War Surgery of the Extremities

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SEPSIS IN WAR WOUNDS OF THE LIMBS

BY

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Infection of wounds received in battle or in air raids is essentially the same as that occurring in wounds due to road or machine accidents in peacetime. The local complications, such as spreading cellulitis and secondary haemorrhage, and the more widespread effects—lymphangitis, septicaemia, phlebitis, and pyaemia—are identical, and neither their pathology nor their treatment will be considered here. I will endeavour to point out what our experience has shown us to be the significant differences in detail between the wounds of peace and war.

The healing process is influenced from the outset by the character of the injury; bruising and laceration of tissue by a rapidly moving projectile, or crushing by masonry, together with diffuse extravasation of blood, provide conditions which are at once the most favourable for bacterial invasion and the least favourable for tissue repair. Furthermore, they would appear to be ideal for establishing gas gangrene, especially as the organisms are present not only in soil but also in rubble, which contains enough calcium to encourage their growth. Taking everything into consideration, it is surprising that most of these wounds do so well.

Contamination and Infection of Wounds

In searching for the explanation of this apparent discrepancy between the anticipated and the actual result, the distinction between contamination and infection of a wound must be clearly recognized. Contamination of war wounds is almost inevitable, and is particularly heavy when the skin wound is extensive, when the deeper tissues are badly lacerated, and when a missile which has passed through clothing is retained. It must be remembered, however, that all the organisms present may not be pathogenic, and will probably not include the haemolytic streptococcus: in a series of 17 air-raid casualties whose wounds we examined bacteriologically in the first forty-eight hours haemolytic streptococci were found in only one.

In such a contaminated wound the organisms are still merely on the surface or in the cavity of the wound, but after the lapse of a few hours the infection of the tissues deep to the surface and surrounding the track of the projectile is bound to occur. The duration of this period before infection becomes established depends on the factors influencing tissue resistance, the most important being the virulence of the micro-organisms, the extent and degree of tissue damage, and the severity of haemorrhage, shock, and fatigue. It may vary from about four to eighteen hours, but by the end of that period the opportunity for mechanical cleansing of the wound by excision, which is clearly the best prophylactic against infection, has been lost.

Early Excision

The best safeguard against infection of a wound is early excision, and if this is thoroughly performed and the surgeon is satisfied that he has been able to reach and remove all the devitalized tissue, the wound may be closed completely, either with or without the local application of an antiseptic. Primary closure of a wound is the best safeguard against secondary infection, and provided the patient can remain under the care of the surgeon who undertakes the operation it should be possible to adopt this method of treatment for most wounds involving only skin and muscle. In exceptional cases it may be possible to close wounds even when a fracture has occurred, but it will usually be best to leave such wounds open.

There are certain exceptions to the rule that wounds should be thoroughly excised with a view to primary closure. If radical excision would involve risk of irreparable damage to important

structures such as nerves and tendons it will often be preferable to lay the wound open, excise as much as can be removed without jeopardizing the function of the limb, and then pack it open. "Through-and-through" wounds can usually be left; thorough excision would involve extensive opening up of tissue and probable damage to the function of the part, whereas we know from experience that, particularly in bullet wounds, contamination is minimal, drainage is free, and healing takes place readily. If a comminuted fracture is caused by a projectile traversing the bone, and particularly if a joint is involved as well, the difficulty of cleansing the wound mechanically by excision is almost insuperable, and primary closure must not be considered.

The need for antiseptics in the treatment of early wounds is open to argument, but could best be determined by experiment. Although excision can scarcely be expected to rid the wound entirely of its organisms, the few that remain will probably be dealt with by the natural defence mechanisms, provided they are not embarrassed by foreign chemical substances. On the other hand, we have treated a large number of wounds either by irrigation with 1 in 1,000 eucalypti or by the introduction of quantities up to 15 g. of sulphanilamide powder without any apparent interference with healing and with a most gratifying freedom from infection. It would undoubtedly be wrong to put in these chemicals if they were unnecessary, and not until two comparable series of wounds have been excised and sampled bacteriologically, and then one group treated with antiseptic and the other left untreated, will we be able to decide upon the value of antiseptics as prophylactic agents against infection. Until this information is forthcoming, however, experience justifies their use.

It cannot be too strongly emphasized that no amount of antiseptic can compensate for inadequate excision. The good results which have followed local treatment by sulphanilamide have led to the suggestion that it should be applied as part of the first-aid treatment of a wound. The value of the drug used in this way is open to doubt, but the harm which could result if its use gave rise to a false sense of security, and consequent delay before excision, is unquestionable.

Prevention of Gas Gangrene

The prevention of gas gangrene calls for special comment. The prevalence of gas-gangrene organisms in war wounds has been shown by bacteriological examination of the tissue excised from wound edges, yet the incidence of true gas gangrene has turned out to be very much less than might have been expected. The comparative rarity of this dread infection is no doubt attributable very largely to early wound excision; and the local application of sulphanilamide may also have played an important part in combating the disease. Several instances are on record, however, in which gas gangrene has occurred in a very high proportion of a small group of wounds; but it must be remarked that something—either the critical condition of the patients or a temporary dislocation of the medical services—prevented their early surgical treatment. In such circumstances there seems to be a clear indication for the prophylactic use of gas-gangrene antitoxin. Statistics are not yet available to indicate exactly what can be achieved by serum used in this way, though steps are being taken to obtain this evidence. Prophylactic treatment means the administration of serum at once, and not when the wound looks suspicious; and it is likely to be required particularly in cases of compound fracture, in lacerated wounds of muscle contaminated by brick dust, soil, or rubble, and in small punctured wounds through clothing. Polyvalent antitoxin has been recommended for prophylactic use (3,000 international units of *Cl. welchii* antitoxin, 1,500 I.U. of *Cl. septicum*, and 1,000 I.U. of *Cl. oedematiens*), but since experience goes to show that infection by *Cl. septicum* and *Cl. oedematiens* is rare it has been suggested that a dose of 7,500 I.U. of *Cl. welchii* antitoxin alone, given intramuscularly at the earliest possible moment, may provide better protection against the usual type of infection.

Treatment of an Infected Wound

If the wound is not seen until a later stage, when organisms have already passed from the surface into the living tissues surrounding the wound and have entered the neighbouring lymphatics, excision is no longer feasible, as it would merely interfere

with the natural defence mechanisms without ridding the tissues of invading organisms. Surgery must aim at the removal of all foreign material and dead tissue from the depths of the wound and at establishing free drainage of all side tracks and pockets; it may therefore be necessary to enlarge the original wound, and counter-incisions may have to be made to give a free exit for infected material.

If the wound can be laid completely open in this way, antiseptics should be unnecessary, and if any portion of the wound is undrained or there are retained fragments of infected bone or slough antiseptics will be useless. Needless to say, the question of suture does not arise, and our experience coincides with that of the many other surgeons who have found strips of vaselined gauze, laid lightly in between the wound edges, to be a very satisfactory dressing.

It is most important to splint a limb with such an infected wound. In the summer of 1940, when we had to manage a large number of wounds which had been infected for several days before they came to us, it was with considerable trepidation that we treated them in closed plasters; but we soon discovered that our fears were groundless and that for most wounds the method possesses many advantages over alternative modes of fixation. It is remarkable how the general condition of the patient improves when the limb has been put in plaster; this is due in part to increased comfort, but also to a diminution in lymphatic absorption brought about by muscular inactivity and by the supporting effect of the plaster which minimizes the local oedema. The remarkable difference between the puffy, swollen, congested tissue around a wound treated on any other splint and the flat skin and supple tissue surrounding a wound which has just come out of plaster seems to me most important as an indication of the mechanical factor underlying the beneficial effect of treatment in plaster upon both local and general reactions to the infection.

A further advantage of the closed-plaster method is the infrequent dressing of the wound, which avoids unnecessary interference with delicate growing cells and diminishes the risk of secondary infection, which is so liable to occur in wounds that are left open.

Secondary ("Hospital") Infection

The frequency of serious secondary infection of wounds in hospitals was pointed out by several observers during the war of 1914-18, and the position may be briefly summarized by stating that whereas a very high proportion of early wounds are free from haemolytic streptococci, an equally high proportion of late wounds are infected by these organisms. To the surgeon familiar with the routine of the "clean" surgery of peacetime, when wounds are closed completely and not looked at until the stitches are removed, by which time sound healing by primary union has occurred, this record of the prevalence of hospital infection by streptococci seems almost incredible: but with war wounds that are open and ready to receive any organisms in their neighbourhood the conditions are so different that our attitude towards the risk of adding further infection to a wound must be completely changed. Infection of a war wound by haemolytic streptococci occurs but rarely at the time of its infliction, the missile, dust, or foreign matter, and even clothing, carried into it being very seldom to blame; the streptococci found in the wound at a later stage have come from the hospital environment.

One is sometimes asked whether the addition of a few extra organisms to an already heavily infected wound can really matter very much, and it may be urged that granulation tissue forms a good barrier against bacteria and their toxins. In reply to this question one has no hesitation in saying that the addition of fresh organisms, certainly of haemolytic streptococci, has often in our experience been associated with considerable and even alarming constitutional reactions, and locally with the development of cellulitis, erysipelas, delayed healing, and inhibition of growth of skin grafts. The neglect of the growing streptococcal population of a ward is likely to have other far-reaching effects, such as outbreaks of tonsillitis and bouts of "unexplained" pyrexia and ill-health, and also skin infections, among the ward staff as well as the patients.

Although streptococci have been mentioned it must not be inferred that they are the only organisms which find their way

into open wounds in hospital wards. The *Staph. pyogenes* is equally important, and there are many other organisms which, though not producing such striking constitutional effects or constituting such a threat even to the life of the patient, may nevertheless delay the healing of a wound by prolonging the process of suppuration. Where do these later invaders come from, and what should be done to prevent hospital infection of wounds?

Sources of Hospital Infection of Wounds

Noses and Throats.—Frequently streptococci are carried in the throats and staphylococci in the noses of patients and their attendants, who show no evidence of disease in these regions. The carrier rate may be greatly increased among the personnel and patients in wards where there are heavily infected wounds, and the necessity for blocking this channel of infection by wearing impervious masks when doing dressings is obvious. The use of these masks is not to be confined to those showing signs of a throat infection; everyone involved in the dressing must wear a mask, which must cover the nose and come well down under the chin to prevent the downward spread of droplets from the mouth.

Fingers.—There are also skin carriers of staphylococci, but the chief mode of transference of infection on the skin of surgeons or nurses is by direct contact with other infected wounds or with material infected from them. Hands may be infected not only by touching the skin near an infected wound or by handling pus-soaked dressings—both of which cannot be too strongly condemned—but also by handling the outer layers of dressings, bandages, plasters, and bedclothes. It is not an overstatement to say that the bedclothes of a patient suffering from a wound discharging haemolytic streptococci may be just as dangerous as those from a case of scarlet fever. There are only two possible ways of avoiding skin contact: either dressings must be done entirely with instruments or sterile gloves must be worn. As a routine the instrument technique is preferable; but for very large dressings and irrigations, and if it is necessary to examine a wound or its neighbourhood by palpation, gloves should be worn.

Air.—Several observers have shown how the bacterial content of the air of a ward varies from time to time, depending upon the activities of the personnel, the air being especially heavily laden with organisms during bed-making and floor-sweeping. Though the total quantity of dust raised during these operations can be considerably reduced by oiling floors and blankets, there are problems in the supply of apparatus and material which render these methods difficult of application in wartime, and it is sufficient for practical purposes if ventilation is decreased so as to stop draughts, and if no sweeping or bed-making is allowed for at least an hour before dressings are done. Wounds should be exposed for the shortest possible time, and if for any reason there has to be some delay in reapplying the dressings the wound should be covered with a sterile towel. When dressings are removed they should be placed immediately in a lidded bucket, which may, if necessary, contain some disinfectant fluid. All receptacles for dressings, instruments, or lotions should have lids or some covering to protect them from airborne infection—in fact, the technique should resemble very closely that of the bacteriological laboratory, where organisms are handled only with instruments which can easily be sterilized, and cultures are kept uncontaminated in lidded (Petri) dishes.

Baths.—Every surgeon knows the benefit to be derived from baths when an infected wound has reached a certain stage in its cure, yet the risk of spreading infection from one patient to others using the same bath has not been properly appreciated in the past. Scrubbing the bath with 2 oz. of undiluted lysol is the surest method of disinfection, but it must be done thoroughly: and if cracks in the surface of the bath appear, re-enamelling must be insisted upon, as the cracks cannot be sterilized.

Plasters.—Once an infected wound has been encased in plaster there is a tendency to regard it as "safe," yet we know that organisms may be grown from the outside surface of the plaster, and it often happens that when a plaster has to be retained for a prolonged period pus runs out at its ends and infects the bedding and everything else with which it comes in contact. The only way I know of dealing with this state of

affairs is to change the plaster; no method of sealing which I have yet seen is efficacious; the incorporation of antiseptics in the plaster is valueless; and the bags of filter-cloth which are so valuable as deodorizers cannot be expected to act as disinfecting agents. It is a good rule, following operation theatre practice, not to remove a plaster in the ward, but to take the patient to a special room where the infected plaster dust will do less harm. It is well to moisten an infected plaster before cutting it, and great care must be taken to avoid contamination of the assistant's fingers when opening up the plaster, and also to boil all the instruments (plaster shears, etc.) before cutting another plaster.

Instruments.—It is a popular fallacy that boiling blunts instruments. If cutting instruments are wrapped in lint so as to protect their edges from damage by bumping up against heavy instruments in the sterilizer they will not be blunted by boiling repeatedly for a period of two minutes, which is long enough to kill even spore-bearing organisms if washing soda (2%) is added to the water. Hollow needles and syringes should always be boiled before use. It is best to store them dry, for the usual method of keeping them in spirit is not safe. The reason for using spirit is to have the syringe available for immediate use in a solution which will not rust the needle and the metal parts of the syringe; but spirit is not a reliable antiseptic, and as its disinfectant properties are most effective at a 70% dilution, the water contained in this mixture will rust the metal parts. If it is essential to keep instruments in a disinfectant solution after they have been sterilized by boiling, dettol or one of its allies should be used. The addition of borax (0.1%) will prevent rusting of needles and other metal parts. Once it is realized that the traditional boiling for twenty minutes is excessive, and that sterilization can be effected in a tenth of this time, much of the objection to boiling as the method of preparing instruments even for emergency use must disappear. Whether boiling immediately before use is adopted or not, the use of spirit is both unsatisfactory and extravagant, and ought to be abandoned. The processes for disinfecting all the apparatus used in doing dressings—bowls, douche-cans, and tubing, as well as instruments—must be carefully scrutinized to ensure their efficacy if infection from one dressing to the next is to be entirely prevented.

Final Healing of Wounds

If all precautions against secondary infection are rigorously practised, local measures designed to promote the nutrition of the tissues around the wound should soon produce a degree of healing which justifies an attempt at closing it completely either by secondary suture or by skin-grafting. If this step is indefinitely delayed, granulation tissue is formed in excessive amounts and the accompanying fibrosis antagonizes epithelization of the ulcer. The application of various growth-promoting substances with the object of accelerating healing have not given any very striking results: it really seems hard to improve on Nature's own methods if she is given a chance.

In choosing between secondary suture and skin-grafting the chief consideration should be the skin loss at the time of the original injury or as the result of later complications. If little or no skin has been lost, suture should give good results; grafting is necessary to repair any considerable area of skin loss. In choosing the time for these operations the two chief factors to be taken into account are nutrition and infection; and if after every effort has been made to eradicate it there is still some residual infection, dusting sulphanilamide powder over the raw surface before applying the grafts may achieve success.

In addition to the local treatment it is most important to pay due attention to the general nutrition and metabolism. Over and over again one sees wounds which are indolent for no local cause, and which quite suddenly begin to heal rapidly with an improvement in the patient's general condition. Experience has taught us the importance of good food in those cases, and experiment has shown how important vitamin C (or ascorbic acid) may be in maturing scar tissue. Fresh air, even in the absence of sunshine, is a magnificent stimulus to metabolism, and it is scarcely necessary to stress the importance of attending to the state of the blood and circulation, and the great value of transfusion for anaemia, and of movement and exercise from the earliest stages of treatment.

The management of the final stages of healing, important though it may be, is really a familiar affair in times of peace, and need not be emphasized when we are dealing with the problems peculiar to war wounds, for with them success or failure will depend almost entirely upon the treatment given in the course of the first few hours after receipt of the injury.

Correspondence

Serodiagnosis of Syphilis

SIR,—The annotation on serodiagnosis of syphilis (March 14, p. 364) is of more than ordinary interest at the present time in view of the increase in the incidence of syphilis owing to war conditions. That the article has evoked no discussion or comment is significant of the scant interest practitioners take in the performance of the tests they ask for on behalf of their patients. It may be confidently asserted that of all the pathological investigations usually asked for the serodiagnosis of syphilis is probably the most important from the point of view of the patient's physical and mental health, and that an incorrect report, whether it be positive or negative, may be fraught with serious consequences to the patient and possibly his family. If an erroneous positive is reported and the test is not repeated as it should be the patient will be doomed to receive at least two years' unnecessary treatment with a lumbar puncture or two during that time, and the incident may lead to a domestic upheaval. If an erroneous negative report is given the patient will receive no treatment, the innocent partner may become infected, and, later on, perhaps the children.

Even though we may be at the most critical phase of the war we should take steps to safeguard the coming generation against the unnecessary ravages of congenital syphilis. By testing and, if found positive, treating every expectant mother during pregnancy one can almost assure the birth of a healthy child. Dr. Earle Moore, the eminent American syphilologist, has written: "The birth of syphilitic babies is preventable. Congenital syphilis is the disgrace of modern medicine."

The syphilis problem in this country is not so serious as it is in the U.S.A. (where it is complicated by the coloured population), but in my opinion it is still of sufficient importance to animadvert upon the complacency, one may almost say the indifference, shown about the matter. For example, very little laboratory research on syphilis has been done here; so long as a Wassermann is asked for practitioners do not seem to mind where or how the test is done. "There is no need to try to prevent congenital syphilis, it is a very rare disease": such is the erroneous current teaching; and so on. The crux of the whole matter, Sir, is that many pathologists do not appear to appreciate the responsibility they shoulder when they undertake the serodiagnosis of syphilis—a responsibility to the State, to the patient, and to his family—for if they did they would not, as is so often done, (1) allow the test to be carried out by technicians, or (2) "simplify" the recognized approved techniques to save time and trouble and by so doing render their results unreliable.

Your annotator states that a similar check upon the standard of performance of the serodiagnostic tests for syphilis to that carried out in the U.S.A. has been done in this country, "though on a rather smaller scale." It has certainly been on a smaller scale, and at too long intervals to be effective, and, of course, dealt only with "approved" laboratories. Moreover, one knows of instances where even in "approved" laboratories under the Ministry of Health's V.D. scheme the tests have been carried out by technicians, though this would not be apparent to an inspector of laboratories, who usually announces beforehand his intention to call. One cannot, therefore, share your annotator's optimism that serum testing under the V.D. scheme may be considered satisfactory, though one agrees with his statement that the diagnosis, tests of cure, and exclusion of syphilis are matters of such importance to the State and to the individual that none but the highest standard should be acceptable. To attain this end *all* tests for syphilis should be carried out in approved laboratories, where hundreds of tests would be done every week by expert pathologists who