THE CLINICAL DIAGNOSIS OF FAT EMBOLISM

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Three conditions which were responsible for high mortality in the recent war and for which there is not yet a fully agreed pathological explanation, or a specific form of treatment, are the crush syndrome, traumatic uraemia, and fat embolism. It is generally believed that fat embolism occurs more often in war wounds than in civilian injuries; but it is hoped to show in this paper not only that the frequency of the condition is under-estimated, and that recognition is comparatively easy provided only that the clinician is on the look out for it, but that it occurs in civilian injuries much more often than is thought. Of patients under my care in military surgical units during 1945 there were seven with fat embolism and, although the majority of all traumatic cases seen at that time were battle casualties, five of these seven were due to road accidents. The details are recorded in Table I.

TABLE I

ANALYSIS OF SEVEN CASES OF FAT EMBOLISM

Case No.	Site of injury	Type of injury	Onset	Petechial rash	Mental change	Fundus	Surgical therapy	Result	Duration
1	Femur	Road accident	Under 24 hours	Chest, neck, conjunctiva	Deep coma —three attacks	?	—	Died	14 days
2	Both tibiae	Road accident	2nd day	Chest, back, abdomen, conjunctiva	Deep coma	?	—	Died	3 days
3	Femur	Road accident	3rd day	Conjunctiva, few on neck	Slight "wandering"	?	—	Recovered	—
4	Femur	Road accident	Under 24 hours	Chest, neck, abdomen, conjunctiva	Delirium— two attacks	Haemorrhage Oedema	Ligation of vein	Recovered	—
5	Femur	Shell wound	2nd day	neck, conjunctiva	Deep coma	Haemorrhage Oedema	—	Died	5 days
6	Right femur, left tibia	Road accident	2nd day	Conjunctiva, few on neck later	Deep coma	Haemorrhage Oedema	Ligation of vein	Died	7 days
7	Tibia	Mine injury	2nd day	Chest, neck, conjunctiva	Deep coma	Haemorrhage	—	Died	9 days

During a three-month period after the cessation of hostilities, at two military hospitals in Germany, eighty-nine major injuries of the long bones were admitted. These included twenty-three fractures of the femur and forty-six fractures of the tibia, the majority of which were due to road accidents. Five cases of fat embolism were diagnosed; four were due to road accidents and the other to an accidental gun-shot wound of the lower end of the femur. Three proved fatal.

Wilson and Salisbury (1944) reporting on 1000 consecutive battle casualties, including 119 fractures of one or more long bones, found that there was clinical evidence of fat embolism in eight cases of which six were fatal—a mortality rate of 75 per cent., or for all fractures

of long bones 5 per cent. Vance (1931), working in New York, reported that post-mortem examination of fifty-nine accident cases with fractures of long bones showed that 20 per cent. had severe fat embolism and 55 per cent. had moderate or slight fat embolism; that is to say that three-quarters of these civilian accidents with fractures of a long bone which proved fatal showed some degree of fat embolism. Robb Smith (1941), working in Oxford, reported that of 125 deaths due to accident, forty-one (33 per cent.) showed gross fat emboli at post-mortem examination. In his paper he stated: "There is little doubt that many of the complications of injury such as traumatic pneumonia, delirium, delayed shock and blast are in reality fat embolism." To this list might be added concussion. The patient who is admitted with a fractured femur and a bruised or even fractured skull, and who lapses into delirium and coma, may easily be classified as a fatality due to head injury. Of ninety-three post-mortem examinations performed by Mavor in the Middle East in 1942 of which forty had a fracture of one or more long bones, seven deaths were due to fat embolism. These figures are given as examples of accumulating evidence that: 1) fat embolism is a relatively common complication in fractures of the long bones; 2) the diagnosis is made less often before death than after; 3) it occurs almost as frequently in civilian accidents as in battle wounds.

Fat embolism usually occurs during the third and fourth decades and is more common in men than in women. It follows that in time of war, military services include a preponderance of those who are prone to this complication, whereas the civilian population is correspondingly depleted. Furthermore the gravity of wounds, and the long journeys down lines of communication over rough roads or tracks, may account for a higher incidence in war-time. But there is no evidence of any specific etiological factor relating to missile wounds. During peace-time severe accidents are less frequent and often they are treated by junior members of the hospital staff. The surgeon himself seldom sees the patient with a fractured femur who is admitted to a small remote hospital during the week-end rush on the roads and is dead within forty-eight hours; he is simply informed that an accident case with head injury died after admission from secondary shock, concussion, or cerebral haemorrhage. Fat embolism can so easily be mistaken, not only by the clinician but by the pathologist, that unless the possibility is kept constantly in mind the correct diagnosis will be missed. Many a petechia has blushed unseen by the surgeon who failed to pull back the bed clothes, examine the base of the neck, and inspect the conjunctival sac.

PATHOLOGY

Fat emboli within the capillaries can best be found by the method described by Robb Smith in which a snippet of lung is cleared with potassium hydroxide. Microscopically there are petechial haemorrhages which may be distributed widely but are sometimes less obvious. Horizontal sections of the brain generally show a remarkable picture of densely packed petechiae throughout the white matter but none in the grey matter (Fig. 1).

Excellent surveys of the literature by Scuderi (1934) and Grossloss (1935) indicate the mass of experimental and pathological evidence which has accumulated, but there is still no proof as to the source of the fat. It may arise from the wound area; it may arise as an abnormality of general metabolic processes; or it may be that there is both embolism from the wound and general metabolic disturbance. Busch (1866) injected vermillion into the medulla of a long bone, fractured it, and after five minutes found pulmonary fat emboli stained with the dye. He showed that nearly all the fat travelled through the veins and not lymphatics. Gauss (1924) demonstrated that when veins inside the rigid walls of a bone are damaged they tend to remain open whereas those in soft tissue do not. At least one observer has found that blood taken from the femoral vein on the side of injury has a higher fat content than on the opposite side. Reiner (1907) reported good results from the application of a tourniquet, insertion above the tourniquet of a cannula into the femoral vein by way of the internal saphenous vein, release of the tourniquet, and drainage of the excess of fat.

On the other hand Lehman and Moore (1927) showed that the femur contained only a maximum of 65 c.c. of fat whereas the lethal dose, if man can be considered to show the same tolerance as the dog, is 120 c.c. Groendahl (1911) found that ligation of the femoral vein and removal of the lymphatic inguinal glands on the side of injury did not prevent fat embolism. Vance reported post-mortem evidence of fat embolism not only in 75 per cent. of fatal fractures of long bones but also in 12 to 14 per cent. of non-traumatic deaths. Catsaras (1920) found fat embolism in the lungs of 18 per cent. of sixty-seven patients dying from post-influenzal pneumonia. Fat embolism has been reported in a case of concussion without fracture (Ribbert 1894); in diabetes mellitus (Fitz 1881, Machlis 1924); in pulmonary tuberculosis (Heitzman); in chronic osteomyelitis (Field 1913); and after orthopaedic operations (Coolidge 1901, Codivilla 1910, Turner 1913, Schwamm 1926).

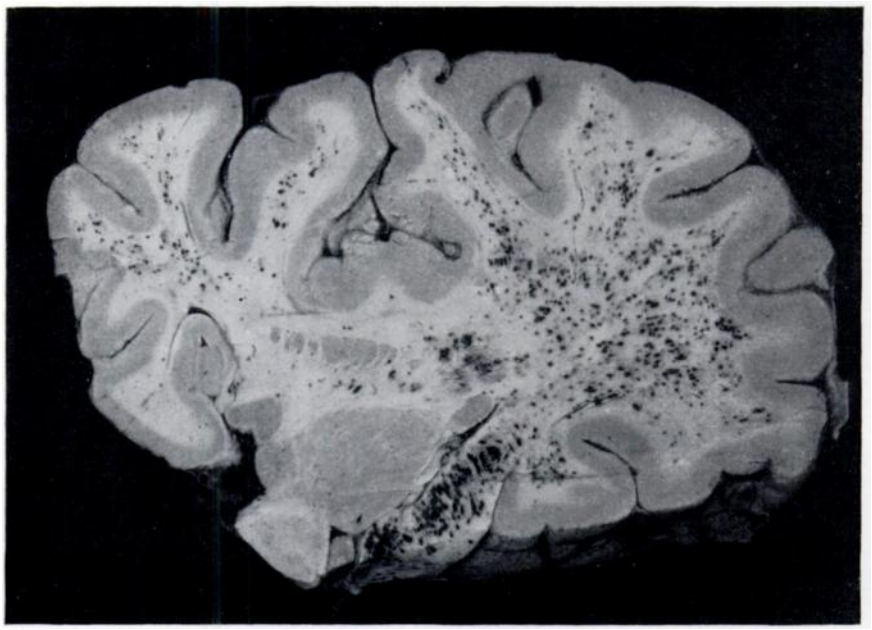

FIG. 1

Horizontal section of brain showing many petechiae in the white matter but none in the grey matter. (By courtesy of the British Journal of Surgery.)

Whatever be the origin of the fat globules the view that their harmful action in the tissues is due to simple embolism and obstruction of blood-vessels cannot be accepted. Histological evidence shows that the fat, in disintegrating, causes destruction of the wall of the vessel with perivascular oedema and haemorrhage. A globule of inert fat would not be expected to act in this way. Hirsch (1941) pointed out that the reaction of tissues to unhydrolised fat was similar to that of inert oil-like liquid petrolatum. On the other hand hydrolysis of fats liberates fatty acids and other chemical bodies which presumably are responsible for destruction of the wall of the vessel and for pathological changes in the perivascular tissues.

CLINICAL FEATURES

Scuderi (1934) concluded: " The symptoms and signs are very difficult to elicit clinically. The symptoms are indicative only in a general way and are not at all conclusive. The signs are of more value but they are not conclusive enough." These observations were unduly pessimistic. Only the lesser degrees of fat embolism, not endangering life, lack symptoms or signs to aid the clinician. In serious cases there are always signs, sometimes extensive

and obvious, but often unobtrusive and not recognised unless carefully sought. If the clinician knows what to look for, and where to look for it, the diagnosis is easy.

Clinical history—The typical clinical picture is that of a man in the third or fourth decade who in consequence of a road accident has sustained a compound fracture of the femur and is admitted to hospital, perhaps after a long and rough journey with the limb improperly immobilised, suffering a considerable degree of shock. The response to intravenous transfusion of blood or plasma is good; within three or four hours the blood-pressure and pulse rate are normal, and the patient is perfectly conscious and co-operative. Operative treatment of the wound and reduction of the fracture under intravenous and inhalational anaesthesia is arranged. An hour after operation the pulse is of good volume, the blood-pressure is maintained, and the general condition is satisfactory. The fact that consciousness has not yet been regained calls for no comment. Some hours later, however, when it is found that the patient is still deeply unconscious, the possibility of fat embolism is brought to the fore. The patient may remain in this state and die quite soon, in which case the anaesthetist is liable to be blamed for a poorly administered anaesthetic, or the patient be blamed for an idiosyncracy to the particular drug used. In such cases the anaesthetist should demand a post-mortem examination and a special search for evidence of fat embolism.

Other degrees of cerebral disturbance may occur. The patient is often unco-operative—refusing to eat food, refusing to use the urine flask, constantly calling for the nurse, repeatedly ringing his bell, and generally making himself a nuisance. This attitude, which is of important clinical significance, may well be overlooked in so far as it is not reported to the surgeon by the nurse. Other patients are restless or violent, perhaps needing two orderlies to keep them in bed. They may lie in a semi-conscious, delirious, stuporous, or comatose state with pale sweating skin and stertorous breathing. A patient may exhibit varying degrees of disturbance at different times, first sinking into deep coma, then regaining full consciousness, only to be plunged once more into coma when a fresh crop of emboli lodge in the brain. Alternate elevation and depression of consciousness due to successive showers of emboli is very typical and accounts for the association of fresh, recent, and old healing lesions of the brain which is often found at post-mortem examination.

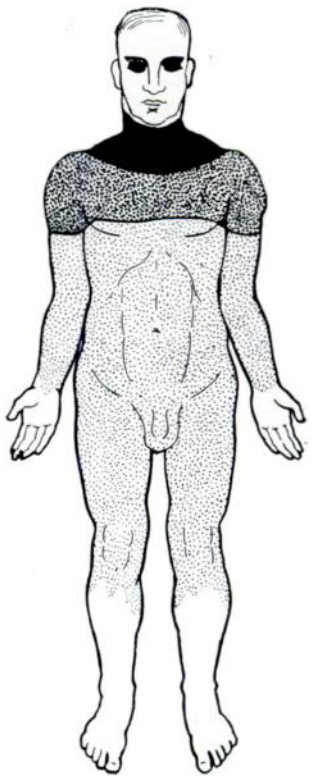

FIG. 2

Petechial haemorrhages are most common in the supraclavicular regions and the conjuctivae.

General clinical signs—*Pulse*—The pulse rate is slightly raised; the volume is good. The veins are dilated and there is some dilatation of the right side of the heart. Killian (1931) reported dilatation of the heart in ten cases. *Blood-pressure*—The blood-pressure is normal or raised, thus at once ruling out the possibility of severe secondary shock. *Respiration*—There is respiratory embarrassment, raised respiration rate, frothing at the mouth, cyanosis, deep stertorous breathing, and often Cheyne-Stokes breathing in the terminal stages. There may be pain in the chest with signs of oedema and consolidation at the bases. *Temperature*—The temperature is high; a reading of 102–105 degrees is usual and it may go even higher in the terminal stages. *Central nervous system*—The signs are usually of a general nature with changes in the conscious state, muscle rigidity, loss of sphincter control, convulsions, and sometimes Jacksonian fits. Local signs such as facial paralysis (Aberle 1907), absent ankle jerks and positive Babinski response (Watson 1937) have been reported.

Petechial haemorrhages—Petechiae may be abundant or sparse; their number has no relation to the prognosis. When few, they are to be found at the base of the neck and in the conjuctival sac; they must be sought carefully in a good light or they may easily be missed. In the conjuctiva they occur chiefly in the inferior half; the lower lid must be pulled down to reveal them (Fig. 3). Even in a case of grave prognosis there may be no more than one or two conjunctival petechiae. The other common site is the posterior triangle of the neck. When abundant they extend over the chest and abdomen and sometimes to the limbs. They are most thickly distributed over the neck, deltoid region, anterior aspect of the axilla and chest (Fig. 2). They may appear in recurrent crops which synchronise with the attacks of coma.

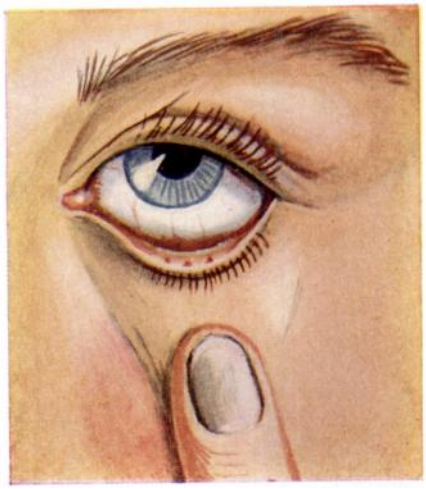

FIG. 3

Three petechiae seen on the inner side of the lower lid.

The fundus—Globules of fat coursing through the retinal vessels were first seen by Muller (1860) and have been reported in a case of diabetes mellitus by Bantin (1926); these globules disappeared after the administration of insulin. Oppenheimer (1929) reported retinal fat globules in a case of fat embolism. This sign, however, is not the essential finding in fat embolism. More typical are the pathological changes in the substance of the retina itself, described recently by McArdle (1946). They consist of yellow-white glistening patches of perivascular oedema, or patches of perivascular haemorrhage, occurring along the line of the vessels (Fig. 4). When searching for them each vessel should be traced from the disc to the periphery. It was not until the fourth case of this series came under my care that I learned of these changes from McArdle, but in the last four cases they were deliberately sought and were found in every one. Wilson and Salisbury (1944) were unable to find fat globules in the vessels but they make no mention of the retinal changes just described. Examination of the fundus in a patient who is uncooperative or unconscious is not an easy task even for one who is skilled in this work. The patient may need quietening with paraldehyde; the room should be darkened; the pupils should be dilated with homatropine. The aid of an ophthalmologist is advisable.

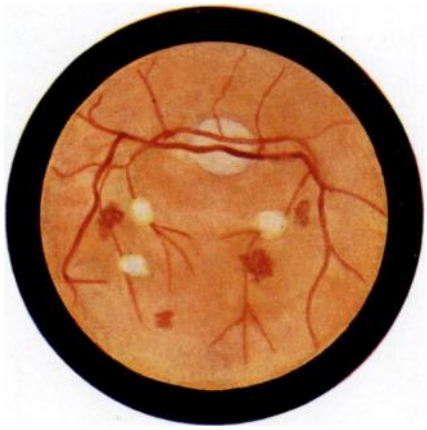

FIG. 4

The fundus showing petechial haemorrhages and oedematous patches.

Fat in the sputum and urine—Fat has been found in the sputum in patients suffering from fat embolism, but it has also been found in many other conditions and it is not to be regarded as a valuable clinical aid. Fat in the urine is more significant but is not easy to find and is frequently absent. Unfortunately it often does not appear until late in the course of the disease. It is important to remember that fat floats in the bladder on top of the urine and is therefore voided only with the last few drops.

Blood examination and lung puncture—It has been estimated that the smallest embolus which can obstruct a lung capillary has a measurement of 12 microns. It has been recommended that a specimen of blood be taken and a search made for fat globules in excess of this size. Lung puncture is another possible clinical aid and has been carried out in some cases.

Summary of Important Points in Diagnosis

1. History of injury, usually fracture of a long bone or severe soft tissue damage.
2. Interval in which there are no symptoms or signs suggesting complications.
3. Mental changes such as failure to co-operate, restlessness, delirium, stupor, or deep coma. Failure to recover consciousness from an anaesthetic.
4. Alternate elevation and depression of the conscious state.
5. Temperature 102 degrees or more. Blood-pressure normal or raised.
6. Stertorous breathing, cyanosis, frothing at the mouth, moist sounds in the chest.
7. Jacksonian fits and muscle rigidity.
8. Petechial haemorrhages especially at the base of the neck and in the conjunctival sac.
9. White patches of oedema or petechiae in the fundus.
10. Blood urea usually normal. No anuria.

Some of the conditions for which fat embolism may be mistaken are:

1. Secondary shock.
2. Cerebral concussion.
3. Cerebral compression.
4. Blast injury.
5. Crush syndrome.
6. Traumatic uraemia.
7. Badly administered anaesthetic; idiosyncracy to anaesthetic.

TREATMENT

There is no specific treatment and, when the condition has become established, very little can be done. Preventive treatment includes protection from long journeys over rough roads, and care to avoid unnecessary manipulation. Correct splintage is important. Siegmund (1918) showed that the longer the distance of transport to hospital, and the rougher the road, the greater was the incidence of fat embolism.

Deep incision into the wound with evacuation of the haematoma has been carried out by some surgeons on the assumption that local tension increases the liability of fat to enter the venous sinuses. Others, in simple fractures, aspirated the haematoma. Von Klapp (1931) ligated the femoral vein. Various substances have been injected intravenously. Wegelin (1923) injected sodium carbonate in an attempt to saponify the fat. Schanz (1910) injected physiological saline in order to flush out the cerebral capillaries. Yoshimasu and Killian put their faith in adrenalin. Since there is right-sided cardiac dilatation it is reasonable to suppose that intravenous infusion is detrimental. For this reason venesection has been advocated. Oxygen is valuable for cyanosed patients.

Ligation of the profunda vein—In view of the high mortality of fat embolism, and the lack of specific therapy, it has been thought justifiable to ligate the vein draining the injured area. Von Klapp advocated tying either the femoral or external iliac veins. Ligation of the femoral vein is a formidable procedure, not without risk to the limb; and ligation of the external iliac vein is of doubtful value in so far as it does not drain the femoral area.

Experience of ligation of the profunda artery, which proved a life-saving measure in cases of persistent secondary haemorrhage from compound fractures of the femur in wounded and debilitated prisoners of war, and which was never followed by vascular complications in the limb, stimulated me to consider ligation of the profunda vein as a means of arresting venous drainage from the area of the femur. It might be argued that such an operation is akin to shutting the stable door after the horse has bolted, but in this case it does seem that more than one horse is in the stable. The vein was ligated in two cases:

Case 1—Patient with severely comminuted fracture of the shaft of the left femur and small perforation of the skin from within. Twelve hours after the anaesthetic for reduction and immobilisation of the

fracture he became delirious. An extensive petechial rash appeared over the arms, neck, and chest Haemorrhages were present in both fundi and there was one patch of retinal oedema. He was taken to the theatre and the left profunda vein ligated through a vertical incision over the line of the femoral vessels from one to five inches below Poupart's ligament. The femoral artery was exposed and retracted medially to locate the profunda artery arising from its postero-lateral aspect. The profunda vein lies on the antero-medial surface of the artery (Fig. 5). The patient was a little delirious after the anaesthetic and then recovered full consciousness. He did not relapse again and the rash slowly faded.

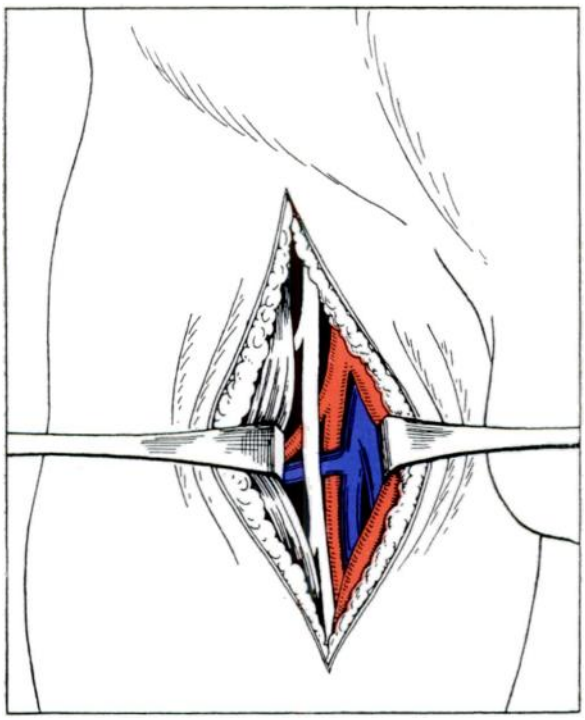

FIG. 5

Operation for ligation of the profunda vein. The femoral artery is retracted medially, distal to the origin of the profunda artery. This exposes the junction of the femoral and profunda veins.

Case 2—The patient had a fracture of the shaft of the right femur and a fracture of the shafts of the left tibia and fibula. He did not regain consciousness after the anaesthetic and remained in deep coma. There were a few petechiae at the base of the neck and in the conjunctiva. It was impossible to tell from which side the emboli arose but, in view of the grave condition of the patient and the success of the previous operation, it was decided to ligate the profunda vein on the side of the fractured femur. The patient, however, remained in deep coma and died four days later.

No conclusions can be drawn from two cases but since the disease carries with it a high mortality, and the operation is simple, it may be considered worthy of further consideration and trial.

SUMMARY

1. Fat embolism occurs in a high percentage of all cases of injury and it is a relatively frequent complication of fractures of the long bones in civilian accidents as well as battle casualties.

2. The diagnosis can usually be established by the clinical features together with certain physical signs which must however be sought deliberately.

3. Important clinical features are the mental disturbance, alternation of coma with full consciousness, petechial haemorrhages in the conjunctiva and skin, and typical changes in the retina.

4. Evidence is still conflicting as to whether the fat arises by embolism from an injured bone, or by general metabolic disturbance.

5. The fat is harmful not so much by reason of mechanical obstruction of vessels as by erosion and rupture of the vessel wall due to the liberation of fatty acids.

6. Preventive treatment appears to be of some value but no satisfactory specific treatment is yet available for the established case.

7. Ligation of the profunda vein has been tried in two patients, one of whom recovered and the other died.

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