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THE TREATMENT OF ACUTE EMPHYSEMATOUS
GANGRENE.

(Preliminary Communication.)

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IN the present European conflict the outstanding feature of medical importance is the incidence amongst the wounded of cases of tetanus and acute emphysematous gangrene. As to the actual extent to which these two conditions are prevailing, it is impossible as yet to say. It is evident, however, that sufficient material is forthcoming upon which to base a more extended knowledge than is at present extant. The very high mortality previously associated with both these diseases is generally recognized in all text-books on surgery. Thus in Rose and Carless' "Manual of Surgery," 1911, under the heading of "Acute Spreading, Acute Emphysematous or Spreading Traumatic Gangrene," appears the following: "This is one of the most rapidly fatal and serious conditions met with in surgery."

The object of the present communication is to draw attention to a new method of treatment of emphysematous gangrene, which in our hands has been attended with well-marked success.

Amongst the cases of shell and gunshot wounds admitted to No. 8 Military General Hospital at Rouen, France, during the months of September and October, there occurred seventeen examples of gangrene affecting the extremities. Three of these were of the purely traumatic variety and directly due to interference with the vascular supply. The remaining fourteen, on the other hand, were all types of the condition variously termed infective gangrene, emphysematous gangrene, or hospital gangrene; eight of these involved the upper extremity, and six the lower. All were the direct result of severe shell wounds infected on the field by earth or refuse. The first three cases admitted to the hospital were treated upon existing lines, and all rapidly proved fatal. The first patient was extremely weak and toxæmic upon arrival, and did not recover from the shock attendant upon amputation through the upper third of the thigh. In the remaining two patients the gangrenous area had already extended to the abdominal wall and amputation was out of the question. Both cases were treated by application of hydrogen peroxide to the wounds, but both rapidly succumbed.

The fourth patient also appeared *in extremis* when he reached the hospital. He had been wounded on September 14, during an engagement on the Meuse, and reached Rouen three days later. Upon arrival he presented a very large lacerated wound upon the posterior aspect of the right knee, extending upwards into the muscles of the thigh. The wound was extremely foul and the tissues around were œdematous, devitalized and emphysematous. Typical blebs were present on the skin surrounding the wound, and from the contained fluid a long un-encapsulated anaerobic bacillus was cultivated. Amputation was performed through the upper third of the thigh, but at the operation it was evident that the infection had spread to a high level, and that it was impossible to remove the limb above the area involved. The patient was much collapsed and the operation was concluded as rapidly as possible. Within twenty-four hours it was evident that the infection was spreading rapidly in the flaps covering the stump. It then appeared to one of us that it might be possible to limit the spread of the disease by infiltrating the tissues above the gangrenous area with oxygen. The handiest method available was the injection of hydrogen peroxide into the tissues under pressure. Small incisions were made therefore *into the healthy tissues above the infected area*, and through these punctures hydrogen peroxide was pumped into the subcutaneous and sub-

fascial planes by means of a Higginson's syringe. The evolution of oxygen was rapid and the stump soon assumed enormous proportions, emitting a resonant note on percussion. From this moment the spread of gangrene was arrested. The existing gangrenous portion sloughed away, the surrounding skin area assumed its normal tint, and the circulation was re-established. The man made an uninterrupted recovery and when convalescent was transferred to England.

The success which attended this case decided us to employ the same method on a subsequent occasion. On September 30 the next opportunity occurred. A patient was admitted with a large lacerated shell wound on the outer surface of the left thigh in its upper third. A very offensive discharge was present and the skin around was discoloured and sodden. Œdema, with definite crackling on palpation, extended up to the crest of the ilium. The patient was jaundiced and his general condition very weak. Amputation of the limb could not be entertained, and hydrogen peroxide (10 vols.) was injected subcutaneously above the line of the advancing œdema. Small punctures were also made through the tissues just above the wound and hydrogen peroxide was injected under pressure. Twenty-four hours later it was evident that the infection was arrested. The jaundice disappeared, and subsequently the whole gangrenous area came away in a huge slough involving skin, subcutaneous tissues, and fascia, leaving a very large granulating area. This had considerably diminished in size when the patient was transferred to England, his general condition being excellent in every way. Thiersch grafting was necessary to restore the limb to its functional ability.

The rapid arrest of the infection in these two cases proved to us that in the method we had not only a valuable means of saving life, but also of obviating the necessity for amputation and so preserving the function of many limbs that otherwise would be sacrificed. In fact, since adopting infiltration we have not found it necessary to remove a single limb for acute infective gangrene. The procedure now adopted by us in all cases where infection of a wound by anaerobic organisms is suspected may briefly be summarized as follows:—

Operation.—Half an hour before operation the patient receives a hypodermic injection of atropine sulphate $\frac{1}{100}$ gr. and morphine tartrate $\frac{1}{4}$ gr. General anæsthesia as a rule is employed, but if the patient is profoundly septic, and the wound involves the lower extremity, spinal analgesia is recommended. A point is then

selected three to four fingers' breadth above the line of advancing gangrene as shown by the dusky, copper-coloured tint of the integument. An incision about $\frac{1}{4}$ in. in length is made through the skin and subcutaneous tissues as far as the fascial sheaths of the muscles. A pair of sinus forceps is then introduced into the wound and the whole of the subcutaneous tissue opened up as widely as possible. The nozzle of an ordinary Higginson's syringe is introduced into the incision and neutral hydrogen peroxide (10 vols.) at body temperature pumped into the subcutaneous spaces under pressure. The dissemination of oxygen is aided by kneading and massage. It is essential that the belt of oxygen be complete above the line of advancing gangrene, and therefore it is usually necessary to repeat the procedure at various points. This done the gangrenous area itself is treated in a similar manner by puncture and infiltration. Finally the wound is thoroughly explored and cleansed. All foreign material and dead and contused tissue is removed and the cavity irrigated, first with normal saline to wash away debris and clot, and then freely with hydrogen peroxide. Drainage by rubber tube and gauze is established and the whole limb dressed with dry gauze and wool. Although much drainage may be anticipated we consider it a mistake to employ huge quantities of wool and gauze in these cases. The aim should be to allow free access of air to the wounded tissues, coupled with efficient protection to the same.

The operation is followed by considerable shock, due undoubtedly to the wide separation of connective tissues and stimulation of nerve endings. The usual measures are instituted to combat the shock, and morphia is freely administered to relieve the pain, which is generally very acute. At the close of the operation the limb, in the case of the upper extremity, is ballooned to twice its normal size and the emphysema frequently extends to the trunk and neck. In our series of cases shock was much more marked when the upper extremity was involved than in the case of the lower. A point of pathological interest is the bright yellow colour of the fluid which exudes from the tissues of the diseased limb on section. This is even more evident in the presence of hydrogen peroxide. What the exact nature of the pigment may be, it is impossible with our limited facilities at the front to ascertain.

Risks of the Operation.—We consider that the dangers of the operation are mainly twofold: (1) Shock; and (2) air embolism. As previously stated, there is undoubtedly an element of shock associated with the procedure, due to the stimulation of nerve endings and varying in degree with the extent of the area infiltrated. It

is most marked in our experience in cases where the upper extremity is involved, and especially when it is necessary to infiltrate the subcutaneous tissues of the thorax. At the same time the collapse is no more severe than that associated with amputation carried out under similar conditions, and it can certainly be combated by care and the adoption of ordinary measures. The operation should not be performed without general anæsthesia, and an allusion has already been made to the value of the spinal method of analgesia in cases involving the lower extremity.

As regards the risk of air embolism, we have not had a fatality of this nature directly attributed to the operation. At the same time we recognize its possibility and advocate particular care in avoiding trauma to veins both at the sites of puncture and also during the separation of the subcutaneous tissues. Concerning a third possible objection, that the operation may not be efficient to check the progress of the infection, in our experience this risk does not exist. Certainly in every case in which it has been employed arrest of the gangrene has been assured. Further experience with a longer series of cases may cause us to modify this statement, although a consideration of the facts, both clinical and *post-mortem*, go to prove that acute infective gangrene of the type now occurring in France is essentially a local process spreading by direct continuity in the subcutaneous tissues, and that it can be effectively checked by the establishment of "outposts" instituted in the manner described.

In our cases the organism present has almost invariably been the *Bacillus aerogenes capsulatus*. In two cases only did it prove to be the bacillus of malignant œdema.

The results so far obtained may be stated as follows:—

Total number of cases..	..	..	..	..	..	14
Upper extremity ..	..	..	..	..	..	8
Lower extremity ..	..	..	..	..	..	6
Cases treated by infiltration ..	..	..	..	..	..	11
Cured ..	..	..	..	..	..	8
Cases not treated by infiltration ..	..	..	..	..	..	3
Cured ..	..	..	..	..	..	0

Of the three deaths occurring in cases treated by the infiltration method, one was due to osteomyelitis of the femur and septicæmia; another to shock; whilst the third was a fatality under anæsthesia in a subject of lymphatism and not attributable to the condition present or to the operation. In the case of osteomyelitis of the femur an extensive compound comminuted fracture was present. The anaerobic infection was completely arrested when septicæmic symptoms developed, and this was confirmed by autopsy.

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The conclusions at which we have arrived, and on which we are at present basing our practice, may be stated as follows :—

Conclusions.—(1) Acute infective gangrene due to *B. aerogenes capsulatus* or *B. oedematis maligni*, in the case of the extremities, is at first a purely local process spreading by direct continuity in the subcutaneous tissues. The muscles and deeper tissues are only involved in the immediate neighbourhood of the wound. When gangrene of the whole limb exists it is due to severe trauma, especially to the main vessels. Acute infective gangrene and traumatic gangrene may be superimposed.

(2) Amputation of a limb for acute emphysematous gangrene is unnecessary unless the whole of the tissues are involved over a very extensive area. It is sufficient to remove only dead and dying tissues and *amputation high above the infected area is contra-indicated and may prove fatal from shock.*

(3) Infiltration of the healthy subcutaneous tissues with oxygen above the line of spreading gangrene is sufficient to check the advance of the infection and in the majority of cases the limb may be saved.

(4) The most convenient means of applying nascent oxygen to the tissues is by the injection of warm neutral hydrogen peroxide.

(5) The operation is not unattended by risk, and care must be taken to obviate shock and trauma to veins.

Note.—Since this paper was written four other cases of acute emphysematous gangrene have been admitted to No. 8 General Hospital. Three of these involved the upper extremity and one the lower. All have been treated by the method of infiltration and all have recovered without the sacrifice of a limb.

One of these cases was further complicated by severe tetanus and was successfully treated by daily lumbar injections of anti-tetanic serum (1,500 units) and the adoption of the Trendelenburg position.

The direct subcutaneous administration of oxygen or air apart from hydrogen peroxide is under consideration as a means of checking the spread of anaerobic infection.

Under circumstances (such as, perhaps, in clearing hospitals and ambulance trains) where the more thorough method of infiltrating hydrogen peroxide cannot be carried out as above described, it is possible that injecting it in smaller quantities with an antitoxin or other suitable syringe might arrest the disease until, at least, the patient arrived at a fixed hospital. We have treated a case successfully by this method.