PART II

SURGICAL
CHAPTER 31
WAR WOUNDS

In considering the treatment of war wounds it is simplest to regard the prototype of battle injuries as an uncomplicated wound of soft tissues, that is, of skin, subcutaneous tissues, fascial planes and muscle. The difficulty and complexity of surgical treatment are greatly increased by involvement of bones and joints, major blood vessels and nerves, or the head, the thorax and the abdomen with their contained organs. Every type of injury produces individual problems of expert attention and of nursing, and the time and method of transport of patients before and after operation demand special care. The growth of surgical knowledge and the development of highly technical methods in delimited fields have resulted in great expansion of surgical services in war, particularly in the more settled areas behind the forward battle zones. Nevertheless, it is still an important principle to regard the relatively simple flesh wound as setting a therapeutic standard, a basis for all wound treatment.

It is not easy to deal with the evolution of the treatment of war wounds in the 1939-1945 war from a strictly chronological point of view. At first sight it may appear that this surgical evolution centres round the introduction of sulphonamides and penicillin. It is true that the concept and practice of chemotherapy have marked an epoch in the history of medicine. Some surgical techniques have been revolutionised by penicillin, yet it is important to remember the other factors in surgical success, some revived from the half forgotten struggles toward the light in 1914-1918, others established by experience under the altering conditions of 1939-1945.

At the beginning of the war military surgical knowledge was little advanced past the standard reached in 1918. The 1914-1918 war saw a great advance from the apathetic beginning of that period, and excision with delayed primary suture was at last established as practicable in 1918. The ultimate goal, excision and primary suture, regarded as a crime a few years earlier, was seldom possible, but was regarded as the ideal towards which surgery was tending. Carrel and Dakin not only stimulated the use of antiseptics, but emphasised the caution necessary to maintain the vitality of those allies of repair, the tissue cells. The use of their method, controlled by bacteriological tests, made secondary suture a common procedure.

Between 1918 and 1939 these lessons were applied in the practice of traumatic surgery to some extent. Incidentally it is sad to reflect that apart from war, the experience of the traumatic surgeon is gained largely from efforts to repair the ravages wrought by modern forms of transport, particularly motor vehicles. Later, the Australian Army in the Middle East was to be seriously impressed by the wastage of soldiers from traffic accidents. During the earlier part of this period 1918-1939 Winnett Orr pursued his work on the closed treatment of osteomyelitis in long bones,
and his principles were followed in the handling of compound fractures and large soft tissue injuries. This method is of course quite a distinct addition to the techniques of excision and suture.

The Spanish war gave opportunity for evaluation of surgical methods and Trueta and others attracted the attention of the surgical world by the encouraging results obtained by excising all damaged tissue, and enclosing the part in plaster without suturing the wound. Bombing of cities in Spain showed how disruptive was the action of irregular fragmentary missiles, producing wounds more damaging than civil injuries in peacetime could show.

Resuscitation by the use of parenteral fluids, chiefly blood, made major advances during this period too, and the accurate knowledge gained of the degree and rate of fluid replacement required in conditions of medical and surgical shock was of untold help to the surgeon, even though some of the earlier civilian teaching was modified by military practice.

But when we return to the problem of the treatment of what may be called the basic damage of the war wound we find in 1939 a feeling of uncertainty. Chemotherapy with the sulphonamide drugs raised hopes that this might be a potent weapon against the bogey of infection, but the memories of 1918 enjoined caution. Military surgical methods in 1939 were substantially those of 1918: the organisation for their application was essentially similar. Surgeons in 1939 could not foretell if they would have to deal with such great numbers of casualties as in 1914-1918, or cope with wounds inflicted by missiles of all shapes and sizes, and heavily contaminated with the debris of soiled battlefields as in Gallipoli and France. There was little doubt, however, that infection, shorn of most of its power in civil surgery by aseptic techniques, would again be a menace. As Graham Butler truly pointed out, in 1914 there was a lack of understanding and experience what to do in the face of sepsis. By 1917 the doctrine was firmly founded that thorough surgical preparation was necessary of the damaged tissues for their work of repair, and “excision” of wounds, advocated by Milligan and others against opposition at a much earlier stage, at last won its place. This practice, advocated in the Napoleonic wars, was thus belatedly recognised. In 1939 it was known that when wounds were the source of their own infection hopes of sterilising them by antisepsics were doomed to be shattered.

However, there was still some lack of clarity in the means by which such preparative surgery could, with the help of the chemotherapeutic methods then available, become reparative. Surgeons who had learnt valuable lessons in the previous war did not always realise that the semi-static warfare of the Western Front had imposed on the minds of administrators its pattern of transport and moving of the wounded. In 1939 modern transport had revolutionised war, and the treatment of war wounds needed revision rather because of the effects of mobile warfare on the steady working of medical units than because of scientific considerations. One lesson taught by Winnett Orr and others in the later stages of the 1914-1918 war was not absorbed by all in spite of its importance, the
value of immobilisation of adequately drained wounds in plaster casts. Trueta in Spain further extended the idea to the treatment of recent wounds, and its value was apparent in securing comfortable transport and minimal interference for the wounded. His experience was so recent when war broke out in 1939 that the impression was fresh in the minds of those who realised that soon they would be treating wounds received not only in the field, but also in bombing raids in centres of civil population.

In Australia in 1939 a new edition of the *Manual of Injuries and Diseases of War (Australia)* was published, based largely upon the British *Injuries and Diseases of War*. The methods of wound treatment described here were simply those of 1918, and the accent was not placed on such aspects as Trueta’s work on immobilisation and the possible advances of sulphonamide prophylaxis and therapeusis. Excision of the wound was rightly emphasised as a major advance in the previous war. Trueta’s own summary in 1939 was more comprehensive than the advice in this manual and ran as follows. Early surgery was the watchword: after cleansing, shaving and skin disinfection, the skin edges were excised and then all non-viable muscular and cellular tissues, as judged by the contractility, colour and bleeding of muscles, the wound was opened for drainage, most bone fragments were removed, a fracture was reduced by traction, a dressing applied, and the limb encased in plaster.

In addition to this information available to Australian surgeons, Sir Thomas P. Dunhill, who was acting for some time in 1939-1940 as Consulting Surgeon to the A.I.F., sent from London to Australia detailed accounts of recent experiences and advances in war surgery. In this way recent trends in traumatic surgery were made known to the officers of the A.A.M.C. and some opportunity given to form judgments of the advantages and drawbacks of plaster immobilisation, the treatment of burns, the current views on amputation and other important subjects.

Before campaign experience in the Middle East is discussed some reference may be made to the confusing terminology of wound treatment. “Débridement” and “excision” have been used as though interchangeable. It is rather futile to attempt an apt translation of “débridement” as writers differ in their ideas of the measures it implies regardless of its derivation. Trueta defines it as including “the removal of all foreign matter, the excision of all the tissues immediately surrounding the wound, including devitalised soft parts in the vicinity, and the opening up of cellular spaces”. Excision *en bloc* is obviously impracticable in most instances, but the word is taken to mean the removal of a thin skin edge where this is dirty or ragged or devitalised, and also of such other tissues as are judged incapable of survival, and infected. The operation is logically extended to the relief of present or expected pressure by swelling, and to the sacrifice of functional tissue which shows evidence of a dangerous type or degree of infection, as in muscle infected by gas gangrene.

“Primary” and “secondary” suture also require some definition, especially since the introduction of the somewhat contradictory term “delayed primary suture”. Technical Instruction (M.E.), No. 20, in forbidding
primary suture in battle casualties pointed out that it is a frequent cause of bad results, and in wounds of limbs may necessitate amputation. “There is always another day in which either to act or regret—a secondary suture can later be performed”. Secondary suture was taken to be repair by suture of a wound which had begun to granulate. Delayed primary suture meant the closure of a wound within a few days of the injury.

**WOUND TREATMENT IN THE MIDDLE EAST**

At the end of 1940, the time of personal testing and proving arrived when the first campaign in Libya and Cyrenaica began. The conditions under which forward surgery was carried out there varied according as the military situation was one of movement or not. The prime difference from the practice of the last war was the attachment of surgical teams to field ambulances. The most important problem in surgical treatment in the desert was to decide whether to pass wounded men over a long rough route to a casualty clearing station, or to risk holding up the necessary movements of the main dressing station during the patient’s post-operative period. This is dealt with in more detail in the account of these operations (Volume II).

The Australian medical services attached to the 6th and 9th Divisions A.I.F. enriched their experience in this campaign by working under conditions of rapid movement in victorious pursuit, of temporary immobility, of equally rapid movement during retirement and finally of siege in Tobruk. During these operations, wounded were removed by road, rail and sea, and in only a few exceptional instances by air, to the intermediate units and to hospitals in Alexandria and Kantara and also in Palestine. Then came the brief valiant episode of Greece in which the surgical work was carried out in field ambulances and one casualty clearing station, and finally, when retirement was imperative, in one hospital, some of whose staff were taken prisoner, much to the benefit of the wounded. Almost at the same time, the 7th Division A.I.F. engaged in the attack on Syria, a brief campaign in which, after the first difficult stage of evacuation of the wounded, the routes to hospitals in Palestine were disposed according to the method of the military manuals for the first time. The end of this campaign marked an epoch, and although the largest set battle in which Australian troops participated in this war, El Alamein, introduced some new features in details of surgical treatment, the policy laid down by judgment and general knowledge in 1940 was consolidated into the practice dictated by experience by the end of 1941.

The surgical creed of the A.I.F. was simply expressed at this period in the Technical Instructions, Nos. 20, 21, 22, 23 and 24, for the A.I.F. in the Middle East.

Instruction No. 20 began thus:

“The following simple instructions will act as a guide for all those who have not had previous experience of war wounds. Experience will no doubt lead to modification of technique. Until that experience has been gained, it is recommended that the well recognised procedure detailed below be adopted.”
The primary treatment thus laid down consisted of toilet and excision of the wound, placing no sutures except in wounds of the skull, thorax, abdomen or large superficial joints like the knee joint, and, after the first 36-48 hours, in amputation flaps. Sucking wounds of the chest, in Australian opinion, required sutures; plugging with bandaging or strapping was found unsatisfactory. Wounds of the face and jaw also required retaining sutures. It was emphasised and not without need, that dressing wounds with "Vaseline" and gauze does not mean packing them tightly with gauze, but simply loosely filling the space with "Vaseline" and covering with a few layers of gauze. This was particularly important when a plaster was applied. Where this had been done, and when any large wound had been excised the patient was retained for observation for twenty-four hours to ensure that the plaster was not constricting the limb, and that there was no risk of reactionary bleeding. This instruction was issued because it was learned that some medical officers were contemplating the trial of primary suture in wounds of the extremities. Instructions were also given for the handling of fractures of the upper and lower extremity in the field, wounds involving large joints, wounds of the face, jaw and mouth, wounds of the chest, and burns. These will be dealt with later in the appropriate sections on regional wounds.

Controversy in and out of Australia centred for a time on the question of primary suture. During the 1914-1918 war, this had suffered ups and downs, but with the improved methods of the later period was being regarded as an occasional method of choice by the end of the war, and as having some value in selected injuries in civilian practice. H. R. G. Poate, Consulting Surgeon to the R.A.A.F., writing in Australia defended primary suture, with proper safeguards, but Colonel W. A. Hailes as Consulting Surgeon to the A.I.F., forbade it strictly except as laid down in the instructions quoted above. These two points of view were not irreconcilable and Hailes could not do other than lay down a definite safe rule, the only safe rule at that particular surgical period in the Middle East. Care was taken to acquaint surgeons in Australia of the methods found most valuable in the Middle East. Hailes described these in regular letters to Major-General Maguire, D.G.M.S., during the latter part of 1941. These accounts followed up the methods used till the wounded man reached the base. This was stressed as important, for although the functions of the forward surgeon were limited by considerations of movement and nursing, the goal of rapid and complete restoration of structure and function was always to be kept in sight. The establishment of special sections in hospitals helped to keep prominent this aim in treatment, particularly a facio-maxillary (plastic) unit, and others for orthopaedic work and fractures, and to a less official extent, for wounds of the head and chest.

Opportunity was taken during the early campaigns to test the value of closed plaster: on the whole good results were obtained. Reference has been made above to the precautionary instructions concerning possible constriction of a limb by an encircling plaster. Some aspects of plaster
are better discussed in dealing with injuries of limbs and long bones, though the general principles apply more or less to all wounds for which plaster was used. By the time wounded arrived in base areas one of the drawbacks of plaster immobilisation in a hot climate became evident, as the odour soon became offensive. Experience showed that an offensive discharge seeping through the plaster and a coincident rise in temperature and pulse rate did not necessarily mean a serious infection. Removal of the plaster, cleansing and redressing often revealed a wound which could quite justifiably be recased in plaster. Major Brooke Moore, commanding the portion of the 2/5th Australian General Hospital in Greece after the withdrawal of the Allied forces, found that the particularly voracious local bugs invaded plasters to an extent that was a serious objection to the method, even had local supplies of plaster been adequate. In the Middle East naphthalene was issued through the Army Service Corps, and this helped to mitigate the odour of plasters; half a handful of crystals was placed over the part of the plaster covering the wound before the last few turns of the bandage were made.

Apart from such difficulties plasters needed a certain amount of supervision during transport of patients, and it was never desirable or safe to disregard any complaint of discomfort. Dunhill in one of his London letters said:

"Simple treatment, plaster and sulphanilamide give comfortable and safe transport, but the patient should not be left too long without removal of the plaster, inspection of the wound and treatment according to the condition found. This is not a disproof of the Trueta method. The Spanish wounded were close to a hospital where skilled surgeons were able to give the full treatment at a very early stage."

Colonel Hailes, writing to Major-General Maguire on 10th August 1941 about the experiences gained to that date, spoke more definitely:

"The first plaster that is put on is for travelling only: tell them that there must be something unusual about Spanish patients, but Australian surgeons cannot correct the position and keep it corrected in plaster. The beautiful picture painted in some of the recent text books will need to be forgotten, at least in part."

This warning was of course not intended to discourage the value of closed plasters used properly, provided the method was not regarded as a talisman in the quest for repair. The wound cleaned, excised and kept secure from movement and from extraneous sepsis, was given a good start: much often remained to be done even after local defence against infection was established. Observation in base areas showed that prolonged immobilisation in plaster had many drawbacks, notably the slowness of healing by secondary intention where skin loss was considerable. Large lacerated wounds, as Rank pointed out, sometimes showed a large surface of exposed muscle which closed in and left a small final wound to heal. Others with loss of much skin often left unstable scars. Other causes of delay in healing or soft tissue wounds were not dependent on the size or nature of the wound, such as the presence of fragments of foreign material, sloughing of tendinous structures and sepsis in bones. The ubiquity of infecting organisms such as streptococci and staphylococci was a constant threat to healing.
Transferring wounded from barge to ship at Tobruk.

Hospital ship Manunda.
Blood transfusion at C.C.S. in the Western Desert.

Unit collecting blood from army personnel at a forward operational base —Netherlands East Indies.
The experience gained in the first desert campaign showed that excision of wounds as practised by the surgical teams attached to the main dressing station of field ambulances was nearly always adequate. As time went on and results could be checked by the career of the patients in base hospitals an increasing number of young surgeons became familiar with the correct technique under the tutelage of seniors. The thoroughness of this early surgery had an excellent clinical and educational influence. The importance of detail was stressed. Excision of the skin edge depended on the site of the wound and the condition of the skin and deeper tissues. All bruised pieces of muscle or fascia were removed, and blood clot cleared from recesses of the wound. Incisions were made, the wound being extended if necessary, in order to obtain access; these were specially needed when the damage, as so often was the case, was greater than the size of the wound of entrance suggested. Deep fascia was slit to prevent subsequent compression of soft tissues. Foreign bodies were removed as far as possible, particular attention being paid to fragments of clothing and embedded dirt. Loose long fragments were usually removed unless they had sufficient promise of vitality to be useful in repair. Such operative procedures had always to be based on sound anatomical and physiological principles. Important structures such as leashes of nerves and blood vessels had to be remembered and respected. It was sometimes desirable to explore such structures for possible damage. The amount of soft tissue excised was influenced too by the degree of deeper damage, such as fractures of bones. In fact it later became an aphorism that after operation on a wound causing compound fracture of a long bone it should be possible to see the fracture site. Surgical treatment of wounds other than first aid demanded a ready anatomical knowledge and adequate operative experience.

From the beginning sulphonamides were given to all wounded on admission to a forward operating theatre. At first the practice varied in amount and detail. In some medical units a single daily dose of five grammes was used; in others an initial dose of two grammes was followed by one gramme every four hours. Sulphanilamide or a mixture of sulphanilamide and sulphapyrazine was also introduced into the wound and dusted on the surface. The prophylactic value of these drugs was not doubted by surgeons, though at first it was overrated, for the dust of the desert, though all pervading, was bacteriologically more or less harmless. Yet during the Syrian campaign at a later date where the terrain was cultivated and in places closely occupied, only seven cases of gas gangrene were seen among 1,500 battle casualties. It is not suggested, however, that this low incidence was due only to the administration of bacteriostatic drugs.

After the whole experience of the Middle East had been assessed, an instruction was issued in Australia dealing with the use of sulphonamides in surgical practice. In this the principles laid down were the rapid attainment of a high blood concentration, the maintenance of adequate concentration during each twenty-four hours, and administration by mouth.
where possible. A single course of treatment did not exceed ten days, and a leucocyte count was advised before another course was begun. The usual fluids and alkalies were given during a course, and close observation was made of the urinary excretion, and of any urinary abnormality or vesical symptoms. The dosage recommended was two grammes at once followed by one grammme every four hours, up to a permissible total of 35 grammes. The drugs available at first were sulphanilamide and sulphapyridine, and a little later sulphathiazole was also obtainable. Sulphanilamide was more used than other preparations during the early campaigns because of supply difficulties. The distances to be covered in the desert in transporting wounded were in part responsible for the introduction of greater elasticity in the interval between doses of sulphonamides. Backed by some experimental work, as told in the section on chemotherapy, the Australian surgical services found that large doses given twice or even once in twenty-four hours afforded an adequate blood concentration to ensure therapeutic result. In countries where the evacuation route was often long in both time and distance this was a significant contribution to the practice of sulphonamide prophylaxis of wounds. Further developments in chemotherapy will be described later. Other factors in the treatment of battle wounds in a forward area such as anaesthesia and resuscitation may be left also to later sections.

In more settled areas more deliberate surgery was undertaken. Types of wounds varied somewhat in different campaigns. In the desert, grenades, land mines and booby traps were responsible for multiple wounds in which many fragments were embedded. The cleansing of such wounds was sometimes a long and difficult task, especially in parts such as the buttock where deep injuries were inflicted on soft parts. Excision and plaster casing suited these injuries well. Secondary haemorrhage was sometimes a worrying complication, though it was rare in amputation stumps. It was dealt with where possible by seeking the vessel in the wound, but in certain sites, such as deep in the palm, between the leg bones, in the buttock, or in some parts of the neck this was not always possible. Due consideration was of course paid to collateral supply, and vessels whose ligation was known to be dangerous, such as the popliteal or the common femoral, were avoided. Direct control of a bleeding vessel in a wound was preferable to more remote control because of the already existing trauma. In a few instances gangrene necessitated amputation of a limb.

In hospitals where saline baths were available this method gave some excellent results with large wounds of soft tissues. After the bath a light sprinkling of sulphanilamide was applied, and dressings of tulle gras; skin grafting was used as early as possible. The bath method was found particularly useful in the treatment of severe burns. Wounds of regions in which "specialists" usually hold the field received only emergency treatment in forward areas, unless the clinical signs were such as to make further early action imperative.

Infections of wounds varied with the terrain. In Libya and Cyrenaica there was a curious contrast between the ease with which superficial
wounds healed and the indolence of the ulcers of the skin which were common in most parts of the Middle East. The rarity of gas gangrene has been commented on above. Gas infection occasionally occurred, apart from gangrene; the clinical distinction was a most important one, both statistically and prognostically. The former required only local treatment. Gas-forming organisms were found afterwards to be of much greater surgical importance in New Guinea. Though anaerobic bacteria were common in the Middle East, their virulence did not appear to be high. In any case infection of wounds was not a serious problem in the Western Desert.

Captured Italian prisoners were sometimes found to have wounds healing well, though they had received only rudimentary attention. The ready availability of skilled surgery was certainly an important factor in prevention. This provided good drainage and ensured that the effects of anoxia of tissues were minimised by the encouragement of good blood supply and the avoidance of inflammatory oedema with its destructive pressure. The manoeuvre of splitting deep fascia, for example, had prophylactic value, and helped to discourage an environment favourable to anaerobes.

*C. diphtheriae* was an occasional infector of wounds, though more often seen in septic ulcers. A grey or greyish yellow slough on the wound appeared, due to a thin layer of necrotic tissue, which spread at the edges. The occurrence of several small outbreaks of diphtheria in the Middle East forces emphasised the need of remembering it.

In the forward areas the prophylactic value of sulphonamides was difficult to assess, owing to the variable conditions. In base areas more careful evaluation was possible. There was no doubt felt of the value of systemic administration. No accurately controlled assessment of the value of sulphonamides used locally or systemically could be made in the A.I.F., as special teams for investigation could not be spared. Statistics, dependent on variable conditions, were unreliable. In a base hospital where the powdered drug could be insufflated on to a granulating surface previously cleansed by saline baths, the disappearance of streptococci could be proved. In forward areas no such conditions could be secured and statistical results were correspondingly less reliable. Though selectively useful in local application, the same fallacy appeared as in 1914-1918 when too much was expected from antiseptics. Suppuration and infection in pockets of wounds defeated sulphonamides used locally. Septicaemia was not a menace in 1940-1941, and the knowledge that sulphonamides would control general streptococcal infection permitted wound excision to be carried out safely over a longer interval period.

No large scale cultural observations could be carried out on war wounds of the A.I.F. in the Middle East, but the prevalence of the haemolytic streptococcus was undoubted. The observations of Keogh and Freeman on "desert sores" confirmed this. Other common aerobic organisms played the part of secondary invaders, and as will be seen, gave trouble after the usual pathogens had been controlled by specific measures. The need for making routine anaerobic cultures of wounds did not arise in the Middle
East; they were only made as required. Surgeons thought that the universal use of sulphonamides had some action in preventing a greater incidence of anaerobic infections. Further information on bacteriological findings is given later.

Tetanus was practically banished from war surgery by immunisation. One soldier died from tetanus who had only one inoculation, and in the concluding stages of the war an occasional instance of localised tetanus was seen following a wound. In 1940 Middle East administrative instructions laid down that wounded men immunised with tetanus toxoid were to be given 3,000 units of antitetanic serum, and if they were found later not to have been immunised, doses of 1,000 units were to be repeated weekly for three weeks. A later technical instruction was issued in Australia enjoining the use of tetanus toxoid in a stimulating dose of 1 c.cm. as soon after wounding as possible, instead of antiserum. Medical officers checked the records of immunising injections in each man’s paybook: if the records showed incomplete immunisation or were missing, prophylactic antitoxin was given. Regular “refresher” injections of toxoid were given as a routine at yearly intervals to all servicemen and women.

The constitutional effects of serious wounds early aroused attention. For many years, especially in the pre-Listerian days when chronic sepsis was common, the evil effects of localised infection on the whole body had been recognised. More recent studies emphasised the importance of maintaining correct levels of red blood cells, haemoglobin and plasma proteins, and the supply of the correct aminoacids and vitamins in the diet. During the 1939-1945 period these aspects of the care of wounded men were well studied, and as time went on it was found that even in these days of aseptic surgery and the use of specific drugs, chronic infections of wounds had not been banished, and still had to be treated. Before penicillin was available organisms not controlled by sulphonamides and other measures could cause overt or covert sepsis which severely drained the blood and other tissues of the necessities for full living. At a meeting of surgeons in Egypt in 1942 the loss of protein due to large infected wounds was discussed, and attention was called to the need for seeking local abscesses, and effecting drainage in such conditions. Emphasis was placed on the value of a high protein diet containing in particular adequate vitamin C. Further reference will be made to these constitutional effects of wounds.

The influence of surgical specialties in base areas helped to effect striking improvements in wound treatment. The work of high grade general surgeons and others specially trained in plastic surgery, orthopaedics, thoracic surgery, and ophthalmology not only raised the standard of work in field hospitals to a high level but reflected on the methods used in forward areas. The influence of plastic surgery on traumatic surgery in general was great, and insistence upon the ideal of rapid physiological restoration of a sick or wounded man encouraged the early application of physical and occupational therapy.
All the advances brought by these and other applications of continuous study were potent factors in accelerating and improving the healing of war wounds.

**WOUND TREATMENT IN THE PACIFIC CAMPAIGNS**

When the Middle East chapter closed for the A.I.F. in 1942 with the return to Australia of the 9th Division, new problems arose. The Pacific Islands presented great difficulties of terrain and transport, of climate and of endemic disease. During these later years the importance of maintaining the surgical principles already laid down was emphasised. For example, in some of the forward posts in New Guinea, such as Myola, during the first New Guinea campaign men sometimes arrived as late as two days after being wounded. This was later duplicated in other areas. Oedema of muscle in the limbs had by that time resulted in plugging of the wound in the deep fascia, and adequate excision or incision was necessary in order to allow drainage. After some of these earlier New Guinea campaigns Brigadier Hailes, Director of Surgery, found it necessary to issue the following Technical Instruction, No. 81, which drew the attention of medical officers once more to the importance of adequate early surgical measures.

"Surgery in Forward Areas in Recent Operations.

"The standard of surgical work both in regard to the quality of the surgery and the condition of the wounded on arrival at Australian General Hospitals is generally satisfactory, but it was noticeable that excision of the wounds had been neither as extensive nor complete as in former campaigns. As a consequence suppuration under the ensheathing fascia and secondary haemorrhage were more troublesome.

"The attention of all surgeons operating in forward areas is drawn to the fact that, although there is every reason to be conservative over the amount of skin removed, the wounds will be laid widely open and extensively excised. The incision and excision of the ensheathing fascia and lacerated muscle will be maximal.

"The excision of the wounds should be cone-shaped with the base of the cone at the wound of entry, and also at that of exit if one is present, and the apex at the site of fracture or location of the foreign body. This will allow for adequate drainage and prevent a bottle neck obstruction. This is often the result of swollen damaged muscle blocking the track or the exit through a small opening in the deep fascia. To achieve this the fascia can be divided across as well as incised in the length of the limb, or a segment comparable to the base of the cone referred to above can be excised; this applies to the deep fascia throughout the body and nowhere more so than to the fascia of the thigh.

"A compound fracture of the thigh is not adequately excised unless the site of the fracture can be readily visualised from the wound of entry in the case of a penetrating wound and from both the wounds of entry and exit in the case of perforating injuries.

"All wounds will be left widely open. No sutures will be used.

"It is realised that this wide excision is contrary to the practice in some theatres of operation as judged by articles in the current medical press.

"In the operational area in and around Australia wide excision and not conservatism will be the routine. In the case of uncomplicated soft tissues injuries from rifle bullets the surgeon must use his own judgment. If the exit wound is large the wounds will be excised. If a bone is fractured the wound or wounds will be excised.

"Except in the case of very small and multiple wounds and some thoracic injuries all penetrating and perforating wounds of soft tissue inflicted by any missile, other
than certain wounds due to rifle bullets, will invariably be excised. If the case is seen too late for a stereotyped excision it will be treated by ample incision and excision of sufficient pulped fascia and muscle to allow for adequate drainage. Buttock wounds are particularly dangerous; all such will be opened widely and extensively excised; no sutures will be inserted."

Colonel C. W. B. Littlejohn, Consulting Surgeon in the area, found that more radical excision was often necessary. It must be remembered of course that in a long war with expanding forces large numbers of new medical officers come to duties in some ways strange to them, and others take up responsible positions with little more than civilian experience behind them. Continual vigilance was necessary. Some new problems appeared. For instance, *Salmonella* infections were not uncommon in the islands, and one of these due to *S. enteritidis*, was sometimes associated with metastatic suppuration. Abscess formation in soft tissues or in bone was occasionally seen in forward areas due to this cause.

Streptococcal infection had been important in the Middle East, but with the move of battle fronts to the Pacific Islands staphylococcal infection was more common and troublesome. The type found was the haemolytic *Staphylococcus aureus* coagulase positive. Where both streptococci and staphylococci were present in a wound the latter were not readily disposed of until penicillin became available. The different roles of these organisms were illustrated by a few examples of symbiotic bacterial gangrene which occurred in army practice. N. J. Bonnin reported one instance of this condition after operation for empyema. The usual characters of this gangrenous ulcerative lesion were exhibited; wide excision with skin grafting effected a cure. The streptococcus in this symbiotic partnership was eradicated, but the staphylococcus persisted in the empyema wound after the skin ulceration was healed, even though penicillin was obtained for use in the later stages. Another type of ulcerative lesion was seen and described by K. W. Starr in which a micro-aerophilic streptococcus caused extensive ulceration and invasion of the scalp and outer table of the skull. Lacking the symbiotic effect of the staphylococcus, the lesion was not associated with gangrene, and repeated excision and dermatome skin grafting eventually gave a good result.

In the Pacific campaigns as in those in the Middle East no large scale investigations were made in the bacteriology of war wounds, but the predominance of the staphylococcus over the streptococcus was evident. Late in 1943 Perry examined 226 unselected war wounds in the Moresby area, and isolated *Staphylococcus aureus* 137 times (61 per cent) and *Streptococcus haemolyticus* only 30 times (13 per cent). Certainly respiratory infections were not common in the islands, and the routine use of sulphonamides in the wounded probably had an individual and a mass effect in lessening the incidence of streptococcal invasion. Secondary invaders did not seem to be so important at that time, but Perry found *B. proteus* 50 times (22 per cent), *Ps. pyocyanea* 19 times (8 per cent) and coliform organisms 27 times (12 per cent). In the later years when sulphonamides and penicillin accounted for the Gram-positive bacteria the
Gram-negative varieties became significant, and even if not initially present, often appeared. In New Guinea the staphylococcal infections were more serious and important than the streptococcal. Thus, in one hospital in a period of nearly a year no streptococcal blood infections occurred, but four staphylococcal general infections were seen. In this series about 35 per cent of the organisms found in wounds were *Staphylococcus aureus*, and 20 per cent *B. proteus*, while haemolytic streptococci made up only 7 per cent and were thought to be secondary invaders, like proteus, the coliform group and pyocyaneus.

Anaerobic bacteria in wounds in the islands were also found to differ from those found in the Middle East. The notes published in England in 1940 by a committee representing the Medical Research Council and the London Sector Pathologists gave information concerning the cultural and other properties of the clostridia. In this pamphlet the predominance of *Cl. welchii* during the 1914-1918 war was emphasised, and this was expected also in the Middle East. However, Major McLennan, R.A.M.C., found that in anaerobic infections among members of the British forces in that area *Cl. oedematiens* was the commonest type, with only small numbers of *Cl. septique* and *welchii*. It was fortunate that these infections were rare in that theatre of war, for the effect of sulphonamides on *oedematiens* was slight, and a specific antiserum acting on this organism and its toxin was not readily obtained owing to the small demand, and to its rarity. The only measures left were local excision, of undoubted value, X-radiation also of value, and amputation. Practically all fatalities were due to *oedematiens*, which had a troublesome feature of later sporing in the tissues, causing a severe exacerbation after two or three weeks. Anaerobic infections were much commoner in New Guinea, though even here they were not statistically formidable.

Anaerobic cultures were not found a necessary routine in the Middle East, and in New Guinea they were not commonly attempted at field hospitals. Little more could usually be done than to demonstrate the presence or absence of the most easily identified pathogen, *Cl. welchii* by the characteristic reaction in litmus milk.

During the early stages of the Kokoda trail fighting, cultures from 29 grossly infected wounds were sent to Melbourne, where they were investigated by Dr A. W. Turner of the Council for Scientific and Industrial Research. He found *Cl. welchii* 8 times, *Cl. septique* 5 times, *oedematiens* 7 times, *sporogenes* 9 times and *bifermentans* 10 times, and on every occasion also some unidentifiable though apparently pathogenic clostridia. Only three of these patients died. Later, at the end of 1943 Captain Perry found that from his 226 cultures *Clostridia welchii* were isolated only twice and unidentified varieties a few times. The latter series was taken from wounds already submitted to thorough treatment in forward units, whereas the former came from wounds of men debilitated by hardship received practically direct from the front line. The frequency of the various varieties of clostridia in New Guinea conformed more to the usual findings in previous military actions, though it appeared that not all the
gas-forming organisms met there were virulent. At the 2/9th Australian General Hospital in the Upper Moresby area 100 men with anaerobic infections were admitted in four months of active campaigning. Many of these infections were mild but some were severe. Serum was used for definite clinical infections, the dosage being 30,000 to 60,000 units, but surgical measures with blood transfusion and sulphonamides were thought to be more important aids to recovery. Of course there were many factors of difference touching the nutrition of the men, the facilities for surgical treatment and for evacuation along the line of communication, as well as those concerning the local terrain. The distinction between the presence of gas-forming organisms in wounds and the presence of active gas gangrene infections is most important. The British report mentioned above summarised well the clinical features of frank infection, and pointed out that gas gangrene is a clinical concept. In this and other writings and instructions clear pictures of the clinical state were drawn. Local signs such as swelling and crepitation were suggestive, so too were the signs of general toxaemia, which sometimes reached a serious climax very swiftly. The tendency of the condition to invade single muscles or groups of muscles was characteristic, and helped the carrying out of radical excision of infected tissue. This could be recognised before the later stages of frank gangrene by the brick-red colour of the muscles which were non-contractile and did not bleed when cut. It also sometimes invaded areolar tissue, particularly where effusion of blood had occurred.

Such information was widely diffused, and measures taken to follow up the results of front line work. Thus the efficacy of single measures to counter anaerobic tissue infection cannot be assessed. No doubt the small incidence of gas gangrene in wounded Australian soldiers was largely due to prompt recognition and adequate surgical excision, relief of tension and drainage, without which chemotherapy and passive immunisation would probably have been in vain.

Before the war W. J. Penfold and Jean C. Tolhurst had investigated strains of Cl. welchii isolated from civilian patients, and produced formol-toxoids which produced active immunity in animals. It was hoped at the time to apply this to human prophylaxis, but this was not done. The matter was well discussed in 1940, but it was felt by a panel of hygienists and bacteriologists that the evidence and the need were alike slender at the time. Combined toxoids of tetanus and gas gangrene were investigated experimentally, but no action was taken. Fortunately the rarity of gas gangrene justified this opinion.

During the first campaign on the Owen Stanleys the difference made by the terrain was apparent in the incidence of wound infections. During the first phase, before a practicable airstrip was captured from the Japanese, the conditions were difficult and practically all supplies were very scanty, but the climate on the ranges was cool and insects and pathogenic bacteria were almost absent. All wounded men received 6 grammes of sulphanilamide on the first day and 4 grammes each day thereafter for seven days. The sick and wounded had to walk over the ranges, or
be carried on stretchers by native bearers or be held in the field ambulances till well enough to move. During the next phase, airfields were soon available at Kokoda and on the coastal strip to the north of the mountains. Surgical teams, attached to the main dressing stations, were again used. Adequate excision of wounds was here necessary on account of the prevalence of infections. One obvious difference in the wounded in New Guinea to those treated originally in Libya was their long clothing, muddy and sodden, a contrast to the relatively clean and often brief garments of the desert. The extra time involved in removing this and in washing the wounded men added to the strain on the staff of forward surgical posts. Anaerobic infections were not infrequent, the commonest organisms being welchii, oedematiens and septique in a ratio of about 3:4:5. The contrast with the findings in the Middle East will be noted. In the last phase of this campaign the fighting was in shocking country, with patches of tall kunai grass interspersed with thick jungle and mud everywhere kept liquid by the constant rain. Air transport, weather permitting, lifted the wounded over to Moresby, but as this was not always reliable, it was fortunate that the use of sulphanilamide extended the safe period for wound excision to three days, as will shortly be told. Though over 100 cases of anaerobic infection were seen here, it appears that most of these were saprophytic in type. A few rapidly fatal infections were seen of oedematiens type, in the opinion of the Surgical Consultant, Colonel C. W. B. Littlejohn.

In spite of the unpromising conditions in New Guinea, where actions were fought both in mountainous country and in hot humid swamps and jungle, experience proved that the safe period for excision of wounds could be extended. The advisable limit of time between the wounding of a soldier and his submission to surgical treatment was previously placed at eighteen hours. This time interval was gradually lengthened, and after the first campaigns in New Guinea it was proved that wounds could be excised as late as seventy-two hours after their infliction. Technical Instruction No. 51 pointed out that this delay was not only safely possible, but essential, owing to the prevailing conditions of terrain and transport. Emphasis was again placed on the removal of devitalised tissue so as to permit efficient drainage, and minimise the strangling effect of inflammatory oedema. The value of wide incision of wounds was also stressed. Shell dressings were found convenient for application to wounds after surgical treatment; they were sterile and comfortable. Gloves were not always used for minor wounds in all forward posts, but always for major procedures. Undue sweating of the hands in gloves was often troublesome. Laundering of gowns was often difficult: this alone with other maintenance work often occupied the time of one orderly. Where gowns could be dispensed with the surgeon’s costume often consisted of trousers, gaiters, boots, cap, mask and apron, a gown being donned when required. Operation sheets after being washed and soaked in “Dettol” or similar antiseptic could be used moist in this climate without additional discomfort. Where sterile drums were available these were of the greatest value, as individual gear remained ready sterilised till the moment it was needed. The oral
administration of sulphanilamide to wounded men was rigidly enforced. It was found that medical officers working with surgical teams could use considerable influence with the soldiers to ensure that they took the tablets at regular intervals, as these sometimes had to be entrusted to the men themselves during their movement to base. So firm was the belief of many wounded men in the efficacy of this treatment that they relinquished the remaining doses to nurses in hospital with great reluctance. The administrative details of siting forward posts, surgical teams, and field medical units rather belong to the operational part of this history, but it is desirable here to point out how radically the battle zones of New Guinea differed from those in which Australian troops had their first experiences in this war.

Technically the surgical problems could not always be answered in the same way. The mobility of desert warfare in which even the main dressing station of a field ambulance with an attached surgical team was fifty miles from the fighting, was replaced by a relative lack of movement in an area where most things had to be carried or dropped from the air, and the line of communication was often tenuous and uncertain. The siting of a surgical post therefore depended not on the level of the unit to which it was attached but was decided by a combination of logistics and pathology.

In some of the later island campaigns it was not practicable to transport wounded to settled areas within the interval of time before operation just mentioned. Extemporised surgical posts had to deal with the wounded early, and forward units had to hold them for a time till their movement was surgically safe. This applied particularly to emergency conditions, abdominal wounds, and compound fractures of the long bones. Operations were often performed under extemporised shelters by day and under blacked-out conditions of intense discomfort by night. The surgeon sometimes stood perforce in mud while operating. Compound fractures have been dealt with at night with no other light than a small headlamp and a pocket torch. On the Owen Stanley Ranges and other mountainous parts a problem was to protect patients from bitter cold and rain: on the soaked muddy levels of the coastal strips the intense humid heat produced entirely different hazards. Patients with fractured femurs whom the surgeons expected to return to base by air could not always have weight traction applied, as they might be called for at any time should planes land in the vicinity. This element of unpredictable evacuation was a special difficulty during part of the first New Guinea campaign. In amphibious landings treatment might be undertaken in a beach unit, or on a landing craft or a larger vessel. These diverse conditions all imposed on the surgeons limitations of their own peculiar type, and comparisons of methods and results in such circumstances can hardly be fairly made.

Many patients were transported on native-made stretchers carried by a team of native carriers. As the natives rested the poles on their shoulders the transverse space in the stretcher was limited, and patients with injuries of the thorax or long bones were apt to suffer from compression by the poles.
In certain areas infection was more common, and, as already remarked, gas gangrene was a definite risk. Yet careful technique and rigid instruction and supervision of orderlies assured satisfactory conditions of asepsis.

In the island campaigns a large proportion of the wounds treated involved the upper and lower extremities. Seventy-five per cent was a common proportion of these injuries to the total, and about half of these were complicated by compound fracture. Wounds fell mainly into two classes, those due to gunshot wounds and a larger proportion caused by fragments of grenades, shells and mortars, the latter being commoner. Deaths were usually due to severe and complicated injuries often involving large areas of soft tissue and viscera in one or more of the body cavities. Bullet wounds inflicted by the small .273 calibre Japanese bullet often did little harm unless they struck bone and caused shattering or damaged a large blood vessel. It was possible for a blood vessel to be endangered without much, if any, external sign.

Sword wounds were also seen, usually on the head or shoulder, and often of tangential nature. Occasionally lesions of the brachial plexus were produced by indirect violence.

By the time the Salamaua campaign was fought in 1943, it became evident that one of the most important tasks of a field ambulance in jungle warfare was the building of medical posts and other shelters. Experimentation proceeded in the best methods by which the "bush carpenters" of the unit could provide adequate shelter and a well lit operating theatre capable of being blacked out at night, and mark tracks for night traffic. On the coastal plains an overhead shelter alone was sometimes used in emergency even for operating: this was possible because the almost constant rain at least fell vertically. Some training was necessary too in minor infantry tactics and in defence against hostile patrols and shell-mortar fire. It will be seen that even though the conditions under which forward surgery was done were more static than in flat extensive battlefields like the desert, they imposed singular difficulties and hazards. As many patients in this and similar campaigns were transported by small sea craft their comfort and protection against weather were important considerations in their after care. Similar precautions were necessary where jeep ambulances were used, which were jeeps with double-decker stretcher racks. Further details will be given in following sections of the work in various branches of surgery. One complication of all varieties of forward surgery deserves special mention here, malaria. Severe malaria was not well tolerated by the severely wounded, especially under the unfavourable climatic conditions. Quinine was given by the intravenous route practically as a routine to all seriously wounded men, and to all with abdominal wounds in some of the heavily endemic areas. Blood for transfusion was not easy to get in forward posts; though it was sent by air from the mainland, unavoidable delays occurred in its ultimate distribution to distant points in difficult country. As a result of various unfavourable factors the recovery rates were lower in some areas. In the battle for Salamaua even careful following of the technique established for abdominal surgery in
the Middle East could not produce better than about 33 per cent recoveries. It must be remembered too that the time elapsing before operation was sometimes much greater than the average in the Alamein battle. The mere necessity for holding patients for even a short period in some of these areas which were exposed to air raids imposed conditions of hardship on sick men. In the later stages of some of these operations the conditions were very different, with greater security of comfort, and the boon of air transport. Mere figures of results cannot express the difficulty or the value of the work done by some of the surgical teams.

In the later phases when assaults were made on Japanese held areas in Borneo ascendency had been established by sea and air, and the operations proceeded smoothly. Controlled landings, early setting-up of well equipped units, freedom from serious external attack, and adequate and prompt evacuation of wounded by sea allowed surgical teams and staffs in forward and semi-forward units to work under favourable conditions. Operating facilities were also available afloat in some instances. These advantages were exploited to the full and the results were very satisfactory. Full supplies of penicillin had by that time made a vast difference in the surgical prevention and control of infection, both in the sea-borne forces engaged in these operations and in the forward base established at Morotai. The story of the influence of antibiotic therapy is best left to a separate section, but it may be anticipated by pointing out that before the introduction of penicillin no one could have dreamed of the possibility of wounds being under control before arrival of the wounded at a forward base, or of compound fractures of long bones being immobilised there by open operation and plating.

In general surgeons have shown that they have amply earned the right to use every scientific advance that the military situation can permit for the practice of their art. In the Australian forces surgeons have shown both their readiness to meet the limitations of circumstance half way, and their ability to give their patients the full benefits of refined techniques wherever this is safely possible.

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