the empty stomach was found to be flattened out over the front of a greatly distended lesser sac. This exploratory wound was therefore closed, and an incision was made in the back of the left loin immediately below the twelfth rib. On opening the lesser sac by this route four or five pints of clear fluid gushed out, followed by a little pus. On digital exploration of the lesser sac a fragment of the copper band of a shell, 1 in. in length, was found lying free in the cavity, and was easily removed. The loin wound was drained.

Captain G. E. Loveday, R.A.M.C.(T.), examined a specimen of the fluid and reported that it contained both trypsin and amylopsin.

After-History.

The patient made a somewhat slow recovery, and vomited for some ten days after operation. He then improved more rapidly, and after a change to an auxiliary hospital was discharged as fit for general service.

[I am indebted to Colonel F. H. Westmacott, A.M.S., Officer Commanding 2nd Western General Hospital, for permission to record this case.]

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THE TREATMENT OF INFECTED WAR WOUNDS BY MAGNESIUM SULPHATE.

BY

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CAPTAIN W. J. TULLOCH and I have recently[1] described the treatment of infected war wounds by a concentrated solution of magnesium sulphate. In these articles we claimed as advantages for this dressing:

(*a*) Its cheapness, ease of application, and infrequent and painless renewal.

(*b*) That it is not easily absorbed and therefore gives rise to no constitutional disturbances.

(*c*) That it induces the growth of firm, compact, bright red granulations, interferes with the proteolytic activities of the discharges, and stimulates the growth of epithelium.

(*d*) That the magnesium ion has a decided inhibitory action on the growth of at least two of the organisms commonly present—namely, streptococci and *B. coli*—has also a less evident effect on the development of staphylococci, and a slightly inhibitory action on the propagation of the *B. pyocyaneus*.

General Principles of Wound Treatment.

The ideal method of wound treatment in military surgery has yet, I think, to be found, but, in order to discover it and to make it efficient, certain general principles must be considered.

1. The application must be easily carried out and readily applied.

2. Once dressed, it should be possible to leave the wound untouched for some time—that is, until the patient can receive more individual attention, or for such a period that he can be transferred from the field ambulance or casualty clearing station to a base hospital in France or England (about one to seven days).

3. Its action during this period should be continuous, and it should from the first exercise a beneficial effect upon the wound, so that on arrival at the base hospital sepsis should be either abolished or so inhibited that the health of the patient has not deteriorated, and so that further treatment may not be prolonged by dealing with conditions which were preventable.

4. As a necessary corollary to these principles it follows that all special apparatus used for flushing wounds should be abolished, thereby saving much time and labour to the members of the surgical and nursing staffs and much discomfort to the patients; special splints for the immobilization of each fracture would be unnecessary, and a return made to the simpler and more easily applied apparatus in general use for fractures, because the first dressing applied to the wound could remain untouched for several days.

Stages of Wounds.

In dealing with these wounds the two important stages through which they pass are to be borne in mind:

1. *Processes of disintegration* are set up immediately on receipt of the injury. As a result of trauma the wound passes through various stages of molar or molecular gangrene, the tissues which have had their vitality too seriously sapped die and are cast off, and in so doing they become a medium for the development and growth of organisms. Treatment applied to the wound at this stage should have as its object cleansing the wound, getting rid of the sloughs, limiting sepsis, and preventing the proteolytic activities of the wound exudate as much as possible. This stage requires attention in the field ambulances and casualty clearing stations soon after the receipt of the injury and often under disadvantageous circumstances. When large numbers are passing through the surgeon's hands and accommodation is limited it is impossible to treat them on ordinary lines so thoroughly as is desirable. All that may be possible is to apply some dressing which will protect the wounds and diminish the chances of infection until greater individual time and attention can be given to them further behind the firing line.

The important point to remember is that if this part of the treatment is not carried out early, and with great efficiency, this first stage in the process of repair will be prolonged and rendered more serious.

2. *The phenomena of repair*, which begin when the processes of disintegration have been completed. Any substance applied to wounds at this stage which may interfere with the living leucocytes and prevent their phagocytic activities is to be avoided, and only those selected which will have a prohibitive effect on the proteolytic processes, and stimulate epithelialization of the wound. When this stage has been reached the patients should have arrived at the base hospitals, where more individual attention can be given. It is now, however, rarely that patients are transferred to the hospitals in England in this state. It more commonly happens that Stage 1 in the treatment of their wounds has to be continued on their arrival, and the condition of the wounds, if not worse because of increased infection, is quite as bad as when they were inflicted some days previously; they are discharging pus freely, and bacteriological examination immediately on arrival in the hospitals in England as a rule shows that all the pyogenic organisms usually found in infected wounds are present in abundance. The treatment of war wounds, therefore, resolves itself into two stages: (1) the cleaning of the wounds, (2) the encouragement of healing.

Antiseptics, and especially pure carbolic acid, have a limited scope. They may arrest sepsis so long as the organisms have not gained an entrance into the deeper tissues—that is, they must be applied very early after the infliction of the wound; they prevent the formation of toxins, but at the same time so affect the vitality of the tissues that a further field is provided for the development of organisms for whose destruction they had been employed.

The most satisfactory method of treatment during this stage is the employment of some form of more or less constant lymph lavage, or continuous irrigation with fluids that will prevent the absorption of toxic products while not interfering with phagocytosis. It is on these lines that most of the recent treatment is based—for example, Wright's hypertonic (salt) solution, eusol, Carrel-Dakin method, etc. These methods of irrigation not only get rid of the discharge by flushing, but, what is of equal or more importance, the wound is allowed to remain open, or is enlarged to allow of the free escape of the products of disintegration and sepsis.

Magnesium Sulphate Cream.

During the past year we have been using in our wards a preparation of magnesium sulphate, made of the consistency of cream, as soon as the patients arrive in hospital. To make the conditions as closely as possible resemble those that exist in a casualty clearing station, about a hundred cases were dealt with as follows:

The dressings with which the patients arrived in hospital, most of which were applied from two to five days previously, were removed. A culture was taken by Dr. Helen Clark of the organisms—aërobic and anaërobic—present in smears from the wound, and without any preliminary cleansing of the wound itself or of surrounding parts; magnesium sulphate cream was then applied to the wound under a suitable dressing. The dressing was left untouched for from three to ten days. Bacteriological and clinical examination was then made of the discharges and

the wound. The results have been such as to encourage me to report the technique and results of this treatment.

The following cases, treated in one or other of the war hospitals in Sunderland, are typical of those submitted to this treatment.

CASE I.

J. McL.; gunshot wound of left leg, October 23rd; admitted November 6th, 1916. A large wound at the back of the calf, at the bottom of which a fracture of the tibia and fibula could be seen. This wound communicated with a smaller wound on the inner side. The temperature was 101.4° and the pulse 98. The wounds, which were dirty and discharging pus freely, were dressed with magnesium sulphate cream. On November 9th the temperature was 98.4°, and the wounds, which were then dressed, were much cleaner. On November 11th they were covered with bright red granulations. By December 4th the wounds were much smaller, the through opening had closed, and on December 20th the granulations were level with the surrounding skin.

CASE II.

J. B., aged 21; gunshot wound of left wrist. When admitted the left wrist and hand were swollen and there were two wounds, one over the lower end of the radius and the other in the palm close to the styloid process of the ulna. The edges of the first-named wound were ragged and necrotic and there was a purulent discharge. The temperature was 100.2°. *X*-ray examination showed a longitudinal fracture of the radius into the wrist-joint. The wounds were dressed with magnesium sulphate cream and an anterior splint applied. When dressed on November 15th there was a little serous discharge and the surface of the wound was covered with lymph, underneath which were healthy granulations. On November 21st the wound was covered with bright red granulations, and on January 4th, 1917, it was healed save for a sinus leading down to the necrosed bone, which was removed, under an anaesthetic, with a sharp spoon. On April 30th the wound was superficial and almost closed.

CASE III.

H.; gunshot wound of foot, October 22nd, 1916; admitted November 1st, with a lacerated wound midway between the two malleoli over the dorsum of the foot, extending inwards and downwards towards the scaphoid bone. The wound was discharging pus freely and the surrounding skin was swollen and red. Bubbles escaped on pressing the edges slightly. Bacteriological examination of the pus by Dr. Helen Clark showed *B. perfringens*, staphylococci, streptococci, and Gram-negative bacilli. *X*-ray examination showed a large foreign body in the scaphoid bone which was easily removed under a general anaesthetic. The cavity was cleaned with methylated spirit and dry gauze, and filled and dressed with magnesium sulphate cream. When dressed on November 11th it looked healthy, and the magnesium sulphate cream was reapplied. On November 20th there were only two granulating spots, and the wound, which had almost healed, was dressed with boric ointment.

CASE IV.

P.; gunshot wound of right foot, October 21st, 1916; admitted November 1st. The skin over the lower third of the leg was red and brawny and discoloured as high as the knee. There were two incisions about five inches long on the dorsum of the foot, and another along its outer border, which seemed to be an enlargement of an original wound in front of the external malleolus, which was packed with gauze. Behind the external malleolus was a deep lacerated wound with a small drainage tube. There was a copious discharge of foul pus from the wound track below and in front of the malleolus. There were two longitudinal incisions, one on each side, in front of the ankle and in front of the lower part of the leg. Bacteriological examination of the pus showed streptococci, staphylococci, and *B. coli*. *X*-ray examination showed a fracture of the astragalus and a foreign body lying in or internal to the bone. Under a general anaesthetic the wounds were cleaned, the foreign body removed, and the foot and leg dressed with magnesium sulphate cream. When dressed for the first time, seven days later, the incised wounds were all looking healthy, but there was sloughing of the edges of the original wound and a good deal of sero-purulent discharge. On November 15th the wounds were all looking clean and were dressed again with magnesium sulphate cream. A superficial abscess on the outer side of the leg in its lower third was opened on November 22nd, mopped with dry gauze, and filled with magnesium sulphate cream. On December 20th an abscess was opened on the inner side of the foot and about 3 oz. of pus evacuated. The cavity was found to communicate under the tendo Achillis with the wound just behind the external malleolus. It was mopped out with dry gauze and filled with magnesium sulphate cream and closed with silkworm gut. When dressed on January 1st, 1917, the wound looked healthy, and on January 12th all wounds on the outer side of the foot and leg were healed. Those on the inner side were closing rapidly. On January 22nd all wounds were healed.

CASE V.

G. R., aged 44; gunshot wound of right knee, April 9th, 1917. When he came under my care, on May 12th, the evening temperature varied between 102° and 104°, and he was complaining of great pain in the knee and sleeplessness. There were two through-and-through wounds on each side of the patella and two incised wounds above into each side of the subcrural pouch. In each wound there was a drainage tube. On that day, under a general anaesthetic, a horseshoe incision was made round the patella dividing the ligamentum patellae. On opening the joint pus gushed out. The knee was bent to its full extent, washed out with ether, and filled with magnesium sulphate cream. Plentiful dressings of cotton-wool and sphagnum moss were applied. The wound was dressed every third day with magnesium sulphate cream until the 25th, when, his temperature having been normal for three days and the discharge having ceased to be purulent, the patient was again placed under an anaesthetic; the joint was then washed out with methylated spirit and bipped. The entire wound was sutured, the ligaments, including the patella, with catgut, and the skin with silkworm gut. The patient's progress was uninterrupted, and he was discharged from the infirmary on September 14th, 1917, with his knee-joint movable about 15 degrees, and he was able to bear his full weight on the leg.

CASE VI.

C. L.; gunshot wound of back, October 28th. When admitted, on November 6th, 1916, there was a large gaping wound about six inches long over the left scapula, dividing the latissimus dorsi and partially the infraspinatus muscles. It was dirty and discharging pus freely. Magnesium sulphate cream was applied without previous washing of the wound. On November 12th, under an anaesthetic, the wound and surrounding skin were cleansed with petrol, the edges of the wound excised, and the refreshed margins undermined and brought together with silkworm gut passed through pieces of drainage tube after the cavity had been filled with magnesium sulphate cream. When dressed, five days later, the wound looked healthy and the discharge was serous. On November 24th, when the sutures were removed, there was very little gaping and healthy granulations covered the linear margins. On December 18th the wound was soundly healed and the movements of the arm were good.

Preparation of Magnesium Sulphate Cream.

The cream is prepared in the following manner:

1.5 lb. of magnes. sulph. exsiccatum are mixed with 11 oz. of glycerin acid. carbolic. (1 to 10). The dried magnesium sulphate is in the form of a fine white powder, which contains 12 per cent. less water than the ordinary. The glycerin acidi carbolici is put in a hot mortar and the sulphate added, slowly stirring and mixing with a warm pestle all the time. The result is a thick white cream, so hygroscopic that if exposed to the air it rapidly absorbs moisture and becomes fluid. It must be preserved in a covered jar. The carbolic acid was first added for its analgesic properties, as it was thought that this application without it would be painful. We have found this precaution to be unnecessary, as the only discomfort of which the patients complain when carbolic is not present is that the cream feels cold for a short time after its application.

The wound is packed and thickly covered with the cream, and the dressing of gauze and cotton-wool is left unchanged for from three to eight days. A profuse discharge of serum takes place, so that more wool may have to be applied over and around the original dressing. On removing the dressings, any discharge there may be is sero-purulent, escapes easily, and the wound surface is covered with bright red granulations, filmed over by a thin layer of greyish lymph containing a few pus cells. A similar dressing is again applied spread thickly on gauze. In the case of deeper wounds, such as fractures, the cream is syringed into the deepest part of the wound by passing a piece of drainage tube attached to the syringe into it, and filling the wound with cream. More cream spread on gauze is applied to the surface of the wound.

After a few dressings in this manner, in the case of superficial wounds, a bright red granulating surface presents, covered by a greyish film of lymph. The dressing is now changed to magnesium sulphate solution for a few days, when the edges of the wound are either brought together with sutures, or skin grafts are applied under local anaesthesia.

In deeper wounds where a fracture is also present, after three or four applications of the cream, at intervals of three to four days, the patient is anaesthetized, the wound is freely opened up, loose pieces of bone are removed, it is washed out with ether or petrol, then dried with gauze mops and smeared thoroughly with bipp or X.Y.Z. paste.* The deeper layers of the wound are brought together with catgut sutures, and the skin edges with retention sutures of double bipped silk passed about 1 in. from the margin and tied over a dossil of gauze on each side spread with one or other paste. In some cases, before the sutures are tied, the cavity is filled with magnesium sulphate cream. The sutures prevent a too rapid escape of the magnesium sulphate cream by osmosis.

The guides to closure of the wound are bacteriological findings of the discharge and the amount and clinical

* Xeroform (bismuth tribromophenol), hydrarg. ammon., of each equal parts; paraffin. liq., to make a paste.

nature of it. As soon as the bacteriologist reports a marked diminution in the number and character of the organisms present, and we find an almost complete absence of purulent discharge, the wound is closed. Bacteriological examination of the discharges is made from each dressing when it is removed, and I am indebted to Dr. Helen Clark, bacteriologist to the Northumberland War Hospital, for her valuable assistance and help in this matter.

In a previous paper on magnesium sulphate solution it was claimed that this dressing produced firm, compact granulations, and also that rapid epithelialization of the wound took place under it. There is no doubt that under the concentrated magnesium sulphate cream the granulations are not so vascular and firm as with the concentrated watery solution, and moreover are covered by a layer of lymph, and that the epithelium from the edges of the wound does not close in so rapidly. This is what would be expected in an application which has so powerful an influence in controlling sepsis. Abscesses, if opened by a small incision, their pus contents evacuated, and cavity mopped out with gauze, filled with magnesium sulphate cream, and closed by sutures, generally heal with one or two dressings. Wounds, however, especially those of long standing, that have become sluggish do heal up under it. As would be expected in the presence of a preparation whose main claim is the production of profuse lymph lavage, those wounds do best which have no dependent counter-opening and which can be filled with the cream.

Conclusions.

Magnesium sulphate cream presents the following advantages:

1. Simplicity of application and the rapidity with which large numbers of cases can be dealt with—as in field ambulances and casualty clearing stations.
2. The infrequency of dressings, which even in the most septic cases need no change from three to eight days.
3. The combined osmotic action and the inhibitory effect on the growth and development of such ordinary organisms as are usually found in wounds—aërobic and anaërobic—together with its non-toxic action on the patient, make this a valuable dressing in the first stage of wound treatment, where the aim is to get rid of sphacelated tissue and minimize sepsis.
4. Its sphere of action as a rule ceases after the first stage, because epithelialization is inhibited and granulation tissue formation delayed as soon as the wound has been cleansed.
5. In the second stage of wound healing, that is, the encouragement of repair, other remedies should be employed, though it is useful with chronic sinuses or wounds which require stimulating.

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POST-OPERATIVE THROMBOSIS AND EMBOLISM.

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IN a discussion some years ago at the Royal Medical and Chirurgical Society, upon the complications following appendicectomy, I called attention to a possible cause of embolism, and suggested a remedy. In view of the interesting communication from Dr. McCann (March 9th, p. 277) it may be worth while to recall some of the observations.

All will agree with the sound conclusions as to technique enforced by Dr. McCann, and it is, I expect, to improvements in this regard rather than to any detail in ligature that the diminished incidence of the complication is to be attributed. Once sepsis has begun, its spread would be encouraged by bruised tissue, which is a soil favourable to the growth of bacteria. Herein lies, I take it, the truth of Dr. McCann's theory. Careless division of vessels, leaving parts poorly nourished, will determine extension of sepsis in an amputation, but in this, as in the special field alluded to by Dr. McCann, the primary step is a certain degree of sepsis introduced at the operation. That this may be an auto-infection cannot be altogether denied, and the experiments on *bistournage** by Chevalier give support to Dr. McCann's views. It will be remembered that, while a mild illness occurred in rams inoculated but not injured, those in which the spermatic cord was twisted all had gangrene at the site of injury and all died.

It is only on such a basis that we can explain the many cases of local phlegmon, of all degrees of intensity; the acute periostitis in young people resulting from a slight injury; and the acute psoitis following a strain. It is an injury that determines a joint infection in septicaemia. During this war acute suppuration of the knee has been seen to follow the manipulation required to deal with a septic compound fracture of the femur, and again of the ankle-joint under similar conditions. One of the most tragic cases coming under my notice was that of a surgeon who had scratched his finger while operating on a septic case. The injured part healed in two or three days, and he was apparently quite well and discharging his duties. He reached up to pluck a flower, and felt a "rick" in his "shoulder"—that is, vaguely; it might have been in one of the muscles. Four hours later he had a rigor, and an acute phlegmon developed in the pectoralis minor, from which he nearly died. This was a true replica of Chevalier's experiment.

If there be these acute auto-infections, so there are the milder varieties, and however perfect our technique may be, it must occasionally happen that we operate upon a patient in apparent health, yet in whom a septic infection of the blood is present. So long as the infective agent is within the endothelial-lined vessels the individual is protected, and the blood ultimately deals with and destroys the bacteria or neutralizes the products of bacterial life. Once this endothelial barrier is broken, as in the instance above related, by a rupture of muscle fibre, the infective agent escapes, and multiplies in the bruised tissue, the small blood clot, and the unprotected normal tissues. While we must be very careful in admitting such an explanation—one altogether too comfortable to the surgeon—we cannot exclude the possibility of such an occurrence. The practice adopted by many of having the patient in bed and under observation for a few days before operation is a wise precaution, and fully justified in the light of such events.

It remains to consider whether we can adopt any means of limiting the extension of the thrombosis. The disaster has occurred chiefly where primary union has taken place, and where none of the ordinary clinical evidence of sepsis has been manifest. It is, however, just in mild phlebitis that the detachable clot is formed. Where a vigorous sepsis occurs, with even double thrombosis and oedema of the legs, the clot is adherent and not likely to be detached. Looking back on the course of a case where uninterrupted recovery has followed, say, a simple appendicectomy, with no disturbance of temperature or pulse worth recording, small changes in the general condition of the patient will be recalled. There has not been the romping recovery, the subnormal temperature, the strong relish for food, the alert mental outlook one is accustomed to see. Small evidences of a disordered organism may be recalled, too slight to be recorded by the thermometer, or to affect a change in pulse rate. The pulse lacks tension, the blood pressure is probably low, sleep is not sound and prolonged, the mind is easily tired, and other small departures from the normal can be recorded. Finally, the patient is moved to a sofa or sits up, and then the oedema of the foot and ankle is discovered. At one time I made it a rule to examine the upper part of the thigh, where oedema shows itself in the recumbent position, before allowing the patient to get up. More than once it has been present. It is well to do this when the slight symptoms mentioned are present in a case where the wound runs a normal course.

It is a common observation that post-operative pulmonary embolism is seen only in connexion with operations on the abdomen. The inguinal canal and scrotum, as well as the rectum, must be included in this region. After an operation for inguinal hernia in a lady, a severe embolic attack occurred, through which she struggled for twelve hours, with great dyspnoea, cardiac pain, and cyanosis. A second attack followed the next day, and from this she also recovered. After a radical cure for

* That is, sterilization by torsion of the spermatic cord.