50° or 60° below freezing point does not encourage the ward sister to open the windows. The lowest temperature we experienced was 67½° below freezing point (Fahrenheit)—that is, -30° Réaumur.

XVI. Frostbite and Trench Feet.

After our experience in the 1st and 4th London General Hospitals R.A.M.C.(T.) of frostbite and trench feet occurring in British, Colonial, and Belgian soldiers, we expected to meet with numerous examples of these troubles owing to the extreme cold of the Russian winter. To our astonishment, we saw far fewer cases than we encountered in the various London hospitals. The Russian soldier knows nothing about socks or stockings. He wraps his foot in a square piece of flannel and then puts on an excellent loose-fitting top-boot. Despite the fact that he has to face a temperature 30° to 40° lower than that encountered by his British comrade, he is far less liable to suffer from frostbite or trench feet. Admittedly he is more inured to extremes of cold, but as the result of our experience we recommend, as the best way to prevent frostbite and trench feet, a flannel wrap around the foot and a loosely-fitting top-boot.

XVII. Mortality.

On the question of the percentage of deaths we regret that, owing to the loss of many of our records, we can make no authoritative statement as to the exact percentage of deaths that occurred in our hospitals. It is, of course, obvious that no comparison can be made between the Petrograd base hospital and the field hospital in this respect. In the former institution we met with much the same type of case that finds its way into the big London general hospitals R.A.M.C.(T.), and the death-rate was low, certainly under 1 per cent., and probably nearer ½ per cent. The cases admitted into the field hospital were, naturally, in general, suffering from far graver injuries. The majority of them were not sent to us direct, but were transferred, by the courtesy of our Russian colleagues, from neighbouring hospitals for treatment because of the gravity of their injuries. Thus during our time at Cherukoff, with the sanction of the General of the Russian Red Cross, our admissions were confined to cases sent to us by the surgeons of the various Russian field hospitals, and every patient admitted was in a serious condition. W. D. H. can testify that during the time that he had charge of the field hospital the mortality was 4 per cent. Later on, as our hospital became better known and only the gravest cases were sent to us, it rose to nearly 5 per cent., the most frequent cause of death being gas gangrene.

REFERENCE.

1 *Lancet*, August 12th, 1916.

A METHOD OF EARLY CLOSURE OF RECENT GUNSHOT WOUNDS.

BY

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EARLY closure of the gunshot wound has been for nearly three years the ambition of the surgeon and the pathologist, and although several methods have stood the tests of time and practice and have proved extraordinarily efficient, no apology is needed for making further suggestions. This paper is written to bring forward the use of a mechanical aid to excision of the wound—namely, the staining of the track of the missile, and, secondly, the use of a paste as the method of sterilization.

Excision of the Wound.

Ever since the possibility of an early closure of the wound was demonstrated by Gray and Carrel, it has been my custom in quiet times to examine and consider and operate on the wounds handed over to us in the casualty clearing station from the point of view of an early suture. In these later days the surgical organization of the armies has become so efficient that a surgical "push" in the old sense does not exist, and incisions of the fresh wound for the sole purpose of preventing spreading sepsis have been replaced for ever on the Western front by full and often final excisions. Hence this view now can be, and ought to

be, the universal one. And this outlook is the secret of success.

To the surgeon who so looks on the virgin wound which nature and the host are really anxious to close, asepsis is even more of a god than it was in his theatre at home. His operation is planned beforehand with the care and thought requisite for a possibly difficult procedure. The skin, on which rests the final visible proof of his good workmanship, is in the secondary suture preserved with the jealousy of the miser, and in a primary closure is removed with the thoroughness that eradicates rodent ulcer, so nice and so accurate becomes the generous but parsimonious balance. The incision is nowhere useless; its centre corresponds with the centre of the work, but as reckoned by ordinary war standards, it is almost appallingly long. Every part and pocket of the track is offered to his vision, and as his confidence in the certainty of early suture increases, so and at the same pace the number and length of his incisions grow and the exposure becomes automatically greater. Thought having been given to the blood supply cut off by the passing missile, the track disappears before the knife to a depth that is living and will live—it bleeds. Obstructing bridges of tissues are divided unhesitatingly with this knowledge of quick reunion, and the old operation of "removal of the foreign body" develops into an operation of some magnitude. The missile and the clothing come away buried in the tissues which surround them. Haemorrhage is arrested with more thoroughness than of old, and the toilet is as fairly finished as if the operator himself had broken the undamaged skin. Then, and only then, will all be well. Even if suture be impossible, a greater saving of life and limb will result. This is grandiose but not impossibly Utopian; it is a practical everyday affair to the surgeon who steadily preserves that outlook.

Depth of excision has always been cultivated, and after excising wounds in the usual way for nearly two years I attempted to stain the track. Since that first attempt, I have been of the opinion that formerly a complete surface excision of a deep and complicated muscle wound must have been for me a rare and happy event. Of course, by reason of important structures and the impossibility of invariably staining the whole track, complete excision is often impracticable, but the staining makes a more thorough removal possible, and also it indicates the points to which simple mechanical cleansing must be more particularly directed. When staining has been thought unnecessary, the final results have become immediately worse. In every case it is a help. It is never a hindrance, and the time expended on the actual staining is negligible. Certainly the operation is somewhat more prolonged, because the stain insists on a more thorough surface excision, and consequently multiple wounds demand multiple surgeons. At first I used a 1 per cent. watery solution of methylene blue, but later a ½ per cent. watery solution of brilliant green, for the sake of uniformity of material and its antiseptic action.

Wound Sterilization.

After complete excision, the problem resolves itself into the sterilization of a freshly infected surface. Here the first question was that of the antiseptic. Almost all available were tried, but the work of the Middlesex School in showing its peculiar antiseptic properties, its particular selective potency over the special organisms found in these war wounds, and more especially its fulfilment of practical requirements, has made me give whole-hearted support to brilliant green. But this is not all. I found that instillation of a watery solution of brilliant green through Carrel's tubes in wounds possibly incompletely excised sometimes resulted in a thin creamy yellow pus containing cocci; at this stage brilliant green, however applied, did no good; strong or weak solutions would neither sterilize nor affect the stationary condition of the wound. Dakin's solution, eusol, and other antiseptics would clear this up, suggesting the false inference that brilliant green was of inferior potency; and the simplest and one of the most effective of these complementary antiseptics was boric acid. And this might suggest that antiseptics suitably combined according to their predilection for the special organisms to be attacked might be of more value than the single antiseptic on which we commonly rely. However that may be, a combination of brilliant green and boric acid, suitably

applied, has proved of greater service than brilliant green alone. As has been stated by Webb, solutions of this dye give excellent results in the Carrel method of treatment. Solutions of the same strength by weight of brilliant green frequently possess different intensities of colour, and clinically it would appear that the antiseptic value varies with this intensity and not with the actual strength by weight.

Now the main principles of the sterilization of the wound are that the surfaces of the cavity shall be kept apart until the antiseptic has done its work, otherwise organisms will be imprisoned and spreading sepsis result; secondly, that fresh infections from without shall be impossible; and, lastly, that the local condition of the wounded part and the general condition of the patient shall be improved by providing rest in every sense of the word. And my second argument is that an adhesive preparation, which could be everywhere applied under an anaesthetic, which could remain active until the wound was sterile, and which could be removed when the wound was ready for suture, would best fulfil these requirements. Such a method reduces dressings to a minimum; the work of the medical officers, sisters, and orderlies can be diverted from the wards to the theatre, where all effort and assistance can be concentrated in the endeavour to make the first operation the last operation. The avoidance of dressings in the ward removes opportunities for daily reinfection, and early suture of the wound excludes it. Wounds are exposed for the purpose of diagnosis, rarely for treatment. As an ordinary example, with the paste to be described, a compound fracture of the humerus was looked at four times in four weeks—namely, at the operation of excision, on the fourth day for a smear count, on the fifth day at the operation of suture, and on the sixteenth day for the removal of sutures. The avoidance of pain and fear is no small matter.

A paste which would adhere to the freshly cut tissues in the presence of blood and effusion and which could be so prepared as to disappear in a given number of days, like hardened catgut, or which could be dissolved or removed at the operation of suture was required. But this healing balm has yet to be found.

Two years ago, and again later, amongst other methods I had worked at what I called the method of distension, which I will briefly relate simply as a blind alley of work. Here, after excision, the wound was primarily closed and the cavity made water-tight with two controlled inlet and outlet tubes. The wound surfaces were kept apart by light distension with various antiseptic fluid preparations until a normal temperature and pulse were reached, generally in a few days, when the tubes were removed and the sterilized surfaces fell into apposition. This primary suture was fascinating and was successful in primary amputations, excisions of joints, and in some fractures, but I discarded it because it was not safe, as no primary suture of a possibly highly infected wound can be.

The mucilages of tragacanth and acacia and gelatine had here been tried, but they would not adhere to the tissues satisfactorily for a sufficiently long period. Then Morison's bipp came into use and provided us with the best application we had seen. The results were startling, but it could be used only in small quantities on account of its poisonous effects; when very freely applied, blue lines on the gums, rapid pulses and high temperatures were not uncommon. Also slow or non-union of the skin edges was troublesome; this is commonly attributed to the liquid paraffin, but by altering its constituents it can easily be shown that the insoluble bismuth is the chief factor in producing this tardy union. However, bipp provided the requisites for the quality of adhesion—namely, the combination of an oily fluid and an amorphous powder. Experimentally, mixtures of the contents of the dispensary of a casualty clearing station and compounds obtained elsewhere were tested on raw beef in moving water, and in other ways, but nothing perfectly satisfactory has been reached. The media tried in actual practice have been varying mixtures of animal fats, suet, the hard and soft paraffins and soaps to produce pastes with requisite melting points, starches prepared in various ways, repetitions of the old mucilages, the heavy and light magnesias, calcium lactate and ordinary French chalk, liquid paraffin, olive oil and glycerin. None have been actually harmful; some could not be worked into the tissues, others remained unaffected in the tissues and could not be completely removed, and their

presence delayed healing, and others were absorbed too rapidly; none fulfilled all the requirements in the fresh wound, and, with the exception of the last five, they were definitely useless for the purpose.

Liquid paraffin and French chalk were most suitable, but, the latter being insoluble, a minimum quantity to make the paste adhere in the presence of wound fluids was determined; and this small amount does not appear to have any deleterious effect.

If necessary, the liquid paraffin can be replaced by olive oil; glycerin calls out so much fluid that it is only suitable for wounds which can be immediately closed or very rapidly sterilized.

The following paste was therefore made and is now the only one in general use:

Boric acid	...	...	...	11 oz.
French chalk	...	...	...	1 oz.
Liquid paraffin	...	...	...	8 fl. oz.
Brilliant green	...	...	...	17½ gr.*

* That is, 1 in 500.

The boric acid and French chalk must first be intimately mixed in a mortar, then the liquid paraffin worked in, and finally the brilliant green dissolved in rectified spirit. Considerable time and energy are required to avoid a paste with many isolated masses of boric acid. It is kept in jars and used chiefly from large syringes with very wide nozzle apertures or from grease pumps. Departures from the quantities and constituents of this paste have been invariably productive of worse results. If the chalk is omitted it will not adhere to any but the driest and freshest of wounds, and intimate adhesion to the tissues is an essential quality of a paste. No toxic effects have been observed.

TECHNIQUE.

Primary Operation.

After sterilization of the skin every endeavour is made to cover the wound track or surface with a one-half per cent. watery solution of brilliant green. In the case of a track this is done by injecting the dye through a metal or rubber tube of fine calibre, closed at one end like a Carrel's tube, and perforated by very many of the finest holes, so as to act as a spray; at the distal end are two rather larger holes to permit freer exit of the fluid. Tubes perforated for a distance of two, four, and six inches are used. A tube perforated for a suitable length is passed along the wound track, if possible up to the foreign body or fracture. The staining solution is then injected along the tube without force, so as to avoid opening cellular planes. Movement of the limb assists the insertion of the tube, and movement of the tube helps to a complete staining.

In the case of a surface wound, the syringe and occasionally gauze soaked in the fluid are used. At least two minutes should elapse before the excess dye is wiped away. Haemorrhage prevents staining.

The wound is then excised, using the stain as a guide. If a secondary suture is intended, only the damaged tags and a film of skin are removed, more will be cut away at a later date. Wide exposure and good visibility are essential for the removal of every particle of stained tissue; one or two incisions, each eight or nine inches long, are frequently required in a fractured femur. The excision proceeds systematically from the skin to the missile, which is removed last, preferably enclosed in its enveloping tissues. Irremovable structures are cleaned, and dirty bone is gouged. Only dry swabs or gauze soaked in spirit are used. A most scrupulous and exacting search for all bleeding points is essential.

The wound is dried throughout with spirit or 1 per cent. picric acid in spirit, and the paste is then rubbed into the tissues with all thoroughness into every recess. Five minutes may be so spent in extensive wounds. The syringe or pump is used to bring the paste to all deeper parts before rubbing it in, and later to fill the cavity to the brim. The deepest parts are treated first. Bone fracture areas are packed with it. Sutures may be inserted to bring together the skin edges which have been divided by the knife; with increasing experience more and more partial and complete primary sutures are done. Dry gauze dressing and firm bandages are applied, and splints are freely used.

After-Treatment.

Where the case progresses favourably—that is, where the temperature and pulse are descending, pain is slight or absent, and the patient is eating and sleeping well—the wound is not examined until the patient's general and local conditions suggest that the wound may be closed; in wounds of the soft parts this usually occurs on the third to the fifth day. It is impossible to give any rule as to the time for suture. Smear counts have generally been taken, and average reports of 0.2 to 2 organisms per field have been received. On the other hand, wounds with a greater number per field, even up to 9, have been intentionally and successfully sutured. It is really unnecessary to wait until the evening temperature is normal, but it is safer, and it is our usual practice. The clinical aspect of the wound and the patient's general condition are the best guides; in a patient possessing a sense of general well-being and local comfort, a normal pulse and temperature, a good appetite, and a good sleeping capacity, the wound, although glazed and green with the paste, but otherwise of good appearance and with no swelling, may be safely sutured; and experience shows that all of these requirements are not necessary. In a dubious wound or a fracture, smear counts are always made, and with cocci over four, or *Bacillus perfringens* anywhere, the case is left. If for any reason suturing is inadvisable and the paste originally put in has disappeared, the wound is repasted.

Where the case progresses unfavourably, the excision or the pasting has been incomplete, and repasting or further operative measures are required. Nitrous oxide anaesthesia is occasionally used for deep repastings in the ward. Re-filling with paste and hot fomentations are frequently sufficient, as the temperature and pulse may be slow in coming down although there is no sepsis.

The Suture of the Wound.

Under an anaesthetic the wound is gently wiped out, dried with spirit, and the skin edges freshened or further excised. A very thin film of paste is then everywhere rubbed in and the excess removed. Silkworm-gut sutures are used for the skin. Closure of the cavity, preferably by under-running gut or occasionally buried catgut sutures, is of great importance. There should be no tension on the skin; undermining followed by pasting can be safely done. Deeply running sutures have fine rubber tubes threaded on them. No drain is used with the exception of a minute one in a few fractures.

Primary Suture.

This is always done after pasting, where the wound has been completely excised without the blade of the knife entering the original wound cavity. It is frequently done in other cases and even in some minor bone injuries, but only experience with this paste can indicate the suitable ones; here the wound is filled with paste and only lightly sutured or else a very temporary drain is inserted. Primary suture will always be less safe than secondary suture, and the gain of two or three days and the avoidance of a short anaesthesia is not commensurate with the risks run in a case of the slightest doubt.

Abdominal incisions, head wounds, excisions of joints and other relatively clean wounds are pasted lightly in the absence of, and heavily packed in the presence of, a remaining cavity, followed by partial or complete primary suture as the case indicates.

All amputations in which flaps have been fashioned are filled with paste, particular attention being directed to the bone, and the flaps are apposed by two or three sutures; the closure is completed after wiping and slight repasting two or three days later when the pulse and temperature are normal. Flapless amputations are performed only in certain cases of gas gangrene or of extreme collapse.

RESULTS.

I shall not give any records; the staining and the paste are matters for trial by the individual surgeon. A strong, firm scar rapidly results; the skin unites well over a cavity such as is left by a pulped tibia. Extensive wounds of the buttock, and wounds complicated by division of large arteries or by fracture of any of the long bones, have been quickly closed. Fractures have been successfully sutured in three to five days, and wounds dividing muscle have been closed by partial primary suture with safety, which must be the outstanding feature of any method.

After the Carrel-Dakin treatment of any wound secondary suture can be safely and successfully performed at an earlier date and in the presence of a higher average field count if this paste is used.

It has also been packed into acutely inflamed cavities, such as in acute suppurative arthritis of the knee, with excellent results, but this has not been sufficiently tested to warrant a definite expression of opinion.

Where the foreign body has not been removed, I believe that pastes ought not to be used.

In conclusion, the case for complete excision must be again pleaded; it should begin and end all discussions on the wounds of war; without it, good antiseptics and this medley of pastes are almost useless in quickly healing the broken skin. Many good methods of sterilization have been doomed for want of it; a good paste will cover a multitude of sins, but ultimately the omissions will surely be found out. The pathologist has provided and is providing us with the means of sterilization, and now it rests solely with the surgeon as to whether the compound fracture shall become sterile in a few days or pass through months of continued suppuration.

My thanks go out to our consulting surgeons for their help and stimulation, to our pathologists and medical officers for innumerable suggestions in this and other work, and to the sisters for assistance in many practical details.

THE SPREAD OF INFECTION IN OPEN BONE, AND ITS BEARING ON THE TREATMENT OF PROJECTILE FRACTURE.

(Preliminary Communication.)

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This paper gives a brief review of certain features in the spread of infection through fractured bones, which we have observed when studying this problem at a base hospital in France.

Our methods of laboratory work and the precise details of our observations will be fully described elsewhere. Here it will be enough to say that the material used was chiefly obtained from freshly amputated limbs. The injury to the bone was accurately mapped out up to the furthestmost fissuring, and the spread of bacterial infection along the bone was ascertained by cutting the latter into series of sections, and taking cultures from samples gouged out at each level in succession. Blood cultures were made from the patient at the same time so as to control the possibility of any general septicaemia that might be present, because the latter would have confused our attempt to analyse the local spread of the sepsis through the bone from the original wound.

When pathogenic organisms are implanted into normal bone from the blood stream pus is produced at the site of implantation, and so long as the bone remains closed they spread along lines determined by its anatomical conformation, produce further pus, and ultimately lead to necrosis. Before the war the description of these processes and of the subsequent course of repair made up the bulk of the accessible information about the interaction of bacteria and bone.

It has long been a surgical platitude that if a bone in a condition of early acute osteomyelitis is opened up until normal looking bleeding marrow is reached, it will recover without incident beyond the separation of sequestra. In projectile fracture of the shaft of a long bone the wound itself establishes some drainage simultaneously with the introduction of the infective agent—that is, organisms are implanted on to the surface of a widely open marrow, and although the complexity of the cavity and rigidity of its walls renders perfect drainage of the bone wound an unrealizable ideal, yet the conditions on any given surface of exposed marrow are adequate to prevent that spread of the inflammatory process which leads to pus formation in a closed bone.