9. It is desirable that naphthalene-creosote powders should be supplied in sealed tins of a uniformly small size, or of sizes suitable for the immediate requirements of a convenient number of persons proposed to be treated at one time.

10. In experiments with gases, sulphur dioxide has maintained its reputation as the most efficient gaseous insecticide, and all lice exposed to an atmosphere of the gas die within five seconds. As ordinarily used for disinfecting purposes and as a result of lack of penetration sulphur dioxide cannot be depended on to kill all lice in verminous clothing.

11. For the emergency cleansing of clothing by means of petrol, immersion of the verminous clothing in petrol remains the most suitable method. To secure the insecticidal action of the vapour of petrol a regulated oven would have to be employed.

12. The superior value of certain chlorine derivatives of ethylene and ethane as insecticides and their non-inflammable properties indicate their use in the cleansing of verminous heads. The desired result is obtained and irritant effect on the scalp is obviated when the hair is gone over carefully with pieces of cotton-wool moistened with either trichlorethylene or tetrachlorethane. Tetrachlorethane, although less powerful than trichlorethylene, is very actively insecticidal, and is to be preferred to trichlorethylene on account of its less irritant properties.

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MEMORANDUM ON THE TREATMENT OF INFECTED WOUNDS BY PHYSIOLOGICAL METHODS.

(Drainage of Infected Tissues by Hypertonic Salt Solution, and Utilization of the Antibacterial Powers of the Blood Fluids and White Blood Corpuscles.)

BY

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1. INTRODUCTORY.

THE treatment of septic war wounds divides itself naturally into three therapeutic procedures:

(1) In the *first* we have a number of different aims to pursue concurrently, and have therefore to be ceaselessly on the watch. We have to promote the destruction of the microbes which have been carried into the deeper tissues. We have to re-establish normal conditions in those tissues, resolving the infiltration in the walls of the wound and getting rid of the infected sloughs, and we have to prevent "the corruption of the discharges," and inhibit microbic growth in the cavity of the wound.

Further, during the whole period occupied by these operations we have to be constantly on our guard to prevent active and passive movements which would propel bacteria along the lymphatics, and carry poisonous bacterial products into the blood.

(2) When the microbes in the deeper tissues have been exterminated and physiological conditions have been restored, and the wound has been rendered to naked eye inspection perfectly clean, the difficult portion of our task has been accomplished, and the time has come for dealing with the surface infection.

(3) As soon as this has been suppressed, or all but suppressed, all our thought ought to be given to promoting the processes of repair, bringing together the tissues, and covering over the denuded surfaces.

2. INADEQUACY OF THE TRADITIONAL METHOD OF TREATING WOUNDS BY ANTISEPTIC APPLICATIONS, INCISION, AND MECHANICAL DRAINAGE.

Inefficacy of Antiseptic Applications.—The ordinary antiseptic combines with every kind of albumin. It thereby loses its bactericidal and its penetrative power. Its *bactericidal power* is, of course, not finally abolished until the antiseptic has encountered and combined with its full complement of albumin. Its *penetrative power*—and penetrative power means capacity for diffusing outwards through any medium in a chemically active condition—is, in the fluids of the wound, very rapidly abolished. For, when the medium which is to be penetrated contains even a trace of albumin, this will immediately quench the "*antiseptic emanation*"—meaning by this that fractional quantum of antiseptic which is carried out by diffusion into the surrounding fluids.

These general truths are firmly based upon experiment. It can be demonstrated that none of our ordinary antiseptics extirpate microbes enveloped in dead or living tissues, or in serous or purulent discharges; and that none diffuse into the walls or recesses of the wound. The sterilizing action of antiseptics applied in the wound will thus be strictly limited to the destruction of any microbes which may be lying bare; and sterilization will not extend beyond that portion of the wound surface to which the antiseptic is actually applied.

Inadequacy of Drainage as Usually Practised.—The theoretical requirements for a complete scheme of drainage are, *first*, that there shall be an outflow from the infected tissues to the external surface, or to the surface of a wound cavity; and, *secondly*, where a wound cavity exists, that there shall be drainage from that cavity to the exterior.

Drainage from the Tissues.—In the customary treatment of wounds, drainage from the tissues is not specially insisted upon—mere incision with or without fomentation being assumed to do in this respect what is necessary. In reality, however, in oedema only will sufficient drainage be given by this method. In tissues of normal density nothing like adequate effusion will be obtained, the lymph flow being here rapidly arrested by clotting and desiccation. And, where we are dealing with densely infiltrated tissues, incisions may fail to furnish even as much as a drop of exudation.

Drainage from the Cavity of the Wound.—Drainage tubes, of course, do not induce any outflow of lymph from the tissues. They drain only from the cavity of the wound—outflow ceasing as soon as ever the well head in the tissues dries up.

Summary of Criticisms on the Traditional Method of Treating Wounds.—It has appeared above (*a*) that antiseptics do not exert any effective action in the wound either in the direction of extinguishing the infection or keeping down bacterial growth; (*b*) that the usual procedure of incising and inserting drainage tubes provides, in place of that continuous welling out from the lymph spaces to the exterior which we require, a drainage which rapidly stanches at the source; and (*c*) that in the ordinary treatment of wounds no steps are taken to disperse infiltration; or accelerate the separation of the sloughs; or bring antibacterial lymph or phagocytes to the seat of infection.

In short, the treatment of wounds by a combination of antiseptics, incision, and mechanical drainage, is a therapeutic method which constantly disappoints, because it fails to kill the infecting microbes and at the same time fails to give to the organism opportunity for ridding itself of the infection.

And lastly—and this point cannot be too much insisted upon—in the ordinary treatment of septic wounds not nearly enough care is taken to prevent those active and passive movements which lead to the mechanical impulsion of microbes along the lymphatics, and to *auto-inoculations*.

3. THE IDEAL OF PHYSIOLOGICAL TREATMENT IS TO GIVE INTELLIGENT AID TO THE ORGANISM IN COMBATING THE BACTERIAL INFECTION.

Saline dressings supply a means for evoking, in the infected wound, certain requisite physiological reactions. By their aid we can, while at the same time inhibiting bacterial growth, drain the tissues, resolve infiltration, and promote the separation of the sloughs—besides giving other assistance.

4. PHYSICAL AND PHYSIOLOGICAL ACTION OF CONCENTRATED SALT SOLUTIONS.

(1) A concentrated salt solution will attract water; and, except in the case where a membrane which is impermeable to albumin is interposed, the outflowing current of water will carry out with it the whole of the protein substances which it holds in solution. This means that

hypertonic salt solution applied to tissues lying bare in the wound (or to granulating surfaces) will operate as a *lymphagogue* drawing out from the infected tissues lymph which has spent all its antibacterial energy, and drawing into the tissues from the blood stream lymph inimical to microbic growth.

(2) Brought into direct application upon leucocytes a hypertonic solution (what is in view here is a solution containing 5 per cent. salt) will disintegrate leucocytes, setting free the tryptic ferment they contain.

Such a hypertonic salt solution will also exert a number of inhibitory actions.

(3) It will inhibit the action of the tryptic ferment set free in the wounds.

(4) It will inhibit coagulation and so prevent the sealing up of the orifices through which lymph pours into the wound.

(5) It will inhibit leucocytic emigration into and prevent phagocytosis in the cavity of the wound.

(6) It will inhibit microbic growth.

5. Physical and Physiological Effects of Normal (0.85 per Cent.) Sodium Chloride Solution.

Normal solutions of sodium chloride exercise—as many other substances also do—a positive chemiotactic effect on white corpuscles. In other words, they will when applied to the surface of the wound bring leucocytes to the surface.

In moderately dilute solutions (solutions of 0.85 per cent. are here in view) salt does not interfere with the activity of trypsin, nor does it inhibit blood or lymph coagulation, phagocytosis, or microbic growth.

6. Therapeutic Employment of Hypertonic Saline Solution in the Early Stages of the Infected Wound.

By the time the patient reaches the *Casualty Clearing Station* his wound will generally have assumed the characters of a lymph-bound, infiltrated, and sloughing wound; or it will be fast getting into this condition. And even though under care in hospital the wound may have been coming out from this condition, it will, on long journeys, when redressing is difficult, be very prone to fall back into it. (*Vide infra, Subsect.* 14.)

The first requirement when we have an infected, lymph-bound, infiltrated, and sloughing wound will be—to get rid of the coating of scab and fibrin adhering to the surface of the wound, and set the lymph-flow going, to resolve the infiltration, and to promote the separation of the sloughs.

This involves two successive operations. In the *first*, we make use of the hypertonic solution undiluted; in the *second*, we turn its dilution to profit.

Stage in which the Hypertonic Solution comes into Operation Undiluted.

The striking feature here will be the outpouring of lymph. But there will at the same time: (*a*) in the depth of the tissues, (*b*) on the surface, and (*c*) in the cavity of the wound, be evoked other reactions which cannot be directly followed by the eye.

(*a*) *In the depth of the tissues* there will be substituted for the spent lymph which has been extracted lymph freshly drawn from the blood stream. This means that there will be substituted for a lymph which is favourable to the growth of all microbes indiscriminately a lymph which will stop the growth of *sero-saprophytic bacteria* and *imperfect serophytes* (such as the gas-gangrene bacillus); and at the same time seriously impede the growth of serophytic bacteria, above all the growth of the streptococcus.*

Further, the microbes in the tissues, which when immersed in the spent lymph were insusceptible, will, immersed in the fresh lymph, become susceptible to phagocytosis.

And in the induction of the phagocytosis in the interior of the tissues, the imbibed salt will, we may take it, play a contributory rôle. For we have seen that salt, appropriately diluted, stimulates leucocytic emigration.

(*b*) *In the more superficial regions of the walls of the wound and adhering sloughs*, the hypertonic salt solution will break down the leucocytes and set free tryptic ferment†—ferment which will, as we saw, not come into action so long as the concentration of the salt is maintained.

The coagulation of the lymph on the face of the wound will also, as we saw, be inhibited by the hypertonic salt solution.

(*c*) *In the cavity of the wound*, microbic growth will at the outset be completely arrested by the hypertonic salt, and it will, after the lymph has begun to pour out, be inhibited to different degrees according to circumstances by the combination of salt and antitryptic exudation.

So long as the salt solution is maintained at full strength, both emigration into and phagocytosis in the cavity of the wound will be inhibited.

Sum Total of Clinical Effects Produced by the Undiluted Hypertonic Salt Solution.—There will have been established, in the depth of the tissues, conditions favourable to the extermination of the microbic infection; and in the cavity of the wound conditions which will restrain microbic growth.

Stage in which the Dilution of the Hypertonic Salt Solution is turned to Profit.

As soon as the hypertonic solution in the cavity of the wound has been sufficiently diluted by outflowing lymph, the salt diffuses out from the infiltrated walls of the wound and the sloughs; and with this the tryptic ferment previously set free in these comes into action, and goes about its work of *cleansing digestion*—resolving the products of inflammation in the infiltrated tissues, and severing the connecting strands by which the sloughs are bound to the face of the wound.

At the same time—and this, be it noted, serves as a signal to the eye that the dilution of the salt solution has reached the point where all its inhibitory effects are abolished—leucocytes emigrate into the wound, and the discharge begins to assume a purulent character.

Now, also, the bacteria begin to multiply in the cavity of the wound.

We cannot afford to let all this go on very long unchecked. For as more and more trypsin finds its way into the exudate, or is set free in it from leucocytes disintegrated by microbic poisons, the effusion comes to furnish a more and more congenial nutrient medium for microbes, and the check imposed by phagocytosis is more and more completely removed. Finally, the exudate becomes tryptic, and if the redressing of the wound is any longer delayed, ground will now be rapidly lost (*vide infra, Subsect.* 12—*Indications which call for the redressing of the wound*).

It will have to be remembered, in connexion with this description, that the conditions will in every wound be perpetually changing, and that these changes will not keep time in the different parts of a large wound.

7. Under Certain Special Circumstances the Hypertonic Salt Solution should be used in a Different Way.

Method in which Hypertonic Salt Solution should be used when Gas Gangrene, Streptococcic Cellulitis, or other Acute Tissue Infection supervenes, or where we are dealing with an Infection of a Joint.—Our whole concern here must be to draw out as rapidly and exhaustively as possible the corrupted lymph‡ which occupies the tissue spaces, replacing this with uncorrupted lymph drawn from the capillaries. To achieve this we must, after freely incising the tissues, or opening the infected joint, apply hypertonic salt solution and maintain this in full strength until we have got the upper hand of the infection.

* The inhibition of microbic growth obtained with the serum of the patient with a large or even moderate-sized wound is much greater than that obtained with a normal serum. This, as comparative experiments have shown, is connected with the fact that the antitryptic power of the wounded man mounts up with very steep ascent (that is, in the course of a couple of days), to a level 3 to 8 times higher than the normal.

† The presence of trypsin in the wound can be very easily demonstrated. We need only collect a sample of pus or slough on a small swab of cotton wool; introduce this into milk containing ½ per cent. of calcium chloride cryst., and then place this at a temperature of 50° to 55° C. (that is, in water just not too hot to hold one's hand in). If trypsin is present the milk will now rapidly clot. But it must be borne in mind in connexion with clotting obtained with a slough that since, under the conditions of the experiment, we dilute our material, our test will give a positive result even when we have in the wound sufficient salt to prevent the ferment being actually operative.

‡ This lymph has ordinarily lost some, and in very severe infections it may have lost all, its antitryptic power. Further, in gas gangrene—and let me here interpolate that we have in gas gangrene, when fully developed, a profound acid intoxication—the lymph in the focus of infection often shows a much diminished alkalinity.

Method in which the Hypertonic Salt Solution should be used where we are threatened with Secondary Haemorrhage.—Our aim and object here must be to prevent any digestive action in the neighbourhood of the endangered artery. Translated into practice this means that we must apply hypertonic salt solution and maintain it at full strength so as to prevent any trypsin which may be liberated in the wound coming into action.

8. GENERAL INSTRUCTIONS FOR THE CARRYING OUT OF THE LINES OF TREATMENT INDICATED ABOVE.

Concentration in which the Hypertonic Salt Solution ought to be brought into Application.—For all ordinary purposes the best hypertonic solution to employ is a 5 per cent. solution of common salt. Where we require more vigorous lymphagogic effect we may resort to a 10 per cent. solution, or even to a stronger solution. But these are very painful when applied to skin edges and sensitive granulations; and salt applied in saturated or nearly saturated solutions will often cause sloughing of the superficial tissues (*vide Subsect.* 10, *Footnote*).

Most Convenient Form of Stock Solution to keep on Hand.—The most convenient stock solution to keep on hand is a saturated saline solution, made by shaking up water with an excess of salt and then allowing this to settle. Such a solution contains at ordinary temperature 35 per cent. of salt.

Diluted 1 part of the saturated solution with 6 parts of water it gives a 5 per cent. solution.
Diluted 2 parts of the saturated solution with 5 parts of water it gives a 10 per cent. solution.
Diluted 1 part of the saturated solution with 39 parts of water it gives a 0.85 per cent. (physiological solution).

N.B.—Hot water should be employed for making the dilutions required for saline dressings and irrigations. For the physiological reactions which are to be evoked, whether these be active hyperaemia and transudation, or tryptic digestion, or emigration and phagocytosis, are all impeded by cold and favoured by heat.

9. METHOD OF APPLYING HYPERTONIC SALT SOLUTION SO THAT IT MAY PRODUCE AN ADEQUATE LYMPHAGOGIC ACTION, AND AFTERWARDS PROVIDE OPPORTUNITY FOR DIGESTIVE CLEANSING OF THE WOUND.

This will be the proper way of employing hypertonic salt solution in the infiltrated and sloughing wound. The following are the points to be borne in mind:

(*a*) For the achievement of an adequate lymphagogic effect, we must use quite considerable quantities of hypertonic solution. The dressings ought to come directly out of the hot solution, and be applied dripping wet.

(*b*) In order that there may follow upon the lymphagogic action a cleansing digestion, the amount of salt employed must be kept within such limits as will allow of its being within a reasonable period diluted by the outflowing lymph. In other words, we must not use too much hypertonic salt solution, nor use too concentrated a solution; nor supplement with large packs of saturated salt solution or salt tabloids.*

In order to anticipate that pullulation of microbes which will supervene when the exudate becomes tryptic we ought to redress the wound as soon as the discharge begins to be purulent.

The procedure in carrying out these principles will, of course, vary according to the anatomical conditions of the wound. In point of fact, three different anatomical types of wound have to be considered:

(*a*) The wound which from the beginning lay fully open, or which has been opened up so as to render every portion of its surface fully accessible;

(*b*) The wound where, owing to folds, or blind passages, or a tunnelled way, portions of the surface are not fully accessible; and

(*c*) Tubular wounds which are throughout their whole course more or less difficult of access.

(*a*) In the *first* case we have only to pack the wound with gauze thoroughly wetted in hot 5 per cent. salt solution. We cover this in with any impermeable tissue, such as jaconet. When the time comes for redressing the wound all trace of pus ought, before reapplying the saline, to be carefully removed. For pus treated with strong salt is converted into a sticky intractable substance which forms an impermeable coating on the walls of the wound.

(*b*) *Where the wound is pocketed or tends to flap together* the best procedure is to employ a bath of warm 5 per cent. saline. Should the position of the wound render immersion in a bath impracticable, it ought to be irrigated with warm 5 per cent. saline solution, the fluid being distributed over the whole surface of the wound by an arrangement of bandages.[1] The bath or irrigation ought to be discontinuous—intervals for digestive cleansing alternating with periods of lymphagogic and leucocytolytic action.

(*c*) Where we have a *tubular wound* it will, of course, be futile merely to insert a drainage tube, and cover its mouth with a piece of gauze wrung out of hypertonic salt solution. The rational procedure will here be to make windows in the tube, to cut it open longitudinally, and to lay into the hollow a folded strip of gauze, thoroughly wet with saturated salt solution. The tube thus armed is to be introduced into the wound after this has been syringed with 5 per cent. saline.†

10. METHOD OF APPLYING HYPERTONIC SALT SOLUTION WHERE WE WANT TO MAINTAIN ITS STRENGTH UNDIMINISHED, SO AS TO OBTAIN ITS FULL LYMPHAGOGIC EFFECT AND SUPPRESS ALL DIGESTIVE ACTION.

It will be remembered that this is the way in which hypertonic salt solution should be used where we are threatened with secondary haemorrhage, or are dealing with an infected joint, or with gas gangrene infection, or streptococcic cellulitis (*vide supra, Subsect.* 7). Let us consider how, using the ordinary hypertonic solution and the stock of solution of saturated salt, to effect our object in the three types of wound already referred to—the *completely* accessible, the *incompletely accessible*, and the *tunnel* wound.

(1) In the first variety of wound we, as before, pack with gauze thoroughly wet with 5 per cent. salt, but now reinforce by a backing of gauze thoroughly wet with saturated salt solution, and, as before, cover with some impermeable material. Or, as an alternative, we at short intervals renew the hypertonic solution, feeding this in with a syringe through a drainage tube going down to the face of the wound.‡

(2) In the case of the only *partially accessible wound* we resort as before to a bath of 5 per cent. saline or to irrigation with this solution, varying our procedure only in the respect that we make the bathing or irrigation continuous, or as nearly as possible continuous. When immersion in a bath and irrigation are both impracticable the wound ought to be dressed as in (1).

(3) In the case of the *tunnel wound*, we at short intervals renew the supply of salt; first withdrawing the old wick; then syringing out with 5 per cent. of salt; and then substituting for the old wick a new one taken fresh from saturated salt.

* In this connexion it will be well to emphasize that to fill into the wound cavity large numbers of salt tabloids must be pronounced wrong practice in the case where we judge the wound to be one which stands in need of digestive cleansing.

† This procedure might at first sight seem open to objection, (*a*) on the ground that saturated salt solution would here be brought into application upon the tissues; and (*b*) on the ground that to obstruct a drainage tube by gauze would be to render it useless. In connexion with the former objection, it will suffice to point out that direct contact of the saturated salt solution with the tissues is avoided by the interposition of the wall of the tube; and that the salt in the wick will come into operation only through the medium of the weaker salt solution with which the wound has been syringed out. In connexion with the latter objection, consideration will show that it is only in ordinary *drainage ex vacuo*; that is, it is only when we aim at keeping our wound cavity empty, and when we are dealing with viscid pus, and when unaided gravitation supplies in our scheme drainage our whole motive force, that it becomes incumbent to provide an unobstructed conduit to the exterior. In *drainage ex pleno* such as is here proposed we deal with a watery lymph effusion which wells over from the wound; and which only hermetical sealing could bank back.

‡ Another method which has been extensively practised is that of packing the wound with tabloids of salt, holding these off from actual contact with the tissues by several folds of gauze. This would seem to give in different cases different results. In certain cases—such as when an open knee-joint is packed with tabloids of salt, disposed throughout the gauze with close and regular interspacing—the interior of the wound remains perfectly dry. The explanation would seem to be that the salt here comes into application in the form of a saturated solution all over the surface of the wound, condensing the tissues until they become impermeable to lymph; and at the same time pickling them in such a way as, perhaps, to restrain all microbic growth in their interior. In other cases—for example, where a bagful of tabloids is introduced into the well of a large wound—there is obtained the ordinary lymphagogic effect. Here it would seem that the salt operates in form of a saturated solution upon the portion of the wound only lying nearest to the tabloids. And hereabouts the tissues look and feel exactly like pickled meat. In regions more remote from the tabloids the salt will naturally be much less concentrated. And it is presumably from these regions that the copious lymph outflow is derived.

11. NATURE OF THE EXTERNAL COVERING TO GO OVER THE WET SALT DRESSINGS.

The most usual practice is to place immediately outside the saline dressings a thick packing of dry cotton-wool, and again outside this a bandage. This seems to be dictated by the idea that the cotton-wool will soak up the discharges, and the notion that the capillarity of the cotton-wool, and evaporation from its outer surface will reinforce the drawing action of the salt. In point of fact, however, all the cotton-wool does is to suck out some of the salt solution from the dressings, and to evaporate this to dryness, putting in this way a certain quantum of salt out of action. Moreover, the notion that capillary action and evaporation would promote drainage from the tissues is in conflict with everyday experience, which shows that when we apply a dry dressing or let a wet dressing evaporate, the outflow of lymph from the wound ceases, and the dressing sticks to its surface.

The rational method of covering in saline dressings is to use, instead of cotton-wool, an impermeable covering.* Then, instead of the salt solution being carried outwards by capillarity and evaporation, it will, by diffusion, be carried inward.

The difficulty that with this form of dressing discharges will escape from under the impermeable covering can be met either by frequent redressing or by placing cotton-wool outside the jaconet.

In the case of wounds of the extremities perhaps the simplest method of all is to dispense with all coverings over the salt dressings, merely renewing the salt packs at frequent intervals. But here, if we want to clean off sloughs or resolve infiltration, we shall have to alternate with our dressings of hypertonic saline solution dressings of physiological saline solution.

12. INDICATIONS WHICH CALL FOR THE REDRESSING OF THE WOUND.

A septic wound requires to be redressed under two quite different conditions.

(*a*) It requires redressing as soon as tryptic ferment is set free in the cavity of the wound, such trypsin being set free from leucocytes broken down by microbic growth.

For here, as soon as the originally antitryptic exudation becomes tryptic, all manner of sero saprophytic microbes will multiply unrestricted; and bacterial poisons may be absorbed; and, at the same time, phagocytosis will be inhibited; while the young tissue elements, which are the agents of repair, will be subjected to destructive digestion.

(*b*) Again, every septic wound ought to be redressed as soon as it becomes lymph-bound.

For as soon as the exudation stanches and lymph fresh from the blood ceases to come into application, the microbes in the tissues, being now no longer inhibited by their growth or phagocytosed, find congenial conditions and multiply.

It requires to be emphasized in connexion with these two indications for redressing that in the case of the septic wound intervention is much less urgently called for, where we have *retention of corrupted discharges*, than where the wound becomes *lymph-bound*.

In the case of the *former* all we have to fear is a pullulation of microbes in the cavity of the wound, some absorption of septic products, and some injury of the tissues of repair.

In connexion with a *lymph-bound wound* we may at any moment have a wide extension of the tissue infection, taking the form of gas-gangrene or streptococcic cellulitis.

13. PRINCIPLE UPON WHICH CASES OUGHT TO BE CHOSEN FOR REDRESSING WHERE PREFERENCE MUST BE GIVEN TO THE MORE URGENT.

What has been said above on redressing ought to be specially kept in mind where it is impossible to inspect and redress every wound.

In such cases the surgeon has, as a rule, simply pursued the practice followed in ordinary aseptic operation wounds. That is, he has with a view to preventing the invasion of microbes from without, redressed the cases where the discharge has soaked through, giving to these preference over those with unsoiled dressings.

In septic wounds—for here the microbes are in the citadel and not outside the walls—we ought to follow an exactly opposite policy. Where the outside dressings are wet with discharge, in other words, when presumably lymph is being actively poured out, we may be confident that the wound is not coming to any harm. We may accordingly, when other work presses, quite properly postpone redressing such cases. The contrary will hold of a gravely wounded man whose dressings are unsoiled. In such a case it is always possible that we may underneath quite clean dressings have a lymph-bound wound. We ought without delay to satisfy ourselves with respect to this.

14. PRECAUTIONS TO BE TAKEN IN HANDLING THE WOUND TO PREVENT AUTOINOCULATIONS AND A DISPERSAL OF SEPTIC INFECTION ALONG THE LYMPHATIC CHANNELS.

Like the acutely sick all the wounded are suffering from a bacterial infection. And the same general therapeutical principles apply. So long as microbes in large numbers are harboured in the tissues we have pyrexia. And the patient's condition will be aggravated by all dispersion of the infection and absorption of bacterial poisons into the blood. So that in every case the infected man will need to be kept at rest; and the really heavily infected will require to be kept at *absolute rest*.

This requirement is, of course, in the case of those suffering from infected compound fractures more or less perfectly complied with by the application of apparatus for fixing the limb.

But not only wounds complicated by fracture, but all wounds with the infected tissues in their neighbourhood, ought so far as possible to be immobilized. Moreover, this ought to be begun immediately after the wound has been inflicted, and to be continued so long as appreciable infection persists in the depth of the tissues.

In connexion with operative procedures it is, of course, impracticable to conform completely to this requirement. But none the less the requirement should never be lost sight of. It is scientifically reprehensible to cast loose, as is so often done under an anaesthetic, a fractured limb from all splints, deliver it over to an orderly for energetic washing and disinfection, and permit the foot or hand below the fracture to be used as a handle for raising or turning over the limb. All the necessary passive movements ought to be reduced to an absolute minimum. And the light hand of the skilful surgeon will, in operating on an infected case, be a very valuable asset.

In the same way, seeing that very efficient apparatus has now been devised, fractured limbs ought no longer to be put up in such a way as to allow of sagging or displacement during redressing.

Again, in changing the dressings on large flesh wounds on an arm or leg, great care ought to be taken not to manipulate, or flex or extend, or unnecessarily disturb the position of the limb.

It is difficult to doubt that when these precautions are neglected bacteria from the infected area will be propelled along the lymphatic channels in the direction of the heart. And measurements of the opsonic power of the blood and, indeed, simple inspection of the charts, establish that all readjustments of the position of a fractured limb, and probably all redressing of large wounds, are followed by elevations of temperature corresponding to very serious autoinoculations.

The same will, of course, apply to shocks and jolts received when the infected patient is being carried from the ward to the operation theatre, or is being transported by train or motor.

15. MANNER IN WHICH WOUNDS SHOULD BE DRESSED IN PREPARATION FOR LONG JOURNEYS DURING WHICH THEY CANNOT BE KEPT UNDER CLOSE OBSERVATION.

What has been said in the preceding subsections has an important bearing upon the procedure to safeguard the patient against that delay in redressing which is inevitable during the long hours which will be consumed in travelling from the front to the base, or from the base to England, and in settling down into a new hospital. The danger from microbic pullulation in the cavity of the wound and

* The prejudice against the use of impermeable coverings no doubt originates in the observation that discharges, w en confined after they have become tryptic, will set to work and digest the surface of the wound. The proper remedy is not to discard the impermeable covering, but either to redress before the discharges become tryptic, or prevent them becoming tryptic.

tryptic digestion, and, on the other hand, the much graver danger of a tissue infection taking origin in a lymph-bound wound, have here to be provided against. This means that we have to arrange for a continuous outflow of lymph, and at the same time to arrange for the surface of the wound being kept thoroughly wet.

The proper course will be to dress the wound as indicated in *Subsects.* 10 *and* 11, *supra*, applying outside the impermeable covering dry cotton-wool. Thus treated the patient may arrive at his destination with soaked dressings, but he is not likely to arrive with corrupted pus, and we can be practically certain that he will not arrive with a tissue infection spreading from a lymph-bound wound.

16. METHOD OF CORRECTING CERTAIN UNDESIRABLE AFTER-EFFECTS WHICH MAY SUPERVENE UPON THE ILL-CONSIDERED, OR TOO LONG CONTINUED, USE OF HYPERTONIC SALT SOLUTIONS; AND INDICATIONS AS TO WHEN THE HYPERTONIC SALT SOLUTION OUGHT TO BE DISCARDED IN FAVOUR OF A WEAKER SOLUTION.

The *rationale* of the therapeutic employment of hypertonic solutions is, as we have seen, to be found in the fact that (1) they drain the tissues; (2) break down the leucocytes in sloughs and in the walls of the wound, and so give us, quite apart from any destruction of leucocytes by microbic agency, the trypsin we require for the digestive cleansing of the wound; (3) they produce active hyperaemia; (4) prevent clotting of the lymph in the walls of the wound; (5) suspend the action of the tryptic ferment set free from the leucocytes; and (6) inhibit bacterial growth—the inhibitory actions last in question being exerted only so long as the strength of the salt solution is maintained. In addition—but this counts of course as a disadvantage and not as a therapeutical asset—hypertonic solutions repel leucocytes and prevent phagocytosis.

If we want, in employing hypertonic salt solution, to turn its therapeutical qualities to best advantage, we must be continually on the watch to anticipate and correct any of the defects of its qualities.

(1) Where blood continues to ooze from an operation stump or wound which has been packed with hypertonic salt solution, this will be due to this anticoagulative agent having been applied before bleeding has stopped. The proper procedure will always be to postpone the use of hypertonic salt until all oozing of blood has ceased. Applied then, the salt will not resolve the blood clot; and where the hypertonic solution applied is a 5 per cent. solution, a very little dilution will bring it to the point when blood clotting will no longer be inhibited.

(2) When the face of the wound is found covered with a firmly adherent glutinous coating, this has been derived from leucocytes broken down by the direct application of strong salt.

The way of avoiding this obstacle—it is, as a matter of fact, a serious obstacle to effective draining and irrigation—is to clean out all pus from the wound before bringing the hypertonic salt solution into application.

(3) Where, as very rarely happens, the granulations become oedematous this will be due to the over-prolonged application of concentrated salt solutions.

It would seem that here the salt which is imbibed into the granulations is not sufficiently promptly carried off by the circulation, with the result that fluid is drawn into the salt-impregnated tissues, both from the underlying strata and also, when their salt content diminishes, from the discharges.

The remedy will be to discontinue the application of salt, and to apply hot fomentations in order to activate the circulation and promote absorption.

(4) Where the granulations assume a bright coral red colour and bleed at the least touch, it will be well to reduce the concentration of the salt solution—in the case where drainage of the tissues is still required to 2.5 per cent., and in the case where no further lymphagogic effect is required to 0.85 per cent.

(5) Quite apart from the development of any undesirable secondary effects, it will be well, as soon as every trace of induration has disappeared and all sloughs have been got rid of, to substitute for the hypertonic a physiological salt solution.

The *rationale* of this is that there will here still remain on the face of the wound, even though it looks to the naked eye perfectly clean, serophytic microbes, which, though quite at home in the serum, can be killed by phagocytosis.

In order to kill these—and let us note that they are not killed but only inhibited in their growth by hypertonic salt solution—we must bring leucocytes to the surface of the wound.

17. THERAPEUTIC APPLICATION OF PHYSIOLOGICAL SALT SOLUTION.

What remains to be done is (*a*) to destroy the serophytic bacteria—streptococci and staphylococci—which still survive upon the face of the wound; and (*b*) to reduce the extent of surface lying open to infection, holding before ourselves always as an ideal the closure of the wound by secondary suture.

Destruction of the Serophytic Microbes remaining on the Face of the Wound.—A surface infection such as we have still to deal with can be effectively combated by keeping the wound wet with physiological salt solution, and redressing at short intervals. The application of physiological salt solution will, as we have seen, promote the emigration of phagocytes, the frequent redressing will prevent the setback that will occur every time that leucocytes die off and set free their trypsin in the wound; and the combination of the two will, in the case where the deeper tissues have been freed from infection, either exterminate the surface infection, or at any rate so nearly exterminate it as to make it safe to embark upon an operation for the closure of the wound.

18. FINAL STAGES IN THE TREATMENT OF THE WOUND.

Conditions under which Wounds may be Closed by Secondary Suture.—Secondary suture may be safely embarked upon when we have favourable bacteriological conditions in combination with favourable anatomical conditions.

The bacteriological conditions may be pronounced favourable when (*a*) microscopic examination of fluid from the depth drawn out by a "lymph leech"; or, failing this, clinical evidence points to the probability of our having got rid of all the deep infection, and when (*b*) stained impression preparations made from the wound surface show that we have there large numbers of perfectly well-conditioned polynuclear leucocytes, and a complete absence of microbes, or only here and there a stray microbe.

The anatomical conditions are favourable when we can, with or without undercutting, bring together the skin edges without putting too great a strain upon the sutures, or leaving underneath any hollow spaces. The operation of secondary suture may be undertaken either before the wound surfaces are covered in with granulations, or subsequent to this—the former of these dates being, from the bacteriological point of view, the more favourable, in the respect that there will be less risk of infection lurking below the surface.

It will, in every case, be advisable—for the conditions may change within the lapse of a few hours—to let the operation follow immediately upon the examination of the impression preparations.

In connexion with secondary suture, as in every other case where a wound is sewn up without adequate guarantee for its asepticity, it will always be imperative to keep the patient under the anxious observation of the operator for at least a week afterwards.

Procedure where the Wound cannot be Closed by Secondary Suture.

When the anatomical conditions do not allow of the wound being closed by secondary suture, we must fall back on the policy of persistently combating the surface infection, consolidating the granulations, and encouraging the covering in of these by epithelium. In the present state of our knowledge perhaps the best we can do will be to employ dressings of physiological salt, or, better, of Ringer's solution (for this contains a large assortment of physiological useful salts), redressing the wound frequently. Where we are dealing with a large defect of skin, grafting may usefully be resorted to.

REFERENCE.

[1] See the author's Memorandum on the Irrigation of Wounds, BRITISH MEDICAL JOURNAL, October 16th, 1915; and *Lancet*, October 16th, 1915.