Additional Points on Cases

1. It is notable that most R.A.F. crew members who have been involved in a flying accident seem to remember the traumatic experience vividly and in detail. This is contrary to Kardiner's observation; but his cases were of much longer standing—years, instead of weeks or months, having elapsed since the event. It is probable that hysterical processes entered far more often into the psychodynamics of his group.

2. There is, in a considerable proportion of the cases coming under my observation, retrospective evidence that there was conscious fear at the time of the occurrence. "Delayed inhibition" in the Pavlovian sense does not seem to have been the process responsible in them for the subsequent psychoneurosis.

3. It is possible that some stupors are essentially states of extreme preoccupation with the frightening experiences (cf. Hoch's (1921) *Benign Stupors* and the preoccupation with death).

4. Other stupors are presumably hysterical (avoidance) methods of dealing with the same kind of experience.

5. The long persistence of conditioned responses after trauma, up to two years in some R.A.F. cases, and probably indefinitely longer, has its parallel (Anderson and Parmenter, 1941) in sheep with experimental neuroses.

6. Some phobias, not of war origin, have probably the same kind of basis, extended to other situations recalling the original traumatic one in some way.

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GAS GANGRENE

WITH SPECIAL REFERENCE TO VASCULARIZATION OF MUSCLES

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The various factors in the pathogenesis of gas gangrene have still to be assessed. Of these, muscle ischaemia, while generally recognized as playing a part, has not received the attention it deserves. The present paper attempts to elucidate some of the problems of surgical treatment, with particular reference to the possible effects of vascular injury in promoting gas gangrene in war wounds.

Out of a series of 6,000 wounded 20 cases of gas gangrene were encountered in this general hospital during the first two months of the fighting in Normandy. It is seldom that the surgeons of a large general hospital have had the opportunity provided in this beach-head of seeing their patients within six to eight hours of wounding, of undertaking the primary surgery, and of observing the sequence of events at first hand from day to day. Adequate notes are available in 16 of the 20 cases encountered, and in only one of these had the initial operation been undertaken at a forward C.C.S.

Three factors are essential for the establishment of gas gangrene—the presence of pathogenic clostridia, an adequate mass of ischaemic or necrotic muscle, and delayed or faulty surgery. The first two are unavoidable, and can be effectively countered only by early adequate surgery. When casualties are heavy it is impossible to operate on all cases within the optimum period, but if those likely to develop gas gangrene are given priority it would go a long way towards eradicating this disease. Apart from gross destruction of a limb, gas gangrene is most lethal in the thigh and buttocks, and all cases of shell wounds in these areas should be given operative priority.

Muscles are supplied by one or more arteries. Should one of these be injured, then that part of the muscle supplied by the injured vessel becomes ischaemic. When this occurs the re-establishment of the collateral circulation within the muscle appears to be extremely slow, and in open wounds invariably results in necrosis. This not only is borne out by my own operative experience, but has recently been proved experimentally in rabbits by Le Gros Clark (1945). He states: "After ligature of the lower vessel of supply to the tibialis anticus . . . the normal vascularization of the lower half of the muscle is not restored for about a week. If both of the main vessels supplying the tibialis anticus are ligatured revascularization is delayed for a fortnight." And again: "In spite of anastomotic connexions, the interruption of one vessel of supply to a muscle (or one of its branches) may lead to a relatively extensive and well-defined area of ischaemia lasting for several days. This is important in relation to the infection of muscles in war wounds." I would go further and state that, combined with the presence of clostridia, it invariably results in gas gangrene.

I have stated that sufficient ischaemic or necrotic muscle is essential for the establishment of gas gangrene, and the following examples illustrate this. In the first, a small ragged piece of shell passes through the thigh, causing no arterial damage; it leaves in its wake a tract thinly lined with avascular muscle. Such cases, whether operated upon or not, will not develop gas gangrene: natural resources can cope with such damage. Now, if a similar piece of shell passing through the thigh should strike an artery—say the profunda femoris—we have a very different picture. Two groups of muscles are rendered ischaemic and form a suitable pabulum for micro-organisms. If clostridia are present in such a wound gas gangrene will be extensive and rapidly fatal; only early adequate surgery can be life-saving. On the other hand, should a smaller artery be lacerated—say one of the perforating branches of the profunda femoris—then a more limited area of muscle is rendered bloodless. In such a case gas gangrene, if it develops, will be less extensive and not so rapidly fatal. Such examples are often met with in war surgery, and they illustrate the paramount importance of the total exploration of all shell wounds, however small.

A surgeon who fails to remove significant quantities of ischaemic muscle is guilty of faulty surgery, for gas gangrene is very likely to develop. The thigh is more sinned against in this respect than any other part of the body, and failure to carry out adequate surgery in this region has been responsible for most of the recorded cases of gas gangrene in this war. Muscle deprived of its blood supply for six to eight hours dies. If operation has not been undertaken within this period all bloodless muscle must be excised. If one group of muscles is avascular it should be removed; if two groups are involved the limb should be amputated.

Of the 16 cases under review 14 occurred in the lower limb and 2 in the upper. The disparity is accounted for by the more abundant arterial anastomosis of the arm and by the relative vulnerability of the leg owing to its greater mass. It will be found that the cases come under two distinct categories—namely, massive gas gangrene resulting from damage to the main artery of a limb, and localized gas gangrene (in the early stages) resulting from laceration of muscular branches. Seven of each type occurred in the lower limb and one of each in the upper, as tabulated below. There were two deaths, both resulting from gas gangrene following injury to the popliteal artery.

	Main Arterial Damage	Injury to Muscular Branch
Upper limb	1	1
Lower limb	7 (two deaths)	7

Upper Limb

1. *Case of Main Arterial Damage.*—Cpl. A. was wounded in the abdomen and right elbow on June 29, 1944. He was in a forward position, and was not rescued till the morning of July 2—60 hours after being wounded. On admission to hospital the same day his condition was fair. He had an intestinal fistula and did not complain of abdominal discomfort. There was a foul-smelling wound on the anterior aspect of the elbow, the skin was mottled, and the arm above and below the elbow was greatly swollen. Rigor mortis

had set in in the hand; it was impossible to move any of the fingers. Amputation above the elbow was carried out the same day; the abdomen was not disturbed. On exploration of the amputated limb the radial and ulnar arteries were found to have been severed just below the bifurcation of the brachial artery; anaerobic myositis was found in the muscles of the upper forearm.

If the radial and ulnar arteries are severed below the recurrent branches the forearm is cut off from all blood supply and early amputation should be performed: two similar cases were encountered in which both arteries had been ligatured and amputation was carried out later. Ligature of the brachial artery, on the other hand, does not necessarily endanger the life of the limb: in three cases the artery was ligatured in the region of the elbow, and in all of them the limb survived.

2. *Injuries to Muscular Branch.*—L/Cpl. B. sustained a shell wound on the outer aspect of the arm on July 18, 1944. The entry wound was small; there was no exit wound. When seen, 20 hours later, gas gangrene was well established. On opening up the arm the long head of the biceps was completely gangrenous and was the only muscle involved; it was removed *in toto*. The upper tendinous part was first cut through and the muscle dissected out towards the elbow. On reaching a point about the middle of the arm, where the shell fragment had pierced the muscle, an artery was encountered. It was a branch of the brachial, which, having passed through the short head of the biceps, was entering the substance of the long head. It had been severed by the missile, thereby depriving the muscle of its blood supply. No other artery entered the muscle.

This case is a good example of the complete death of a single muscle followed by early gas gangrene. I saw a similar case in the biceps in the North African campaign; but it is the only single muscle in which I have encountered complete destruction, and this is accounted for by the fact that it is supplied by a single artery.

Lower Limb

Cases of Main Arterial Damage

Seven cases of gas gangrene come under this heading. Five resulted from injury to the popliteal artery and two to injury of the dorsalis pedis. As the history is very similar in each case they will not be recorded in detail.

Injuries to the main blood vessels of the lower limb are a most potent cause of gas gangrene, and in my experience almost invariably result in amputation. In the series of 6,000 cases there were 9 in which the popliteal artery was injured; in every case amputation had to be performed. Out of four cases of ligature of the femoral artery three resulted in amputation. Should gas gangrene supervene in such cases it is very rapid, and often fatal within 24 hours on account of the vast area of muscle involved. When a main artery has been ligatured in the leg the patient should be watched hourly and amputation performed at the first sign of clostridial infection. Particularly dangerous is the case in which the femoral artery has been ligatured and there is an additional wound of the lower leg; in such a case primary amputation should be carried out. Severance of the anterior tibial artery is more prone to cause gas gangrene than the posterior tibial, for in the calf the peroneal artery can carry on the circulation. If the anterior tibial artery requires ligature its muscles below this point are ischaemic and should be removed.

The thigh is the most interesting site in the body for the study of gas gangrene, and an intimate knowledge of the vascular supply of the muscles is of paramount importance. The muscles of the upper part of the thigh are supplied by arteries emerging from the pelvis, and those of the lower thigh by the profunda femoris and its branches. Should the femoral artery be injured below the origin of the profunda femoris it is the lower leg which is temporarily deprived of its blood supply, and dry gangrene may ensue. The muscles of the thigh are unlikely to be involved by gas gangrene owing to their receiving a normal blood supply by way of the profunda femoris.

Wounds of the popliteal artery present a very different picture, for after ligature of the vessel the calf muscles exposed in the wound are avascular and gas gangrene is more likely to occur. Once clostridia gain an entry the spread down the leg muscles is only a matter of hours, and as large masses of muscle are involved the toxaemia is extreme and rapidly fatal. Exploratory incision of the popliteal fossa should therefore not extend further down the limb than is absolutely necessary. The larger the wound the more avascular muscle is exposed; it is a happy hunting-ground for micro-organisms, and the danger of gas gangrene is greatly enhanced.

The site at which the popliteal artery is ligatured is of considerable importance. If the injury is above the origin of the inferior geniculate arteries the collateral circulation may prove sufficient, but, should it be below, the collateral circulation is most precarious. Only two very insignificant arteries are available—the anterior and posterior tibial recurrent. Of these the latter is inconstant, while the former is very small and incapable in itself of establishing the collateral circulation.

A wounded soldier seldom comes to operation under six hours. By that time muscle necrosis is setting in if arterial damage is present. On approaching a wound of the popliteal artery one should first ascertain if the circulation below the knee is adequate. If the foot and leg are warm operation should be postponed, for interference with the artery may cause spasm, as illustrated by the following case:

Pte. C. sustained a shell wound of the posterior aspect of the knee on July 11, 1944. He was admitted to hospital the next day; there was a small haematoma in the calf. The foot was warm and the dorsalis pedis pulsating; injury to the popliteal artery was not suspected. On account of the swelling of the knee-joint it was thought advisable to explore the wound to ascertain if the joint had been penetrated. The wound was enlarged and the blood-clot was evacuated. The popliteal artery was found severed above the inferior geniculate arteries, and was ligatured. Pulsation in the dorsalis pedis ceased. Gas gangrene was present in the lower limb next day, and although amputation through the thigh was carried out the patient died. If the operation had been postponed until the collateral circulation was more fully developed the chances of survival of the limb and the patient would undoubtedly have been enhanced.

If the limb is cold and pulsation is absent in the dorsalis pedis, then treatment depends on whether the injury is above or below the inferior geniculate arteries. If it is above, then the probable explanation is arterial spasm. The wound should be explored and the damaged segment of the artery excised and the artery ligatured. On return to bed vasodilatation should be encouraged by hot drinks, heat to the uninjured limbs, and alcohol. Smoking, which has a vasoconstrictor action, should be forbidden. There should be no external pressure on the limb in the form of encircling plaster or bandage. The limb, if fractured, should rest on a Thomas splint with light traction. Heat is contraindicated; it increases oxygen demands, so hastens the onset of gangrene and favours the growth of pathogenic organisms. The limb should be exposed to the air or packed in ice. Should the injury be below the origin of the inferior geniculate arteries, then there is but one course—amputation of the limb.

The remaining two cases of injury to the main artery causing gas gangrene occurred in the dorsalis pedis, with much destruction of tissue; gas gangrene was present on the dorsum of the foot.

Injury to Muscular Branches

Damage to the smaller arteries and to those of individual muscles is particularly interesting and important in the thigh. The profunda femoris is the main source of supply to the muscles in this region. Its lateral circumflex branch supplies the greater part of the quadriceps; the main artery itself supplies the adductor and hamstring group of muscles. If either is injured muscle ischaemia will be extensive. This artery is liable to injury in fractures of the femur, especially when the bone is comminuted by a missile entering from the lateral side. In the great majority of compound fractures of the femur in war this artery escapes injury, so ischaemia will be limited to the torn and ragged muscle in the vicinity of the fracture, and gas gangrene is most unlikely to develop. If, on the other hand, the artery is injured high up in the thigh, the adductor and hamstring group of muscles are almost wholly deprived of their blood supply; in which case primary amputation should be performed, for gas gangrene is apt to be extensive and rapidly fatal. When the injury is lower in the thigh, more limited areas of muscle are involved and local excision may suffice. This artery is the key-note to gas gangrene in the thigh, and a thorough knowledge of its distribution is essential to successful surgery. In carrying out débridement of a wound it is important not to injure the profunda femoris or its branches;

when this occurs the patient returns to bed with a fresh mass of ischaemic muscle, in which gas gangrene is most likely to develop. There is nothing more disturbing to a surgeon than to find clostridial infection 48 hours after a well-done operation.

The seven cases of injury to muscular branches are of particular interest and will be recorded in detail; comments as to the vascular distribution will be made in each case. All underwent operation about the 24-hour period, and, as only localized areas of muscle were involved, generalized symptoms were not far advanced. They were diagnosed by the presence of clostridia and the typical "deadhouse" smell.

Gdsmn. D. was wounded on July 30, 1944, and admitted to hospital the next day with a wound in the buttock. Early gas gangrene was present in the upper part of the gluteus maximus; all gangrenous muscle was excised. The missile had pierced the muscle in the region of the greater sciatic foramen. During the operation the superior gluteal artery was sought for as it emerged from the pelvis; its superficial branch was found to have been severed.

The gluteus maximus is a large muscle and is supplied by several arteries. The superficial branch of the superior gluteal supplies the upper portion, the inferior gluteal the middle portion, and the lower part of the muscle is supplied by the first perforating branch of the profunda femoris and the medial circumflex arteries. The superficial branch of the superior gluteal artery having been severed in this case, the upper part of the muscle underwent necrosis, and gas gangrene resulted. If the missile had severed the superior gluteal artery gas gangrene would have been much more widespread. This artery is practically the sole supply to the gluteus medius and minimus, and both these muscles would have been involved. It is common knowledge that certain buttock wounds may result in serious gas gangrene, and I believe this is the explanation.

L/Cpl. E. was wounded by a shell fragment on July 10, 1944, and admitted to hospital next day. There was a large foul-smelling through-and-through wound in the upper thigh medial to the femur. On enlarging the wound an extensive amount of gangrenous muscle was found, involving the adductores brevis, longus, and magnus, also portions of the semitendinosus and semimembranosus; it was confined to the region of the mid-thigh. The profunda femoris artery was severed in the region of its second perforating branch. All necrotic muscle was removed.

Gnr. F. sustained multiple shell wounds of the left calf on July 14, 1944. On admission next day the calf was swollen and foul-smelling. On exploration of the wound the gastrocnemius was found to have been traversed by a missile from the lateral to the medial side and about 3 in. below the knee; muscle injury was extensive. The part of the muscle distal to the track was gangrenous. No particular arterial damage could be found, but one concludes that the sural arteries, as they run down in the substance of the muscle, must have been severed, thereby depriving the muscle beyond this point of its blood supply.

Prisoner of War G. was admitted on July 24, 1944, with an antero-posterior through-and-through wound of the mid-thigh lateral to the femur. On exploring the wound a mass of early gangrenous muscle was found, involving the middle third of the vastus lateralis and vastus intermedius, also a small portion of the lateral border of the rectus femoris. The track of the missile was in the vicinity of the descending branch of the lateral circumflex artery; this artery was sought for and found severed.

The vastus lateralis and vastus intermedius are supplied by three arteries—the upper third by the transverse branch of the lateral circumflex, the middle third by the descending branch of the lateral circumflex, and the lower third by the lateral superior geniculate arteries. The rectus femoris gets part of its blood supply from the descending branch of the lateral circumflex. In this case the descending branch of the lateral circumflex was severed near its origin, thereby depriving part of the above-mentioned muscles of their blood supply, and gas gangrene supervened.

Spr. H., admitted on July 18, 1944, was in similar case to the above, except that the descending branch of the lateral circumflex was injured lower down; the gangrenous area was thus far more limited.

Pte. I. was admitted on July 26, 1944, with multiple shell wounds of the posterior aspect of the thigh. On exploring the wound the semitendinosus was found gangrenous except at its upper end; all gangrenous muscle was removed.

The semitendinosus has a dual blood supply. The upper part is supplied by the medial circumflex, and the main body of the muscle by a branch of the second perforating artery. This artery divides into two branches—one supplies the semimembranosus and the other the semitendinosus. On removing the main body of the muscle this last artery was not located; it had evidently been severed by a missile.

Pte. J. was admitted on July 26, 1944, with multiple shell wounds of the left thigh; his case was similar to the above, but, in addition to the semitendinosus, the semimembranosus was also gangrenous. Both muscles were partially removed.

The semimembranosus, in addition to being supplied by a terminal branch of the second perforating artery, is also supplied by the third and fourth perforating arteries after they pierce the adductor magnus. The point where the second perforating artery divides into its terminal branches is very close to the third perforating artery as it emerges from the adductor magnus; so that a missile is very apt to injure both arteries, as occurred in this case.

Discussion

The distribution of clostridia is widespread. Cutler and Sandusky (1944) found the incidence of clostridial contamination in aerial warfare as great as that of land warfare and that of accidental civilian wounds. I have seen an Italian sailor come off a ship with well-established gas gangrene. The clostridia can be grown from the skin (Roberts, Johnson, and Bruckner, 1933) as well as from wool (Schenken, quoted by Mais, 1940). It can be grown almost without fail from the battle-dress. MacLennan (1943) states: "Their absence from war wounds is a matter of surprise rather than satisfaction; their presence, for resignation rather than alarm." There still exists a fallacious belief that direct contact with the soil is the chief causal factor in the establishment of gas gangrene; the Cutler and Sandusky findings must surely stamp this out for ever. It is the clothing that is the important vehicle, especially the battle-dress, which is largely composed of wool. Tropical kit, being made of cotton, does not harbour the clostridia to the same degree, and should there be an increase of gas gangrene in the European theatre of war in excess of the desert campaign this will probably be the explanation.

MacLennan has shown that in the desert warfare 30% of all wounds contained the organism of gas gangrene, yet only 1% of those so contaminated developed anaerobic myositis. Why is the percentage so small? The answer undoubtedly is that in only 0.33% of all wounds has arterial damage been inflicted and a sufficient amount of ischaemic muscle produced in which the clostridia can multiply.

We must resign ourselves to the fact that many war wounds are contaminated with clostridia, and that, provided ample necrotic muscle is present, gas gangrene will ensue. Early reports on penicillin would indicate that it is powerless to stem the progress. At present the elimination of gas gangrene can come only from early and efficient surgery, which can be greatly aided by a thorough knowledge of the blood supply of the muscles.

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The Joint Consultative Council of institutions recognized by the Minister of Health for the training of health visitors, and of organizations of health visitors, has issued its report for the year 1944 from 7, Victoria Street, London, S.W.1. The council, whose chairman is Prof. Winifred Cullis, D.Sc., originated in a conference of representatives of training institutions convened by the Women Public Health Officers' Association in November, 1931, and was formally constituted in January, 1932. During the last 14 years it has been a useful means of conveying the conclusions of its members to the Ministry of Health, the Royal Sanitary Institute, and other bodies, on matters affecting the training and examination of health visitors, and has been responsible for five publications based on independent inquiry. An inquiry into the alleged shortage of health visitors in 1941 was conducted by the Joint Consultative Council, but the results were not published. Though the position has altered since then, there was in 1941 no acute or general shortage of health visitors.