MEMORANDUM ON THE TREATMENT OF THE BACTERIAL INFECTIONS OF PROJECTILE WOUNDS.

BY

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It is proposed in this Memorandum (a) to synthesise the experience obtained in connexion with wounds in this war; (b) to supplement this by setting out the chief data which have been furnished by a bacteriological study of the wounds; and (c) to lay down certain broad principles of treatment for the guidance of those who have not seen the conditions in the present war, or who have seen only an early or a late phase in the history of the wounds.

The present Memorandum will be followed up, as soon as certain researches are completed, by Memoranda on the Employment of Antiseptics and Vaccines respectively.

I.—CHARACTERS OF PROJECTILE WOUNDS AND BACTERIOLOGY OF THE INITIAL INFECTION.

The wounds made by projectiles are not in any respect comparable to clean-cut, swabbed-out, aseptic operation wounds or to any of the accident wounds seen in civil surgery.

Where the projectile has passed through the flesh there will, in the ordinary case, be a torn and ragged track, with an irregular surface of heights and hollows produced by the hernia of muscle and the retraction of the severed fibres. Where the projectile has come against bone this will be generally splintered, and the track will lead down into widely ramifying crevices between comminuted fragments.

There will also in practically every artillery wound be included foreign matter—a projectile, or shreds of clothing, or fragments of bone, and with these lacerated muscular and connective tissues which will slough. In addition, the wound will be full of blood clot and effused lymph. And lastly, the projectile, when it has traversed soiled clothes or a soiled skin surface, will have carried in microbes, and these will have been sown all along the track.

This deep sowing of microbes, taken together with the blockage of the wound by blood clot, and the not infrequent obliteration of a section of the track by hernia of muscle, will, in the case of any deep or perforating wound, make the effective sterilisation of the wound by antiseptics impossible.

Of the microbes which are carried into the wound the most formidable are the anaerobes and facultative anaerobes. These are found in very large numbers in practically every case arriving at the base from the front.

Three species of microbes here come into consideration. The *streptococcus*, the one microbe which is, one may say, invariably present, is primarily responsible for the suppuration which will supervene in the wound. The *tetanus bacillus*, or a bacillus which is morphologically indistinguishable from this, is present in the pus from a certain proportion of cases. And in practically all the wounds we have also the *bacillus aerogenes capsulatus* of Welch (*bacillus perfringens*). This

produces a characteristically offensive, thick, frothy, rusty brown, sometimes almost faecal, discharge.*

The anaerobic infections of the imprisoned discharges which are here in question, may, if unchecked, lead to graver consequences. The streptococcal infection may lead to an infection of the tissues in the form of erysipelas or deep cellulitis, and it may culminate in septicæmia. The tetanus infection will, if the microbe cultivates itself sufficiently freely and elaborates enough toxin in the wound, give rise to tetanus. And the bacillus of Welch, when it manages to invade the tissues, will generate gas, producing a gas phlegmon and also an obstructive gangrene in the affected limb (so-called *gaseous gangrene*).

II.—MEASURES FOR CHECKING THE ANAEROBIC INFECTION OF DISCHARGES AND PREVENTING THE DEVELOPMENT OF TETANUS, GAS PHLEGMON WITH GANGRENE, AND STREPTOCOCCAL INFECTION OF THE TISSUES.

The rational line of treatment for the prevention of the grave sequelæ which are here in question will be to check at the earliest possible moment the anaerobic infection of the discharges.

The wound ought to be freely opened up. It ought then to be carefully cleansed with an antiseptic solution (*vide* Memorandum on Antiseptics—Therapeutic Employment); all foreign bodies, sloughs, and blood clot (as far as this is possible without risk of hæmorrhage) being carefully removed. Then a very wide drainage-tube which will admit air to the interior ought to be inserted, and, especially in those cases where there is much laceration, steps ought to be taken to promote the outflow of lymph from the walls of the wound (*vide infra* Section IV.).

By such steps we may hope to put an end to the anaerobic infection and to obtain instead of foul smelling, gas impregnated, decomposing discharges a more or less "laudable pus."

Where owing to the exigencies of war conditions it is for the moment impossible to carry out the required surgical measures or where from the nature of the case the wound cannot be effectively drained, it will be specially important to abstain from doing anything which might still further favour the anaerobic infection.

(a) Wounds should not be sewn up after operation. We can never be sure that the projectile has not carried in infection, and we cannot under war conditions and during transport count upon the patient being kept, as he should be, under continuous observation. Plugs, except where there is actual risk of hæmorrhage, should never be left behind in the wound, for they bank back the discharges and establish anaerobic conditions. For the same reasons it will be necessary to see that the wound is not wrapped up air-tight, that discharges are not allowed to dry upon the bandages, and that the mouths of drainage-tubes are not blocked by the pressure of the dressings.

(b) Moreover, it will, pending the opening up and cleansing of the wound, be very desirable to take certain specific prophylactic measures. By an injection of antitetanic serum we may hope to neutralise any tetanic poison which may be absorbed from the wound.

(c) Further, by the injection of a prophylactic dose of a vaccine containing the bacillus of Welch and the streptococcus (issued as *Combined Antigangrene and Antisepsis Vaccine*) we may hope to stave off an invasion of the tissues by these micro-organisms (*vide* Memorandum on the Employment of Vaccines).

* Probable derivation of these anaerobic microbes.—All these microbes would seem to be of faecal derivation. The bacillus *perfringens* in particular is an inhabitant of the alimentary tract, and it can (by implanting in boiling milk and anaerobic cultivation) be readily recovered from the faeces of men and animals, from earth soiled with faeces, and from the soiled uniform of the soldier.

It must, however, be clearly realised with regard to these measures that they are only temporising methods, and ancillary to such cleansing and drainage of the wounds as may in a particular case have been for the moment practicable.

III.—TREATMENT OF STREPTOCOCCUS INFECTIONS OF THE TISSUES AND GAS PHLEGMON.

When by an unchecked anaerobic infection of the discharges the resistance of the tissues has been lowered, and these have been invaded by microbes, it will be necessary to take immediate steps to stem that invasion.

We have at disposal two different methods of procedure: (a) We may take steps to increase the antibacterial powers of the blood fluids; and (b) we may lay open and effectively drain the tissues (*vide infra* Section IV.) and so bring back to these their normal resisting power. These methods will be applicable according to circumstances, separately or in combination.

A streptococcal infection which takes the form of erysipelas can practically be always promptly extinguished by an injection of streptococcus vaccine (*vide* Memorandum on Employment of Vaccines) without recourse to any surgical measures.

When a streptococcal infection takes the form of a diffuse cellulitis vaccine therapy will rank only as an auxiliary measure, and the laying open of the infected tissues and the establishment of effective lymph lavage by the method indicated in the next section will be the essential.

What applies to the case of streptococcal cellulitis applies *a fortiori* to all infections of the tissues by the *bacillus of Welch*. In every case these must be opened up and effective lymph lavage induced.

In connexion with the actual surgical measures we have two cases to consider:—

(a) Where the infection follows a superficial course manifesting itself in dusky blotchings of the skin and gaseous emphysema in the subcutaneous tissue, it will suffice to open this up freely by incisions carried down to the plane of the muscle. (And it is here thrown out as a suggestion that a more efficient evacuation of the lymph would be obtained if the incisions were disposed transversely instead of axially to the limb.)

(b) Where the deeper tissues are diffusely invaded, and where the limb, owing to the internal tension, has assumed a blanched, wax-like appearance, incisions into the subcutaneous tissue would not relieve matters, for the underlying muscle would protrude into and block the wounds. In these eminently dangerous cases it will generally be necessary to amputate. But it may sometimes be possible to save the limb by the free opening up of the deeper tissues and the introduction of large drainage-tubes.

In amputating for diffuse infection of the deeper tissues, or, as the case may be, for a progressive infection of the subcutaneous tissue, it is advisable, inasmuch as it is in these cases essential to obtain an absolute maximum of drainage, to do the flapless amputation—i.e., to cut across all the tissues at one and the same level and to leave the wound completely open.

IV.—GENERAL CONSIDERATIONS IN CONNEXION WITH DRAINAGE AND MEASURES FOR PROMOTING THE OUTFLOW OF LYMPH FROM AN INCISION OR THE INFILTRATED WALL OF A WOUND.

The primary object of all opening up of wounds and infected tissues, in short, of all drainage operations, is, of course, to provide issue for pus and infected discharges.

But the mere provision of an outlet is not enough, nor is it enough to see the outlet so disposed as

to allow of gravity carrying off accumulated discharges.

What we are seeking to secure will not have been attained until such lymph as may have become poisonous to leucocytes and impotent upon bacteria has been extracted from the tissues; until that lymph has been replaced by a lymph which is favourable to phagocytic activity and inimical to microbes; and until this last is being "drawn" into the wound and is establishing in it conditions which are favourable to healing.

When anything less than this has been achieved by the use of the knife and, in particular, in the case where in despite of incisions the infective process has advanced, our drainage operation will have failed in its object, and our failure will be attributable to a sealing up of the fenestræ in the tissues and a stanching of the lymph outflow.

The remedy for this is to apply to the wound a hypertonic solution of salt to promote the outflow of lymph.

For ordinary use the best application will be a 5 per cent. solution of common salt combined with $\frac{1}{2}$ per cent. citrate of soda to render the lymph incoagulable. Where citrate of soda, or a similar decalcifiant, is not available a simple 5 per cent. solution of salt will serve. Sea water, this being equivalent to a 2.5 per cent. solution of salt, may also be employed. In dealing with dry and infiltrated wound surfaces stronger solutions of salt (up to 10 per cent.) will be found to resolve the induration and to clean up the wound surfaces much more quickly than weaker solutions.

In the case of deep wounds the simplest procedure will be to pour in the hypertonic solution and then plug lightly with gauze. Superficial wounds may be dealt with by laying on gauze thoroughly soaked in the solution. The limb should then be wrapped in waterproof material to prevent the bed becoming soaked with the very copious discharge, and an application of vaseline will prevent irritation of the skin and stinging on freshly cut skin surfaces.

The "drawing agent" has done its work as soon as it has checked the spreading invasion of the tissues or has cleaned up the dry and indurated wound surface, and this last has clothed itself in bright coral red granulations. The hypertonic salt solution may then be replaced by some simple dressing (*vide* the final paragraph of this Memorandum).

V.—TREATMENT OF THE SUPPURATION WHICH WILL SUPERVENE UPON THE LAYING OPEN OF WOUNDS AND INFECTED TISSUES.

The laying open of the wound or the infected tissue effects, as consideration will show, only the conversion of a more into a less dangerous form of infection, and we are, after our operative procedures, faced with a suppurative infection of our open wound and of our superadded incisions, and have now to check that infection.

It will in practically every case be an infection by the streptococcus combined with staphylococcus. And in very many cases there will be a superadded infection by coliform organisms, in particular by the *bacillus proteus*.

The therapeutic methods which we have here at disposal are the following:—

(1) Provision of Satisfactory Drainage and Lymph Lavage.

The first and most important thing will be to provide in the dependent portion of the wound a

free outlet for the discharges and to secure, when we are dealing with infiltrated wound surfaces, a free outflow of lymph (*vide* Section IV.).

If, by either of these methods or by a combination of the two, we succeed in providing effective lymph lavage for our wound, we shall have very little difficulty with the infection.

But it will in a very large proportion of cases be quite impracticable to obtain all that would be desirable in the matter of drainage, and it is all-important to recognise in connexion with these cases that "conservative surgery," as applied to the wounded, means making, for the purpose of conserving a limb, legitimate sacrifices with respect to drainage. The question, and it is the most anxious and responsible question in all surgical procedures, as to how far one may sacrifice drainage, can only be arrived at by balancing in each particular case the advantage of preserving a limb against the risks of long-continued suppuration and eventual septicæmia.

We require here to have clear conceptions as to what amount of help is obtainable, on the one hand, from *vaccine-therapy*, from the employment of *antiseptics* in the wound, and from *frequent dressings*.

(2) *Vaccine-Therapy in its Application to Suppurating Wounds.*

It is important in connexion with this method of treatment to realise (a) that it aims at increasing the antibacterial powers of the blood, and (b) that the conditions which determine our success or failure are essentially the same when we employ vaccines as when we set ourselves to combat infections by the aid of the antibacterial power of the normal blood.

Ideally favourable conditions for the successful employment of a vaccine will be given when this is employed in treating a perfectly well-drained wound (let us say, such a wound as that furnished by a flapless amputation); or again, in treating an incursion of a microbe into a tissue where there is a very free lymph flow (let us say, such an infection as erysipelas). Here, by the use of an appropriate dose of the proper vaccine or vaccine mixture, successful results may be confidently expected.

The most unpromising cases for vaccine treatment are those where we are dealing with an unopened abscess sac, or a quite undrained wound, or an old-standing cicatrised tissue infection. Here the microbes are shut off from the blood fluids, and in these cases the utmost we have any right to expect is to prevent an extension of the infection and to ward off septicæmic complications.

In the case here specially in view, that of the imperfectly drained wound, we may expect to obtain by the repeated inoculation of the appropriate dose of the proper vaccine or vaccine mixture, not anything in the nature of dramatic results, but a certain improvement in the local conditions, together with a certain protection against septicæmia.

We may, in short, expect from vaccine-therapy results which will make it possible to employ conservative methods in a larger proportion of cases; to hold on longer to these methods; and to carry them oftener to a successful issue. It would therefore be advisable to carry out vaccine-therapy as part of the routine treatment of suppurating wounds. (*Vide* Instructions issued with Antisepsis Vaccine.)

(3) *Employment of Antiseptics in Wounds.*

It is notorious that the results of the treatment of suppurating wounds by antiseptics

are disappointing, and that the reasoning which led to the universal adoption of this therapeutic method was, in point of fact, too unsophisticated.

It was tacitly assumed of chemical agents which acted as antiseptics in watery solution that they would do so also in blood fluids and pus; and that they would also penetrate a certain distance into the tissues and into blood clots. We know now that antiseptics do in these respects very much less than was anticipated.

It was further tacitly assumed that an antiseptic which gave good results with one particular microbe or group of microbes ought to give good results indiscriminately with all. But it is possible that particular antiseptics may be appropriate to particular microbes and groups of microbes; that, for instance, such an antiseptic as peroxide of hydrogen, which has very little effect on ordinary pyogenic microbes, may be specially effective on anaerobic micro-organisms.

But, at any rate, the principle has emerged that in choosing our antiseptics and the strength in which these are to be used we ought to guide ourselves by actual experiments on wounds and on the microbes which come into consideration in connexion with those wounds. And it would be clearly inadmissible in choosing antiseptics for employment in projectile wounds to leave out of sight the fact that anaerobic microbes and their spores have to be dealt with, and that the antiseptics we employ ought to be competent to kill these.

Again, it is still tacitly assumed by practically everyone who employs antiseptics that even if treatment with an antiseptic effects only a partial sterilisation, such partial sterilisation will always be something to the good.

This amounts in point of fact to the assumption that by substituting a smaller for a larger sowing the number of microbes in a culture will always be sensibly reduced.

In reality this will depend upon two factors: (a) the nature of the culture medium, and (b) the shorter or longer period allowed for the cultivation.

When we are dealing with a culture medium which is ideally favourable to the multiplication of microbes, the smaller sowing will, after a short space of time, give exactly the same number of microbes as the larger.

When we have a culture medium in which microbes develop very slowly the smaller sowing will for a very long time give a correspondingly smaller number of microbes.

When a cultivation medium which is unfavourable to microbes is after a certain lapse of time converted into a medium which is favourable to them, it will not be the larger or the smaller sowing, but the date at which the character of the fluid changes which will govern the result.

We have now to apply these general principles to the case of the cultivation of microbes in wounds; and we may consider first the evolution of events in wounds treated without antiseptics, and then inquire in what respect the use of antiseptics could modify this evolution.

There will after washing out remain behind in every wound a certain quantity of pus. In one case it will be a question of minimal collections left in the shallow depressions of a granulating surface; in another a question of quite large collections held up in inaccessible pockets.

This residual pus will furnish the sowing of microbes, and a culture will be set going as soon as lymph begins to trickle into the wound.

But the new culture will start off very slowly. And for two reasons: first, because the lymph in the condition in which it exudes inhibits nearly all microbial growth; secondly, because we have in the lymph phagocytically active leucocytes.

For a certain time these natural checks of microbial growths will be maintained. The conditions will, however, when the lymph is fouled by an appreciable mixture of residual pus, change rapidly. Phagocytosis will be arrested, and the effused lymph will be transformed into a medium which will be eminently favourable to the multiplication of all manner of microbes. If we now wait for only a few more hours we shall have in the wound a very luxuriant growth.

Coming now to the question how good could come of the employment of antiseptics in wounds, we recognise, in the first place, that we might by these means achieve an appreciably smaller sowing of microbes. Further, it is conceivable that if we were to leave behind in the wound a sufficiency of antiseptic we might obtain from it such a reinforcement of the growth-inhibiting power of the lymph as should more than offset the setback inflicted by the antiseptic in paralysing the phagocytic action of the leucocytes. Lastly, it is possible that an antiseptic, left behind in the wound in sufficient quantity, might prevent the residual pus converting the lymph into a good nutrient medium.

In reality these possibilities do not amount to much. It is clear that that appreciably smaller sowing of microbes which we are working for would be realised only where the whole wound surface can be thoroughly washed with an antiseptic. But these are precisely the cases where the effect of a smaller sowing of microbes would not make itself very much felt, for where the wound is left practically free of residual pus the natural checks of microbic growth would be longest maintained.

With regard to the other possibilities, all that is necessary to say is that they must rank only as possibilities, and that up to the present experiment has not furnished anything in confirmation of the idea that the introduction of antiseptics into wounds would be likely to contribute to the arrest of suppuration.

It must, however, be emphasised, in conclusion, that in the treatment of the wounded in hospital it is essential to look beyond the individual to the aggregate. And even if it were finally to emerge that the employment of antiseptics did not do anything towards the arrest of suppuration in an infected wound, the taking of careful antiseptic precautions, and the washing out of the wound by antiseptic solutions, would none the less be indispensable. For if such precautions were omitted, infective microbes would inevitably be carried from one wound to another, and there would inevitably, by such "passaging," be bred out in hospital very virulent strains of microbes, which would, as in pre-Listerian days, induce all manner of fatal septic infection.

(4) *Frequent and Efficient Dressing of the Wound.*

Coming back from this general consideration to the question of the treatment of the individual infected wound, it will be clear from what has been said above that the frequent and efficient washing out and dressing of the wound will be a factor of dominating importance in the treatment of the infection. Where comparatively long intervals intervene between the dressings, where pus is left

behind in the wound, where the discharges are confined by plugs or multiple folds of dressing, and where, in the case of a deep wound, too small drainage-tubes are employed little or no progress will be made. Where large drainage-tubes are employed, where the wound is frequently washed out, where no pus is left behind, and where only a very light dressing is employed, we shall be making progress.

And clearly, so long as a wound is heavily infected, the ideal method of treatment, if only it were always practicable, would be immersion in a bath or continuous irrigation with some aseptic or mildly antiseptic fluid.

When the continuous bath or, as the case may be, lymph lavage induced by hypertonic salt solution has brought the infection under control, what remains of that infection may very often be extinguished by freely exposing the open wound to the air. The part which the drying off of the wound surfaces and the concentration of the discharges plays in the killing off of the residual microbes has not yet been investigated.

NOTE.—The recommendations with regard to surgery which are put forward in the Memorandum have been formulated in consultation with Colonel Sir B. Moynihan and Colonel F. F. Burghard.

IRELAND.

(FROM OUR OWN CORRESPONDENTS.)

Death of Captain John Esmonde, R.A.M.C., M.P.

Captain John Esmonde, Member of Parliament for North Tipperary, died on April 17th from pneumonia, after a few days' illness. He was the son of the late Mr. James Esmonde, J.P., of Drominagh, co. Tipperary, and was educated at Clongowes and Stonyhurst, and subsequently in the school of the Royal College of Surgeons in Ireland. He obtained the Licence of the College in 1884, and in 1891 he became a Licentiate of the Apothecaries' Hall. He practised in various districts in England for some 24 years and then returned to his native county. In 1910 he was elected to Parliament as a member of the Irish Nationalist Party. After the outbreak of the war he accepted a captain's commission in the Royal Army Medical Corps, and was given duty in Ireland. Though of late years his activities were rather political than professional, he did not lose his professional interests. During the passage of the National Insurance Act through the House of Commons he gave cordial help to his professional brethren, who will join with his political colleagues in regret at his early death. He was only 52 years of age.

The Women's National Health Association.

The annual conference of the Women's National Health Association was held last week in Dublin under the presidency of Lady Aberdeen. Discussions took place on the medical inspection of school children, infant mortality, and kindred subjects, and reports were submitted dealing with the various activities of the association.

Cerebro-spinal Meningitis.

Dr. A. Gardner Robb, medical superintendent of Purdysburn Municipal Fever Hospital, Belfast, has issued a circular to the medical practitioners of Belfast urging the importance of early serum treatment in cerebro-spinal meningitis. He appeals to them to send any cases they may wish to