access of the antiseptic, constantly renewed, and free escape of the discharges are essential to clean and quick healing.

One of the old fashioned and one of the most successful methods of cleansing the dirty sloughing wound is by constant immersion and irrigation in a bath. For wounds of the hand and forearm, of the foot and leg, this procedure is very simple; but in wounds of the thigh, body, or chest it is difficult or impossible. It is not a matter of any importance as to the antiseptic used in the water; salt solution, a weak solution of carbolic acid, potassium permanganate, or tincture of iodine, all give the same results.

In the treatment of all gunshot wounds where the septic processes are raging, and the temperature varies through several degrees, an immense advantage will accrue from placing the patient out of doors. While in France I developed a great affection for the tented hospitals. There is great movement of air, warmth, and comfort; when a sunny day comes the side of the tent may be lifted and the patient enjoys the advantage of open-air treatment. Major Adye-Curran was the first to convince me of the striking effects caused by exposing uncovered septic wounds to the air and the sun. Wounds which were sullen in healing quickly brightened and became clean. Even in the winter and in Leeds and Sheffield we have some patients out of doors day and night. On Monday last I saw at the 3rd Northern General Hospital with Lieutenant-Colonel Connal a row of beds in the open occupied by ruddy, happy men with quickly healing wounds. I asked many of the patients how they liked the exposure, and all at once replied that they were quite happy and "wouldn't go inside to sleep if they could help it." I am confident we do not sufficiently take advantage of the immense help which open-air treatment can give to patients suffering from the serious wounds of war. I find that wounds clean more rapidly, patients sleep better, eat better, and feel better when they are kept out of doors night and day. The vagaries of the temperature chart need not influence our decision as to the wisdom of this treatment. Many years ago I learnt at Johns Hopkins Hospital that a high septic temperature was an indication for moving the patient on to a balcony rather than a reason for dreading the effects of exposure.

I cannot properly omit mention of the vaccine treatment of patients suffering from septic wounds. It is remarkable to find such widely divergent opinions among physicians and surgeons as to the virtue of a vaccine in any disease. When opinions are so wide apart, so confidently expressed, and so utterly irreconcilable, it is probable that opportunities for judgement are not identical. The changes in wounds are often so swift when any one of the recognized modes of treatment is tried, or indeed when little of value is done; a vaccine when tried is so often only one of several agents brought to bear almost at the same moment upon the patient and his wound; degrees of change in a wound are so difficult to express in terms of accuracy, and their appreciation depends so much upon the desires and prejudices of the observer, that argument and experience are alike fallacious. But no one can deny, I think, that a case has been made out for the trial of vaccines in appropriate cases, and in suitable conditions. The principle of the vaccine method is, of course, to fortify the blood serum in respect of those bodies which are inimical to the development or to the life of an invading micro-organism. If, therefore, a wound is imperfectly drained or not properly dressed, the administration of heroic doses of the most potent vaccine is merely futile. When, however, a wound is well drained and there is a free access of serum to the wound, with a free opportunity for its discharge into the wound and of rapid escape from it, then it would seem reasonable to suppose that the more potent the bactericidal power possessed by the serum, the greater will its effect be in causing the wound to clean and to heal. This suggests that the vaccine treatment, in conjunction with the application of Wright's solution, will be likely to give the best results. Of the great value of the streptococcus vaccine in the serious wounds of this war I am thoroughly convinced, and I have no doubt whatever that advantage would be gained by a freer use of it in cases of infection with this most obdurate organism. So much has reference to the therapeutic use of these agents.

Their prophylactic virtues, if they possess any, have not yet been given a full trial in this war. It would be interesting to watch the effects of vaccines given before a man goes into action, or to a man immediately after his wound is inflicted. But the factors at work are so many, so variable from time to time, from place to place, and from man to man, that the scrutiny of inoculated cases would require powers of analysis denied to most of us. Sir Watson Cheyne, the redoubtable champion of the antiseptic methods—and, indeed, one of the earliest and most successful pioneers of modern surgery—has suggested that bacteriologists have a very great opportunity at the present time, and that they may profitably be employed in raising the immunity of new recruits against all the ordinary bacteria which occur in wounds received in war time.

One of the most sensational experiences in connexion with all wounds, even the most trivial, is the inordinate length of time that micro-organisms may remain dormant in the tissues long after healing is complete. I have seen tetanus and gas gangrene develop in wounds many weeks after their infliction when relatively trivial operations were performed upon them for the purpose of extracting bullets, shell-casing, or fragments of khaki cloth. Even the passive movement of a stiff joint, in whose neighbourhood there is a healed wound, may light up a raging septic process which threatens or takes the patient's life. It appears to be more especially in cases where compound fractures of bones have occurred at the primary injury that these grave troubles are apt to arise. A knowledge of the danger must warn us always to be on guard against premature surgical interference in wounds recently healed, or in sinuses which fail to close.

REFERENCES.

¹ BRITISH MEDICAL JOURNAL, 1915, ii, p. 318. ² *British Journal of Surgery*, 1915, iii, p. 276.

REMARKS ON DELAYED TETANUS.

THREE CASES, IN ONE OF WHICH GAS GANGRENE
DEVELOPED SEVENTY-THREE DAYS AFTER
A WOUND.

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At the 2nd Birmingham War Hospital we have had the unusual experience of three cases of tetanus occurring respectively fifty-one, fifty-three, and forty days after suffering wounds, the three cases being under treatment simultaneously.

CASE I.—*Tetanus with an Incubation of Fifty-one Days.*

Private M., aged 20, wounded August 20th, 1915, by shrapnel in the left shoulder and lower lumbar region of spine. The injured parts were treated immediately by iodine, and two hours later the patient was given a prophylactic dose of antitetanus serum subcutaneously. A few days later bits of shell were removed from the lumbar wound.

When he was admitted to the 2nd Birmingham War Hospital, on September 20th, the shoulder wound was found to be healed; the lumbar wound was suppurating, and a radiograph showed fracture of the body and transverse process of the fifth lumbar vertebra, but no foreign body. There was threatening of suppurating in the right axilla, and four days later a considerable amount of pus was evacuated from this region.

On October 10th he experienced difficulty in opening his mouth; some days later rigidity was noticed in the muscles of the back and in the sterno-mastoids.

I first saw the patient on October 30th; he was then sweating rather profusely, risus sardonicus was well marked, the masseters and sterno-mastoids were only slightly rigid, the belly muscles were very rigid; there was no distinct opisthotonos, though the muscles of the back were rigid. Antitetanic serum was at once given subcutaneously and continued until November 11th, when the tetanic symptoms had practically disappeared; altogether 37,500 units of the serum were given.

The symptoms in this case were much less severe than in the two about to be recorded.

CASE II.—*Tetanus with an Incubation of Fifty-three Days.*

Lance-Corporal M., aged 22, was wounded on September 25th, 1915, by a bullet which passed through the left forearm, fracturing the radius and ulna, and by another bullet in the upper part of the right arm. A dose of antitetanus serum was given subcutaneously two days later.

On admission to the 2nd Birmingham War Hospital on October 1st, 1915, the forearm wound was healing well; the

wound in the upper arm was suppurating. On November 13th a tiny fragment of cloth was removed with a probe, and later a piece of the casing of the bullet was removed with a fragment of cloth wrapped up in it, as shown in the drawing. Cultivations taken from this under anaërobic conditions failed to grow the tetanus bacillus.

The casing of the bullet is shown with a piece of cloth through it like a wick. The case entered base first.

On November 17th there was marked stiffness of the neck and back and inability to open the mouth freely. The sterno-mastoids and the muscles of the abdomen were rigid; he was sweating profusely. The temperature was 98° F.; 3,000 units of antitetanus serum were injected subcutaneously and repeated at first every six hours.

During the next few days the symptoms were very severe, difficulty in swallowing was pronounced, spasms were severe, sweating was profuse. An erythematous rash appeared twenty-four hours after the first injection; this was a source of much inconvenience to the patient, and he also experienced a good deal of discomfort in his joints on the tenth and following days. By November 25th a distinct improvement in the tetanus symptoms had occurred, and after this there was no real anxiety as to the patient's condition.

On December 4th, when the doses of serum had been reduced to two in twenty-four hours, a fresh lot of serum caused a recurrence of the rash. On December 8th all symptoms had disappeared. The records show that the temperature at its highest was 102° F., the quickest pulse-rate was 138, and the total quantity of serum given was 153,000 units.

CASE III.—Tetanus with an Incubation of Forty Days, followed by Gas Gangrene Seventy-three Days after Injury and Forty-two Days after the Wound had Healed.

Private S. was wounded in the right upper arm on September 25th, 1915, a flesh wound only. He was admitted to the 2nd Birmingham War Hospital on October 1st and transferred to a convalescent home on October 27th. The case paper states that the wound was then healed. There was no evidence that a prophylactic dose of antitetanus serum had been given.

On November 3rd he complained of pain in the shoulder and back, but was up and about. The next day he was confined to bed, as he complained of difficulty in swallowing and of stiffness of the lower jaw.

On November 8th he was sent back to the hospital. The note then made states that the reflexes generally were increased and ankle clonus was elicited; the muscles of the jaw, neck, back, and abdomen were very rigid; the tongue was occasionally bitten, the right arm was rigid, clonic spasms and slight opisthotonos occurred occasionally, sweating was profuse. Antitetanus serum (3,000 units) was given subcutaneously and repeated every six hours. Bromide and chloral were given by the mouth.

On November 10th the pulse was very rapid and weak; respirations 40. He had had no sleep until morphine gr. ½ was given subcutaneously; this was followed by three hours' sleep. During the following days the records gave alternating accounts of slight improvement and relapses, but the patient was extremely ill and frequently delirious; the pulse varied from 100 to 160, the temperature from 100° to 104.5° F.

On November 18th the tetanus symptoms were much less marked and the amount of serum given was diminished and finally stopped on November 29th, when the patient had recovered from tetanus. He received altogether 189,500 units.

On November 30th there was dullness and crepitation at the base of the right lung, and on the same day a small abscess was discovered in the right thigh, from which a streptococcus was cultivated.

During the next days the patient improved somewhat, as did the physical signs in the lung, but on December 5th the temperature rose to nearly 104°, the pulse was 120, the tongue was brown and dry, and the patient was generally delirious. On December 6th the conditions remained practically the same, but it was noted that the base of the right lung was almost clear and that the scar of the wound was unaltered. On December 7th the note was, "Much the same, scar unchanged." On December 8th he was very delirious, at times unconscious, the scar was distended and livid, with brown discoloration around, the shoulder region was tympanitic. Free incisions let out stinking gas, but very little discharge; the tissues were quite insensitive when incised. The patient died early on December 9th.

For the clinical notes I have to thank Major Housman, R.A.M.C., Dr. Archer, and Dr. Foster.

Pathological Report.

The following pathological report is by Dr. C. J. Lewis, visiting pathologist to the hospital, to whom I am greatly indebted for the trouble he has taken in investigating the bacteriology of the case.

At the autopsy subcutaneous emphysema was found over the whole of the chest and neck, the lungs were densely black and

emphysematous, the spleen was enlarged, black, and semi-gangrenous at the upper part.

On December 6th, 1915, a specimen of pus from the (right) thigh yielded *Streptococcus pyogenes* in pure culture.

At the post-mortem examination cultures were made from the spleen and from the gangrenous area near the right shoulder. The former yielded the streptococcus and the latter an anaërobic bacillus in addition to the streptococcus. This bacillus belonged to the type of organism described sometimes as *B. perfringens* and sometimes as *B. aërogenes capsulatus*. It was identified by its morphology and staining reactions, by the characters of its colonies, by the odour of its cultures, and by the rapid production of much gas.

Deferred or latent infections are always of great interest. They occur in infections of the most diverse kind, but are more common perhaps, or at all events more frequently recognized, in tubercle and are less common in connexion with organisms which develop quickly. In carcinoma we occasionally see something parallel to the development of latent infection. Many years, ten or more, after the excision of a carcinomatous breast and when the absolute cure of the patient seemed assured carcinoma may develop in the supraclavicular lymphatic glands. The explanation can only be that for a very long period cancerous emboli have existed in one or more of the glands, have been kept in check but not killed by the resistance of the surrounding tissue or by something circulating in the blood. Then, owing to some alteration in the patient's resistance, the embolus starts growing vigorously, and a fatal process of disease is established. What the circumstances are, what the particular factor is which activates the disease, whether in recognized bacillary infections or in malignant emboli, we are often unable to recognize, but sometimes we are provided with a striking illustration which almost resembles an experiment in a laboratory. The following is an example. A young girl suffered from typhoid fever, and experienced an osteitis of the lower end of one radius. This subsided and the patient worked regularly in a factory for five years, then went for a day in the country on a bank holiday, dressed without regard to the weather, and was, early in the day, soaked to the skin, and so remained until the end of the day. She was indisposed as the result of the chill thus sustained, and a few days later the forearm became painful and swollen. On admission to the General Hospital, five weeks after the incident above related, the lower part of the girl's forearm was found to be swollen and tender, the skin over the radius was red, and fluctuation could be detected. Pus was evacuated, a sequestrum the size of a horse-bean removed from the radius, and cultivation gave a pure culture of the *Bacillus typhosus*. The organism in this case appears to have been activated, after five years of quiescence, by changes in the general body tissues induced by chill, rather than by changes in the locality, for there was no evidence of local injury. It is a commoner experience to find that local damage activates the infection; this is especially true of injuries in the neighbourhood of joints, and may be true in some cases of tetanus in which operation, in the presence of the tetanus bacillus, hitherto not recognized by its clinical effects, has been followed by the development of the disease.¹

To return to the cases I have related. It is certain that two of the patients received each a prophylactic dose of antitetanus serum; in the third case it is uncertain whether a similar precaution was taken. A point of great interest arises: May a prophylactic dose delay the onset of tetanus by directly influencing the growth of the infective organism and so reduce its virulence that it only shows its clinical effect under some special condition favouring more vigorous growth? Or alternatively, does the antitoxin given prophylactically neutralize the first formed toxin and so prevent the development of clinical symptoms, despite the growth of the infection, until all the antitoxin has been saturated? Some light may be thrown on these questions by scrutiny of the cases of delayed tetanus furnished to the War Office, especially if the statistical report is supplemented by experimental observation on animals.

The occurrence of gas gangrene seventy-three days after the infliction of a wound and forty-two days after the wound had healed, appears to be unique as far as I can learn by inquiry and such search as I have been able to make in current literature.

My impression is that the *Bacillus perfringens* was activated by the association with it of a streptococcus in

a subject exhausted by a severe attack of tetanus which, though recovered from, had made a deep impression on the patient.

REFERENCE.

¹ Dean and Mount, BRITISH MEDICAL JOURNAL, January 15th, 1916.

THE TREATMENT OF TETANUS.

WITH SPECIAL REFERENCE TO THE USE OF ANTITETANIC SERUM AND THE LOCAL TREATMENT OF THE WOUND.

BY

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As a result of his recent statistical analysis of 231 cases of tetanus Sir David Bruce¹ comes to the conclusion that the therapeutic value of the antitetanic serum is doubtful, although he still recommends its use.

The study of individual cases, however, may sometimes serve to supplement the statistical method, and a series of four cases of tetanus recently under my care are of interest, for in them the serum appeared to be of unmistakable value. In two the symptoms subsided under treatment by large doses of serum; on the reduction of the dose the symptoms reappeared with great violence, and on the renewal of large doses the symptoms once again subsided.

The four men were all wounded last autumn. None of them had received a prophylactic dose of serum.

CASE I.

Granulating shell wound of buttock; fragment of shell palpable beneath skin over sacrum. Incubation period, ten days. The symptoms were trismus, rigidity of neck and abdomen, painful spasms of legs. Respiration not affected; able to swallow fluids.

The patient stated that slight stiffness of the jaws had been present on the day preceding the beginning of serum treatment, which therefore commenced on the second day of the disease. From the second to sixth day 9,000 units were given daily; on the second, fourth, and sixth days 3,000 units of this dose were given intrathecally, the remainder being divided equally between the intravenous and subcutaneous routes.

Seventh day: Improved; able to open mouth; 5,000 units given subcutaneously. Eighth and ninth days: Improvement continued; serum omitted. Tenth day: Improvement maintained; 4,500 units given subcutaneously, with the aim of preventing relapse. This was insufficient for its purpose, for on the eleventh day a severe relapse occurred, with agonizing spasms of the legs; 3,000 units given intrathecally, 7,000 units intravenously. Twelfth day: Symptoms subsided; 7,500 units given subcutaneously. Recovery.

Duration of symptoms, twelve days; this period is reckoned up to the last day upon which slight tetanic spasms were present, although in this and the succeeding cases slight stiffness of the affected muscles persisted for several days longer.

CASE II.

Bullet wound of thorax; fractured ribs; small effusion into left pleura, regarded as sterile haemothorax. Incubation period, twelve days. Trismus; severe respiratory spasms with deep cyanosis; deglutition impossible.

For the first five days 9,000 to 12,000 units were given each day, part subcutaneously and part intravenously; for the first three days 3,000 units of this dose were given intrathecally. Sixth day: Marked improvement; spasms few and slight; deglutition easy; 7,500 units given subcutaneously. Seventh day: Improvement continued; serum omitted. Eighth day: 5,000 units given subcutaneously to prevent relapse. Ninth day: Severe relapse; 10,000 units given intravenously, 6,000 subcutaneously. Tenth day: Considerable improvement; spasms less frequent; 7,500 units given intravenously and repeated in afternoon. Eleventh day: Large haemorrhage from rectum, and death.

Duration of symptoms, eleven days.

Post-mortem Examination.—A superficial erosion in rectum; lower gut packed with scybala, although an enema had been given on alternate days. Small septic effusion in left pleura.

CASE III.

Shell wound of thigh. Two days after the injury the wound had been freely incised for gaseous cellulitis. At the time of the onset of tetanus large sloughs of muscle were in process of separation by granulation.

Symptoms of tetanus occurred ten days after the date of original wound. Trismus and backward curvature of spine; deglutition and respiration unaffected. The patient stated that slight stiffness of jaws had been present on the day preceding the initiation of serum treatment, which thus commenced on the second day of disease.

Second day: 3,000 units intrathecally, 3,000 intravenously, 3,000 subcutaneously. Third and fourth days: 6,000 units intravenously, 3,000 units subcutaneously. Fifth day: No

definite spasms, but occasional twitchings; 4,000 units intravenously, 2,000 units subcutaneously. This dose repeated on sixth day. Transferred to England, having been free from tetanic symptoms for twenty days. Duration of symptoms, six days.

The muscular sloughs were allowed to separate by granulation.

CASE IV.

Granulating shell wound of thigh. Incubation period, nine days. Trismus, rigidity of neck, painful spasms of wounded leg, tongue frequently bitten. Respiration and deglutition unaffected.

First day: 3,000 units given intrathecally, 4,000 units intravenously, 2,000 units subcutaneously. Second to eighth days: From 7,500 to 10,000 units given daily, chiefly intravenously; on the fourth day 3,000 units of this dose were given intrathecally. Ninth day: Spasms absent; serum omitted. Tenth day: Slight spasms present; 4,000 units intravenously, 1,000 subcutaneously. Eleventh to thirteenth days: Spasms absent, serum omitted. Fourteenth day: Very slight spasms; 4,500 units subcutaneously. Transferred to England, having been free from spasms sixteen days. Duration of symptoms, fourteen days.

In Cases I and II formidable symptoms subsided under large doses of serum, reappeared when the doses were diminished, and again subsided when the large doses were repeated; in each case the relapse occurred on the day following the injection of about 5,000 units subcutaneously. Hence it appears probable that small doses may fail where large ones succeed. Although Case II ultimately died from complications, the effect of the serum in influencing grave tetanic symptoms was marked. The cause of the rectal haemorrhage is not clear; it would be of interest to learn whether purpuric symptoms have followed large doses of serum in other cases.

The value of intrathecal injection was shown in the relapse of Case I; after the injection, the agonizing spasms of the legs completely subsided, and did not recur. Possibly the intrathecal route is specially valuable when the wound is in the lower part of the body and the spasms localized to the lower limbs, for by this route the serum is brought into immediate relation with the affected lower part of the cord.

Daily Dose.

The effectual daily dose would appear to be about 10,000 or 12,000 units; this may be given twice a day in critical cases. The major portion of this dose should be given intravenously; subcutaneous injections being also used to maintain the effect. Intrathecal injections should be given daily, or at such intervals as the symptoms demand. The dosage must be reduced gradually, in order to avert relapse.

It is worth noting that three of the above cases exhibited a characteristic narrowing of the palpebral fissure, a symptom which I have also observed in several other cases of the disease. This is probably due to a slight continuous contraction of the orbicularis, although the drooping upper lids may sometimes resemble bilateral parietic ptosis. It is more persistent than the risus sardonicus and occurs earlier in the disease, and may therefore be of diagnostic value.

Local Treatment of the Wound.

All will agree as to the desirability of the vigorous treatment of soiled wounds as a preventive of tetanus; but when once the disease has declared itself, I consider that operative surgical interference with the surface of the wound, although recommended by several authorities, is a proceeding of considerable danger. This view is based on theoretical considerations, and on the study of eleven cases during the war.

Tetanus usually shows itself after an interval of a week or more from the time of the injury. By this time there will have been formed the protective inflammatory barrier, the function of which is to check absorption from the surface of the wound. Any active surgical treatment, such as scraping, incisions for drainage, or the removal of sloughs, is likely to make breaches in the inflammatory barrier, and to expose the tissues to the access of the tetanus toxin; and this will hold good whether the toxin gains entrance by way of the nerves, the circulation, or the lymphatics.

The following case illustrates this point:

A patient with septic compound fracture of the leg was well on the road to recovery from a severe attack of tetanus; a