stocking for a foot or more of the limb—in these latter cases a hand may be passed completely round the circumference of the limb deep to the skin and superficial to the fascia. There is no best method of treating these cases. They often have multiple fractures and are gravely ill. The closure may have to be subordinated to resuscitation and reduction of any fracture. At operation the difficulty lies in the recognition of how much of the flap is dead, or will become dead because of progressive thrombosis. As a rule much more dies than is expected at primary operation.

Unless special grafting experience is available, the patient is fit, and the operator is certain which parts of the flap are dead, it is much better to be conservative. Excision of black and grossly soiled tissue, and a very thorough toilet are done, haemostasis secured, and the flap, or flaps, fixed in anatomical position by a few sutures. There should be no delay in excision of sloughs once the line of separation is apparent—generally in the second week. The raw area is then covered by split skin grafts at the same operation or within two to four days of the removal of the sloughs.

In exceptional cases (when the non-viable parts of the flap are clearly demarcated and the patient is fit) it may be possible to do an excision and a primary free graft replacement.

General Treatment

Many factors influence the healing of wounds, but the most important is the upset in protein metabolism resulting from trauma. Any severe protein loss demands protein replacement. A high-protein diet is essential and should include eggs, lean meat, milk and soya bean products. Blood plasma transfusions should be given as necessary. A patient with haemoglobin below 70 per cent. is unlikely to produce a well healed wound after suture. Dehydration must be overcome. Much was expected from the giving of hydrolysates but the position in that respect is disappointing. The deficiency of vitamins important in healing (A & C) is aided by including milk, oranges and green vegetables in the diet, and administering ascorbic acid in tablet form.

Rehabilitation, both physical and mental, must keep pace with the local treatment. There must be suitable graduated exercises at prescribed intervals for the patient's wounded parts and for the maintenance of health and strength in his unwounded parts, also occupational therapy, all carried out in cheerful surroundings. They are of fundamental importance in the rehabilitation process.

Crush Injury (Ischaemic Muscle Necrosis)

Interest in the effect of crush injuries upon renal function was revived by the large number of such injuries sustained during air raids upon British cities. This type of injury may be even more prevalent in future warfare. 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; associated with decreasing secretion of urine. The urine contains the pigment myo-haemoglobin and resembles haematuria. Microscopic examination shows the presence of pigmented casts and granules. The blood urea rises and haemo concentration may reach a high level, presumably from the escape of fluid into the tissues. The oligaemia normally present in shock is aggravated by the effect upon the kidney of myo-haemoglobin liberated from the damaged tissues. A third and little understood factor is the production of a toxic substance from the injured muscle.

The onset of anuria is heralded by the urine becoming dark and more and more scanty; the tongue and skin are dry and the blood urea rises to uraemic levels (300-400 mg. per cent.). During the early stages the patient is not necessarily in any particular distress and he is usually mentally alert. Patients developing oliguria may recover or may proceed to anuria, dying on the sixth to the eighth day.

Treatment is based on the elimination of pigment and toxin derived from the damaged tissues, by promoting diuresis and keeping the urine alkaline. Treatment unless early will be ineffective, for renal damage occurs in the first few hours of the " shock " phase, and when the damage has become established there is no reason for giving alkalis and it may precipitate alkalosis. The importance of giving plenty of fluid after injury to enable the kidney to get rid of waste products, has been stressed. The practice in the Army in 1945, in cases of this nature was to give 3 per cent. sodium citrate in 5 per cent. glucose as an intravenous drip, sodium citrate was given by mouth or sodium bicarb 2 gm. hourly, normal saline and glucose were also given intravenously.

Attempts to limit the escape and absorption of the pigment from the damaged limb, by compression bandage, by high application of an Esmarch's bandage, by linear incisions through skin and deep fascia—are all of doubtful value and these methods probably are best avoided.

Since the war peritoneal dialysis and the artificial kidney have been introduced with some promise of success, and injection of novocaine around the coeliac ganglia in an attempt to abolish possible spasm of the renal vessels has been advocated.

Closely allied to the syndrome just described 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 the upper third. It may also *follow* prolonged application of a tourniquet. Anuria may also be associated with major muscle wounds, gas gangrene, abdominal wounds, burns, and the transfusion of excessive amounts of blood or of incompatible blood.

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 alkalinization of the urine by oral administration of sodium bicarbonate in the doses described above.

Fat Embolism

This condition occurs more frequently in battle surgery than is sometimes suspected. It may complicate any major injury particularly if the bones of the lower limb are involved. Fat droplets may become entangled in the pulmonary circulation, or escaping into the systemic venous system may cause cerebral changes and blockages of the capillaries of the skin. Curiously, there is rarely any clinical evidence of renal inefficiency.

Pulmonary or cerebral symptoms and signs may predominate. There is pain in the chest, breathlessness, pallor and cyanosis, and the temperature is raised. Frothy sputum, sometimes bloodstained, may be brought up. The more characteristic picture is for the patient to become drowsy 24 to 36 hours after operation and lapse into coma. There may be occasional fits or paresis. In battle cases papilloedema was not seen, retinal haemorrhages were rare, neck rigidity occasionally developed, reflexes were usually exaggerated and signs of pyramidal tract involvement such as an extensor plantar response sometimes appeared.

Purpuric areas may appear in the subcutaneous tissues. Petechial haemorrhages may appear in crops, 12 to 36 hours after the onset, especially over the neck and upper chest.

Obviously the diagnosis presents difficulties in differentiating between fat embolism and the effects of blast, and laboratory aid in the detection of fat in the sputum, urine and blood may not be available in the Field. Possibly blast is frequently held to be responsible when fat embolism is the true explanation.

There is no effective treatment for either condition. Early immobilization of the injured part may lessen the risk of fat dissemination and the giving of oxygen through a B.L.B. mask may help to diminish the respiratory distress.

Tetanus prophylaxis at the base

It is repeated that to the toxoid protected it is unnecessary to give anti-tetanic serum. The tetanus-prone case may already have received 3,000 units and that dose need only be repeated at weekly intervals if the surgeon considers that there is grave risk of tetanus developing. To those not actively immunized, the dose of 3,000 units already given is repeated at weekly intervals for two or more weeks.

SECTION IX

GUNSHOT WOUNDS INVOLVING BONE

TREATMENT OF FRACTURES, IN THE FORWARD AREA

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.

At the regimental aid post or field ambulance, the limb should be most carefully splinted, so that no unnecessary pain or injury may be caused on transit 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

Operation

The surgical treatment of wounds involving bone differs in no way from that employed for other wounds as already described. Especially in the case

of G.S. wounds causing fracture of the femur is severe shock to be expected and all steps necessary to prevent or overcome it, must be taken without delay.

The method of dealing with comminuted fragments of bone has undergone some change. Formerly, only fragments attached to the shaft or with considerable muscular attachment were conserved. Now, all fragments unless grossly contaminated are retained to act as chip grafts with the excellent prospect that if surgery is early and adequate, and with the aid of chemotherapy, a great number of patients will be spared the complication of delayed or non-union with the months or years of invalidism and secondary operations these complications entail.

Splinting

The duty of the forward surgeon is not to secure accurate reduction of the fracture, but with the fragments in reasonable position and the joints in their position of optimum function *to immobilize the limb as a whole* so that the journey onward will be made in reasonable comfort and security. This, according to British ideas, can best be achieved by relying on plaster of paris, the Thomas' splint, or in the case of serious leg fractures, a combination of both. The splint must not constrict the limb in any way, nor must there be any danger of constriction should the limb swell. Plaster splints therefore must be padded and split throughout their entire length before evacuation. The Tobruk splint loses its stability by being split, and is not split. Padding therefore must be adequate. The worst preventable medical catastrophe in war is the limb made gangrenous by ignoring these rules.

All splints must be suitable for the conveyance of the patient in ambulance cars, ambulance trains, planes, etc., and should require a minimum amount of attention during the journey.

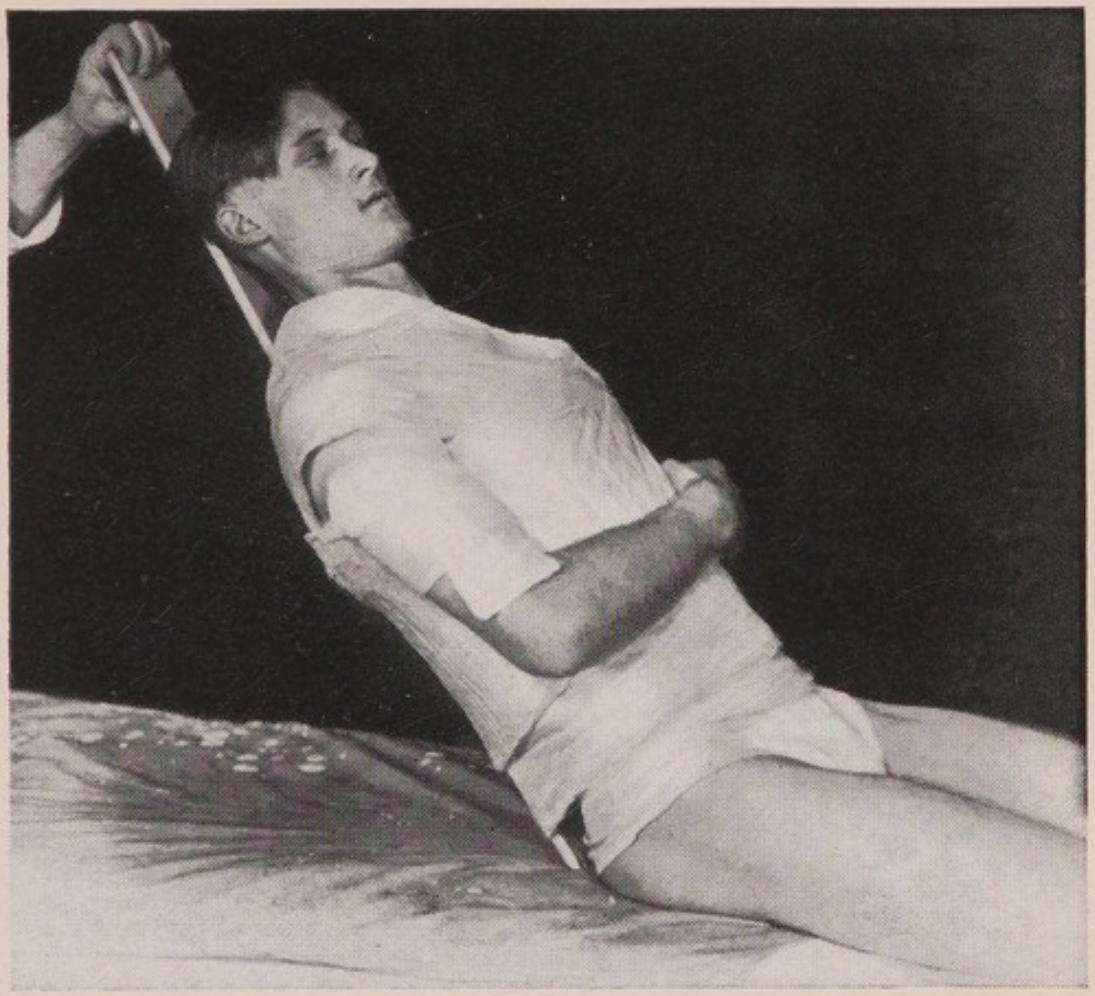
Upper Limb

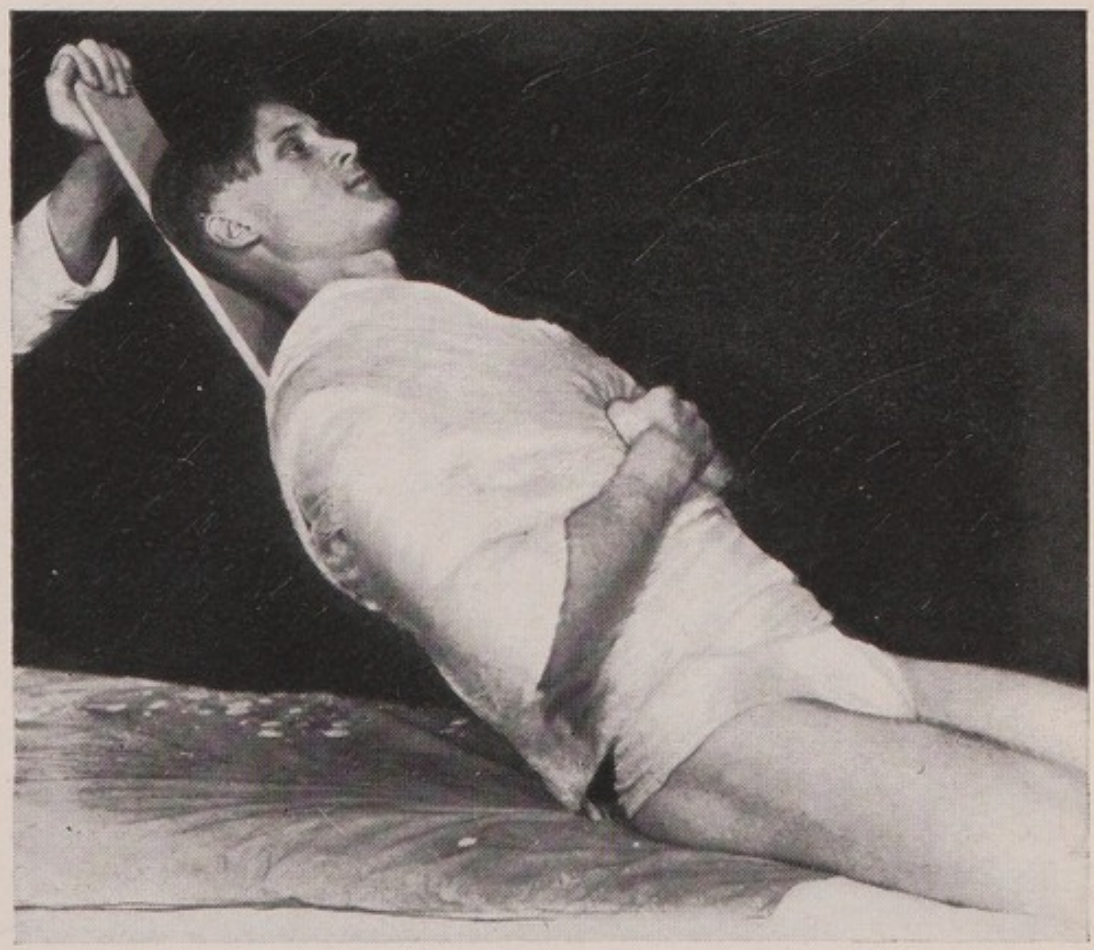
Shoulder and arm.—The thoraco-brachial plaster. After the primary operation a large pad of wool is placed beneath the axilla between the arm and thorax. The whole thorax and arm is encased in wool. Plaster is applied around the arm and chest to include the shoulder and elbow. The forearm and hand are laid obliquely across the chest, padded, and immobilized by further turns of plaster as shown in the illustrations.

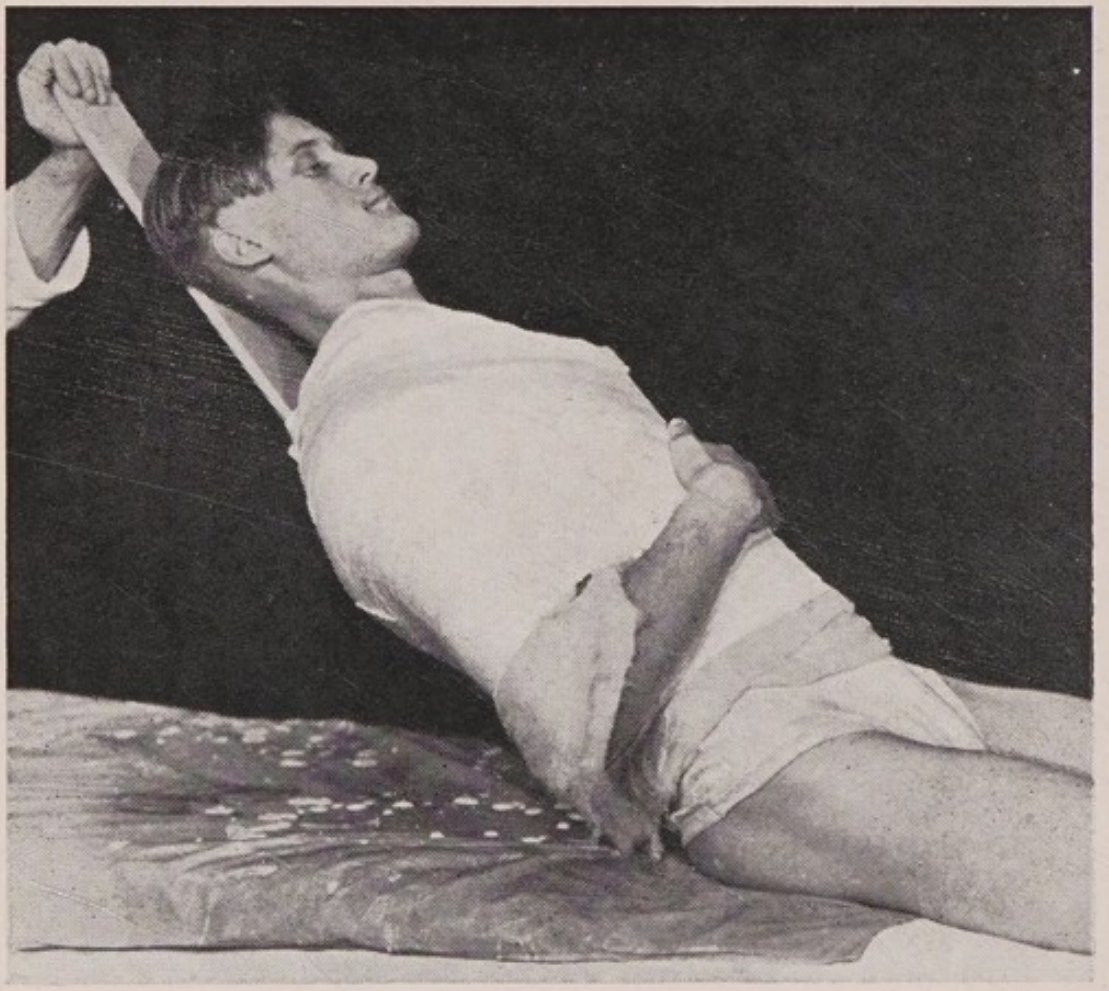
Elbow and Forearm

Following primary operation, with the elbow flexed to more than a right angle, the forearm in mid rotation and the wrist moderately dorsiflexed, the limb is padded and encased in plaster from the middle of the upper arm to the proximal of the two transverse creases in the palm. The plaster is split throughout its entire length, before evacuation.

The hand.—There should be no elaborate splintage. The hand in the position of rest, should be encased in cotton wool padded into the palm and between the fingers. The padding is generous so that pressure bandages can be applied safely. This, during the stage of reactionary oedema is important ; no undue tension will develop unless infection supervenes. When only the hand is injured a short cock-up splint aids dorsiflexion. The arm is slung.







Lower Limb

Femur and knee joint.—At RAP 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 RAP. 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, 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 surgical centre. At CCS level 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.

Method of application of the TOBRUK SPLINT for transportation of Fractured Femurs, G.S.W.s Knee, Severe Leg Fractures.

1. After the primary operation with traction applied to the leg and with the knee supported and flexed 10 degrees, apply felt or gamgee protection to the malleoli and heel.

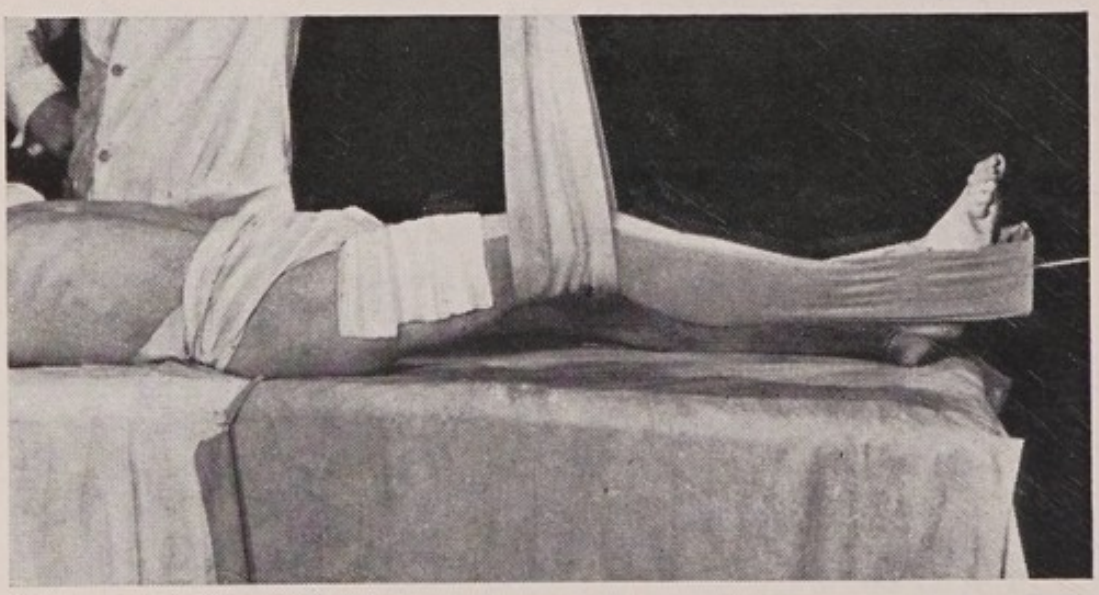
2. Apply traction elastoplast as high up as the wounds permit.

3. The Thomas' splint is applied with fixed traction and fixed counter traction, the limb being supported by a series of 4 in. flannel slings just as H. O. Thomas used to fix a fractured femur. A pad of wool is placed beneath the fracture site to restore the normal anterior bowing of the thigh. Ample wool is placed over the front and sides and under the limb, filling the gap between the limb and the side bars of the splint. The ring is held out by a pad to keep the ring fitting snugly against the tuber ischii. Two shell dressings or wool can be used for this purpose.

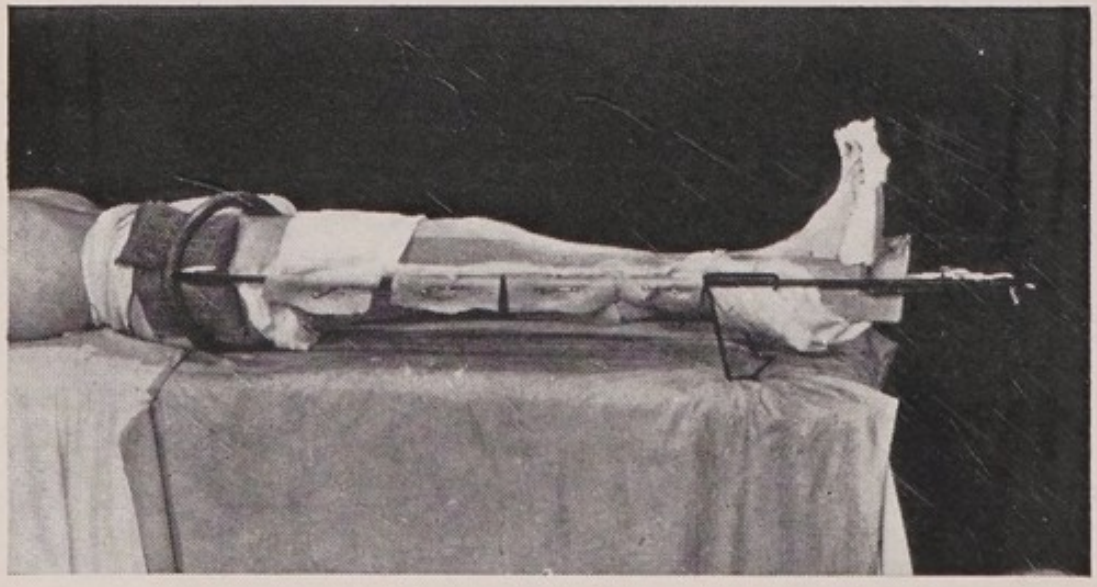
4. Plaster bandages are applied around the splint and limb, incorporating the ring and the pads under it on the outer side and extending down to the toes, including the foot which is held at right angles, the heel and sole having been adequately padded. The toes must not be cocked up. The ends of the traction strapping must not be incorporated in the plaster otherwise traction will not be effective.

Some surgeons prefer to apply plaster only as far as 3 in. above the ankle, and to fix the foot to the footpiece by bandaging only. This has the merit of not interfering with the tightening of the traction, but may allow some rotation of the foot.

5. The lower end of the Thomas' splint must be fixed to the suspension bar of the stretcher so as to prevent movement. Firmer and wider support for the footpiece is sometimes made by adding a Cramer wire base. The suspension bar must be firmly fixed to the stretcher. For fractures of the upper third, fixation of the ring to a second suspension bar attached to the stretcher at this level may be used to advantage.



Extension bands applied and suspension bandage to flex knee 10 degrees. Pads of felt protect malleoli and heel.

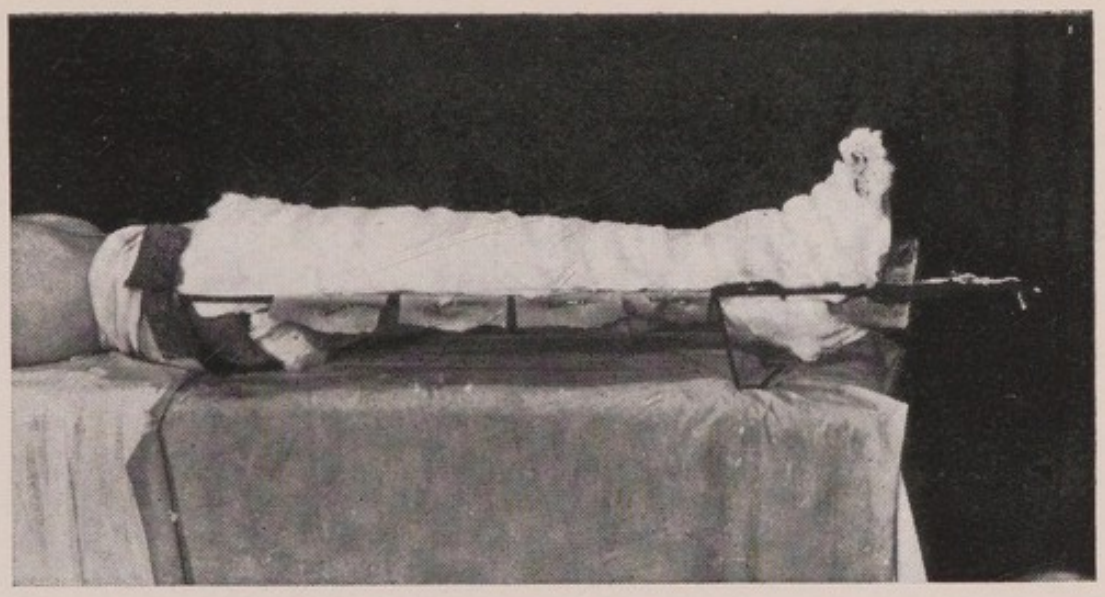


Thomas' splint in position with fixed traction and countertraction. A spreader is shown but equally effective traction results if the strapping is taken round the sides of the splint tied to the end and tightened by twisting with a stick " Spanish windlass " fashion.

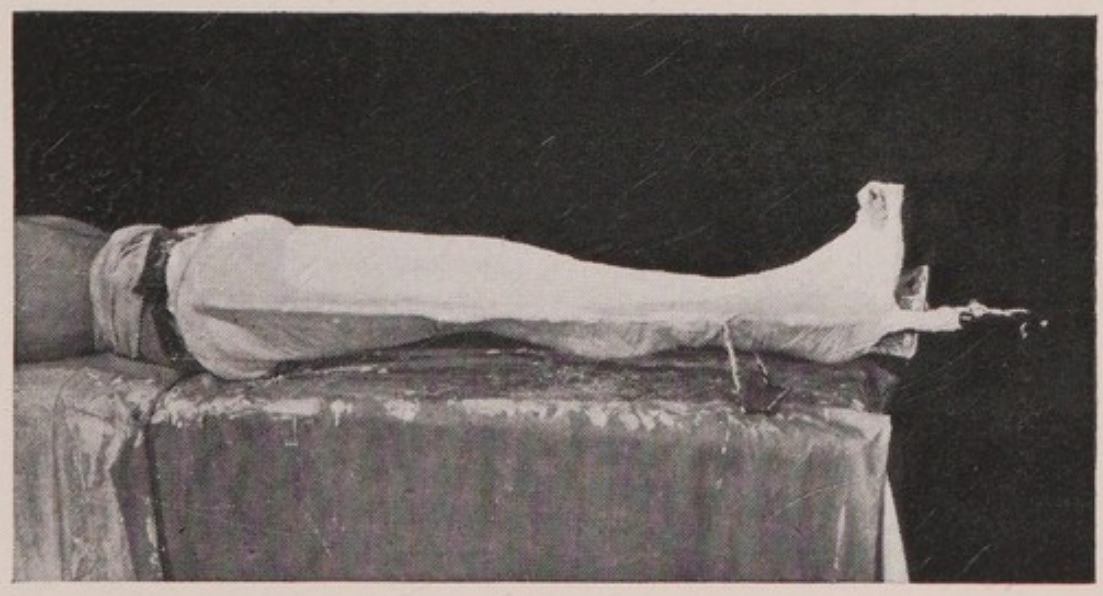
A pad on the outer side keeps the ring snugly against the tuber ischii.

A pad of wool is placed under the fracture site to restore the normal anterior bowing of the thigh, ample wool has been placed under the limb.

The foot is held at right angles to the leg on a footpiece adequately padded under the sole and heel. The toes must not be cocked up.



Wool envelops the limb, filling the gaps between it and the side bars of the splint, completing in front the padding which has already been done behind.



The limb and splint are encased in plaster as has been described. It is moulded to grip the side bars. If the foot is included in the plaster, the traction strapping must be kept free to allow effective traction and tightening of the windlass.

Fractures involving the trochanters or neck of the femur are not well immobilized in a Tobruk plaster and may be put up in a very carefully applied plaster spica.

Leg.—Severe fractures are best immobilized in the Tobruk plaster. Less serious fractures may be put up in a padded plaster cast from groin to metatarsal necks with the knee flexed 10 degrees, and the foot placed at right angles. The splint is split throughout its entire length before evacuation. The limb and plaster may be slung.

Transportation of Patients with Fractures

Properly immobilized fracture patients should travel well for four or five days unless there has been haemorrhage, and need no more than routine

watchful nursing on the way. As soon as shock has been overcome and immobilization is adequate they can be moved, but the patient suffering from a gun-shot wound of the femur requires special attention. If his limb is not adequately immobilized the resultant shock may be fatal. Such a patient is better retained for 48 hours after operation. If he is unfit to travel for 10 days, it will be advisable to hold him for definitive treatment and if conditions permit, not evacuate him for eight weeks.

IN BASE AREAS

As a rule all severe cases and all femurs are segregated into orthopaedic centres attached to large base hospitals.

The first aim in treatment is to convert an open into a closed fracture, with all the benefits which will accrue—a sound scar, elimination of early sepsis and of late chronic osteomyelitis which was such a feature after the war of 1914-18 following the policy of allowing so many such wounds to heal by granulation. The reader is referred to the section dealing with the closure of wounds in general. The treatment is identical and must be all the more meticulous when bone is involved for if dead space is not obliterated the skin will invariably break down and a discharging sinus communicating with the bone will result. This is the least serious of the complications which may ensue.

For the infected wound which does not receive early operation, treatment again is on the same lines as already described—the removal of all foreign and necrotic tissue, adequate drainage, with the limb immobilized on a splint, general and local chemotherapy—all with the same object of early closure. If this object is not achieved, degrees of infection will persist varying from the mildly infected small sinus with local sequestration to the dangerous " sump " formation, most commonly seen in the thigh. From inadequate drainage, this sump around the bone ends, tracks along the fascial planes, and without necessarily showing marked external signs, results in the gravest toxaemia, eventually with renal involvement. When that stage is reached, adequate drainage is an exceedingly difficult matter; blood transfusions, high protein diet, chemotherapy, all may fail and amputation in so toxaemic a patient will be a hazardous procedure.

This was the picture so frequently seen in earlier wars and also in enemy hospitals in the most recent one. Prevention—by adequate early surgery and skilful wound closure, with chemotherapeutic aid—is the only real solution to the problem.

If conservative methods succeed in overcoming this grave condition the stage of chronic osteomyelitis will still remain to be dealt with. Sequestra should be removed when judged to be lying free, but wide excision of bone jeopardizing stability must be avoided. Much later, excision of all infected tissues, and skin cover by tube graft may be possible as a preliminary to dealing with the gap by bone graft at a later date.

TREATMENT OF INDIVIDUAL FRACTURES

Principles

1. The type of splintage chosen should be applicable for treatment until the fracture has united. It should be borne in mind that unexpectedly the patient may have to be evacuated.

2. Overtraction results in delayed union. When mobile traction is used, the smallest adequate weight must be employed for the shortest time compatible with maintaining proper reduction during active movement.

3. Internal fixation of missile fractures is indefensible, nor does any form of chemotherapy justify it, nor in future is it likely to.

4. 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.

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.

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.

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 correctly used will suffice.

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. While the wound itself requires treatment, the fracture is best treated on a Thomas' splint.

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 lower end of the tibia if the wound permits, or through the os calcis, is effective.

Upper limb.—(When the fracture has been converted into a closed one).

Humerus.—" U " plaster from nape of neck down over elbow and up to axilla with circular turns, is used with the addition of a narrow arm sling. A shoulder spica is sometimes required as part of definitive treatment, particularly when the head of the humerus and glenoid cavity are comminuted. This splint is uncomfortable in bed and when travelling, and the plaster spica with the arm abducted only thirty degrees has no advantages over the " U " plaster.

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 as part of his " quadriceps drill."

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 contraindication 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.

SECTION X

GUNSHOT WOUNDS OF JOINTS

In the war of 1939–45, gunshot wounds involving joints were not nearly so formidable injuries as they had been in previous wars. Until then, this type of injury—and especially when the knee joint was involved—was one of the most serious limb-destroying and life-destroying of lesions. It is only because of early and expert surgery and chemotherapy that it has been possible to record this advance. When there has been gross sepsis, painful fibrous or bony ankylosis is the rule in patients who recover. When gross sepsis is prevented joints with good function should be the rule rather than the exception.

Treatment in the Forward Area

The surgical treatment of joint wounds is on the same general lines as already described. The tissues superficial to the joint are dealt with in exactly the same fashion. The rent in the capsule is enlarged to allow full exploration of the joint but none of the capsule must be sacrificed unnecessarily. Loose fragments of bone and cartilage, and foreign bodies are removed, unless preliminary X-ray examination has shown the latter to be deeply embedded in bone ; blood clot is washed out and the capsule is closed if possible. It was the practice in 1945 to inject about 25,000 units of penicillin into the joint. The skin is left widely open ; the wound dressed with dry gauze, the limb padded and put up in plaster of paris, extension being applied when possible.

The optimum position for joints liable to subsequent stiffness is :—

Shoulder.	Abduction 45 degrees ; anterior to coronal plane 10 degrees.
Elbow.	100 degrees extension ; hand just supinated from mid position.
Wrist.	Comfortably dorsiflexed.
Hand.	Position of rest ; thumb opposed.
Hip.	Abducted or adducted so that legs are of equal length ; Flexed 20 degrees.
Knee.	Flexed 10 degrees from normal hyperextension.

Ankle and foot—at right angles—neither inverted nor everted.

In the case of the knee joint, the Tobruk splint was found to be the best form of immobilization. With due attention to extension during transit, these patients travelled exceedingly well.

Penicillin systemically was given to all joint cases routinely.

At the Base

The surest way of converting a penetrating wound into a pyarthrosis is by movement of the joint. If a patient on arrival at the base is *afebrile*, has a normal pulse and there is a record of a small wound only, it is well to leave the patient alone for 4–6 weeks—more stiff joints result from flares-up of infection than from prolonging the period of rest. Otherwise, the plaster is removed with extreme care, d.p.s. is carried out and the plaster re-applied. In the case of the knee joint, this is done without disturbing the Thomas' splint if possible.

If the patient is febrile, the wound must be inspected in the theatre. There may be pus under tension within the joint or a more superficial inflammatory process. The parts may require to be laid freely open, and all tension must be relieved. Peri-articular inflammation requires antibiotic treatment systemically. Strict immobilization at all times is essential.

Established pyarthrosis results in the gravest toxaemia. The treatment is to drain freely and relieve all tension. Drainage is often difficult. When the knee is involved, incisions on either side of the patella are of greater value when the patient is nursed on his face : removal of the patella may aid drainage. In the case of the shoulder and hip—and infection at these sites is sometimes overlooked—more effective drainage is sometimes obtained by removing comminuted fragments of bone than by an operation planned for drainage, similarly in the elbow, by removal of comminuted fragments of olecranon. These cases must remain strictly immobilized all the time, with extension whenever possible, and antibiotic treatment continued parenterally and perhaps locally also.

General treatment as already described is equally important.

Amputation in the presence of severe toxaemia is hazardous but must be considered before it is too late.

SECTION XI

AMPUTATIONS

Amputations

Amputations are of two kinds : emergency and final. An emergency amputation is only a stage in treatment and foreshadows another amputation in future. A final amputation as the name implies is intended to be the last operative treatment which the injury demands. 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 perform an amputation of emergency type. Nearly all front line amputations fall into the " emergency " category.

Emergency Amputations

When to amputate

(1) By reason of the severity of the damage.

In the case of recent injuries (first 24 hours) amputation of *upper extremity* should only be considered when part of the limb is mangled and devitalized 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, fingers or thumb.

In the case of the *lower extremity* after recent injury, amputation may be considered warrantable 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 vascular injury does not justify it.

(2) By reason of infection and other complications.

(*a*) Clostridial gangrenous myositis of segmental type,

(*b*) gangrene due to vascular injury,

(*c*) continued sepsis associated with severe nerve or bone injury,

(*d*) secondary haemorrhage.

In the upper limb when there is a gunshot wound involving the humerus and haemorrhage has recurred for a second time, amputation should be through the site of fracture above the elbow.

In the lower limb when there is a gunshot wound of the thigh involving the femur and secondary haemorrhage has recurred for a second time, the limb should be amputated through the site of fracture. When there is a gunshot wound of the leg with fracture of tibia and fibula and secondary haemorrhage continues from the wound or into the leg, the level of amputation should be above the knee.

In dealing with the blood vessels at amputation it is important to remove all clot and ligate the vessels at a level where each artery and vein can be defined.

The decision to amputate both for primary and complicated injuries must often be difficult and a source of anxiety. When in doubt, the surgeon should obtain a second opinion if it is available.

Where to amputate

As a general rule amputation should be at the lowest level at which the tissues are viable. An amputation ensures that the infected tissues are adequately drained, so there is no need to go above the infection. The principal exception to this is that an above-knee amputation is indicated in severe lesions just distal to the knee and similarly in the case of the elbow.

The general rule that amputation should be at the lowest possible level requires amplification. When conditions are unfavourable and for any reason sepsis in wounds becomes a problem, then this rule must be adhered to. If on the other hand conditions are very favourable and d.p.s. is possible at the optimum time, then amputees will reach England with well healed stumps far longer than the ideal, yet so well healed that they will sometimes be averse to any final operation to suit the limb fitter's wishes. When conditions are as favourable as in 1944–45 and there is practically a guarantee that a d.p.s. wound will heal by first intention it may be regarded as justifiable for an experienced surgeon to plan primary amputations as definitive ones.

How to Amputate

Patients requiring amputation are often profoundly shocked, in dire need of vigorous resuscitation and surgeons must be prepared to operate rapidly. A tourniquet is applied, skin is fashioned into anterior and posterior flaps, the combined lengths being approximately equal to 1½ diameters of the limb at the level of the bone section.

The deep fascia is incised at the same level as the skin and reflected upwards with it in a single layer. The muscles are cut through ½ inch distal to the proposed level of section of the bone, the blood vessels at the same level, and it is probably advisable to divide the main nerves at a higher level. Using an amputation retractor the bone is sawn through without disturbing the periosteum. The main vessels are sought for and ligated. The tourniquet is then removed and all bleeding points secured. There is no stitching. After insufflation with penicillin powder the flaps are allowed to fall into place. Dry dressings are applied and the stump immobilized. D.p.s. follows as for an ordinary wound.

A through-knee amputation may be considered in the severely shocked multiple injured patient. It requires large skin flaps—but there is no bone

and little muscle to be divided. Almost always a secondary above-knee amputation will be necessary.

British surgical opinion is against guillotine amputations, Syme's and Stokes-Gritti type of amputation likewise.

Final Amputation

As explained above, the level of the emergency amputation may be at the site of election, but as a rule the saving of life, rather than the level of bone section will have been the primary consideration.

The sites of election are :—

Lower limb

(1) 10 inches length of femur measured from the top of the great trochanter.

(2) 5½ inches length of tibia measured from the knee joint. Syme's amputation popular in other countries where the climate deals more kindly with a stump than England, should only be performed by an experienced surgeon and never in the presence of sepsis.

Upper limb

(1) 3 inches above the elbow joint.

(2) 3 inches above the wrist.

Conservation of the hand is of vital importance and is dealt with in Section XII. Fingers or parts of them must be preserved if viable.

The amputation as regards flaps, and section of fascia muscle nerve and bone is as described for the emergency amputation. Bone section should be at right angles to the shaft. The end of the tibia should be bevelled in front and the fibula divided at a level one inch higher.

Bleeding points must be secured so that the wound is dry. It may be considered wise to drain the angle of the wound.

The skin edges are accurately approximated.

The stump requires copious dressings and firm bandaging. Much the best method of providing support and correct fixation is by plaster of paris, which in the case of the below-knee amputation extends up as far as the groin, and in the above-knee, as a hip spica. The dressings are not disturbed for ten days (except for delayed closure or to remove and drain) unless a rise of temperature or pain requires investigation in the operating theatre.

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 XII

FOREWORD TO THE SECTION ON HAND WOUNDS

Notwithstanding the foregoing advice that except in the case of the scalp and abdominal wall, primary suture should not be carried out, there is a further possible exception to this advice when conditions are entirely favourable. Wounds of the hand treated in the way that a plastic surgeon would wish, will retain or recover degrees of function which could not be achieved if skin cover were delayed. So important is full function of the hand to enable the soldier to fight again or work again in industry, that the methods considered ideal are given in detail in the following paragraphs. These ideal methods are time consuming and their adoption will depend on prevailing conditions.

In war, the hand is liable to severe lacerating injury quite apart from gunshot wounds. There can be no doubt that these are the methods of choice for such a case. They will not be the ideal methods when meticulous time consuming surgery will be at the expense of others whose lives and limbs may be in danger. They are, for the general surgeon, the ideal methods of treating war wounds involving the hand and digits, when the services of a plastic surgeon cannot be made available, and when he is convinced that, everything considered, by these methods he will succeed. There will be no possibility of practising them at forward operating centres during rush periods, nor when primary surgery is long delayed. It is better to risk some degree of scar formation rather than a catastrophic flare-up from closure following imperfect excision.

HAND WOUNDS

The general principles by which successful results are obtained in wounds of the hand are similar to those for wounds in other parts of the body with one important modification. This concerns the time of wound closure. Reduction of scar tissue to the absolute minimum is the objective of hand surgery. Minute amounts of scar which would have negligible effects elsewhere in the body can cripple a digit. For this reason a delay of two to four days between the excision of the wound and closure is not acceptable. The closure must be "Primary" and not "Delayed." Delay in closure even for a short time has two effects. It increases the scar tissue, and, because of retraction of the skin plus oedema of the deeper layers, may prevent a closure by approximation which would have been possible earlier. In hand wounds, healing must be uniformly quick and quiet. For this reason the anti-infective steps in treatment—the toilet and excision—have to be meticulous and thorough. The accessibility of hand tissues for thorough excision, and their good vascularity make for quiet and quick healing with minimal scar deposit, provided all dead and infected material has been removed and the wound closed primarily.

Primary Closure and Primary Repair

A primary closure of skin does not necessarily imply a primary repair of tendons and deep structures. Except in clean cuts in clean hands seen within six to eight hours, and except when the operator has special experience in

reparative hand surgery, the repair of deeper structures is best left till after primary healing, and softening of the scar.

Tourniquet

It is almost impossible to do the delicate detailed work of excision of hand wounds thoroughly, except in a bloodless field. A *pneumatic* tourniquet should be used routinely in the work. It may be left on for one and a-half hours, then repeated for a similar time after a release of five to ten minutes. Before closure of the wound the tourniquet is released, while the hand is elevated and compressed over dry gauze for up to five minutes. Arterial spurters are then secured and ligated with three 0 catgut or fine silk. While the hand is again elevated and compressed the tourniquet is re-applied and the closure completed. The hand is elevated again, and firm compression over gauze applied before the tourniquet is finally released.

For digital injuries and amputations a rubber tube around the base of the finger is sufficient, and safe for periods up to one hour.

Anaesthesia for Hand Wounds

In battle conditions general anaesthesia will be used because of convenience.

Local analgesia by digital, wrist, or elbow block is very suitable for individual cases. When digital blocks are used *no adrenalin* is added to the local; 1.4 cc. of 1 per cent. procaine is infiltrated well proximally in the web by a fine needle which is passed forward through the dorsal skin at the level of the knuckle, once on each side.

PRIMARY TREATMENT

The primary treatment of a hand wound comprises the toilet, the anaesthesia, the excision, the haemostasis, the closure and the after care.

The Toilet

1 per cent. cetavlon or warm soapy water is used. The primary toilet may often be done by the man himself. It should take up to 20 minutes. At least 4 pints of fluid should be used. The whole of the hand and the arm to the elbow should be meticulously cleaned with the use of a sponge, nylon scrubbing brush, and nail file.

A second toilet with CTAB lavage of deeper layers is done after the anaesthetic.

The Excision

The excision comprises 1 to 2 mm. of the complete skin margin to give a non-contaminated non-bevelled edge which can be accurately apposed. It may be done by a No. 15 Blade, using hooks to steady the edges, or by straight, sharp 4½ inch scissors after the edge has been undermined for about .5 cm. Scissors are used for the removal of soiled and devitalized tags of deeper layers. Muscle is excised radically, back to contractile and bleeding fibres.

The Haemostasis

When the excision is completed the tourniquet is released and the dry gauze pressure applied for two to five minutes. Spurting bleeding points are then secured by haemostat and ligated with fine silk or three 0 catgut. The tourniquet is then reinflated.

The Closure

The closure is primary, and the methods of closure available are :

(1) Approximation.

(2) Free Graft.

(3) Flap—Local or Distant.

All three methods may have to be used in complex or extensive wounds.

(1) Approximation

Approximation is the method of closure when the edges lie together without tension. Undermining on the anterior aspect of palm or digits is small—not for more than 1 cc. If this amount of undermining does not produce the desired apposition without blanching and tightness when the digits lie together an alternative method must be used. Skin edge approximation is done by sutures inserted on a Gillies needle-holder with the hand held in full pronation so that the needle passes through the skin and some subcutaneous tissue at right angles to the skin surface. A suture inserted in this manner corrects any tendency for inversion of the edge. Each side is taken separately. The sutures are at 3 to 4 mm. intervals, with bites 3 to 4 mm. broad and 3 to 4 mm. deep.

(2) Free Grafts

Free grafts may be used when the edges cannot be approximated without tight tension and the raw area is chiefly soft tissue, not bone. Split skin or dissected full thickness skin grafts from the arm may be used. A full thickness graft is cut to an accurate pattern of the defect and fixed by many marginal sutures. The split skin free graft is not cut to the pattern and is sutured with marginal overlap over the defect.

(3) Flaps

Flaps, either local or distant, should be used for cover when bone or tendon or joint capsule are exposed in the wound. It is always an advantage to use a flap of hand or finger skin as this has more sensory end-organs in it than most flaps from elsewhere in the body. For defects on the anterior aspects of digits it is often possible to design a local flap of dorsal skin ; the dorso-lateral secondary defect is covered by a free graft. Palmar and thenar flaps are of value for thumb and index losses of the tip. Of the more distant flaps the cross arm flap is available for some digital and palmar defects—the lack of bulk in the subcutaneous tissues of the forearm is an advantage. For men a thoraco-digital flap, with the hand placed flat above the opposite breast, provides very suitable cover for a number of hand defects, because the position is easy to maintain and the flap is without bulky subcutaneous tissue. An abdominal flap is used for women to avoid scarring the breast.

Equipment for Hand Repairs

The tissues of the hand are handled by Gillies tissue hooks or by the lightest tissue forceps which hold dermis and subcutaneous tissues rather than compressing the full thickness of the skin edge ; 4½ inch ophthalmic scissors —straight and curved, pointed and blunt—for the excision of deep layers. No. 15 BP blades are used for the skin. Only light fine pointed haemostats

are used on hand tissues and care is taken to apply them accurately to the minimum of tissue. No. 16 and No. 18 curved needles are used for most of the work, but for very small flaps atraumatic No. 6 needles are needed. Serum proof 04 and 06 silk which ties a stable knot with two loops is easy to handle and is a very suitable kind of suture material. It may also be used for the deeper vessels. Fine and medium nylon are acceptable sutures for hand skin. The nylon knot is less stable than silk and needs several loops for security. Nylon can be left in hand skin longer than silk before causing reaction. Tantalum and stainless steel (" Fagusta "—triple foil which does not kink) are valuable materials for skin closure when, because of a plaster, the skin sutures have to stay in for three to four weeks, and for tendon and nerve sutures, and for interossous wiring. If catgut is used in the hand, to secure bleeders or for closure of muscle and deeper layers of soft tissues, the calibre should not be thicker than three 0.

The After Care

A dry atraumatic intimate dressing such as nylon derivative is preferable. If tulle gras is used it should be as non-greasy as possible. Outside the intimate dressing compression is provided by bulky fluffed out cotton gauze. This is maintained in place by zinc oxide strapping and bandages. Small digital wounds are fixed with cotton bandages ; the larger repairs have light crepe compression outside cotton gauze, which in these cases is particularly bulky and extends from digit tips to well above the wrist.

The rules regarding immobilization are : only the affected digit is completely immobilized ; it is immobilized semi-" flexed " ; some degree of active movement in other digits is practised from the start ; at least slight movements are started in the affected digit by seven to ten days. The key to the proper immobilization of the hand is the wrist joint. When this is extended fingers and thumb automatically come into correct position of function.

Dorsal skin heals more rapidly than palmar skin and sutures can be removed from dorsal at the fourth to eighth day. The healing of palmar skin takes up to three weeks to consolidate. If sutures are completely removed from these wounds before the tenth day the wounds may gape. Some sutures are best left in for at least fourteen days. They seldom mark the skin in this site.

SPECIAL INJURIES

Traumatic Amputation of Digits

The principle of conservation of all tissue and of maximum length, is of very great importance in the primary treatment of digital injuries. It holds with particular force for the thumb and index where primary proximal amputation is seldom if ever justifiable. For other digits primary proximal amputation may be undertaken when extensive injuries make it certain that there will be no future function in the digit. The skin of such an injured digit may be used, when filleted of bone and tendon, to provide cover for a palmar or dorsal defect. Traumatic amputations cannot be closed by approximation. The result of conservative treatment and of healing by granulation is not only gross delay in healing but a finger stump which is tender and unstable, and often, a stiff finger. The methods of closure available are by free graft, or flap, or both.

The Nail

When the nail is involved in an amputation, it must be cut back about 4 mm. from the edge of the nail bed in order that healing may occur here, between the flap or free graft and nail bed, before the rigid nail grows over a scabbed or raw edge. If this is not done, pocketing may occur along this line and lead to infection of the nail and bone.

(1) Free Graft Covers of Amputation Stumps

This method gives good short and long-term results when neither nail nor bone is involved in the pulp amputation. Dissected or split skin grafts are more certain, but dissected grafts cut to a pattern and accurately sutured to the defect give a better late appearance.

(2) Free Graft Cover Plus Local or Digital Flaps

When phalanx and nail are involved, a free skin graft will not give a good late result, as the graft tends to be adherent and unstable on the bone. In many of these cases there will be a local skin flap formed by the injury which can be used to cover the bone in the stump. Sometimes after cutting back the anterior aspect of the bone in the stump, for not more than 1 to 2 mm., a pulp or skin flap can be approximated to the nail bed over the bone. The remaining raw area in front is then covered by split skin free graft (after the nail has been cut back to 3 to 4 mms.).

(3) Distant Flaps

Some amputations, particularly those of index and thumb treated by primary free graft cover, may need a later repair by a hand flap or one from the chest or abdomen. Such pedicled flaps—from hand or trunk—should not be done primarily, unless the operator has previous experience in their use.

(*a*) Hand Flaps

(i) Thenar.

(ii) Palmar.

Thenar and palmar flaps make valuable repairs for the lateral three digits as they give the stump a cover of hand skin (which has touch corpuscles). Very special attention must be paid to the repair of the secondary defects. This repair is done by dissected full thickness skin grafts cut from the forearm. For index and middle fingers a thenar flap based proximally and not extending beyond the palmar crease is used. For defects of the thumb a palmar flap with a lateral or medial pedicle at the base of the index is used. Immobilization for two weeks before division of the pedicle of the flap is maintained by zinc oxide strapping.

(*b*) Thoracic and Abdominal Flaps

For these flaps the hand must be fixed to the trunk for a period of two to three weeks. A thoracic flap above and lateral to the opposite breast, is very suitable as the position is easy to maintain and the subcutaneous tissues are not too bulky there. This donor site is a very suitable one for men. For women the abdomen is used. The trunk flaps are cut to a pattern of the defect on the digit. Free split skin grafts are used to repair the secondary defects ; they extend on to the base of the flap to seal off this raw area during the period of attachment.

Repair of Tendons

Divided extensor tendons which can be approximated are best repaired primarily. This may be done by a figure of eight stainless steel suture which passes through skin of proximal side to distal tendon, then proximal tendon and on through distal skin. It is removed at the end of the third week. Or it may be done by a three 0 suture—of silk, or fine tantalum, or fine stainless steel—which criss-crosses through—about an inch of proximal and distal tendon is used. When there is loss of extensor tendon substance, a good primary repair results from transposition of one of the extra extensor tendons to index or little fingers.

Flexor tendons above the wrist in clean cut wounds can be repaired primarily in the same way. In " No Man's Land ", between palmar creases and distal digital crease, the prognosis on an end on primary suture is bad. It is often wiser simply to do a skin closure, and do a late repair by tendon free graft when healing is complete and the scar soft.

Repair of Nerves

In clean cut wounds in clean hands a primary repair may be done for digital nerves and for the main trunks. For approximation of a divided digital nerve considerable mobilization of the nerve may be necessary, the finger may have to be kept in flexion for three or four weeks. Fine silk or fine tantalum on atraumatic No. 6 needles are used for the suturing.

Secondary Closure of Hand Wounds

For the reasons given above this is never the method of choice. But hand wounds two weeks or more old may be seen and have to be treated. A thorough toilet under anaesthesia with removal of devitalized and soiled tissues is done. Closure by approximation is seldom practicable. Provided the bed of the raw area does not contain more than a few patchy areas of exposed tendon and bone, the safest cover is by a split skin free graft. Such a graft may need a later replacement by a flap. When the bone and tendon predominate in the base of the wound, a belly hand flap will provide the best and most certain cover.

Late Hand Reconstructions

The majority of late hand reconstructions are best done at special centres. Repair of deeper structures—bone, tendon, and nerve—should be done under a soft stable skin cover. This may occasionally be provided, *e.g.*, by belly hand flap—at the time of the bone and tendon repair. More commonly the scar tissue is excised and replaced by the flap first. The flap is detached from the abdomen and allowed to become soft and free of oedema before it is re-opened along one of its borders and the deep work done. During this waiting period great attention is paid to supervised active movements of digits and of whole arm. These may be combined with light continuous traction applied through light splints to increase joint range. For composite injuries of bone, of nerve, and of tendons, all deep work should be done at the one operation, if this is at all feasible. Each re-opening of the cover flap and exploration means additional deposits of scar tissue. In reconstruction for losses of the thumb the choice will most often lie between pollicization of the index or lengthening of remaining thumb elements. Very occasionally a toe-thumb transfer may be the method of choice for this repair.

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 type 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 then be rolled loosely. Making 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 type 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 ORA 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 from 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 type bandages are used.

Creamed-fabric Method

Sheets of cellona type, 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 for the immobilization of fractures 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.

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 immobilization 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 interleaving the two cut edges.

Spine

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 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 not 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 primary operation. If a main nerve is found divided, primary suture is never justifiable, but it is permissible and does no harm, to bring the ends together by one or at most two stitches, or if part of the nerve has been destroyed, the stumps may be anchored to adjoining muscle or fascia by single stitches to prevent retraction or displacement. If the nerve is not seen no attempt should be made to find it. It is essential that whenever there have been clinical evidences that a nerve is paralysed, *the fact that that nerve has been seen to be divided, has been anchored or has been seen to be intact anatomically, should be recorded prominently on the field medical card.*

2. INTERMEDIATE TREATMENT

Delayed primary suture of the nerve is not justifiable for various reasons including the following : there is always a risk of sepsis ; the amount of disruption of the nerve cannot be determined ; elaborate dissection to mobilize it is harmful ; the nerve sheath is friable but becomes less friable later ; the scar involving all the injured tissues will be continuous and the line of nerve suture liable to be dragged on. The aim, therefore, at this stage is confined to obtaining uncomplicated healing with a minimum of scarring.

Before and after the definitive operation, the object of treatment is to maintain nutrition and mobility in joints and in the paralysed muscles. The two chief causes of stiffness are oedema and muscle shortening. The former is forestalled by elevating the limb, the latter prevented by suitable splinting. 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. It is inevitable if splintage is prolonged or ill-judged.

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.

Whether the paralysis be widespread or not, every joint in the affected part must be put through the fullest possible movement several times a day actively or passively, the only limiting factor being the immobilization required for the healing of the wound or fracture. The patient himself must be instructed how to exercise the parts, keeping the fingers and hand moving, passively if active movement is not possible, and maintaining free range for the toes and tarsal joints in the case of the lower limb. Once any acquired stiffness has occurred, it may take months of intensive physical treatment to overcome it.

Daily galvanism reduces the rate of muscle wasting and later prevents further wasting (stimuli strong enough to produce a brisk contraction, 30 a minute for a total of 90 stimuli, with an interval of one minute between each group of 30 stimuli to permit recovery from possible fatigue).

3. REPAIR OPERATION

The importance of adequate preliminary investigation must be emphasized. The history, the duration, the progress and the complete neurological findings must be studied. Examination by nerve blocking, electromyography, muscle and nerve biopsy, may all be required. In certain difficult cases the differential diagnosis between anatomical and physiological division of a peripheral nerve can only be made with certainty by viewing and testing the exposed nerve at operation. If a missile has passed in the vicinity of the known course of a nerve causing paralysis, and the anatomical state of the nerve is unknown, there is much to be said in favour of early exploration of that nerve ; it is a necessary step in the diagnosis and the higher in the limb the lesion, the earlier should be the exploration.

There is evidence that the earlier the suture of a divided nerve is carried out the better the chances of recovery and that the best time for repairing a nerve is about the third week after injury, provided that sepsis has not been a marked feature. After six months the prognosis worsens progressively.

What is actually done at operation must depend on the condition of the nerve and surrounding tissues. Exposure of the nerve, mobilization or lengthening of the central stump, and suture or grafting are all important parts of the technique of operation outside the scope of this field pocket book.

SECTION XV

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, metabolism is reduced, the tissues are likely to remain viable for a longer time despite the minimal amount of oxygen available for their use, and cooling also delays infection.

Temperatures as low as 5 degrees 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 degrees 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 effected sufficiently if direct pressure is exerted on the wound. This may be direct digital pressure, in the first place, and should be followed by the firm application of a bandage over 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 RAP or ADS

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

If recognized, bleeding points should be ligatured or underrun. Sometimes it may be necessary to leave pressure forceps *in situ*, stabilizing 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 CCS

After the commencement of resuscitation, any wounded who are still bleeding or in whom reactionary haemorrhage is likely, are submitted to operation. The wound should be freely opened by longitudinal incision, clot is cleared and dead tissue excised. Haemotasis 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 be through the wound track in most cases, but formal operative exposure of the vessel will be necessary, particularly when the wound is small, or when it does not give direct access to the vessel.

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 XVI ; concealed haemorrhage into the thoracic or abdominal cavities, in Sections XVIII and XIX.

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 by an inflammatory process of an intact exposed vessel, 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.

Transfusion

Should be commenced early, preferably with whole blood.

Treatment

This should be undertaken if possible 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 and the vessel adequately ligatured above and below it at the nearest level at which it is sufficiently firm to stand ligation. 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. The new wound made for this purpose should not be sutured.

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

While the use of antibiotic and sulphonamide therapy has greatly lessened the incidence of repeated secondary haemorrhage and prolonged wound sepsis, amputation may be a life-saving procedure. (See Section on Amputations.)

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 recorded most often 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.

Haemostatic substances like fibrin foam or oxycel gauze, may be of value (*see* Section XIX).

ARTERIAL HAEMATOMA

This is most frequently seen in a dangerous form in the axilla or popliteal space. If the condition localizes 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

When complete transverse division of a main artery occurs the traction, retraction and contraction of the ends result in only a slight loss of blood. If the vessel is only partly divided bleeding continues and ligature is usually required. Attempts to suture cleanly divided vessels have been followed by occasional success, both with and without the subsequent use of heparin. Wounds caused by projectiles usually show too much laceration for successful suture and there is little place for the procedure in field surgery. Attempts to maintain the circulation by the use of plastic or vitallium tubes, followed by heparinization, have proved successful in some cases, but this must not be attempted if the wound is of over ten hours' duration. Ligature will be required therefore, in most cases, in field surgery. Following ligation, the risk of gangrene of varying severity is considerable, especially if the popliteal artery is involved. The ligature should be applied proximal and distal to the wound and as close to it as possible, and the division of the artery completed. There is no evidence that ligation to the companion vein lessens the incidence of gangrene and, indeed, in the presence of a good collateral circulation venous ligation results in the painful venous obstruction syndrome.

Assisting the Collateral Circulation

Following primary ligations of main vessels the limb should be kept free from bandages, which may compress it, and exposed to room temperature to lower its metabolism. Warmth (up to 45° C.), is applied to the body and unaffected limbs to produce reflex dilatation of the vessels in the cooled limb. Sympathectomy may be employed prior to the interruption of a main artery, but is too formidable an addition to the patient's treatment in primary ligations under field conditions. Repeated sympathetic blocks may be of value.

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 XVI

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. 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 RAP 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 CCS 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 emphasized 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 penicillin-sulphamezathine powder is dusted on. A shell dressing is then applied and secured firmly by bandage or strapping. Morphia is contraindicated 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 CCS, entries should be made whenever possible on the points 2, 4, 5 and 6 above.

Treatment at the CCS or Advanced Surgical Centre

(*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-sulphamezathine 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 the arrival of the patient at a neurosurgical centre in 72 hours from the time of wounding, 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. ¼ should be given unless the patient is unconscious.

Anaesthetic

Regional block anaesthesia with 1 per cent. novutox 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 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-sulphamezathine 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. 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-sulphamezathine 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 help 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 way of detecting 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 cerebrospinal 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, with the usual precautions against renal block.

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 has shown that head injury patients travel well after operation.

2. 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 lateralizing 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.

3. 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 incisions 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 XVII

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 day and night. If possible he should be lying on an air-ring.

Inert patients should be prominently labelled in block capitals. "UNABLE TO MOVE, PLEASE ALTER POSITION DURING TRANSIT." This rule applies to all inert patients whether it be by reason of paralysis, unconsciousness, or multiple wounds. Most other patients on stretchers can alter their position from time to time and should be warned to do so.

When the skin is accessible it should be washed twice daily with soap and water, and care should always be taken after washing, to dry the parts thoroughly. If the skin is soft it should be rubbed regularly with alcohol. Special care should be taken to avoid wetting of the skin with urine.

If there is suprapubic drainage, particular care should be taken to ensure that the suprapubic catheter is draining the bladder properly.

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.

The correct treatment is to drain the distended bladder by a high suprapubic cystostomy through a short transverse or vertical incision about halfway between umbilicus and symphysis, not lower than 2 inches above the highest part of the symphysis. A fairly large catheter, *e.g.*, No. 28 Malecot, is inserted into the bladder through the smallest of puncture openings, with the catheter stretched on an introducer so that on release urine will not leak. The catheter should not be changed for 10–14 days when the wound will have healed and a firm track lined with granulation tissue will have formed through which it is easy to insert a freshly boiled catheter into the bladder to replace the one removed. The high cystostomy is convenient for the patient, should not leak, and is easily closed. It prevents the development of the contracted bladder. The opening must not be made too late, too low or too large.

If circumstances prohibit cystostomy, no harm is done by leaving the bladder alone, distension with overflow will take place and such patients can then wait in safety for a properly performed high suprapubic cystostomy.

In a partial lesion of the cord or where the cauda equina has been injured distension of the bladder will cause pain and discomfort. This can be relieved by suprapubic aspiration with a long needle and a 20 cc. syringe pending a proper cystostomy. Suprapubic aspiration may be repeated two or three times but not oftener owing to the risk of extravasation of urine.

A catheter must not under any circumstances be passed per urethram into the bladder. Experience shows that however careful the aseptic technique, infection invariably follows; and once sepsis has been introduced into a paralysed bladder, cure is difficult or impossible. Even with modern chemotherapy damage done in the forward area cannot be corrected at the base.

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.

Further treatment. Cases with wounds and injuries of the spinal cord should be sent to a special centre as early as possible. If the military situation prevents this, it may be necessary to carry the treatment a stage further.

(I) As for wounds in other situations delayed primary suture is the treatment of choice. Laminectomy should be considered at this stage only if there is a persistent cerebro-spinal fistula requiring closure by fascial graft.

Later, a neurosurgeon may perform laminectomy for one of the following indications :—

1. Gross deformity.
2. Foreign body within the theca in cases where there is an incomplete lesion, as assessed by incomplete disturbance of function.
3. Arrest in process of recovery in cases of incomplete lesion, when the effects of spinal shock have passed off, especially when there is evidence of spinal block to the flow of cerebrospinal fluid.
4. Severe and persistent root pain.

(II) The bladder must be washed out daily with a bland antiseptic lotion. The suprapubic catheter should be changed weekly with full aseptic precautions. When the patient is in bed, the urine is drained into a receptacle on

the floor ; when fit to sit in a wheeled chair, the suprapubic catheter should be connected with a urinal strapped to the leg.

The urine should be kept acid to prevent the formation of phosphatic calculi, which are due to infection and recumbency, and all the other steps necessary for the prevention of decubitus calculi must be taken.

(III) The bowel is at first atonic. On arrival at the base the rectum is almost always distended with hard dry faeces, and there is much associated discomfort if not actual suffering. The accumulated faeces must be broken up and removed gently with the finger, and an enema given. Digital removal may have to be repeated once or twice weekly until the bowel regains some of its lost tone. Later, an enema given once or twice weekly will keep the patient comfortable, and he will be able to use a wheeled chair with impunity.

(IV) Pressure sores must not be allowed to occur. The patient's position must be changed frequently and regularly. He should be turned from side to side at two-hourly intervals, day and night. Nursing and skin toilet must receive punctilious attention.

SECTION XVIII

WOUNDS OF THE CHEST AND ABDOMINO-THORACIC INJURIES

WOUNDS OF THE CHEST IN THE FORWARD AREA

The exact incidence of this type of wound varies greatly with the type of fighting ; in the 1939-45 War they were something in the ratio of 1–4 amongst those killed outright on the battlefield and 1–12 amongst those survivors who reached the Field Surgical Unit ; this is a higher incidence than the 2 per cent. of chest wounds seen in Casualty Clearing stations in the 1914-18 War, and emphasizes the need for a planned line of treatment and the life-saving value of the active measures adopted in the late war at all forward levels. There are two main phases in the treatment of the chest wound : (*a*) the saving of life by the prompt correction of physiological derangements such as open pneumothorax and blood loss, and (*b*) the later deliberate measures designed to prevent infection and to restore full chest function.

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

(1) The perforating wound requires little direct attention ; reassurance and calmness are essential, and the casualty should lie down and be kept warm. Haemoptysis is common, and this should be explained to the wounded ; a short rest is indicated before moving.

(2) The sucking open wound requires active treatment, and the essential is immediate closure of the wound to prevent the sucking noise and to render it air-tight ; an open sucking pneumothorax is fatal because of the effect on the respiratory and circulatory system largely because paradoxical respiration follows : " Paradox " is checked at once when the hole is firmly closed by tight strapping or bandaging over a large dressing. This is usually effective, but occasionally a few temporary skin stitches are required.

Evacuation

The position most comfortable to the casualty is adopted ; if there is cyanosis and dyspnoea these are often corrected by adopting a partly sitting up position ; pallor and faintness indicate a head down position. Morphia should be given (¼ to ½ grain) according to the size and state of the wounded man.

(*b*) **At the Regimental Aid Post or Field Dressing Station**

Here the wound and the physiological state of the casualty are assessed more fully and calmly ; a period of rest to enable the morphia to act and the initial shock to be treated may be very advisable before the patient passes to a surgical centre. Any evidence of continuing haemorrhage in the thorax may, however, indicate rapid evacuation.

CHEST WOUNDS AT ADVANCED SURGICAL CENTRES OR CASUALTY CLEARING STATIONS

The decision as to the need for operation, blood transfusion or aspiration of air and blood can only be made after a full assessment ; if the casualty does not respond quickly to the simple methods of resuscitation it must be assumed that either bleeding or increasing mechanical derangement of the thorax is proceeding or there may be associated wounds, especially involving the abdominal viscera. An exact note is made of all wounds as these may be multiple ; it may be found at this stage that a wound of the upper limbs or of the abdomen has involved the thoracic organs. The chest examination may reveal surgical emphysema (not serious in itself but denoting certain injury of the pleural cavity), haemothorax or haemopneumothorax or pneumothorax alone.

The physical signs of haemothorax may be misleadingly slight and a large collection of fluid may be present even when signs of it are scarcely evident ; dullness at the base, displacement of the apex beat and trachea to the opposite side and poor air entry make the diagnosis certain, but these are frequently poorly exhibited ; if available an X-ray is by far the most efficient single examination ; the film will also show the state of the lung on both sides and the position of retained missiles ; the presence of a missile in the abdomen will, of course, prove that a thoraco-abdominal wound is present ; both postero-anterior and lateral views should be taken whenever possible. The full clinical measures for estimating shock will be employed as a routine.

The Management of Non-penetrating Injuries

With the increase in mechanization and the explosive power of missiles (blast) these injuries are common and vary from simple contusions and fractured ribs to the "stove-in" chest, traumatic asphyxia, pneumothorax (simple or tension), haemothorax, and lung lacerations including rarely the tearing of a major bronchus and blast injuries. The important point to assess is the presence or absence of lesions beyond the chest wall. Haemothorax is commoner after simple fracture of the ribs than is realized.

(*a*) Fractured ribs are treated by firm strapping which reaches beyond the mid-line both in front and behind ; if pain is considerable there is no contraindication to the use of morphia.

(*b*) The "stove-in chest". This serious injury follows the fracture of several ribs both anteriorly and posteriorly; this leaves a large segment of the chest wall quite free to float in and out with the respiratory movement, and in effect produces the same mechanical upset as an open pneumothorax and paradoxical breathing follows; when the patient breathes in the loose segment is sucked in and becomes pushed out when expiration occurs. This not only means that the wounded lung fails to function physiologically but air from it passes to and fro from its bronchus to that of the sound lung with a consequent rise in the lung carbon dioxide; the breathing is accentuated as a result of the mounting CO_2, dysnopea develops and the mediastinum flops to and fro with the breathing movements with resulting cardiac embarrassment; the underlying lung is also contused and often collapses because the cough becomes ineffective and the patient cannot clear the bronchi of retained muco-purulent secretions. The abnormal movement of the loose chest wall segment must be prevented by firm strapping over a large pad of wool; if this is effective the casualty rapidly improves especially if oxygen and morphia are administered. Pain if severe may be checked by the blocking of the posterior intercostal nerves with procaine in oil. If the underlying lung remains collapsed and the patient cannot cough up secretions, intranasal catheter suction drainage through a cocainized larynx or bronchoscopic aspiration may be strongly indicated. Any associated haemothorax should be aspirated any time after twelve hours have elapsed from the time of the original injury.

(*c*) *Traumatic asphyxia* may follow sudden chest compression, rupture of capillaries causes dark blue discolouration of the skin of the face, neck, shoulders and upper chest; sub-conjunctival haemorrhages are common, and rarely retinal ones are present.

The condition though alarming in appearance usually clears up gradually.

Intrathoracic injuries

In these crush injuries contusion of the lung with haematomata formation, often seen radiologically and of varying sizes are common; they often cause slight haemoptysis, and their chief dangers are the risk of later infection which may proceed to suppuration; penicillin should be given as a prophylaxis. Surgical emphysema is common and tension pneumothorax may occur.

Contusion of the heart and an associated haemopericardium do occur; when cardiac contusion is found the pulse is often fast and permanent cardiac damage may result. Blood in the pericardium may cause tamponade with a fast feeble pulse and diminution in the cardiac impulse; radiology helps in the diagnosis and paracentesis may be required.

(*d*) **Blast Injuries**

These dangerous lung injuries follow the direct impact of the ribs on the lung after the driving in of the chest wall, as the result of a nearby explosion, usually that of a bomb. Death may be instantaneous, but many less severe cases survive. The ribs are often not fractured and there may be no chest bruising on the exterior. Shock, restlessness, severe dyspnoea, and chest pain are accompanied by cyanosis and a fast pulse. The clinical picture may lead to a faulty diagnosis of acute "battle neurosis" as the patients are extremely apprehensive and tremulous. Injury to the intercostal nerves may cause abdominal rigidity leading to a suspicion of intraperitoneal

injury. Multiple haematomata of the lungs along the lines of the ribs are present and this causes a slight haemoptysis but more strikingly the ineffective expectoration of frothy mucus. The X-ray appearances of lung mottling occur early.

Treatment is by morphia, oxygen, warmth and absolute rest ; these patients stand anaesthesia badly ; if associated wounds require surgery the anaesthetic agents should be pentothal, gas and oxygen or cyclopropane (if available) or local anaesthesia. If at the close of operation the chest is "bubbly" the retained secretions should be aspirated by a trans-nasal catheter or through the bronchoscope. Great care in venoclysis is indicated as lung oedema may be precipitated.

PENETRATING AND PERFORATING WOUNDS OF THE CHEST

A through and through bullet wound may cause very slight disturbance in the absence of bone shattering ; but pleural penetration may cause a great variety of conditions ; at the outset survival depends on the line of the missile track and the extent of the associated open pneumothorax. Early deaths are due to haemorrhage from wounds of the heart or great vessels or from the effects of an uncontrolled sucking pneumothorax. The single commonest and most important complication of the survivors is the development of a haemothorax, in itself an eminently treatable condition.

Tension Pneumothorax

This results from a laceration of the lung from which air escapes to the pleural cavity in the absence of an open pneumothorax ; the air can escape from the laceration but cannot pass back through it because in expiration lung lacerations become valvular as the lung shrinks in size ; air under pressure therefore accumulates in the pleural cavity ; some of it may escape through parietal pleural tears and produce surgical emphysema which in itself is a valuable method of lessening intrapleural tension. If a real tension pneumothorax develops, the heart and lungs become displaced to the other side ; rarely there is a tension pneumothorax in both pleural cavities. Gross dyspnoea, cyanosis, restlessness (even unconsciousness) develop ; the veins of the neck become distended, the chest is hyperresonant, the breath sounds are absent or faint, the pulse fast and the trachea and apex beat are displaced ; it is a rare but often fatal condition if not promptly recognized and treated. A large bore needle, mounted on a rubber tube, is introduced in the second or third intercostal space near the axilla through a wheal of local anaesthetic ; the rubber tube is led to a water sealed bottle and the entrapped air rapidly bubbles out into the water. A small piece of rubber is previously transfixed by the needle so that it acts as a flange and this is strapped to the skin ; the needle should not be left in the same site for more than 12 hours as it causes sepsis in its track. It can often be dispensed with before this time as the laceration in the lung tends to seal off. Morphia, oxygen and the propped up position are used. These cases often develop fluid in the pleura later and this requires aspiration.

The Question of Primary Operation

In well equipped forward surgical units this problem was largely solved in the later war. The underlying principles were to save life by correcting disordered physiology and to prevent later sepsis by limited but thorough surgical excision of the chest wall wound. The essentials are (1) good

anaesthesia, preferably through an intratracheal tube, (2) a competent surgeon, (3) an efficient sucker (the foot pump type is satisfactory), (4) the rapid excision of the area of damage including the resection of fractured ribs segments, and (5) the complete closure of the sucking pneumothorax by suture of the deep muscles, the overlying skin being left unsutured as in all battle wounds, (6) the thorough aspiration of any haemothorax or haemopneumothorax. It is quite established that early aspiration of the haemothorax does not lead to a restarting of the bleeding, which is usually from the chest wall.

The Primary Operation in the Forward Area

This is done as soon as the shock has been controlled by the usual measures. Under intratracheal anaesthesia or with a close-fitting mouthpiece after a preliminary pentothal induction the wound is excised as in other battle wounds, *i.e.*, minimal skin excision, ablation of all damaged muscle and removal of shattered ribs fragments. The intercostal artery often requires ligation ; usually there is considerable blood in the pleural cavity ; this is mopped and sucked out rapidly. Apart from abdomino-thoracic wounds or where a large missile is rapidly felt and removed no formal thoracotomy is indicated and the temptation to excise or suture damaged lung should be resisted except in the presence of obvious gross haemorrhage. In-driven fragments of bone should be removed and any associated bits of battle dress. Penicillin powder is blown over the wound to " frost " it ; the opening in the pleura is rapidly closed by interrupted catgut sutures ; it is usually a waste of time to try to suture the pleural membrane, the closure being effected by using any muscle in the vicinity. The skin should be left open ; the wound is dusted with penicillin and a dry gauze dressing is firmly strapped in position. Unless the patient can be retained intercostal drainage is not advised. (7) the use of chemotherapy from the start is the standard practice—100,000 units of penicillin should be instilled into the pleural cavity after each aspiration. It should also be administered parenterally.

Certain Cases Require no Formal Surgery in the Forward Area

(1) Some clean through and through bullet cases ; early aspiration of any detected haemothorax to prevent infection and later chest crippling is indicated.

(2) Retained metal fragments with small entry wound. If these are of a size demanding removal the operation is better done deliberately at a base hospital.

Cases in which Urgent Surgery is indicated

(1) All ragged wounds of soft parts.
(2) Compound rib fractures.
(3) Continued bleeding ; this is usually from an intercostal artery.
(4) All wounds with an open sucking element.
(5) Many abdomino-thoracic or thoraco-abdominal wounds.

The primary operation is not done until adequate treatment of shock and collapse, and of retained secretions or intrabronchial blood clots, by posture or/and aspiration, has been carried out. Experience in the late war showed that patients with intercostal tube drainage travelled badly, and there is always considerable risk of such systems ceasing to be airtight. At Advanced Surgical Centre or CCS level a formal thoracotomy, apart from

abdomino-thoracic wounds is rarely called for and the chief aims can be achieved by the limited measures outlined above.

The Post-Operative Treatment

If the indications exist a blood drip transfusion is continued. Over-transfusion carries the real danger of producing a "wet" lung or of overloading the right heart; the semi-recumbent position is the usual one to adopt but changes of position, to aid the postural drainage of bronchial secretions are often required. Morphia sufficient to relieve pain should be given; in usual doses this does not depress respiration, but rather, by removing pain, allows the patient to clear the air passages by effective coughs; every effort must be made to promote this expectoration as continued bronchial blockage leads to atelactasis. Oxygen in high concentrations by the B.L.B. mask should be used, almost routinely, and always if there is the slightest cyanosis. Sulphonamides and penicillin are given routinely.

The Care of the Haemothorax

This, the commonest complication, requires meticulous treatment; its correct handling probably represented the chief thoracic surgical advance in the last war. A blood-stained effusion commonly develops after most missile wounds, and often after crush injuries. Even a small amount of blood will excite an effusion and the haemothorax fluid is largely made up of this secondary effusion. It usually remains fluid but may clot even in the absence of infection. This fluid is a good culture medium for organisms and if not removed even in the absence of infection it causes subsequent loss of respiratory function as the result of permanent gross thickening of the parietal and visceral pleura, especially in the lower half of the chest. There is now no doubt but that the correct treatment is early aspiration (after 12 hours). Air replacement is quite contraindicated.

The reasons for early aspiration are :—

(1) The relief of intrapleural pressure and mediastinal displacement.
(2) To procure early re-expansion of the lung so that a total empyema will not develop if infection supervenes.
(3) To remove a good culture medium for organisms.
(4) To prevent the later development of massive clotting.
(5) To restore respiratory function and prevent invalidism.

As early as possible the patient should be encouraged to breathe with the affected side and at the base hospital these breathing exercises are carried out under the supervision of the ward staff and the physiotherapist.

Method of Aspiration

Morphia (gr. $\frac{1}{4}$) is given half an hour before the aspiration. The patient is propped up comfortably so that the axillary and posterior areas of the chest are clearly exposed; the site of the punctured area is best estimated after a study of the P.A. and lateral chest film; the commonest error is to aspirate too low as often the diaphragm has come up in these patients. After the skin and intercostal plane have been anaesthetized by local procaine (1 per cent.) a really large bore needle attached to a two-way syringe is introduced. (A common error is to use too fine a needle which is readily blocked by blood clot or fibrin.) The aspiration should be thorough, and is repeated every other day, until the radiograph shows no fluid or air in the chest.

As the chief aim is to secure rapid lung re-expansion air replacement should not be practised. At the end of each aspiration 100,000 units of penicillin is injected into the pleural cavity; at the base such therapy can be controlled bacteriologically, but this is not possible in the forward areas.

Signs of Infection of a Haemothorax

Pyrexia 100°–101° F. is common with a simple non-infected haemothorax for several days; infection is suspected if the patient becomes toxic and is clinically failing to improve; if the fluid becomes clotted and changes to a salmon pink colour or smells; if pus cells and organisms are detected in the aspirated fluid.

(*a*) Occasionally the infection may be fulminating of the anaerobic type, and in this rare type signs of tension pneumothorax develop, and the patient is severely ill and toxic, the aspirated fluid smells; in the forward areas treatment consists of intercostal drainage leading to a water-sealed drainage; more than one catheter may be used if the empyema is loculated; intrapleural and general penicillin combined with orally administered sulphonamide, and antigas gangrene serum should be given; with these helps the death rate is not so high as in the 1914–1918 figures, but the condition is a grave one. If the patient improves, treatment along the lines suggested below for " infected clotted haemothorax " is indicated.

(*b*) *The slower pyrexial infections : the clotted haemothorax*

In modern warfare these cases should usually be seen at the Base Hospital for the chest casualty will have been evacuated early as soon as the physiological dangers have been corrected sufficiently to enable safe evacuation; many hundreds of chest casualties were safely evacuated by air within 2–5 days after the " primary " operation and the condition will be discussed later under " Chest Wounds at the Base Hospital."

Pneumonia and Collapsed Lobes

These conditions may develop in the wounded or sound side; pneumonia must not be diagnosed until the possibility of a haemothorax or an atelectasis have been ruled out; the radiograph is invaluable in making the diagnosis; early in the late war many cases were called pneumonia when in fact they were haemothoraces calling for urgent aspiration; collapse will require postural drainage and often aspiration either through the transnasal catheter or the bronchoscope. If it is true pneumonia (which is not common) the casualty should not be moved until the response to chemotherapy has been good.

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, 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. Part of the left third and fourth costal cartilages may, if necessary, be excised to give adequate exposure, or perhaps

better by the para-xiphisternal route. 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 end *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 manœuvres if difficulty in stitching the cardiac wound is experienced. The pericardium should be left open to allow 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.

ABDOMINO-THORACIC WOUNDS

Both cavities may be damaged by a missile entering from the abdomen or from the thorax and although a large proportion of men so wounded die on the batterfield, the prognosis of those surviving to reach a surgical centre is far better now than in the 1914–18 war, and survival rates of 60–70 per cent. have been recorded. Thoraco-abdominal wounds are more frequent than abdomino-thoracic ones and have a better prognosis as have wounds on the right side than those of the left. A through and through wound on the right may traverse the pleura, diaphragm and liver and yet cause surprisingly little upset; on the left side the hazards of such wounds include risks of rupture of the spleen, and of the colon, small intestine and stomach. A large tangential wound of the diaphragm may cause a severe hernia later

The Abdominal Diagnosis

This may be extremely difficult because missile wounds of the lower thorax without peritoneal damage may cause abdominal pain and rigidity and lead to an unnecessary laparotomy. It is essential in all cases to reflect carefully on the probable course of the missile as this may indicate with certainty that the abdomen has been penetrated. X-ray studies are of great value. True abdominal rigidity, absence of peristaltic sounds and a rising pulse rate indicate peritoneal mischief. Shoulder tip pain may indicate irritation of the under surface of the diaphragm. (Phrenic referred pain)

Treatment

The usual resuscitation measures are clearly indicated. If there is a sucking chest wound this must obviously be dealt with as described above; but the difficulty is with the clean through and through wound; if this is on the right side, and if the only organ of the abdomen apparently to have been wounded is the liver a conservative state of mind may well be the correct one, a careful watch being kept on the abdomen and chest. Frequently these cases have a haemothorax which will require aspiration; occasionally the aspirating needle will remove bile from the thorax; these cases notoriously go on to empyema formation. Large shell fragments seen on the radiographs in right-sided wounds should be explored, preferably through the thorax for such often cause subphrenic abscess.

" If the position of wound of entry and exit is a left 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 " (Gordon Taylor). If

the chest injury is thought to be insignificant but there are the signs of serious intraperitoneal damage a full laparotomy should be performed and the lesions dealt with appropriately. If after the abdominal lesions have been dealt with and a small opening is seen easily accessible in the diaphragm it should be closed by suture, but no time should be wasted if the approach to this indicates a difficult operation.

The Thoraco-Abdominal Approach

This is easily performed by those with some experience of thoracic surgery; the commonest error is to attempt to deal with serious lesions through a quite inadequate length of incision. Under general intratracheal anaesthesia the chest wall wound is excised; if this wound lies over the 7th, 8th, 9th or 10th ribs the incision is greatly enlarged from just in front of the transverse process to the costal cartilage, and the appropriate ribs excised subperiosteally; if the original wound does not permit an adequate thoracotomy the chest should be opened along the line of the excised 8th rib; the chest is held widely open by the use of a strong rib-spreader. (Tuffiers or Tudor-Edwards).

The haemothorax is sucked out and any bleeding from the lung is checked; the lung is then covered with a moist saline pad. The diaphragm is inspected and the hole through it boldly enlarged. This enlargement must be free and adequate and later can be sutured with ease; the abdomen is explored through this opening; splenectomy and suture of gastric or small intestine wounds can be readily performed through this incision; if the colon is damaged in most instances it is wiser to exteriorize it through a stab incision in the abdominal wall though quite exceptionally suture without this may be possible.

After the abdominal portion of the operation has been completed the diaphragm is sutured in one layer (it holds sutures well because it has a serous covering on both sides). The chest is then closed in layers, the skin being left open for later delayed primary suture. The phrenic nerve need not be crushed.

In the subsequent post-operative treatment the rules that govern the care of the abdominal wound and the management of the haemothorax must be followed meticulously.

CHEST WOUNDS AT THE BASE HOSPITAL

In an ideal campaign the second phase in the treatment of the chest wound is carried out at this level. But clearly the first aid treatment and the " base," treatment will often have to be carried out at one centre.

In the late war the ideal aimed at was to evacuate the chest casualty from the forward area as soon as possible after 48 hours, sometimes less, after the physiological dangers to life had been corrected and the wound had been excised according to the principles governing all forward surgery. At the base the following duties were indicated :

(1) Post-travel Assessment and Resuscitation.
(2) The delayed Primary Suture of Wounds.
(3) The Aspiration of all effusions whether of Air or Fluid.
(4) The Removal of Lung, Pleural or Mediastinal Foreign Bodies of the size of 1 cm. or over.
(5) The Surgical Treatment of " Clotted " haemothorax.
(6) The treatment of Empyema.
(7) The early rehabilitation of Chest Function.

1. Post-travel Assessment and Resuscitation

This includes careful perusal of the Field Medical Card, a clinical examination and always an immediate radiological survey ; blood transfusion and oxygen therapy when indicated are employed and usually the casualty requires morphia and luminal to procure a sound sleep after the evacuation fatigue. After this the decision as to further treatment can be made.

2. Delayed Primary Suture

This is done usually on the day after admission ; if a large foreign body is present, a thoracotomy through the wound or through a separate planned incision may be indicated ; the original excised wound usually requires no more than penicillin powdering and suture.

3. The Aspiration of the Haemothorax or Haemopneumothorax

This must be thorough ; the specimens aspirated are noted both as to quantity and quality and should always be examined bacteriologically ; if they contain gram.-negative organisms only, it is futile to instil penicillin. If the radiograph and the constant blocking of the needle indicate clotting further operative measures should be considered but if possible should be postponed for two to three weeks, as determined aspiration and chemotherapy may correct the condition.

4. The Removal of Foreign Bodies

Althougn as a general principle foreign bodies of 1 cm. in size or even less should be removed to prevent the development of lung abscess haemoptysis and bronchiectasis later, their operative removal should not be attempted unless all the facilities for thoracic surgery are present ; this includes an experienced surgeon used to the operation of thoracotomy, expert anaesthesia, and very exact radiological facilities. The ideal time for removal is at the time of delayed primary suture so that convalescent rehabilitation can start at an early date and the risks of infection are forestalled. Removal after six weeks is often difficult because of the development of dense adhesions. Localization must be radiologically exact ; the surgeon should know the exact site of the missile, *e.g.*, in the lung, pleura, mediastinum or in the extra-pleural plane ; if in the lung the surgeon should know the relation of the missile to lobes and fissures for when the chest has been opened the relation to bony landmarks is lost. A formal thoracotomy is usually indicated after resection of a long length of rib ; foreign bodies in the lung are usually easily palpable ; they are reached through a small incision in the lung followed by blunt dissection rather after Hilton's method for opening an abscess ; the missile bed is dusted with penicillin powder and the opening in the lung closed by one or two fine catgut sutures. The chest need not necessarily be drained but all post-operative effusions must be aspirated.

5. The Clotted Haemothorax

Usually this follows mild infection ; the haemothorax, usually of large size, becomes difficult to aspirate, clots of fibrin and blood blocking the needle ; the radiograph shows a typical mottled appearance with multiple fluid levels, and pyrexia is a feature; if the clotted haemothorax is left either infection or severe crippling of lung and chest wall function ensues.

As a result of wide experience in the late war the treatment of this condition by wide thoracotomy, evacuation of the clot, and the peeling off of organized fibrin from the surface of the visceral and parietal pleura, became established

as a safe procedure followed by rapid lung re-expansion and became the treatment of choice (by decortication). The operation is done under general intratracheal anaesthesia ; when the pleural cavity has been cleared and the lung " peeled " the anaesthetist inflates the lung under positive pressure and a surprisingly normal appearance is re-established ; usually the chest is drained by an apical and local intercostal catheter leading to a water-sealed system for 48 hours ; from the outset active breathing exercises are insisted upon. The operation is ideally performed in the third to sixth week after wounding.

6. The Treatment of Empyema

With the adoption of the measures already outlined for the treatment of chest wounds this complication should be less frequently seen. In the late war it fell from a 38 per cent. incidence in the early years to one well below 5 per cent. in the last year of the war. It was largely prevented as a result of sound excision of open pneumothorax wounds, energetic aspiration of all effusions, the use of penicillin and the adoption of " decortication " for clotted haemothorax. If an empyema develops it is easily diagnosed from the toxaemia, the pyrexia, and the appearance of the aspirated fluid. If aspiration with penicillin instillation fails to cure the condition while the fluid is thin, recourse to rib reaction should be made as soon as true pus is present ; even in the presence of pus a decortication is often the sound procedure but for smaller encysted empyemata rib resection and drainage is indicated. A large bore tube connected to a water-sealed bottle is employed (closed drainage). When radiography shows the lung to be well re-expanded open drainage is substituted. This tube must not be removed until radiography has established beyond doubt that there is no empyema cavity left ; this is best done by taking posteo-anterior and lateral radiographs after lipiodol oil has been instilled into the tube. Throughout the period of drainage great stress must be laid on breathing exercises and correct posture in bed.

7. Rehabilitation

From the forward area days onwards great importance must be paid to breathing exercises to produce lung expansion and an early return of full chest function. These exercises (carried out at the base under a specially trained attendant) should be used not only for non-septic but also for septic cases. At the same time attention is paid to correct spinal posture and to active movements of the upper and lower ribs.

SECTION XIX

ABDOMINAL WOUNDS

I. Introduction

Abdominal wounds are cases of first urgency. The patient wounded in the abdomen is almost certain to die unless he is operated upon, and very likely to die unless he is operated on early in a centre where he can be assured, not alone of expert surgery, but of skilled resuscitation, nursing and after care, and where he can be retained after operation till he is fit to travel further.

Sorting officers must be alert to discover abdominal wounds, for the abdominal viscera may be injured by projectiles entering at any part of the

body. Every man who has been wounded in the trunk or in the thighs or buttocks should be asked if he has any abdominal pain, and every man who looks iller than his discovered wounds warrant, who is vomiting, has a rising pulse, or who fails to respond to resuscitation, should be examined for signs of abdominal injury. The latent case must always be borne in mind.

When an abdominal wound has been discovered its disposal should be considered with care. The keenness and mobility of the modern surgical unit, and the excellence of its equipment should not tempt the team to undertake abdominal surgery so far forward that conditions both for operating and for nursing are inadequate. Only in the exceptional circumstance of a field surgical team attached to an airborne or mobile field ambulance, or to a divisional CCS, becoming isolated and unable to evacuate its casualties, would it be justifiable to undertake abdominal surgery at such a level. The firm policy of the medical services should be to evacuate all abdominal wounds to an established surgical centre as soon as possible.

II. Wounding agents

The severity of an abdominal wound, and therefore the prognosis, varies greatly with the agent that has caused the injury. Wounding agents vary from campaign to campaign, in different battles in the same campaign, and even in different phases of the same battle, so that from the surgical aspect mortality statistics have no absolute value. The following agents may be responsible for abdominal injuries.

1. *Rifle and machine gun bullets*

Bullets, being of high velocity, are likely to pass right through the body, from front to back, from side to side, obliquely, or even vertically, depending on the line of fire and the position of the man at the time of wounding. The entry wound is small and may be unknown to the patient and undiscovered by the examiner, and there may be no exit wound. A bullet traversing the abdomen usually causes multiple injuries, and with machine gun fire there may be multiple wounds. The exit wound is larger than that of entry, and may be so large as to suggest the entry wound of a mortar or shell fragment. Bullets from aeroplanes may be explosive or may contain phosphorus.

2. *Fragments from shell, bomb, mortar and mine*

These as a rule are large and of lower velocity, and tend to become embedded in muscle, bone, or solid viscus, or to lie free in 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 generalized wounds.

3. *Minute fragments and thin flakes of metal travelling at high velocity*

These are important because they may make a single wound that appears to be a mere superficial scratch or abrasion, yet may cause severe and multiple internal injuries. The need to examine the whole surface of the body when there are any symptoms that may be due to abdominal injury, and to keep any doubtful case under observation, cannot be stressed too often.

4. *Sharp cutting weapons*

Bayonet, dagger and knife.

5. *Blast*

Bombs bursting in the air, or nearby shell bursts, may damage the abdominal viscera by blast alone, but this is uncommon unless the burst is within thirty feet. Underwater explosions, as of depth charges, aeroplane bombs, mines, torpedoes, and bursting boilers, may damage men

swimming in the water up to a distance of several hundred feet. The injuries caused by water-transmitted 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.

6. *Crushes*

Crushes from falling debris, motor accidents, or falls from a height, may cause intra-abdominal injuries similar to those encountered in the road and industrial accidents of civil life. Solid viscera may be crushed or lacerated and hollow viscera torn, particularly at fixed points such as the duodenojejunal flexure. Such cases must be kept under observation.

III. Treatment in the forward areas

The treatment of abdominal injuries is surgical, and the main concern of all who handle such casualties in the forward areas must be to get the man to a surgical centre as soon as he can be got there alive. The "shock" of an abdominal casualty is compounded of many elements, the most serious of which, bleeding from mesenteric vessels and solid organs and leakage from torn viscera into the peritoneal cavity, cannot be combated by the ordinary measures of resuscitation.

Action in front of the Advanced Surgical Centre follows the ordinary rules of rapid examination, dressing wounds, splinting fractures, applying warmth, and moving from RAP to ADS forthwith. Though in civil life morphia is withheld in doubtful abdominal injuries till the case has been seen by the surgeon, in war morphia should be given even in the absence of pain, for it renders an ambulance journey over rough roads tolerable, and lessens fear and excitement.

On reaching the ADS, the patient is classified according to priority and if possible sent on to the Advanced Surgical Centre at once. Three decisions may arise at this stage.

1. *Should the patient be transfused before he reaches the Advanced Surgical Centre?*

It is quite easy to send a shocked patient to the FDS 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 ADS 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.

2. *Should the patient be sent to the nearest FST, or to a better equipped surgical centre further down the line?*

Deaths from abdominal wounds in the forward areas are due to two causes, haemorrhage or peritonitis with ileus. Major haemorrahge demands treatment at the earliest possible moment, but the closure of intestinal leaks is a less urgent matter and survival in cases where infection is a chief problem depends more on the care and thoroughness with which the operation is done and on the efficiency and continuity of the after-treatment, than on early surgery. A patient who is badly shocked two hours after being wounded in the abdomen and whose shock is increasing is suffering above all from loss of blood and should be dealt with by the nearest operating unit; one who is reasonably fit and improving can stand a journey of several hours, and will benefit if he is brought thereby to a well staffed and equipped operating centre.

3. *Should the patient be sent by air?*

Here two conflicting considerations must be weighed up. On the one hand abdominal casualties travel badly by air before operation, since the sudden drop in atmospheric pressure is apt to flood the abdominal cavity with intestinal contents. On the other hand the same cases stand a rough journey by road badly, and tend to deteriorate rapidly if it takes much longer than two hours. Where the choice is between half an hour in a plane and twelve hours over unmade tracks in a jeep, the first should certainly be preferred.

IV. Diagnosis

When the patient has reached the pre-operative ward of a Surgical Centre, marked as a case of suspected abdominal injury, the decision of the surgeon or resuscitation officer who examines him involves an answer to four questions.

1. Does the injury in fact involve the abdominal cavity?
2. If so, what structures are injured?
3. Do these injuries necessarily demand operation?
4. If operation is necessary, should it be done immediately? Very often the answer to this question involves deciding the priority between several men awaiting operation.

1. A study of the history, and an examination of the wounds and the abdomen will nearly always answer the first question. Apart from evidence of visceral damage, welling up of blood intestinal contents or urine, or protrusion of omentum from a wound on or near the abdominal parietes, is sufficient proof that the coelomic cavity has been penetrated. The need to remember the latent case, to question every man who looks unaccountably ill, must once more be emphasized. In the heat of battle a man may not realize more than that he has been wounded somewhere, but usually, when a hollow viscus has been injured there is pain like that of a perforated duodenal ulcer. Vomiting is common.

Difficulty arises particularly in two groups—chest wounds and non-penetrating injuries of the abdominal wall. The rigidity present in some

thoracic wounds may give difficulty in diagnosis, but it can usually be differentiated by the fact that it is variable, and relaxes somewhat when respiratory movement changes from expiration to inspiration.

Tangential wounds and lacerations or contusion of the abdominal wall cause generalized shock and localized tenderness and guarding : but if there is no intra-abdominal injury the shock tends to diminish and the tenderness and guarding to subside, or at most they remain stationary. Increasing shock, a rising pulse, tenderness at some fresh site such as the bottom of the pouch of Douglas, and guarding spreading to fresh and uninjured areas of abdominal wall, are signs of intra-abdominal damage. Auscultation should be practised whenever there is any doubt ; peristaltic sounds are occasionally heard even though the intestine has been perforated, but silence is always an indication for laparotomy. A plain X-ray, if available, may settle the doubt by showing free gas in the peritoneal cavity.

2. In through and through wounds the direction of the track will give an indication of the viscera that have been injured, but too much importance must not be attached to purely anatomical deduction ; the position of the man at the time he was wounded and therefore the relation of his abdominal parietes to the underlying viscera, was probably very different to that when he is lying on the stretcher. In single wounds, an estimate of the direction of the track is difficult without knowledge of where the foreign body lies. An X-ray is invaluable in such cases, but rapid screening or a single film is all that is required since the information is needed to determine the track of the projectile and not necessarily to help in its removal. Full knowledge of the length and direction of the track guides two important decisions—whether operation is necessary and what incision should be used.

The importance of wounds in 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.

3. When penetration of the abdominal cavity can be proved or inferred, operation is usually necessary and should be done as soon as possible. The exceptions are small clean wounds which appear to involve the liver or kidney only, and in which there is no severe bleeding.

4. Except in the small group that are being kept under observation, the best time for operation on an abdominal injury is the earliest at which the patient can stand it. Very often the decision to be made is not so much the best time for any particular patient, as the best order in which a number of patients shall be operated on so that the group as a whole shall be given the best chance. A man whose wounds are probably mortal should be given his chance first, if he is not thereby depriving someone—(who will live if he is done at once but not otherwise)—of his. A badly shocked man should be resuscitated while a less shocked one goes to the theatre. Cases where haemorrhage is apparently the chief problem should take precedence over those in which intestinal perforations dominate the clinical picture. The list should be considered as a whole, and if the unit is overburdened, or expecting to move, or if the numbers of patients with abdominal injuries is greater than can be dealt with in a reasonable time, it may be right to send on those best able to stand the journey to another unit further down the line.

V. Expectant treatment

Patients with traumatic perforations of the small and even large bowel have recovered spontaneously on expectant treatment, and the evidence has been

revealed at some subsequent operation for another condition. Such cases are rare, probably less than ten per cent., but the knowledge that recovery is possible without surgery offers some hope under conditions when active surgery is impossible. The principles of treatment are rest, warmth, morphia, intravenous alimentation, nothing by mouth, and gastric suction. If intravenous apparatus is not available, rectal saline can be given.

Men with abdominal injuries are sometimes brought in several days after wounding, having laid out on the field or been cut off on some raid. Those who have survived so long have usually succeeded in localizing their injuries, and should be treated expectantly, surgery being reserved for some definite indication such as the draining of an abscess or the closure of a fistula.

VI. Pre-operative Care

The cases of abdominal injury in the pre-operative ward of an Advanced Surgical Centre fall into four groups.

1. A few in whom there is no proof of visceral damage. Those are kept under careful and continuous observation.

2. Cases with evidence of intra-abdominal injuries but fit for immediate operation.

3. Cases with evidence of intra-abdominal injury, but unfit for operation because of shock.

4. Moribund cases : those with multiple wounds (*e.g.*, head, abdomen, femur), and those who have arrived late, with advanced peritonitis, cold clammy hands and feet, and a failing peripheral circulation. Such cases do not recover. They are mentally clear and alert, but restless and often in pain. They should be made comfortable, and if possible screened from those who have a chance.

Shocked patients must be resuscitated, but the period of resuscitation must be actively supervised and kept as short as possible. The shock of an abdominal casualty is due to a number of factors, to exhaustion, dehydration from sweating and shortage of water during the fighting, loss of plasma from wounds and into the peritoneum, loss of blood, and toxaemia from early infection. Some of these can be overcome, but others, particularly bleeding from mesenteric vessels and leakage from torn viscera, will continue while the first are being treated. An absolute limit of two hours must be set upon resuscitation; a patient who is not fit to stand any handling then, never will be.

After examining the wounds, determining the probable nature of the injury, and assessing the scope and risks of the operation, the patient should be made as warm and comfortable as possible. He should be given morphia gr. 1/3 if in pain. Fluids by mouth or by the rectum (apart from a few sips to moisten the lips and tongue) should be avoided, even if perforation of the alimentary tract can be excluded, but intravenous fluids should be given to every serious case, and the drip should be kept running when the patient is taken to the theatre.

A severely shocked abdominal patient is nearly always suffering from loss of blood that cannot be controlled till the abdomen is open, and he should be given blood as quickly as possible. Transfusion at the standard rate is like pumping air into a punctured tyre or trying to fill a bath with the plug out. The rate should be a pint in ten or even five minutes, and the aim should be to get the man as soon as possible into the theatre in a condition that will allow the surgeon to find the bleeding point. There will be only one chance.

After two pints have been given, it is usually possible to decide whether the shock is being overcome, or whether the loss is being barely balanced by the inflow. In the first case the transfusion should be continued at a slightly reduced but still rapid rate till a systolic pressure of 100 mm. or over has been reached, when the operation can be started. In the second case the patient, unless moribund, should be taken to the theatre with the blood drip running fast and plenty more in reserve, and the surgeon must make a rapid attempt to find and deal with the source of the bleeding.

Two rules apply :—

give blood only, plasma is useless at this stage
give every man his chance and to hell with statistics.

VII. Operation

1. *Other wounds*

Multiple wounds are the rule in warfare where bombs, mortars, shells and mines are the main weapons, and the treatment of wounds other than the main abdominal one calls for judgment. All wounds should be excised, but in the case of wounds of moderate severity this excision is second in importance to the treatment of the main abdominal wound. If the injured viscera are not repaired the patient will certainly die; if the wounds are not excised they will go septic, but with chemotherapy the sepsis may not be grave.

When other wounds approach the abdominal one in importance, for instance if there is a major fracture or penetration of a large joint, or if an amputation is necessary, a second surgeon should operate simultaneously. When, however, it is necessary to perform two operations, one anteriorly and one posteriorly, it is important to do the latter first, for experience has shown that turning a patient on to his face after laparotomy may cause profound shock, probably because the presence of air in the abdomen allows the whole intestines to fall forward.

2. *The incision*

The wounds in the abdominal wall must, like other wounds, be excised in layers. In many cases one or other wound can after excision be enlarged to give access to the abdominal cavity thus saving time, avoiding a second incision in the abdominal wall, and lessening the risk of post-operative pulmonary and vascular complications. If the wound can be extended without damaging important structures, particularly nerves, and if the visceral injury is known to be in the neighbourhood, this course should be adopted. Thus a wound in the flank may be enlarged to give access to an injury limited to the kidney and colon : one near the mid line may, after excision, be extended vertically and one on the flank may be enlarged transversely inwards or obliquely into the iliac fossa, but those near the outer border of the rectus can seldom be enlarged to admit any but local inspection without permanently damaging the abdominal wall.

If the wound is unsuitable for enlargement, or if the intra-abdominal damage is widespread, a laparotomy incision should be made. The best incisions in Field Surgery are the right and left paramedian going through all layers of the abdominal wall in the same plane, the midline infra-umbilical incision, and the oblique or transverse incisions in the lateral parts of the abdominal wall, extended if necessary into the rectus sheath, but not

dividing the rectus muscle. Transverse incisions across the rectus muscle, advocated by some in civil surgery, are bad in war and are followed in a large proportion by huge ventral herniae.

3. *General plan of operation*

The abdominal cavity usually contains free fluid, blood or intestinal contents, which must be evacuated before the damage can be traced. With a midline incision, a small nick should be made into the peritoneum before it is fully opened and the nozzle of a sucker introduced and pushed down into the pelvis; with a lateral incision the patient may be pushed to the side of the stretcher and tilted, so that the fluid runs into a bucket.

Haemorrhage is the chief cause of death and should be dealt with first; peritonitis is a secondary and less urgent danger. When the abdomen is full of blood, the most likely sources are the mesentery of the small intestine, the solid organs, the liver, spleen, kidney and pancreas, and the large veins on the posterior abdominal wall. The bleeding points must be found and ligatured with fine linen thread or cotton; catgut ligatures are very prone to slip and catgut knots to come adrift when the parts are subsequently handled, tending to loss of blood that the patient can ill spare, and to sub-peritoneal or mesenteric haematomas that obscure the outline of parts to be repaired. Severe bleeding from the liver can be controlled temporarily by compressing the hepatic artery and portal vein in the free edge of the lesser omentum between the finger and thumb : as a rule haemorrhage from tears in the liver has ceased when the abdomen is opened, or can be arrested by light packing and will be found to have ceased when the pack is removed.

When he has dealt with the haemorrhage, the surgeon must proceed to find and repair all perforations in the alimentary tract. The holes may be in unexpected places, they may be very small, and when recent they cannot be recognized by touch, but every one must be found or an otherwise successful operation will fail because of one omission. The structures in the line of the track should be examined first, but all the organs that may have been injured must be looked at. It is usually wise to postpone any repair till all the injuries have been discovered and tabulated together.

The small intestine is the part most frequently injured and will usually be examined first. Loops of intestine many feet apart in continuity may lie adjacent in the abdomen, so that the whole length should be overhauled methodically from caecum to duodeno-jejunal junction, each hole or tear as it is encountered being held by an assistant with a swab, or marked by clipping a pair of forceps to its edges or passing a length of tape through the mesentery. When the mesentery has been torn from the bowel, the length involved should be noted.

After the small intestine, the stomach colon and solid viscera should be examined in turn, a deep retractor and a portable light being brought into play if necessary. 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 mobilize 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.

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.

When all the lesions have been found and considered together, they must be repaired, a step that will be considered in greater detail regionally. At the close of the operation, the abdominal cavity should quickly be mopped clean. Unless the condition of the patient makes it necessary to get him back to bed as soon as possible, the abdominal incision should be closed with more than usual care, bearing in mind that tissue has been taken away by the injury and the surgical toilet, that the layers are infected, and that the use of the abdominal wall for respiration and to assist peristalsis is essential in the phase of recovery. Layer closure should be reinforced by a few stout tension sutures, inserted as the first step in closure and tied as the last, over gauze or short lengths of rubber tubing.

The Question of Drainage

(1) *Intraperitoneal.* An operation for the repair of an abdominal injury is never even approximately a clean one. Many of the haemostases are not 100 per cent. secure, many of the sutures have been done to a time limit rather than a standard and some of them are under tension. Therefore drainage is always a wise precaution. A reactionary naemorrhage is recognized at once if there is a drain, and a failed suture leaks to the surface instead of bursting into the peritoneum. The cliché that " the peritoneum can look after itself " comes from the dog laboratory and not from the battlefield. The statement that drainage provokes adhesions is even more theoretical : which will produce more and denser adhesions, a strip of corrugated rubber, or a collection of serum blood or pus slowly absorbed ? Therefore drain except in completely clean cases : drain especially down to areas of damage, soiling, or extensive repair ; drain not for present soiling but for future trouble. And having drained with some non-traumatic material do not be in a hurry to undrain. In the second world war the surgeons with most experience were readiest to drain.

(2) *Retro-peritoneal.* 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 Use of Sulphonamide Powder Locally

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.

4. Injuries of Particular Organs

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.

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. If no other organ is involved and bleeding is not severe, operation is not indicated. If a liver wound is bleeding it should be cleansed as far as possible of blood clots and liver fragments, and pressure should be applied to its surface. In wounds of moderate size the bleeding may stop after a few minutes' application of a swab wrung out of hot saline. In larger wounds, or those bleeding briskly, the free edge of the omentum should be turned up over the torn surface and fixed by a series of sutures of medium catgut passed through the liver wall away from the wound edge with a blunt needle, or held in position by a gauze swab. Gauze should not be packed in direct contact with the liver surface, since it is apt to restart bleeding if removed early and to promote sepsis if left for more than forty-eight hours. A wound of the upper surface of the liver through the chest may be packed through the wound in the diaphragm, which itself is stitched to the skin.

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 is damaged in only about 10 per cent. of cases of abdominal injury. Bleeding may cease spontaneously, but is very apt to restart. Splenectomy is therefore advisable in every case.

The kidneys may be wounded alone, or as part of an abdominal injury that involves many structures. Compared with the other solid organs—liver, spleen, and pancreas—the kidney stands up to the impact of projectiles remarkably well. It has little tendency to fragment, it does not bleed profusely or long unless the main vessels are injured, and it has considerable resistance to infection. When the kidney is injured alone, a conservative attitude should be adopted ; nephrectomy is required for division of the ureter, injury to the pedicle, laceration incompatible with recovery of function, and, later, for persistent or recurrent haemorrhage. When, however, a lacerated wound of the kidney is associated with one of the colon, nephrectomy should be performed ; leakage of urine into a retroperitoneal space already contaminated by faeces is a risk that cannot be faced.

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 12 per cent. of cases. Wounds may be small or large perforations, linear tears, or complete trans-sections. It is important to remember that a posterior perforation may be the only injury.

Wounds of the stomach carry a high mortality because they are usually associated with injury to neighbouring organs, the transverse colon, jejunum, liver, spleen, pancreas and left kidney. Isolated wounds are relatively benign, for the stomach walls are resistant to injury and its contents are sterile. Tears of the fundus and of the body should be closed by a double row of sutures ; those near the pylorus which leave a narrowing after repair may require gastro-jejunostomy in addition.

The small intestine is wounded in at least a third of the cases, and almost always in several places. The holes are often very small, and they cannot be felt, so that some may be missed unless the whole length of the gut is rapidly overhauled. A single hole should be mistrusted—there must be another. The perforations are often sealed by pouting mucous membrane, so that they may not leak ; blood in the peritoneum is more characteristic of small intestine injury than are intestinal contents.

Perforations of the small intestine should be closed by local sutures if possible. The edges need not be trimmed, and a purse-string suture or a single layer of interrupted invaginating sutures is usually enough. Resection of gut is indicated :—

(1) When simple suture is mechanically unsatisfactory, as when a group of holes are so close that their repair would overlap, when so many injuries are found in a given segment that resection of the whole will save valuable time, or when the injury is on the mesenteric border.

(2) When the viability of a loop of gut is destroyed, by crushing, by thrombosis of the vessels or by detachment of the mesentery.

End to end junction is best, and a single layer of interrupted sutures with occasional reinforcements is quicker and safer than two continuous layers.

Wounds of *the colon* are less common and less often multiple than those of the small intestine ; on the other hand they are more serious :—

(1) Because they are often retro-peritoneal and therefore easily overlooked. These retro-peritoneal injuries may be caused not only by missiles but by indriven bone.

(2) Because the walls of the colon are thinner and their blood supply less free. Simple perforation is uncommon and extensive damage, bruising, and rupture of the outer coats is the rule.

(3) Because the contents escape earlier and in greater quantities than from a small intestine perforation, and are more infective.

(4) Because retro-peritoneal cellulitis, often an anaerobic infection, is a common and very often fatal complication.

Perforations in the colon should be looked for with great care. Those in the fixed portions, and on the mesenteric aspects of the transverse and

pelvic colon, are easily missed. A haematoma in the mesocolon or in the right or left paracolic gutters should always call for a minute examination of the adjacent bowel wall ; a faecal smell may draw attention to a hole that can barely be seen.

The treatment of colon injuries is based on the known insecurity of suture and the dangers of leakage. Simple closure of a wound of the colon, however small, should not be attempted except by experienced field surgeons who are aware of the risk. Men may survive such an operation, but others have died who would still be alive had they fallen into the hands of a surgeon with less optimism and more sense. The rule that injured segments must either be exteriorized, or functionally excluded by a proximal colostomy is one that every surgeon should follow when he is first sent to work at an advanced operating centre.

The whole colon above the last three inches of the pelvic portion is either mobile or can be mobilized. Injuries of these portions should therefore be brought to the surface. A small hole may be made the apex of a loop colostomy, the hole being temporarily controlled by the blades of a pair of forceps introduced through a lateral incision, and used to ease the gut through it. A larger tear involves resection of the damaged portion ; after mobilizing sufficient to allow the colon above and below the injury to be approximated without tension, the injured segment should be removed, and the cut ends above and below it, closed with crushing clamps or long-bladed haemostats, should be brought to the surface as a double-barrelled colostomy. Wounds in the fixed parts of the large intestine, that is the lower pelvic colon and rectum, must be repaired as well as possible, and excluded by a proximal colostomy. The site of a colon injury should be liberally dusted with sulphonamide powder and drained, a drain being put into the retro-peritoneal space after flank injuries, or led down to the site of repair in injuries of the pelvic parts of the bowel.

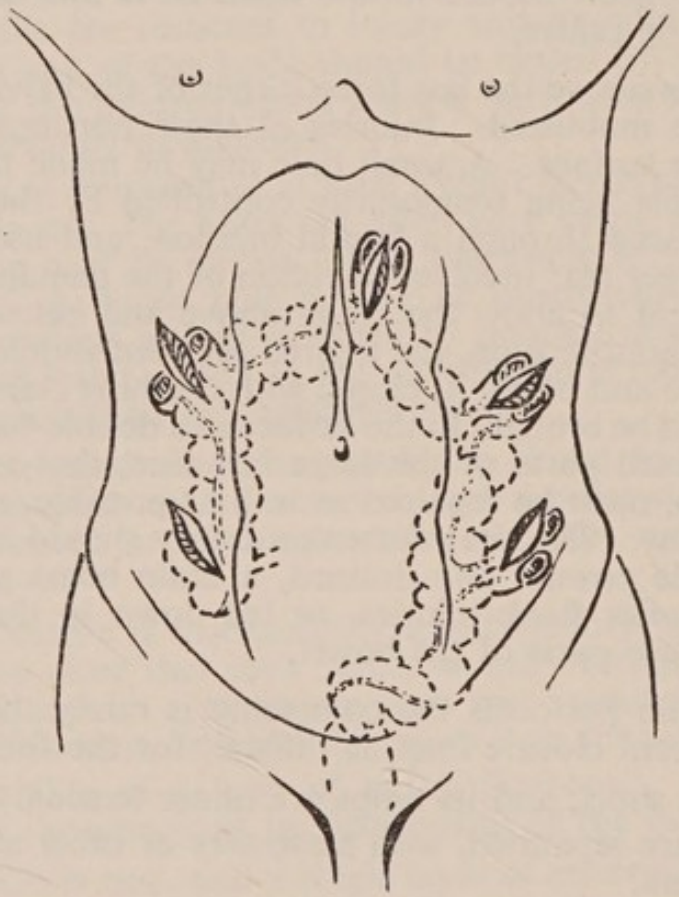
The surgeon who performs the colostomy is rarely the one who has to close it. Subsequent closure may be difficult for the following reasons :—

(1) The loop is short, and its limbs are under tension.
(2) The limbs are separated, with mesentery or other abdominal contents between them.
(3) The colostomy has been made in the midline where the abdominal wall is thin, or is adherent to the scar of an incision that has been infected. In either case, mobilization and extra-peritoneal closure is difficult.

The field surgeon should bear these difficulties in mind, and, as far as the urgency of the case will allow, should observe certain points in technique that will make subsequent repair safer and easier :—

1. A colostomy should, as a rule, be brought out through a small separate incision, made in a muscular part of the abdominal wall. The transverse colon should be exteriorized through a vertical incision in one of the rectus muscles, the lateral parts through a short oblique incision in the hypochondriac regions or iliac fossae. These small purposive incisions hold the colon without suture, they allow easy and rapid closure of the main incision and favour clean healing, and they give sounder repair afterwards.

2. The affected portion of colon should be well mobilized before exteriorization ; the longer the loop the easier the closure.
3. The two limbs of a well mobilized loop can be approximated quickly and easily by a few stitches ; this should be done if time allows.
4. The exteriorized colon should not be stitched to the abdominal wall. In cases in which the opening is a snug fit, a loop colostomy may be held by passing a rubber tube or an unopened catgut phial through the mesentery ; a double-barrelled loop may be held by passing a ring of gauze between the clamps and the abdominal wall and fixing the handles to the abdominal wall with strapping for twenty-four hours.



Sites of election for colostomies in war injuries.

Rectum. Wounds of the rectum may involve the intra-peritoneal or extra-peritoneal portions. Extra-peritoneal injuries are often associated with wounds that can hardly be called abdominal, with bullet wounds passing from buttock to buttock and with tangential wounds involving the sacrum or coccyx in which the injury may be caused by a splinter of bone and not by the projectile. It is very important that penetration of the rectum should be proved or excluded at the first examination, and whenever such an injury is at all possible, or when blood has been passed, the rectum should be examined with a finger and with the proctoscope.

The treatment of wounds of the rectum is that of wounds of the large intestine that cannot be exteriorized—repair, local drainage and proximal colostomy. Repair of rectal injuries, except small ones, is usually impossible without wide mobilization, and is better not attempted in a recent wound.

Drainage must never be omitted. When the wound is on the peritoneal surface of the rectum in its upper two inches, a broad strip of sheet rubber should be introduced beside the injury to the bottom of Douglas' pouch and led out through the lower end of the laparotomy incision, or through a stab in the iliac fossa. When the wound involves the side or back of the upper part of the rectum, of its extra-peritoneal course, the retro-rectal space must be drained by a strip of rubber introduced through the wound if this is in the buttock or sacrum, otherwise through an incision in the median raphe below the coccyx. When the last inch of the anal canal is injured a ¾-inch tube may be passed through the anus to provide drainage and be stitched to the skin, but the sphincters must never be divided.

Colostomy must never be omitted in wounds of the rectum, however trivial they may appear to be. In most cases a standard left inguinal colostomy should be performed, but when the injury of the rectum is such that mobilization will be required for its subsequent repair, a transverse colostomy should be done in order to leave the pelvic colon free and clean for the later operation.

In large wounds of the perineum or buttock encroaching on the anal region but not injuring the sphincters, a colostomy is often advisable in order to prevent faecal soiling of the wound and facilitate early suture or skin grafting. Colostomy has a sinister reputation only because in civil life it is usually permanent and the prelude to death from metastases ; as a temporary life-saving expedient in war surgery it should be used freely.

Bladder. Wounds of the bladder are often associated with injuries of the rectum and of the pelvis or the hip joint. The bladder, like the rectum, may be wounded in the intra-peritoneal or extra-peritoneal portion or in both.

Treatment involves repair of the injury and drainage of the bladder by a tube which should lie at least 1½ inches above the pubis. The bladder wall must be cleared for half an inch round the hole before suture, a step that is more difficult in a ruptured bladder than a full one. If the tear is on the upper part and not too near the pubis, it may be used to transmit the drainage tube. If it involves a ureteric orifice, the ureter should be detached and implanted elsewhere in the bladder. If it is in the base and small it may be left alone, since in a drained bladder it will heal with little trouble unless it communicates with the rectum. When adjacent parts of the bladder and rectum are involved in the track of a projectile, every effort, consistent with survival of the patient, should be made to suture the openings in the two viscera separately and to avoid the formation of a fistula. In the presence of soiling, the pre-vesical space should be drained.

VIII. Post Operative Treatment

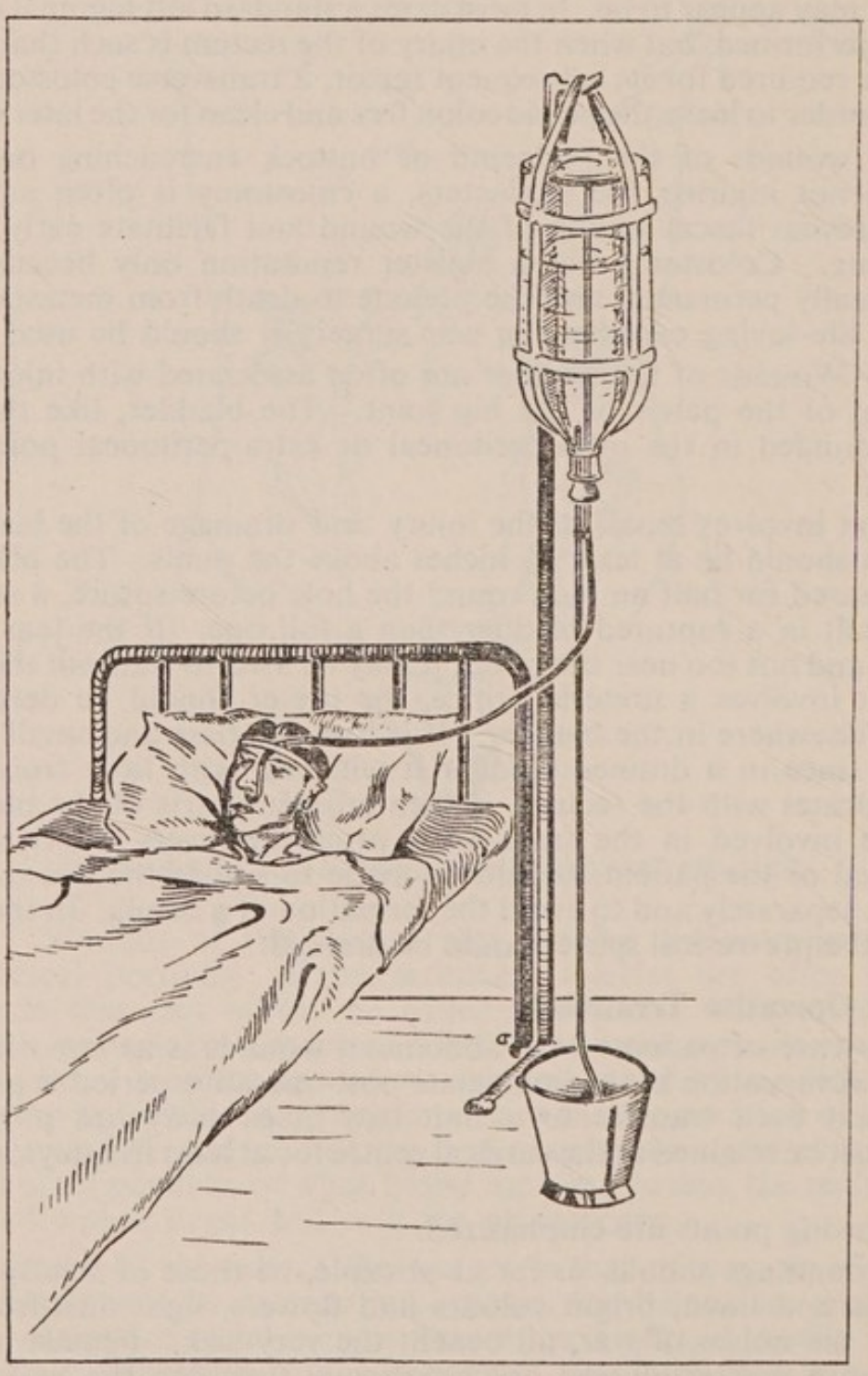
The after-care of patients with abdominal wounds is as important as the operation. Evacuation in the immediate post-operative period is particularly harmful, and even transfer to a unit two miles away has proved fatal. Patients must be retained at the surgical centre for at least five days, preferably for ten.

The following points are emphasized.

The surroundings should, as far as possible, be those of a hospital ward. Clean walls and linen, bright colours and flowers, light dust-free air and relief from the noises of war, all benefit the very sick. Female nurses can do much more practically and psychologically than can the best orderlies.

Abdominal patients cannot be nursed efficiently on stretchers, and real beds are a necessity in any surgical centre prepared to deal with abdominal casualties. The Fowler position should be avoided, at any rate as a nursing routine and for more than short periods. Patients should, as a rule, be allowed to take up the position in which they are most comfortable, but they should be encouraged to abandon that position from time to time, to change from side to side and from lying flat to sitting up.

Ileus must be expected, and anticipated rather than treated when it appears. A gastric tube should be passed through a nostril at the end of the operation and fixed to the patient's cheek with a piece of strapping. In the ward continuous gastric suction is applied and maintained until



brisk peristaltic sounds can be heard and flatus is being passed. A tube slightly larger than a Ryle tube, with bigger holes, should be used; the tubing from a giving set, with a ·22 bullet or a piece of lead tied in the end and two large lateral holes cut above it, has been found very satisfactory. For suction, simple syphonage using an inverted plasma bottle should be preferred to more elaborate apparatus. It must be remembered that one orderly may have to keep twenty suctions going, and any elaboration involving changing of bottles or repeated suction should be avoided.

Patients on gastric suction need continuous intravenous administration of fluids. For the first two days eight pints should be given daily, decreased thereafter to six pints daily but increased again if the urinary output falls below two pints. A rough approximation to the salt requirements of the body is made by giving two pints of normal saline daily, plus one pint for every pint of gastric contents withdrawn by suction, and giving the remainder as 5 per cent. glucose or other non-saline fluid. One pint of plasma should be given daily to counteract the plasma loss, a figure that cannot be measured in the forward units. Blood should be given whenever the haemoglobin estimation shows that it is needed.

Chemotherapy is indicated after any abdominal injury in which the peritoneal cavity has been soiled. Penicillin should be given intramuscularly until the danger of peritonitis appears to have been overcome, and a soluble sulphonamide, which is more effective than penicillin against bacillus coli, may be added to the intravenous fluids. Sulphonamides must not be added to blood.

Stitches should be left in for ten days. When the skin wound has been left open the edges should if possible be approximated by suture after forty-eight hours.

Patients should not be marked for evacuation until they have established equilibrium, that is until the stitches are out, the gastric suction and intravenous medication have been discontinued for forty-eight hours without distension nausea or vomiting, the temperature and pulse have been steady or falling for two days and the bowels have been opened. This point is seldom reached before the tenth day.

SECTION XX

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 nor 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 sulphathiazole-penicillin powder into the socket ; 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 tissues 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 and penicillin drops (1,000 units pure sodium salt per c.c.) 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 and penicillin drops (1,000 units pure sodium salt per c.c.) 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," further instillations of penicillin being given when convenient. 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 greatest 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 hyphaema 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, 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. 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 sulpha drugs should be instituted at as early a stage as possible ; in orbital infections penicillin given systemically is usually preferable.

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, 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, penicillin drops being instilled at the same time.

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 reposition 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 those 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 magnetizable, 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 electromagnet; 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 magnetizable, 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 minimize 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 magnetizable 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. If no special site of entry is indicated, or if the foreign body lies posteriorly, the safest site of entry is by a right angled incision of which one limb runs along the site of the ora serrata, and the other runs backwards from this for a short distance.

It should be remembered in all these cases that one trial with the magnet is not sufficient to determine whether a foreign body is magnetizable or not. Several attempts should be made and if the slightest movement is elicited 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 minimizes 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 eye should receive special attention. They should never be tanned, nor should preparations such as gentian violet be used on the lids : a dressing of penicillin cream or 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 base or 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 reconstruction and mucous membrane grafts in sockets do not always give good long-term results. The best results in extensive reconstructions, 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.

SECTION XXI

(see also Section I)

MAXILLO-FACIAL INJURIES

TREATMENT AT CCS AND HOSPITAL

The treatment of face and jaw wounds consists of three natural phases :—

(*a*) Early or primary.

(*b*) The intermediate or healing.

(*c*) The late or reconstructive.

(*a*) The complete primary treatment of face and jaw wounds is best conducted by special units consisting of a plastic and a dental surgeon working in the proximity of E.N.T., neuro-surgical and ophthalmic units. At least 25 per cent. of jaw and face wounds have associated injuries of either head or eyes. Experience shows that it is better for a patient to arrive at a special unit up to 48 hours after being wounded than that he should have an earlier and incomplete operation.

The same principles cover the treatment of missile wounds and the facial injuries resulting from traffic accidents and brawls.

PRIMARY TREATMENT

These notes will help those who have to undertake the primary treatment of face and jaw injuries when disposal to special units is not possible. At all units where jaw treatment is undertaken the co-operation between the Dental Surgeon and the Surgeon is obligatory.

Anaesthesia

Local.—This form of anaesthesia is perfectly practicable, but time consuming and sometimes distressing to the patient. It is, however, the method of choice in cases of combined face and head injuries as these stand the induction of a general anaesthetic badly. It is also indicated when post-operative conditions do not permit of the proper supervision of the unconscious patient and when skilled anaesthetic services are not available.

General.—The anaesthetic of choice is a pentothal induction followed by intubation and thorough packing off of the pharynx. The anaesthesia is continued by nitrous oxide—oxygen—ether, or, cyclopropane, or, trilene, at a level which gives an immobile patient but one whose cough reflex returns before he leaves the table. A thorough pharyngeal toilet with suction, swab and forceps should precede the insertion and follow the removal of the pharyngeal pack.

Indication for Tracheostomy

Tracheostomy should be performed in cases with :—

(*a*) Wounds of the jaw associated with injuries of the pharynx or larynx.

(*b*) Inter-maxillary fixation of the jaws (I.M.F.) accompanied by nasal airway obstruction due to fracture or other cause.

(*c*) Where there is any doubt in the operator's mind about the continuing patency of the airway, especially with reference to the facilities for proper supervision during the post-operative and evacuation stages.

Arrest of Haemorrhage

A local attack on the bleeding vessel is usually successful. This means digital pressure on the bleeding point while retraction and light are appropriately arranged. A light haemostat may then be precisely applied to the bleeding point. Proximal ligature of the external carotid artery is a rare necessity.

Soft Tissues

Wounds of the soft tissues of the face are a profitable field for excision and closure which in the majority of cases is followed by quiet healing in three to five days. Many of the lesser wounds may then be discharged from the medical lines of communication.

Tissues are handled throughout by plastic hooks and light tissue forceps. Fine silk sutures are used and are inserted by Gillies or Kilner needle holders. When catgut is used for deep layers or ligation of facial vessels, the calibre is three O.

(i) *The Toilet*

Repeated and thorough lavage with 1 per cent. C.T.A.B. or soap and water is the essential preliminary to surgery. All layers of the wound are thoroughly washed.

Mine and Road Wounds : Thorough and repeated scrubbing with a nylon scrubbing brush aided by fine forceps and a needle is necessary in these cases where dirt is ingrained in the dermis and deeper layers.

(ii) *The Excision*

This is minimal but thorough. 1-2 mm. of skin edge are everywhere removed to provide non-contaminated, non-bevelled edges which can be accurately apposed. Skin excision is done by No. 15 blade, or by Ophthalmic type 4½ in. straight scissors after edge undermining for 0.5 cm. Loose and soiled tags of deeper layers and mucosa are removed by scissors.

(iii) *The Closure*

Facial closure may be by approximation, by free graft, or by flap (local or distant). Most facial wounds can be and are best closed by approximation after undermining of the skin edge for 2-5 cms. *This approximation should never be allowed to produce distortion of lips and eyelids.* When a closure is impossible by approximation without such distortion, a free graft to the skin defect, or a mucocutaneous suture of the margins if the wound involves all layers of the cheek, should be done. Primary flaps are not advised unless the operator has special experience of these methods.

The mucosal layer is closed by fine catgut. A water-tight closure of the mouth over a fracture site is desirable. Subcutaneous and muscle layers are best closed together, separately from the undermined skin edge, by interrupted three O catgut sutures.

Fine serum-proof silk, 04 or 06, or fine nylon, taking bites of 3-4 mm. in depth and width, and placed 3-4 mm. apart, are used for the skin. Dry

gauze dressing and pressure strapping is applied. Skin sutures are removed between the 3rd and 5th day.

If the defect is a large one or difficult to close on account of its position, accurate closure should not be attempted. One should concentrate on a thorough toilet and on the removal of black and grossly soiled tissue. All flaps of facial skin, unless they are obviously dead, should be conserved, placed in their normal position and retained by means of a few sutures. Bony fragments should be fixed and the site of any mandibular fracture drained.

Bone Fragments

Surgical Care

The rule is to conserve all bone fragments except those completely detached and grossly soiled. If the mouth has not been excluded by a watertight closure of mucous membrane, the fracture site should be drained. The drain is removed in two to five days. Bone should not be left bare, but should always be covered externally by soft tissue. A mandibular stump should be covered by a muco-cutaneous suture.

Dental Fixation

A primary firm fixation of bone fragments is of the greatest importance to soft tissue healing, to freedom from sequestration, and to early union. This fixation is done at the primary operation. It generally follows the toilet and precedes the closure. Primary jaw fixation is most often by interdental eyelet wires. At the end of operation, the upper and lower jaws are fixed together by wires through the eyelets (I.M.F.). At the same operation impressions are taken for future cast metal splints, which are applied after healing of soft tissues in the second week. Certain cases of multiple fracture with scanty and irregular dentition cannot be fixed by wire. For these, extra-oral pins may be used or cast metal splints should be prepared, if possible, before operation (a delay of 6-8 hours). Fractures with major edentulous fragments may be fixed by extra-oral pins, by intra-medullary pins, or (when the fracture does not communicate with the mouth) by direct wiring of fragments.

Teeth

Care should be taken to extract all loose teeth involved in fracture lines; firmly embedded teeth are best left at primary operation. This holds especially for molar teeth in otherwise edentulous fragments, or indeed any teeth the extraction of which cannot be effected without risk of dislodging a major bone fragment.

Maxillary Fractures

In maxillary fractures there is a high incidence of associated eye, ear and brain wounds (and a comparatively high mortality). Many maxillary fractures are associated with C.S.F. leaks; in these cases the treatment of the jaw fracture is subordinated to the neurosurgeon's early management of the head injury. But the importance of early maxillary reduction in reducing associated bony displacements in ethmoid region and floor of anterior fossa should not be forgotten. Early maxillary reduction reduces the risk of infective sequelae to all areas.

The maxilla may be " floating," *i.e.*, grossly displaced and freely movable with typical dish face, gross malocclusion, blocked nasal airway, and diplopia. These cases need reduction, cast metal splints with fixation through rods from the splints to a plaster of paris headcap, to correct the drop of the facial skeleton.

Lesser and impacted fractures of the maxilla may be indicated by malocclusion and open bite only. Treatment of the maxilla is similar, but plaster of paris headcap fixation may not be necessary. Displaced maxillary fractures need early reduction as consolidation in malposition is rapid. Considerable manipulation by forceps, plus traction by strong elastic or by extension through a Balkan beam, may be needed if the reduction is left for more than a week. Closed fractures of the maxilla with blood in the antrum very seldom need antral drainage.

Open Wounds of Maxilla

The rule is to be conservative with alveolar bone fragments and those in the orbital floor. Other loose and semi-detached maxillary comminuted fragments are best removed. Free drainage of the antrum into the nose should be provided at the primary operation by removal of a good inch of medial wall beneath the lower turbinate. The fixation of displaced and mobile fragments in open maxillary wounds is as for closed fractures.

Malar Fractures

Many malar fractures can be given a stable reduction by manipulation with a Bristow elevator through a temporal approach. Others, particularly when there is diplopia, need fixation by interosseous wire between the angular process or frontal bone and frontal process of malar. Even when diplopia is present, the combination of antral packs and metal fixation through the body of the malar should be avoided at primary treatment. This combination is often associated with a later chronic infection of the bone.

Nasal Fractures and Wounds

See Section XXII

Ashe's and Walsham's (nasal) forceps are used to straighten the septum and to manipulate the nasal bones into normal position. Every effort should be made to restore the height of the nasal bridge line. In the absence of nasal forceps a blunt pointed pair of scissors may be introduced through the nares to elevate the nasal bones. A plaster of paris splint cut to size and with an extension across the glabella on to the forehead for support holds the reduced nose in the midline, and compresses the broadened bridge. The splint is supported by strapping, reinforced by mastiche. It is worn for 7-10 days.

Wounds of the Nose

Open fractures of the nose are treated by excision and primary closure as for wounds elsewhere in the face. The bony reduction is as for closed nasal fractures. Special care by undermining, or in major losses by mucocutaneous suture, is taken to obtain a soft tissue cover for the exposed bone and fracture sites and to avoid distortion of tip and nostrils.

TREATMENT IN THE INTERMEDIATE OR HEALING PHASE

This phase starts after primary treatment is completed. It concerns the feeding and oral hygiene, plus management of the wound and fracture through to healing and union, that is, sequestrectomies, closure of sinuses and fistulae, and the care of the jaw fixation.

Toilet and Feeding

The rule is to make the patient do these important offices for himself. He should be instructed in the use of a toothbrush and spend 5 or 10 minutes on oral toilet after each meal. 2 per cent. sodium bicarbonate or saline may be used. Care is taken to keep the lips soft with vaseline. Lips may need, too, protection by pieces of gutta percha from the wires used for I.M.F. Difficult cases to feed may need a nasal catheter or, in the absence of I.M.F., an 8 in. rubber extension is fitted to a feeding cup, and the fluid poured on to the back of the tongue.

Gastrostomy is very rarely necessary. It has sometimes to be considered in extensive combined wounds of the pharynx and jaws.

Secondary Wound Closure and Closure of Fistulae

Facial wounds are best closed primarily as above. When they are more than two days old when first seen, a full toilet with removal of all obviously dead tissue should be done. In the absence of clinical infection, the margins should be held in approximation by a few fine sutures after minimal undermining. When the tissue loss is too great for this, healing should be accelers ated by a free skin graft spread over the defect. These thin free skin graft- are unsightly and later need excision.

Parotid fistulae which persist for more than 3-5 weeks should be treated by excision and a layered closure, unless the main duct is involved when attempt should be made at repair, or to establish drainage of the proximal duct end into the mouth.

Sequestrectomy

The persistence of a sinus from a mandibular fracture for 3-4 weeks, or recurrence of acute infective episodes about it for this time, indicates the need for exploration of the fractured site. The most likely cause is a sequestrum ; but it may be an involved tooth socket, a retained foreign body, or an undrained abscess cavity. At this early sequestrectomy, only loose and obviously non-viable bone is removed. At 6-8 weeks, if the sinus persists (as it may in a small percentage of cases), sequestrectomy has to be repeated. It is then probably best to be radical and to remove all comminuted fragments and bone at the fracture site back to what is obviously healthy. Such cases, then, need grafting for union. Radical sequestrectomy should therefore be reserved, if possible, until facilities and experience are available for this later bone graft ; otherwise a second conservative sequestrectomy should be done.

TREATMENT IN THE LATE OR REPARATIVE PHASE

Soft Tissue Scar Corrections

The time for a scar correction is when the scar is soft, pale and painless. This generally takes 6–12 weeks after primary healing, and is delayed by infection. The whole scar is excised. The edges are undermined and an

accurate and layered closure using fine sutures is done by approximation. Occasionally around eyelids a full thickness post-auricular skin graft is used. In larger defects local or distant flaps are used.

Epithelial Inlay

A free graft of split skin borne on a stent mould can give and maintain a buccal sulcus after this has been re-established by incision. The mould is best fixed by an appliance to a cast metal splint. It is replaced by an appropriate denture directly healing is complete. This inlay to re-establish the sulcus may be done once the fracture has united.

Bone Grafts

A mandibular fracture without bone loss, should show evidence of proceeding to union between the fourth and tenth week. If, during this period of time, there is no evidence that union is progressing, the fracture site may be exposed, freshened and packed with iliac medullary chips. Bone gaps of more than ½ inch are best grafted by bone with some cortical element and "carpentered" to fit the defect. Skin losses and scarring over the fracture site should be repaired by soft, well vascularized tissues before bone grafting is done.

SECTION XXII

INJURIES OF THE EAR, NOSE, AND THROAT

THE EXTERNAL EAR

Lacerations of the pinna and external auditory meatus require careful cleansing and early replacement of the damaged parts. If a portion of the auricle is lost the defect should be defined by suturing the anterior and posterior layers of skin over the exposed edge of the cartilage. Remaining fragments of the auricle should not be sutured to each other out of the normal position. If the external auditory meatus is torn through completely, careful anastomosis must be made by cat-gut suture and the lumen of the meatus packed with narrow ribbon gauze soaked in paraffin and flavine. Neglect of injuries involving the meatus leads to stenosis.

The contents of a haematoma of the pinna should be evacuated under strict asepsis and the ear protected with sterile dressing.

THE MIDDLE EAR

Injury to the tympanic membrane is common and often 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 last 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 middle 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 the ear be syringed if rupture of the membrane is suspected.

Wax, if present, should 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 tympanic membrane 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 being cleansed.

Until the ruptured tympanic membrane is healed or, if suppuration is present, until the condition has become chronic, acute naso-pharyngeal infection as far as possible is to be avoided. During this period the patient should refrain from blowing the nose, and use ear protection if likely to be exposed to blast.

Chemotherapy and Antibiosis

The prophylactic administration of sulpha drugs and antibiotics is unnecessary unless the condition of the ear is such as to render infection probable. As curative measures both chemotherapy and antibiotics should be used in accordance with general surgical principles. They should always be given in cases with pre-existing otitis externa and in those cases where rupture of the tympanum accompanies a fractured base. These latter patients should be kept under strictest observation as infection may spread quickly to the meninges. Insufflation of sulpha powders into the meatus is inadvisable as it leads to caking.

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 tympanic membrane, oedema of the mucous membrane lining the middle ear, and in serious cases the formation of serous exudate, which is sometimes blood-stained 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 is usually followed by rapid resolution.

If inflation of the Eustachian tube fails, the tympanic membrane should be punctured by a sharp needle of a fine gauge, the meatus first being sterilized with spirit. As the procedure is painless, anaesthesia is not required. Symptoms are usually relieved immediately the pressures are equalized. If treatment is delayed recovery will take three to four weeks, and some deafness may be permanent.

THE INTERNAL EAR

Damage to the internal ear may be caused by continuous loud noise, blast or baro-trauma, with or without evidence of middle ear injury. Patients 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 of severe tinnitus.

NOSE AND SINUSES

Haematoma of the Nasal Septum

After thorough cleansing of the anterior nares the vestibule on each side is swabbed with acriflavine and, with strict asepsis, a free incision is made into the lower and anterior part of the haematoma and the blood is 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

(1) *Simple*

If treated 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 reduction.

(2) *Compound*

Thorough cleansing of the wound and early reduction 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 chemotherapeutic and/or antibiotic course should be given.

The Maxillary Sinus

Simple effusions of blood into the antrum are usually absorbed and are best left alone. If infection is suspected, antral puncture and lavage should be employed.

When the sinus contains foreign bodies 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 several days with gauze impregnated with " sulpha " and penicillin, 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 the 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 head cap. 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 a Thiersch graft. When 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 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 complicated by cerebrospinal 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. Antibiosis or chemotherapy 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, consisting of rest, sedatives, inhalations of menthol and the instillation of ½ 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

Wounds of the naso- and oro-pharynx are commonly associated with fractures of the maxilla or, of its ascending ramus. If the patient survives a perforation or through and through injury, the danger is from haemorrhage and infection of the para-pharyngeal space.

The internal pharyngeal wound should be treated by suction toilet and removal of obviously dead pieces of tissue after digital exploration.

Wounds of the laryngo-pharynx into which saliva and discharges can drip, and infect the tissues of the neck, are more serious. Haemostasis and cleaning of the wound may require a wide and well planned exposure. If primary repair of the pharynx by approximation is readily possible, this should be done. If this is not possible, tissue loss must be accepted and after removal of devitalized tissue, the loss is defined by suturing the skin to the exposed

pharyngeal mucosa to form a pharyngostomy. The defect can be filled in by means of a shell dressing or a vaseline gauze tampon.

The early use of the sulpha drugs and antibiotics to restrict the spread of infection is most essential.

The general management of wounds of the mouth is described under Sections VII and XXI.

THE LARYNX

Indirect Effects

Blows on the neck and wounds in the region of the larynx may cause laryngeal haematoma or, damage one or both vagus nerves. Treatment is complete rest with the patient in a sitting posture and in position for immediate tracheostomy should it become necessary.

Simple Direct Injuries

Blows on the larynx may cause dislocation, or fracture of the laryngeal cartilages, or injure its intrinsic soft tissues. Although, of themselves, these injuries are not serious, there is the immediate danger of laryngeal obstruction from oedema or sub-mucous haemorrhage. Complete rest, sitting up in bed, is essential. Tracheostomy 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 injuries are serious on account of the risk of haemorrhage into the trachea, surgical emphysema, infection and perichondritis.

The immediate treatment is to keep the lungs free from blood as far as possible and maintain a clear airway. Suction is most desirable and should be used if available.

Improvised airways, tracheostomy tubes, etc., should not be left in contact with laryngeal cartilages for longer than a few hours, otherwise stenosis or perichondritis will ensue.

For operation, local anaesthesia is the method of choice. Anaesthetic difficulties are dealt with in Section VII.

Free exposure and careful haemostasis are necessary, the wound then being kept open by packing with gauze impregnated with suitable antibiotics.

Tracheostomy through the third and fourth rings of the trachea should be performed as soon as practicable.

To avoid lung complications, the patient must be nursed in a sitting posture and be allowed to cough. Morphia is contraindicated because of the danger of suppressing the cough.

Effects of War Gases and Smoke.

Inhalation of these noxious vapours produces intense inflammation and oedema of the laryngeal mucosa. Ulceration, secondary infection and perichondritis quickly follow. If the laryngeal condition is deteriorating a tracheostomy should be performed immediately.

Plastic Procedures

Sequelae following laryngeal injuries include fixation of the cords and stenosis from the organization of granulations or from perichondritis, immobility of the crico-arytenoid joints, recurrent laryngeal nerve paralysis and laryngo-oesophageal fistula. All plastic operations designed to relieve these complications must be delayed until healing is complete.

Recovery of function after vagus nerve injury may occur up to two years.

SECTION XXIII

BURNS

On the basis of experience in the second German war burns will form an important part of the work of all service surgeons in future wars. This aspect of their work will certainly increase if A-bombs are used.

Petrol, cordite and phosphorus have been in that order the common causes of service burns ; but the type of burn most often seen in each service tends to vary. Because of protective clothing the Royal Air Force burns —those which reach hospital—are predominantly of parts of functional importance : of the hands and face. The Navy more often has the primary care of large numbers of burns at one time, often under the most difficult circumstances. All types of burns are seen in the Army. The burns in tank crew survivors are chiefly of the hand and face and resemble those of air crews ; but in summer, when the crews often strip except for trunks and boots, the greater exposure of the body means more extensive burns in survivors. The extensive petrol burn is possibly more often seen in the Army than elsewhere. It is generally accidental and often due to negligence, *e.g.*, cleaning a battle dress with petrol while smoking a cigarette. Eighty per cent or more of the body surface may be involved, with full thickness skin loss of the whole of the upper and lower limbs plus parts of the trunk. These extensive deep burns need special management from the start if they are to survive. The depth of different parts of burn should be assessed early in every case, and not left to declare itself by slow slough separation, with its additional sepsis and scar deposit.

Recognition and Significance of Depth of Burn

The management and local prognosis of a burn depends chiefly upon its depth. An anatomical classification of depth is used here because it is clear and without ambiguity. The anatomical adjective (epidermal, dermal, or full thickness skin loss) describing the depth, indicates both the local prognosis and the correct management.

(1) Epidermal Burns

The lax blister lies between the epidermis and Malpighian layer. This Malpighian base is viable, red, has a capillary response, and is sensitive to pain by pinprick. In the absence of infection these burns heal within seven to fourteen days without residual scarring. Scalds are epidermal in depth, but exposure to steam under pressure causes deeper burns.

Flash and Cordite Burns.—If the clothing has not caught fire, flash burns, whether due to petrol or cordite flash, are chiefly epidermal in depth, but dermal patches may be present.

(2) Dermal Burns

In these burns there is patchy heat necrosis of the dermal base of the blister. This base is mottled red and white. It shows a patchy loss of capillary response and of sensation to pain. Healing occurs from " below up " rather than from " without in " ; but the dead dermal elements must first separate, and healing is not complete for two to five weeks. There is some residual pigmentation and scarring. The healed skin may be keloidal, or thin and unstable.

(3) Full Thickness Skin Loss Burns

Here there is heat coagulation of all layers of the skin. The dermal base of the blister is dead. This is indicated by its cheesy opaque appearance, its lack of capillary response and loss of sensation to pain by pinprick. There is also much subcutaneous oedema. Natural healing can only take place by marginal ingrowth after separation of the sloughs. This is bound to be a matter of weeks and may be indefinitely delayed. Throughout the period that the sloughs remain attached and the raw area is without a skin cover, systemic infective complications can occur ; local infection and deposit of scar tissue is of course constant and progressive.

Electric Burns, Hot-water Bottle Burns, Phosphorus Burns

In electric, hot-water bottle, and phosphorus burns, the greater part, or the whole of the area, is full thickness skin loss in depth, or deeper. Whenever clothing has caught fire and has been next to the skin extensive parts of these areas will show full thickness skin loss. This holds too when the patient has been unconscious and in contact with a source of heat, *e.g.*, epileptics, combined head injuries and burns, and hot-water bottle burns.

(4) Charring

Heat coagulation of structures deep to the skin is seldom seen except in electric burns, or when the patient is unconscious or is trapped in contact with a source of heat. The history, and the leathery crinkled yellow-black skin will indicate the nature of the burn. Extensive areas of muscle coagulation are especially dangerous. They can cause early death from uraemia.

Percentage Body Surface Burnt

The early mortality in burns is directly related to the percentage of the body surface which is burnt. It is important to make this assessment early, as it gives a guide to the possibility of onset of shock and the amount of plasma needed to prevent or treat it. The following figures are approximate only. They are rendered in descending scale for ease of memory. Each area is about half that above.

Trunk	36—38% of body surface
Each lower limb	18—19% ,, ,,
Each upper limb	8—9% ,, ,,
Most of both hands, and head and neck ..	5—10% ,, ,,
Face and neck	5% ,, ,,
Both hands	5% ,, ,,

TREATMENT

A burn passes through three natural phases: the primary phase lasts for most of the first week. This is followed by the secondary or healing phase whose period will depend on the depth and the treatment of the burn. It is during this healing phase that a primary skin surface is given to the burn. The third phase is that of reconstruction and rehabilitation. This account is only concerned with treatment in the primary and healing phases.

1. Treatment in Primary Phase of Burn

This phase covers the first week. It includes the periods of primary and secondary " shock," and of the toxaemia of burns when this occurs. Treatment in this phase comprises the preservation of life, and the prophylaxis of infection. The preservation of life at this time is chiefly a matter of maintenance of the circulation by administration of fluids.

Of the great number of local treatments for burns, all that include a gentle and thorough cleansing of the burnt surface can be successful, for epidermal and dermal burns which heal from below up. Applications which are epithelial toxins are barred. The coagulents are thus excluded, particularly Tannic Acid whose rigid eschar can produce ischaemia of a limb or digit, and which is, in addition, a liver toxin. The objection to the Bunyan bag in its present form is the maceration that it causes and which interferes with the high anti-infective properties and the normal healing rate of skin. A nylon derivative bag or one made of Manchester cotton, which are permeable to water vapour, would be preferable.

In the Field

An extensive sterile or clean cloth should be applied to the burn and well beyond it. This should be kept in place by bandages and reinforced by wool to prevent soaking if evacuation is delayed. A nylon derivative envelope which can be applied to the limbs or trunk is a preferable alternative.

Definitive Primary Treatment (CCS or Hospital)

Anaesthesia and Morphia in Burns.—Many burns may be given their primary treatment without an anaesthetic. Morphia should not be given in large doses, but is free from risk and is valuable in moderate amounts. A ¼ grain is the dose for an adult. More than ½ grain should very seldom be given. Pentothal (0·5 to 1 grm.) is the primary anaesthetic of choice for most battle casualty burns. Inhalation anaesthesia is contraindicated for facial burns and burns of the front of the neck and throat, because of the associated burns of the upper respiratory passages.

Local Treatment.—This comprises a toilet with 1 per cent C.T.A.B., or soap and water. The toilet should extend well beyond the area burnt ; care is taken to remove grease and dirt. Blisters are best broken, but there should be no rough rubbing of the burnt surface. A local antibiotic (such as penicillin powder or penicillin cream) is applied to the whole of the burn and well beyond it. On top of the antibiotic, an atraumatic dressing permeable to water vapour (nylon derivative or Manchester cotton) is applied. This dressing should extend well beyond the burn. It should be securely fixed with bandages and strapping over dry gauze packing. Firm pressure is desirable, by the use of bandages and much fluffed out gauze.

In burns of the hand the wrist is fixed in extension.—This automatically brings the digits into the position of function.

Primary Excision of Burns.—Certain local full thickness skin loss burns are suitable for treatment by primary excision and primary grafting. But this should not be undertaken except in special circumstances—where the general condition of the patient is good, when the area of full thickness skin loss is clearly demarcated, and the surgeon has special experience in this work.

There is another rare type of burn for whom a primary excision or amputation may have to be done. Heat coagulated muscle must be removed early or there is a high risk of renal failure in the second week. These cases are seen in epileptics, or when because of a head injury or other cause of unconsciousness, a limb is left in prolonged contact with flames.

Early General Treatment.—Fluids should be given freely by the mouth up to an hour before the anaesthetic. Most burns of over 30 per cent body surface need an intravenous drip. Guides to the amount of fluid to be given intravenously are :—

1. The Blood Pressure.—This should be brought up to and maintained at over 100 mgm HG, systolic pressure. B.P. records are made at 15-minute intervals in early stages of burns of over 40 per cent body surface.
2. Haemoconcentration.—This should be brought to and kept below 105 per cent. Hb. estimates are made at three-hourly intervals.
3. Renal output.—Unless enough fluid is given for the excretion of at least 20 ccs. of urine an hour it is probable that irreversible anoxic changes occur in the tubules and may lead to later renal failure. It may be necessary to insert an indwelling catheter to determine what the excretion is.

Three pints of plasma to one of blood are given, when available. When the drip is first set up it may be necessary to run in fluid at a rate of two to three pints in ½ to 1 hour, to maintain the B.P. and control the haemoconcentration. Eight to ten pints in 24 hours may be given ; but a careful check for signs of pulmonary oedema must be kept. Concentrated serum should be given when local oedema is marked, especially in a case of burns of the neck and mouth with respiratory difficulty.

Evacuation of Burns

Extensive burns travel well for several hours—even up to eight hours after being extensively burnt, or until they have had their first anaesthetic. After this they are seldom fit to be moved for ten days or more. Every effort should therefore be made to get them within eight hours to a medical unit which can hold them and give them full services from the time of their primary anaesthetic. Before evacuating any burn of more than 30 per cent. body surface it is wise to set up a plasma drip.

2. Treatment in the Healing Phase of the Burn

For epidermal and dermal burns the healing phase is short. It is a matter of (i) renewal of the dressing every five or seven days, or earlier if pus, fever, or smell are present, and (ii) of restarting active movements after the first week. Some localized dermal burns of hand and face are best treated as full thickness skin loss burns by slough excision and skin graft replacements in the second and third week.

Full Thickness Skin Loss Burns

In the general treatment great attention should be paid to diet (high protein, high Vitamin C, high sulphur, high iron) and, especially in burns of face and hands, to patient and assiduous feeding by attendants.

Local Treatment comprises :

1. The excision of the sloughs.
2. Surgical resurfacing.

These steps are undertaken towards the end of the second and beginning of the third week.

1. Excision of Sloughs

This should be done under tourniquet when possible. In very extensive cases removal of the sloughs may have to be done in stages, over three or four weeks. These patients may be helped by saline baths which soften the sloughs and allow separation with less haemorrhage.

2. Primary Surgical Resurfacing

This can take place at the same time as removal of the sloughs, or two to four days later. For local burns, medium (1/1600") dermatome cut skin to provide a complete cover by a sheet of split skin graft is best. Such dermatome grafts are particularly suitable to the hands and face.

For very extensive burns where a continuous cover by sheets of split skin is impracticable, a discontinuous grafting method must be used. Hand cut skin from the thigh using the Blair blade is recommended. This skin is spread on greased paper which is cut first into 1 cm. broad strips and then into 1 cm. square patches. These patches are closely packed over the raw area and fixed by circular vaseline bandage followed by wool and crepes. They are dressed at the fourth to fifth day. For very extensive burns three or more grafting operations may be necessary ; they are done at four- to twelve-day intervals. The object is to terminate this period of the burn, which is a period of disease, and have the man substantially healed within four weeks of being burnt, or within six to ten weeks in the most extensive cases. Patch grafts should be combined with sheet grafts for popliteal and cubital fossae, and for hands and face when these are involved in the burn.

3. Treatment in the Late or Reparative Phase

This phase starts when the primary skin surface is complete. It comprises local reconstructions, corrections of deformity, replacements of scar tissue and of inadequate primary grafts, plus the restoration of function and completion of the rehabilitation, general and local, of the patient.

Chemical Burns

Decontamination.—A vesicant agent must be sponged off at the earliest possible moment. An anti-mustard gas dressing is applied if mustard gas has been the agent. Phosphorus burns may be treated by lavage with C.T.A.B. as ordinary thermal burns, but are best first washed thoroughly with 2 per cent sodium bicarbonate followed by 2 per cent copper sulphate, if these are available.

Burns with Fractures

The reduction and fixation of the fracture and the primary treatment of the burn should take place under the same anaesthetic. The burn is given a full C.T.A.B. toilet. The antibiotic plus gauze dressing is applied and extends well beyond it. P.O.P. fixation of the fracture is the most suitable method for most of these combined injuries. Non-infected epidermal and dermal burns will be healed when the plaster is changed. For burns with full thickness skin loss windows in the P.O.P. should be provided through which sloughs may be excised and grafts applied. If an open reduction of the fracture is absolutely necessary it can be done through the burn : but a burn more than six hours old should be regarded as an infected wound, and treatment of the fracture modified accordingly.

Burns in the Tropics

These are most difficult problems. The difficulties chiefly concern the loss of fluid by sweating, the discomfort and unsuitability of covering the body in wool and bandages, the contamination by flies, the prevalence of skin infections, the slowness of healing in hot climates, and the anorexia. Burns in the tropics should have a high priority in the allocation of any air-conditioned space which may be available. They should have a free supply of iced fruit drinks and refrigerated foods. Local dressings should be kept as light as possible ; envelopes of nylon derivatives or Manchester cotton would be of value here. It is for epidermal and dermal burns in the tropics that a light flexible coagulant such as alginates, or even gentian violet, would be acceptable, and would avoid the need for swathing the body in wool and gauze.

A-Warfare Burns

A-bombs cause both thermal and radiation burns. Japanese experience indicates that thermal burns comprise a large proportion of the burns seen in survivors. An additional factor of importance is that within a radius of five or six miles of the bomb flying masonry causes a large number of injuries. Many patients will have combined fractures and burns, as well as the effects of deep irradiation plus a heavy surface contamination of radio-active substances.

Clothing, especially anything metal, must be removed. (Experience will show whether extraction of teeth with fillings is necessary.) All exposed parts should be most thoroughly sponged with soap and water. A local antibiotic and dressing is applied as for a thermal burn. Fractures combined with burns are best fixed by P.O.P. spicas which extend over the burn and the antibiotic dressing. Depression of the marrow function is treated by fresh blood transfusion. Many of the local partial thickness radiation burns will need later excision and free graft replacement.

NOTE

Nursed in a general ward of a hospital, even when no special steps are taken to prevent cross infection, burns exposed to the air without any dressing can run a very favourable course. The exponents of this method insist that dryness of the burned area is of supreme importance and that there must be careful immobilization and scrupulous nursing.

Primary cleansing, when oligaemic shock has been overcome, is with 1 per cent Cetavlon washed off with saline. The parts are then carefully dried with gauze and penicillin diluted with lactose (not sulphonamide) is sprayed on two-hourly until a crust forms. Penicillin systemically is given routinely.

The application of the pressure dressing is time-consuming, and huge stocks of dressings would be necessary for the number of burns casualties likely to occur in scientific warfare. This method then may be of value in certain circumstances, provided that hospital accommodation and nursing can be made available. It may also be a life-saving method in tropical countries when the burned patient is in danger of developing heatstroke.

SECTION XXIV

LESIONS CAUSED BY EXPOSURE TO COLD

The pathological effects of exposure to cold are both general and local.

Damaging effects of exposure to cold occur more frequently in frost and wind, when wet weather suddenly changes to frost. Severe dry frost in calm weather is not so dangerous. In northern countries, therefore, one sees more frost injuries in early spring than in midwinter.

Poor general condition, exhaustion, hunger, thirst, shock, lack of blood, depression, age, lack of opportunity for exercise and low morale 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, *e.g.*, 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, and 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 more often 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 replaced by a feeling of numbness and very soon by 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*

First described in World War II in men who had 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*

Occurred in people who spent nights in cold, damp shelters with their legs pendant over a sharp edge.

5. *Sea-boot Foot*

A condition occurring in those who have to remain relatively immobile for long periods in cold exposed situations (*e.g.*, gun-turrets) while wearing rubber sea-boots or similar footwear.

6. *Chilblains*

A well known and more innocent lesion due to cold which will not be considered herein.

Trench foot, immersion foot, shelter foot and sea-boot foot resemble each other closely as to clinical features and pathology. The hands may be similarly affected. A comprehensive term which covers all these conditions is "peripheral vasoneuropathy after chilling."

The symptoms during exposure are numbness, walking "as if on cotton wool," the hands feel clumsy, but during the period of exposure pain is unusual. The skin in some cases is wax-pale, in others dusky red. 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 :—

In true frostbite the tissues are frozen. The critical level at which irreversible changes occur in isolated tissues is 6 degrees C. (21 degrees F.) but in the body the tissues possess the property of super-cooling and much lower temperatures may be withstood without permanent damage.

If the general body-temperature falls, true frost-bite will rapidly occur. The majority of such cases die of the 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 not so important as the surrounding area which is merely chilled. This latter area

exhibits a neurovascular disturbance similar to, if not identical with, that which is observed over the whole affected area in trench foot and allied conditions.

The important changes are vascular. During exposure and for some hours thereafter, the circulation in the affected extremities is either arrested or very sluggish ; clinically this is manifest by absent peripheral pulses and by pallor or cyanosis of the skin. During this period the minute vessels in the skin and elsewhere are dilated, and their walls, which are very susceptible to anoxia, are damaged. Within 48 hours of return to a normal environment there is a rapid return of circulation in the main arteries, small arteries and arterioles. When the inrush of blood reaches the capillaries, the fluid elements, and occasionally some red blood cells, leak through the damaged walls leaving the majority of the cells conglutinated in the lumina—the phenomenon of *stasis*. This state of affairs is thought to be reversible, *i.e.*, if conditions are favourable normal circulation may be restored in a vessel in which stasis has occurred, but, if the vessel should sustain any additional trauma either mechanical (*e.g.*, by rubbing) or thermal (*e.g.*, by too rapid warming) the condition may progress to thrombosis.The fluid which leaks into the tissues and causes swelling and blistering is of high protein content and its later organization is responsible for fibrosis, especially in the skin and subcutaneous tissues. Profound pathological changes are also observed in the other tissues especially nerve and muscle.

From the clinical standpoint it is helpful to recognize three degrees of damage, viz. :

(1) Erythema or cyanosis of the skin with only slight swelling.
(2) Erythema or cyanosis with marked swelling and blisters.
(3) Gangrene, either superficial (common) or deep (rare).

In cases with second or third degree damage secondary infection is common and there is always a danger of tetanus. In the later stages such cases show motor, sensory, vasomotor and sudomotor disturbances of which pain, flat-foot, cold sensitivity and hyperhidrosis are the most troublesome.

An extremity which has once been damaged by cold is thereafter more susceptible to further exposure.

PREVENTION

It is of the utmost importance to realize that trench foot is invariably preventable. Most cases of frostbite should also be prevented. Only immersion foot can be regarded as a condition which may, under certain circumstances, be unavoidable. As regards trench foot it is the duty of *regimental officers* to see that the preventive measures outlined below are observed. *Medical officers* are entitled to assume that facilities for these measures are available and their duty is to advise upon what must be done, to insist on its importance, and to explain to the men how to avoid the effects of cold and how to recognize the early danger signals.

Preventive measures may be divided into :

A. Measures designed to protect the body against the general effects of cold

(1) *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.

(2) *Diet*

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.

(3) *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 cannot keep warm.

(4) *Clothing*

The value of protective clothing to prevent the injurious effects of cold, both on the body as a whole and locally, is considerable and requires detailed consideration (see below).

(5) *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 vaso-dilatation 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.

B. Measures designed to prevent the local effects of cold

(1) *Frostbite*

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.

(2) *Trench Foot*

The essential measures of prevention are : (1) to provide men with loosely-fitting boots and an extra pair of dry socks ; (2) to keep trenches as dry as possible with provision for warmth and shelter ; (3) to see that men enter trenches with clean. warm, dry feet that have been rubbed with foot soap and dusted with foot powder ; (4) to see that men keep moving so that circulation is maintained ; (5) to arrange for plenty of dry clothing and adequate facilities for drying wet garments ; and (6) to provide hot food in trenches.

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 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 his sweating 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 fur coat (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 pairs of thick 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). Special oiled socks have some protective value.

Keeping Dry

Wet is most dangerous. Every effort must be made to keep dry ; 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 four to five feet 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.

TREATMENT

(1) 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.

(2) Treatment of Local Effects of Cold

Men whose feet have been damaged by cold should not be allowed to walk more than is absolutely necessary. Stripped of their cold and wet clothing they should be nursed in a cool (60 - 70 degrees F.) room. The body should be kept warm and hot drinks given but the affected extremities should be left exposed to the air of the room and elevated as high as possible. Rubbing and the application of direct heat to the extremities are strictly forbidden as they traumatize the already damaged tissues. While the extremities are cold there is no value in attempting to keep them cool by fans, ice-bags, etc., but once they become hyperaemic the patient will be more comfortable if his feet (or hands) are cooled. Ideally this form of treatment should be controlled by skin temperature measurements and the temperature of the feet not allowed to fall below 20 degrees C. A daily toilet of the extremities should be performed under strictly aseptic conditions. After gentle washing with soap and water, blisters are snipped and any loose necrotict issue removed, the digits are separated by pledgets of wool or gauze and the foot or hand is then dried with spirit, powdered, and wrapped loosely in a sterile towel. Dye antiseptics should not be used as they obscure colour changes which should be carefully watched. An injection of antitetanic serum or a booster dose of toxoid should always be given and a prophylactic course of penicillin or a sulpha drug is also advisable. If cooling does not relieve pain sufficiently, intermittent digital compression (15 mins. " on " and 15 mins. " off ") of the femoral artery may be tried but this cannot be kept up for more than an hour or two and in most cases morphia will be required to secure adequate rest for the first few days. Any question of amputation must be deferred until the extent of any gangrene is clearly defined, usually two to three weeks. In the early stages the appearance of a foot in which eventually only portions of toes will be lost may be most alarming. Sympathectomy has no place in the treatment of this acute stage. Except in mild cases several weeks in bed are necessary. When patients get up swelling is apt to recur. Persistent swelling, pains in the feet, cold sensitivity, hyperhidrosis, and contractures of the toes may be the source of much trouble in the months which follow. Sympathectomy sometimes helps these late sequelae. A man whose feet have been damaged by cold, however slightly, should not be allowed to return to combat duty in a cold climate until at least 12 months have elapsed.

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

SURGERY IN THE TROPICS

Before going to a tropical country, the diseases endemic to that country must be studied. The " Memoranda on Medical Diseases in Tropical and Sub-Tropical Areas, 1946 " gives a fair working knowledge of the diseases likely to be met. Their recognition in endemic areas need not present many difficulties, but may not be easy in non-endemic areas. There are many pitfalls however which the text books do not always emphasize, and there are certain general principles. To ignore them, may prove costly.

1. In civilized surgical centres, air conditioning of wards and theatres is some protection against post-operative catastrophes, but non-emergency surgery should be avoided during the severe hot weather months. A death from heatstroke following an operation for hernia is a salutary lesson.

2. Just as any operation on a shocked gunshot wounded man is fore-doomed to failure unless there is adequate pre-operative resuscitation, so also in emergency tropical surgery, the dehydrated sick man must have his loss made good before he is subjected to even a minor operative procedure. Fluid loss before, during and for some days after operation, must be made good. Fluid loss from oversweating must be prevented, bulky dressings and too many bedclothes, unless the early mornings are cold, should be avoided. Pyjama trousers and a sheet, as a rule, are all than can be tolerated.

For the patient on sulphonamide therapy in the tropics, very copious drinks obviously are required, and for the chronic case in danger of decubitus

calculus the same rules hold good. In addition to diuresis—water, tea and barley water being the best drinks—all the other preventive measures must be carried out with care—postural changes, diet, exercises, prevention of constipation, routine urine examinations.

3. Recognized surgical methods may have to be modified to suit conditions and patients. In the treatment of severe burns in heatstroke conditions, the unburned area of skin and its freedom to function may be of even more vital importance than the burn. It may be a matter of risking some degree of subsequent infection rather than immediate death from the effects of heat. A Symes amputation may be a better proposition for the native, than a below knee at the optimum site and the best artificial limb. His climate will deal much more kindly with his stump than will the cold and wet of a more northerly clime.

4. The native's reaction to severe injury or disease may be unpredictable. He can recover from operations of the greatest magnitude or succumb to one which is by no means serious. He can recover the most complete function in what appears to be a hopelessly damaged limb, or he may refuse ever again to flex his normal knee joint after a meniscectomy. He requires more supervision than does any patient at home. Given the opportunity, he can be expected to remove by brute force, his operation dressings, a plaster jacket, any tube whether it be draining his cerebral abscess, or his ileum.

Diagnostic difficulties for the newcomer to the tropics are many. A disease apparently surgical may be purely medical, often there is a surgical complication of a medical disease, quite often two diseases are present. The history is of great importance, a suspected appendicitis in which there is an upset of the common sequence of generalized then localized pain, and of vomiting following pain should be viewed with suspicion. There is no reason why an appendicitis patient should not have a headache, but in the tropics it should give one furiously to think. Many fulminating cases of appendicitis are admitted complaining of diarrhoea. A watchful eye must be kept for the acute appendicitis patient in the dysentery ward. The blood picture is often the other most useful aid and a blood examination must be routine in all abdominal cases, for it may give evidence that malaria at least is partly responsible for the abdominal state.

It can also be expected in the tropics that the white cell count will give good information—6,000 means a medical fever, 12,000 with a dry furred tongue more than suggests the appendix which is gangrenous, a total around 20,000 should draw attention to the liver.

Malaria often appears first on the list of diseases which may mimic a surgical condition. Any injury or operation may precipitate an attack. It is therefore important that the possibility of this disease alone or as a complication should not be forgotten at any stage of an illness which appears to be or is surgical. It may be a relief to know that an alarming sequence of post-operative events is malarial in origin, but it will save much wear and tear to both patient and surgeon if the possibility is foreseen and the attack prevented. The diagnosis of abdominal malarial states should not present very great difficulties if it is remembered that any abdominal organ may suffer the acutest congestion, even necrosis, from occlusion of its blood vessels by parasites. The surgeon should therefore be on the look-out for abdominal as for cerebral signs. When an acute malarial spleen is seen

and handled it appears surprising that rupture does not occur oftener; the pain, tenderness and guarding over a spleen which is not even palpable can be marked, and there must often be the suspicion that even in the absence of any trauma, a malarial spleen is leaking. The patient may need careful watching for many days, at any moment profuse intraperitoneal haemorrhage may occur.

By the same token, splenic puncture should never lightly be undertaken. An exploratory needle in the liver if steadied externally in its up and down respiratory excursion, will not damage appreciably an organ of its consistency, but it can tear seriously the friable spleen. Some such cases have only been saved by operation. Some have proved fatal. Finally it is important not to accept the enlarged congested liver in a malaria case as being necessarily a malarial manifestation. Many an amoebic abscess has been present in addition and has been missed.

In all tropical fevers in which the Peyers patches are grossly involved the surgeon will be called in because of the right iliac signs. Many typhoid cases have been operated on because the surgeon is in such doubt, but again the history and the leucopenia should be sufficient to contraindicate operation. In none of these tropical conditions should appendicectomy be performed unless there is evidence that an appendicitis is not only acute but is obstructive. The character of the pain in that case bears no resemblance to the severest intestinal colic, no resemblance to the spasms in acute dysentery, it suggests to the sufferer nothing less than that his bowel is being crushed in a grinding mill. Operation in the early stages of typhoid may not affect the case very deleteriously, but in the later stages an unnecessary operation will have dire results. There is seldom an epidemic of typhus of any severity without an abdomen or two being explored. These cases die. In the not so late stages of typhoid, the diagnosis of perforation may be obvious, but in the terminal stages when meteorism is maximal and toxaemia profound, it may be a very different matter. In moribund patients unfit for operation there may appear to be quite convincing signs of perforation yet subsequent post mortem examinations reveal none. In many fevers other than those mentioned, abdominal pain is a prominent feature, in imminent heatstroke similarly and it should be remembered also that certain drugs used in the treatment of malaria can produce colicky pain of great intensity with collapse. These conditions all present difficulties to the medical officer and sometimes to the surgeon, but probably more puzzling are those states which are connected with the dysenteric infections.

The amoebic ulcer which perforates is not so very rare, the signs and symptoms may be unmistakable as in acute perforation of a viscus elsewhere, its treatment may be a difficult matter by reason of the state of the bowel. Equally often the perforation will be much more insidious and a retroperitoneal or circumscribed abscess will form and will sometimes evacuate itself into the bowel.

The differential diagnosis of amoebic typhlitis and appendicitis is sometimes far from easy. An unnecessary exploratory operation may be fraught with the danger of setting up haemorrhage which may be very serious, and the danger also is described of amoebic infection of any sinus which may develop, or of the skin, but this latter complication is unlikely except in a case unrecognized and untreated as amoebic. It occasionally happens that during the acute stage of a severe amoebic dysentery, masked by the other

symptoms present, a fulminating appendicitis occurs. When many cases of dysentery are being admitted, the right iliac mass is by no means an unusual feature. As a rule it responds to expectant treatment as quickly as would an ordinary appendicular abscess, and on many occasions later operation has revealed the typical leather-like inspissated remnants of an abscess around a burst appendix. In dysentery and other tropical diseases every effort in reason should be made to avoid operation, but even if a proved amoebic infection is present operation should not be withheld if the history is correct for appendicitis, the pain is of the characteristic type already described, a leucocytosis is present, and the case is early, *i.e.*, within forty hours. Any operation must be carried out with excessive gentleness and if by any chance the appendix is found to be inflamed only as part of a more extensive process, but is not obstructed it will be wise to refrain from removing it. After forty hours the right iliac mass should be treated on Ochsner-Sherren lines " on the threshold of the theatre," and an emetine course given if amoebiasis is proved or suspected. If operation becomes imperative, the minimum should be done.

More seldom in the future than in the past, there will be the occasional case of dysentery other than amoebic which tragically does not respond to any form of medical treatment and which after weeks or months is emaciated to the point of death. Ileostomy or caecostomy as a last resort in some of these cases can be exceedingly spectacular in its results.

In a land where amoebiasis is rife, the amoebic granuloma is quite often seen, and it is wise not to claim any great ability to recognise its true nature, for the case which appears beyond all shadow of doubt to be carcinoma may respond happily to emetine treatment, or unhappily, vice-versa. The case with a granulomatous mass in the rectum or a little higher up, or in the caecum, smooth or craggy, ulcerated or not ulcerated, should be put on an emetine test and have a biopsy done. In the early stages emetine will cure the condition, later emetine and chemotherapy may be successful in overcoming both the underlying and the secondary infection, but surgery may be required to overcome the permanent mechanical obstructive distortion which may result, and may be also the only way of determining that a carcinoma is not also present.

A most important precept which all tropical surgeons must learn is that there must be no operation, however small, on the anal canal within two months of an attack of diarrhoea. Before any such operation, the possibility of amoebic infection must be excluded by sigmoidoscopy and stool examinations. Emetine should be given a trial in any ulceration, fulminating or indolent, situated in the anal canal or orificially.

Hepatic Abscess. In the investigation of any abdominal condition of any obscurity the tropical surgeon should always ask himself the question " is there any possibility of this being an abscess of the liver? " Seldom is any tropical hospital visited without at least one case coming to light which might very easily be an hepatic abscess but in which that possibility has been overlooked. The symptoms may be classical and the diagnosis easy. On the other hand, a man may die, having shown no muddy look, no obvious liver enlargement, no leucocytosis, no radiological signs, no fever or only a pyrexia of typhoid or malarial type. There may be only right basal signs, loss of-weight and night sweats; an extension of the abscess into the lung may further concentrate the attention on the lung; the rigors

and liver enlargement may cloud the issue still more and be held as verification of a diagnosis of malaria ; early jaundice from pressure or toxaemia may be regarded more as evidence of other hepatic conditions; subphrenic, perinephric abscess may appear to be a likelier explanation; the left lobe abscess may give radiological signs which in an emaciated man of cachectic appearance appear to be complete verification of a diagnosis of gastric carcinoma. If therefore in any obscure chest or abdominal condition there are right basal signs, if a malaria case is not responding to treatment, if any patient is going downhill from no discoverable cause, these are all urgent indications for thorough investigation—blood counts, sigmoidoscopy, stool examinations, radiological examinations, therapeutic emetine test, adequate and repeated explorations of the liver. When exploring, a fairly wide-bore needle should be used, and if pus is struck it is advisable to aspirate as much as possible there and then, until some idea of the size of the cavity is obtained. A large abscess requires an aspirator but if the abscess is a small one a second attempt to locate it may not be so successful. If exploration is repeatedly negative an exploratory laparotomy should not be long delayed. Oftener than on the right side, an abscess of the left lobe seems to succeed in evading the exploring needle, but an abscess in that situation amenable to treatment by aspiration will be obvious immediately the abdomen is opened.

If the aspirated case fails to make the progress expected on emetine and chemotherapy, the question of open operation will require serious consideration for it is only too easy to wait and hope too long and to proceed to more heroic measures too late. The same line of treatment also holds good in cases of pulmonary amoebiasis. Many a liver abscess is coughed up, sometimes with partial success, but it seems a most unsurgical procedure to hope for a secondarily infected hepatic abscess, communicating with the chest through an opening which is probably valvular, to be evacuated satisfactorily through a long tortuous uphill and exceedingly unnatural channel by the patient's own efforts. The disease should be attacked at the source and before it is too late.

SECTION XXVI

SURGICAL ASPECTS OF SCIENTIFIC WARFARE

85 per cent. of the injuries resulting from an atomic bomb burst are surgical. This at first sight is an alarming statement but there are several important differences between a deluge of casualties of the type to which military surgeons are well accustomed and those resulting from atomic blast. It has been stated in the introduction that the same surgical problem has been repeated in every war and is likely to be the same in wars to come—the problem of the missile which on impact and on its onward journey, bears devitalisation and infection to whatever tissues impede its passage. The aim of the surgical service in every war is to bring early operative aid to the patient whose tissues have been penetrated in this way by a metallic missile travelling at a velocity high enough to cause deep penetration. The skin penetration of glass spicules after an atomic explosion, is not as a rule, deep.

If in past wars, when a shell, mine, or bomb blew up, the surgeon had not been concerned with the casualties occurring within the circumference of a circle having a radius of 1,000 yards, he would have been spared the major part of his vital operative work. That is not to say that other injuries will not hugely embarrass a surgical service if they occur by the thousand. When, however, it is realised that those who formerly would have required early operative care, will in an atomic explosion have died several times over, from other causes, the situation appears to be quite a different one which can only be appreciated surgically when authentic information is available regarding the extent of the area which is held to be lethal from radiation effects.

Serious cases of injury due to primary blast are unlikely to be met since lethal and serious injury from this cause will occur at ranges where other causes of death are overwhelming. As regards secondary blast, air raids on British cities gave good warning of the type of injury to be expected when buildings collapse and beams and girders crush and imprison. To guess very roughly at the nature of the lesions of the injured survivors of an atomic bomb burst—half will suffer contusions; over a quarter, lacerations of varying severity; and under a quarter will have more severe injuries—fractures of the long bones and skull, severe crushes and lacerations; up to one half of the injured may suffer from burns, and less than a quarter from radiation injuries. These conjectural figures all overlap. To guess at actual figures, at the worst perhaps 12,000 seriously injured survivors might have to be dealt with from one explosion.

If it is accepted that 15 per cent. of the casualties in ordinary warfare, require urgent major operation, then a much smaller percentage can be accepted in the case of atomic casualties. Skin lacerations need operation but conditions may enforce a policy of segregating for operation, only those with deep or extensive lacerations, and restraining infection in those mildly lacerated, with dressings and sulpha drugs. The compound fractures will require operation, so also the charred limbs, and amputation will be necessary in a proportion of these. Delays however will not be so dangerous, for gross contamination from indriven dirt and clothing should not be the vital factor it is in ordinary wounds. As five times the number of casualties of this type will occur indooors compared with those occurring in the open, this appears to be a reasonable conclusion and more especially since a town with solid buildings will have fewer badly injured than a town largely composed of wooden buildings.

It should be noted that a large part of this surgical work is orthopaedic in nature.

Those casualties who by reason of crush injury, or charring of the limbs from contact burns, are in grave danger of oliguria which may progress to anuria, with death on the 6th-8th day, require treatment and nursing from the earliest stages of the shock phase if they are to be saved. Until now the treatment has been more medical than surgical—promoting diuresis and eliminating toxins and pigments derived from the damaged tissues. The more recent suggestions of peritoneal dialysis and injection of novocaine around the coeliac ganglia may prove to be of some value. Surgical treatment of the crushed limbs is of doubtful value and probably is better avoided.

There remains the problem of burns. The number of casualties from this cause and the severity of the lesions, must vary widely according to

the preparedness of a community. When taken by surprise, up to 80 per cent. of those burned will be flashburned. The lesions will be epidermal and dermal, lessening in severity as the limits of the vulnerable area at 4,000 yards are reached. Of these flash burns nearly half will show erythema only, about the same proportion will show blistering and only the remaining 2 or 3 per cent. will have the deeper layers of the skin involved. About one-fifth of those burned may suffer radiation injuries in addition. When the population is wearing inflammable clothing the percentage of severe burns will greatly increase, and when the population is not taken by surprise and the incidence of flashburns is lessened, that of severe secondary burns will be relatively increased.

In general, of 1,000 burned cases, perhaps 400 will require only the application of a suitable cream to deal with organisms already present and to act as a barrier to fresh infection. A penicillin cream is preferable, but while doubt remains regarding the potency of old stocks, a sulphathiazole cream may be the method chosen. Mass spraying may be the method of choice when very large numbers have to be treated. Face masks as dressings are not necessary for burns of this degree. Another 400 will require a suitable dressing in addition. There remain perhaps 200 of greater severity, very severe flashburns, burns from ignited clothing and from secondary fires. They need plasma and are best treated by applying a dressing of the Colebrook type—of penicillin cream, tulle gras, much cotton wool and a pressure bandage. This problem, however, is not an easy one of solution, the dressing takes seven minutes to apply, the storage of inflammable cotton wool in the quantities needed to treat thousands of casualties is a problem in itself, and indeed entire stocks may be lost unless supply dumps are dispersed. A loose-wove bandage also is not an ideal covering, when wet it permits infection from without. Envelopes of the Squire's type or of nylon derivative, or specially fabricated cellophane, for the limbs and trunk, and gloves for the hands, would be preferable.

The definitive treatment of burns is dealt with fully in the section on that subject. During the first week, treatment aimed at the preservation of life and the prevention of infection, must be provided by first aid teams, transfusion and chemotherapy teams, and burns units in sufficient numbers; and of plastic surgeons in the 2nd-3rd week for the surgical resurfacing of burned areas requiring it. The burns problem is one of numbers—of mass treatment and disposal of those mildly burned, and of retaining those severely burned, bearing in mind that the latter travel reasonably well in the first eight hours, but after that are seldom fit to be moved for ten days or more.

This conception of the surgical aspects of atomic warfare may be held to be and may be proved to be unduly optimistic, but it does appear that the surgery required for atomic casualties is more that of the casualty department of a civil hospital—albeit on a grand scale—than of the forward operating centre of the battlefield where every breach of the tissues demands early operation. The fundamental surgical problem of the battlefield becomes aggravated in several directions but remains unaltered.

The treatment of radiation injuries is dealt with in other publications.

SECTION XXVII

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 localized 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 emphasized. 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 mobilize 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 a 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 mobilization 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 PT, 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, on any strain or over use. Careful examination of the passive joint range compared with the sound limb will reveal the AP 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.

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 osteoarthritis.

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.

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 jeopardize 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.

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 immobilization of the knee is a matter of opinion, a successful end result may be achieved with or without this.

SECTION XXVIII

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 L.2. 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 foot strain, 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 Pulheems classification, 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. "L.1. and 2." men should not be expected to remain "L.1. and 2." if employed continuously on sedentary duty.
2. *Classifications must be respected in relation to training and duty.*
   Care in classification is wasted if those in low classifications are asked to do duty beyond their capabilities. It is impossible for the regimental medical officer to watch all duties in relation to Pulheems assessments, 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 foot strain 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 inco-ordinated and balance is bad.

The treatment of foot strain 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 supervized by a physio-therapist 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 foot strain 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 inter-ossei). 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 1914–18 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 foot strain 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, otherwise their feet will soon deteriorate. Boots should be worn for all P.T. work, and flat heeled shoes or plimsolls forbidden.

ADHESIONS

Adhesions should be suspected if there is a sudden onset of pain, which has become chronic in a previously normal foot following foot strain. 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 effect a cure, failing which, operation should be considered.

BOOT ALTERATIONS

Light Boots

May be ordered for men assessed L.7 if necessary.

Shoes are not authorized except in rare cases, and then only on the recommendation of an orthopaedic specialist. The provision of special appliances is covered in para. 23, Section III of the pamphlet "The Application of the Pulheems System of Medical Classification to the Army, 1947".

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 foot strain 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.

PULHEEMS ASSESSMENT

Under the Pulheems System of Medical Classification disabilities of the foot are considered under the quality L. Full details of assessment are given in the pamphlets "Pulheems—A System of Medical Classification for the Fighting Services" and "The Application of the Pulheems System of

Medical Classification to the Army, 1947". The implication of the various assessments under L are given below :—

L.1. Must be capable of very severe locomotor strain for five to six days. Must be able to undertake forced marches and have sufficient reserve left to engage in active fighting at the end of such marches. Must be able to run and climb into tanks and lorries, up hills, up ladders, to jump from a vehicle, to crouch low, to rise quickly, crawl on hands and knees. Must be able to dig quickly and perform all kinds of labour.

L.2.—Must be capable of severe locomotor strain for five or six days. The minor defects must not interfere with the man's ability to run or climb into tanks or lorries, up hills, up ladders, to jump from moving vehicles, to crouch low, rise quickly, crawl on hands and knees. Must be able to dig quickly and perform all kinds of labour. In fact the man is expected to do all that an L.1. man is called upon to do, but at a slightly slower pace.

L.3. Must normally be capable of marching five miles and farther in an emergency. Must be able to do fairly heavy labour and to take and keep protective cover in a crouching and crawling position. Able to stand for periods of two hours.

L.4. Not in use.

L.5. Not in use.

L.6. Not in use.

L.7. Must be able to walk two miles a day at his own pace. Able to stand for moderate but not prolonged periods. Capable of suitable and useful employment without fear of breakdown.

L.8. Unfit for military service in existing standard.

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

Immobilization 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 realize 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.

" Fatigue " and " Stress " fractures have been described in the tibia, fibula, os calcis, vertebrae, pelvis and ribs. The pathology is similar to that of march fracture : the fracture is of the nature of a stress decalcification due to prolonged or repeated use, beyond the physiological strength of the bone. These fractures may occur in soldiers whose training has been too rapid, or when physique has been allowed to deteriorate after training, and they have then been subjected to prolonged severe exertion.

SECTION XXIX

REHABILITATION

Rehabilitation aims at the restoration to health in the shortest possible time of those who have become unfit by injury or disease. Physical treatment is commenced at the earliest possible moment in conjunction with medical and surgical treatment. The improvement in morale and avoidance of depression is of incalculable benefit.

Stage I. At Military Hospitals

Rehabilitation must be planned and consists of :—

(*a*) *Physiotherapy*, which should be carried out by civilian attached members of the Chartered Society of Physiotherapy, or army-trained physiotherapists. Every effort should be made to encourage and extend these departments in military hospitals. Exercises form an important part of treatment and should not only be remedial, *i.e.* for an affected limb, but also general to maintain fitness. P.T. instructors, who have been suitably trained, assist in remedial therapy.

(*b*) *Occupational and diversional therapy* in the wards, for bed patients, and occupational therapy in the department, for up-patients encourage

mentally and physically the return of full function. The work is superintended by a trained occupational therapist with the co-operation of medical officer, ward sister, B.R.C.S. and A.E.C. personnel.

(*c*) *Diversional activities* should be organized. These consist of film shows and other entertainments, *e.g.* Apparatus B now available enabling a patient immobilized in bed to read pages of a book projected by lantern on to the ceiling.

Stage II. At Convalescent Hospitals, usually in U.K., B.R.C.S. or Order of St. John

In time of war these hospitals act as auxiliaries to the parent hospitals, and serve the purpose of relieving beds. Patients are still in need of skilled medical and surgical supervision at regular intervals, and a proportion of these will be bed patients. Specialists from the parent hospital make regular visits. Physiotherapy, occupational and diversional therapy will be available on lines similar to those outlined under military hospitals. For the ambulant patient a daily programme is carried out consisting of games and P.T., gardening, lectures, together with light fatigues inside and outside the hospital.

Stage III. At Convalescent Wing or Depot

The final stage of rehabilitation is completed. Patients should be ambulant, although they may be in plaster, walking caliper, or assisted by crutches. The men are divided into grades according to fitness and they participate in organized games, graded P.T., lectures, entertainments and a return to discipline and a more military life in the form of short marches and drills. Most men are returned to duty within a period of one to two months.

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