Nonfracture-Associated Pulmonary Fat Embolism After Blunt Force Fatality

Case Report and Review of the Literature

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Abstract: Fatal fat embolism is usually considered a sequel to long-bone fracture, although uncommon cases secondary to soft tissue injury and trauma have been reported. We present the case of a 42-year-old male drug addict who sustained multiple blunt traumatic injuries without skeletal fractures but in whom pulmonary fat embolisms were identified. External examination of the body and forensic autopsy revealed severe, widespread soft tissue hemorrhaging (on approximately 30% of the body surface area) of the limbs, although the thoracic and abdominal viscera were intact. Histological examination of the Sudan III–stained sections of the lungs revealed orange drop-shaped and branching fat emboli. The right and left coronary arteries had signs of moderate atherosclerosis. Toxicological screening of a blood sample revealed a methamphetamine level of 1.05 μg/mL. We concluded that the immediate cause of death was pulmonary fat embolism, that the primary cause of death is the blunt force trauma, and that methamphetamine abuse and coronary atherosclerosis were contributory. A literature review revealed that the pathophysiologic basis for fat embolism in the absence of any fracture is perhaps a consequence of acutely increased pressure at the trauma site and altered emulsification of blood lipids during shock. This case reminds forensic scientists to consider fat embolism as a cause of death in cases of blunt force injury without fracture. In addition, these patients must be closely monitored while still alive, with other relevant clinical factors identified for better therapeutic effect, thereby decreasing the mortality rate.

Key Words: forensic pathology, pulmonary fat embolism, methamphetamine abuse, coronary atherosclerosis, sudden death

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Fat embolism in humans was first observed and described by Zenker[1] in 1861, who found fat droplets in lung capillaries of a railway worker who had been crushed between 2 wagons. Fat embolization occurs in 90% to 100% of individuals with long-bone or pelvic fractures.[2] It requires mobilization of free fat, which then enters the circulation and lodges as fat globules in fine venous capillaries.

Pulmonary fat embolism (PFE) has been widely recognized in forensic pathology. This paradigm of fat embolization has been used to support the evidence of antemortem fat depot disruption when the presence of intravascular fat is confirmed at autopsy.[3] In practice, the cause of death in such cases is often difficult to identify. There can be no doubt, however, that identifying the cause is required because the clinical picture is highly variable and the diagnosis often missed. All too often that the diagnosis is made postmortem.[2]

Pulmonary fat embolism is often fatal. It is most commonly associated with long-bone and pelvic fractures. It occurs more frequently in the presence of closed, rather than open, fractures. It can also occur in relation to other trauma, such as a soft tissue injury, after or during liposuction, and with bone marrow harvesting.[4,5] Although a number of investigators have described cases of fatal PFE associated with fractures,[6–9] there are few reports about the detection of nonfracture-associated PFE. We report such a case in which death ensued within a few hours of blunt trauma. We also review the related literature and discuss the pathogenesis of the PFE with reference to death-related medical treatments.

CASE REPORT

A 42-year-old man was tied up and subjected to repeated blows to the limbs and back delivered using a shovel handle. The total duration of the assault was given as approximately 1 hour, after which he was taken to a general hospital. The victim had a long-standing history of methamphetamine (MA) abuse and had indeed used it half an hour before the assault.

At the hospital, he was found not to be anemic. There were 2 superficial wounds and 1 deep, bleeding lacerated wound on his back as well as subcutaneous bruising over large areas of the limbs. The patient's physical examination revealed a blood pressure of 118/77 mm Hg, a heart rate of 66 beats per minute, and a respiratory rate of 20 breaths per minute. The electrocardiogram was normal. Regular measurements of blood pressure, pulse, heart rate, and respiration showed no abnormal changes. No fractures were found. Neurological examination showed no abnormality. The man did not experience nausea and did not vomit. The remainder of the clinical examination was unremarkable. Treatment consisted of cleaning and disinfecting the wounds. The deep wound of his back was sutured.

Several hours later, the patient experienced cardiopulmonary arrest for which cardiopulmonary resuscitation was unsuccessful. He died suddenly without obvious symptoms within 10 hours after admission.

Autopsy was performed approximately 24 hours after death. The body was 170 cm in length and of medium to heavy build. Postmortem lividity was seen widely on the back. Conjunctival petechiae were absent. A number of external injuries were identified including a 4 × 3 cm bruise of the right forehead, irregular

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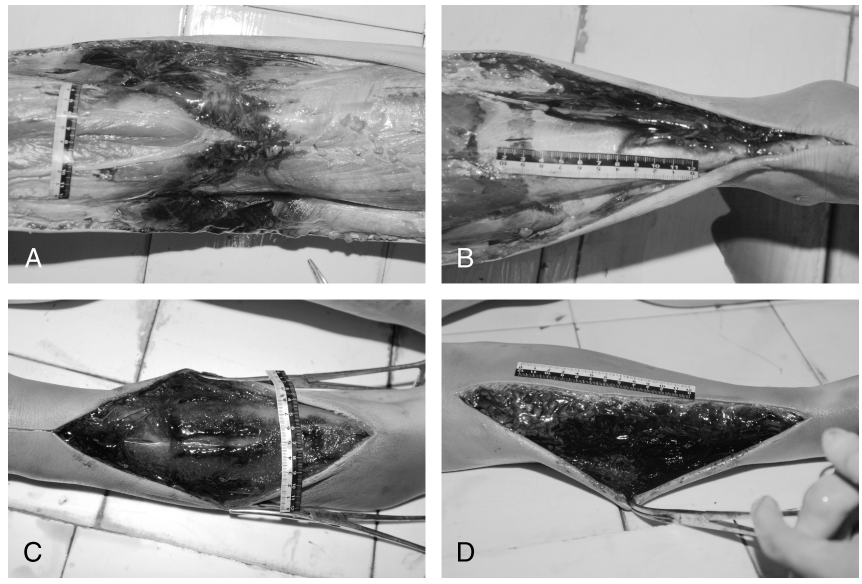

FIGURE 1. Limbs with diffuse subcutaneous hemorrhage exposed through parasagittal incisions. Bruising of the calf (A, B) and forearm (C, D) muscles and the overlying subcutaneous tissues. The hematomas were filled with fat tissue and fat droplets.

abrasions with petechial hemorrhage over the upper lip mucosa, a 1-cm bruise on the neck, irregular abrasions over the left mastoid process, and abrasions on the front of the chest. Extensive bruising was present on the scapulas, with a 6-cm incised wound on the right scapula that was closed with sutures. There was also extensive bruising of the legs, forearms, and hands.

Internal examination revealed no gross evidence of intracranial or chest trauma. No trauma was identified in the abdomen. No organs showed focal trauma, and there was no free blood in the body cavities. The bilateral lungs were of normal size and showed no atelectasis. The left lung weighed 488 g and the right lung weighed 540 g. The cut surfaces of the lungs were dark red.

Subcutaneous examination showed heavy subcutaneous bruising over large areas of the body, extending from the skin and underlying tissues to muscle (Fig. 1). Anteriorly, this bruising was situated on the front of each lower thigh, the knees, and shins. Posteriorly, it was situated in a dense band in the region of the upper shoulder blades, extending from the popliteal fossa down the back to the calves and ankles. Very heavy bruises were present along each forearm, from elbow to wrist. The backs of the hands and knuckles were bruised. There was a diffuse subcutaneous hemorrhaging on the limbs (exposed through parasagittal incisions). The hematomas were filled with fat tissue and fat droplets. Bruising underlay approximately 30% of the body surface area (Fig. 2).

Paraffin-embedded sections were subjected to routine staining with hematoxylin and eosin (H&E). Because the free fat in the paraffin-embedded tissue sections can be dissolved by ethanol and the slides do not demonstrate free fat, frozen fresh tissue sections were used to observe fat in this case. The frozen sections underwent staining for fat with Sudan III. Microscopic examination of the lung revealed fat emboli. However, no fat emboli were discovered in the brain and kidney. The histological findings in the frozen sections of lung tissue showed orange drop-shaped sporadic fat emboli in every microscopic field. Lung capillaries were filled with fat droplets. Fat was also present in the small veins in lung tissue. Free fat droplets were found in the trachea, large bronchi, and some small bronchi. The microscopic examinations of pulmonary fat emboli were shown in Figure 3. There were abundant adipocytes around the subcutaneous tissue hemorrhages (Fig. 4). According to the criteria suggested by the American Heart Association, the right and left coronary arteries had signs of moderate atherosclerosis (grade 3–4).[10] No new or old myocardial infarction was observed. Multiple sections of the brain and other major organs were histologically normal.

Toxicological analysis revealed that the blood MA concentration was 1.05 μg/mL, which was below the lethal level (10 μg/mL of blood is considered "lethal"[11,12]).

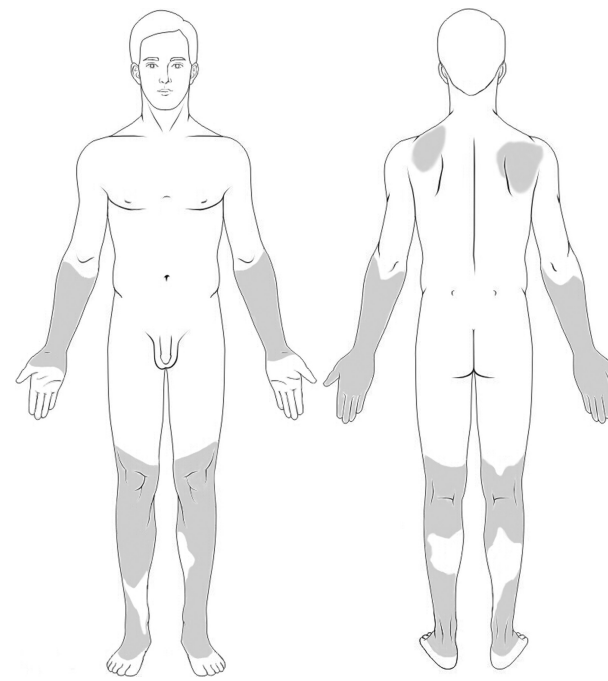

FIGURE 2. Distribution of subcutaneous bruising over the patient's body.

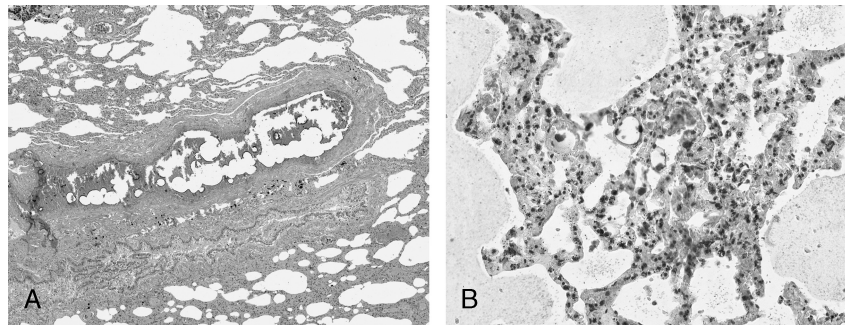

FIGURE 3. Pulmonary fat emboli, microscopic examination. A, Intravascular vacuoles (formalin-fixed tissue, H&E staining; original magnification ×50). B, Multiple fat emboli (fresh frozen tissue, Sudan III staining; original magnification ×100).

The history supplied by the police ascertained that this victim had sustained severe, repeated soft tissue injury for approximately 1 hour. The immediate cause of death in this case was pulmonary fat embolization and the primary cause of death was the blunt force trauma. Methamphetamine abuse, coronary atherosclerosis, and diffuse hemorrhage were contributory causes. Mechanisms of death were respiratory and acute heart failure.

DISCUSSION

Fat embolism has become a well-known sequela of major trauma. The prototypical patient is a young adult, aged 25 to 45 years, who has experienced severe impact trauma to the body as a whole, with resultant long-bone fractures.[13,14] Emboli may also occur after any type of injury to fatty tissue (eg, removal of the mammary glands, removal of fatty tumors, thyroidectomy, liposuction, burns).[15,16] The biochemical theory is that lipase activated in the lung breaks down the neutral present in the emboli. The generated free fatty acid causes direct toxic injury to the pneumocytes and endothelium, with resultant abnormalities in gas exchange. Although there is no specific therapy for fat embolism syndrome, its prevention, early diagnosis, and adequate symptomatic treatment are of paramount importance. Supportive care includes maintaining adequate oxygenation and ventilation; stabilizing the hemodynamics; administering blood products as clinically indicated; providing hydration as needed; prophylaxis for deep venous thrombosis and/or stress-related gastrointestinal bleeding; and adequate nutrition. The goals of pharmacotherapy are to reduce morbidity and prevent complications. Supportive care is the mainstay of therapy for clinically apparent fat embolism syndrome. Mortality is estimated to be 5% to 15% overall, but most patients recover fully.[17,18] Sutton[16] believed that mobility of injured fatty tissue is probably an important factor in the etiology of the fat embolism if there is a break in the venous or capillary circulation. Pulmonary fat embolism is also a potential factor in the cause of death after some surgical operations in which fatty tissue has been injured, especially occurring after operations in the abdomen through the abdominal wall or removal of the mammary glands. Thus, partial hemostasis probably is an important factor to PFE.[16] In the present case, there were extensive injuries to the subcutaneous fatty tissue and a break in the capillary. The disruption of adipose tissue allows free fat to enter torn veins and then produced PFE.

The development of PFE after fracture of long bones has been well described. Although reported less frequently, PFE also occurs in association with soft tissue injury unaccompanied by fracture. In fact, it has occasionally been observed in children. Blunt force trauma has been recognized as a primary cause of PFE for more than a century.[19] Patients dying from trauma with stainable fat droplets in the pulmonary circulation provide anatomical evidence of fat embolism. Several studies have documented the occurrence of PFE as ranging from 47% to 100% in cases of traumatic injury.[20,21] Nichols et al[22] described a 2-year-old child, a victim of abuse who had sustained multiple blunt trauma injuries without skeletal fractures and in whom pulmonary and systemic (brain and kidney) fat emboli were identified. Hamood et al[23] reported a case of fulminant, severe fat embolism associated with minor trauma to soft tissues without any demonstrated injury to the skeletal system in an otherwise healthy young patient who jumped from a height of 5 m. He had landed on his feet and was seemingly not injured.

In the case presented here, fat embolization was suspected for the following reasons. There was an extensive, severe subcutaneous tissue injury and an absence of apparent fracture or trauma to the viscera. Bruising underlay approximately 30% of the body surface area. The depth and distribution of the injuries in the present case confirmed that there was a direct trauma to subcutaneous fat. The hematomas were filled with fat tissue and fat droplets. In addition, the Sudan III–stained sections of fresh lung tissue at the time of autopsy confirmed the diagnosis of PFE. Finally, vacuoles that had a shape similar to that of the fat emboli were observed in the H&E-stained sections.

Two main theories regarding the occurrence of fat embolism have been developed: the mechanical theory by Gauss[24] and the biochemical theory by Lehman and Moore.[25] Gauss[24] held the opinion that injury to adipose tissue, rupture of veins within the zone of injury, and "some mechanism that will cause the passage of free fat into the open ends of blood vessels" would cause fat embolism. Lehman and Moore[25] proposed that plasma mediators mobilize fat from body stores, leading to droplet formation. Several mechanisms have been proposed to explain the pathogenesis

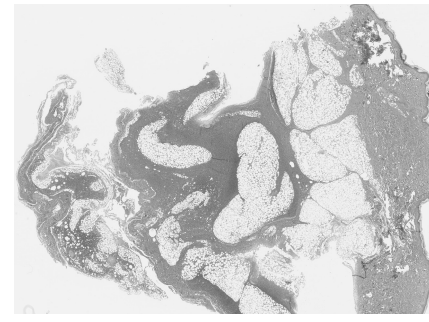

FIGURE 4. The large number of adipocytes around the subcutaneous tissue hemorrhage in lower extremities (formalin-fixed tissue, H&E staining; original magnification ×10).

of fat embolism, including mechanical problems, emulsion instability, intravascular coagulation, and toxic injury, etc. These factors may be acting together or singly.[26] In the present case, the mechanisms producing PFE may be either mechanical problems due to entry of free fat from disrupted adipose tissue into the torn veins or capillaries in area of trauma or several factors acting together.

A survey on the incidence, severity, and origin of PFE in persons dying from blunt force trauma within 24 hours of injury concluded that a significant degree of PFE develops rapidly in most persons dying of blunt force trauma. Although the source of fat for embolization has been suggested to be bone marrow, no evidence of myeloid tissue was found in any of the lung sections. Nor was there a correlation of PFE with the number of fractures. Soft tissue injury is considered the primary cause of PFE.[27] However, this mechanism is in need of further investigation. Evaluation of our case raised the probability that the soft tissue is the primary source of fat for embolization.

Fat emboli due to trauma are transported directly into the right heart by venous blood and then into the lung.[28] Cerebral fat embolism is common and causes encephaledema with petechiae around vessels. A patient was reported with paroxysmal tachypnea, dyspnea, tachycardia, and other symptoms 1 to 3 days after injury.[17] When lipid enters the bloodstream, it can be absorbed by macrophages or be cleaned up by lipases, thereby causing no negative consequences. If a large amount of lipid (9–20 g), however, enters the pulmonary circulation within a short time, it can obstruct 75% of the pulmonary circulation, leading to death due to asphyxiation and acute right heart failure.[29] The mechanical and chemical effects of fat embolism in the lungs cause acute respiratory distress, and the resulting hypoxia can lead to death. Thus, fat embolism can cause sudden, unexpected death.

The postmortem features of fat embolism are relatively nonspecific when the embolism has occurred shortly after release of fat into the circulation.[28,30] In this context, Gresham[26] noted that fat embolism was likely underdiagnosed clinically and at autopsy. Thus, in the case of sudden death with extensive, severe subcutaneous tissue injury and some characteristic changes observed in H&E-stained sections, it is necessary to apply special staining procedures to diagnose PFE.

Because PFE in the absence of fracture is rare and is a diagnosis of exclusion, any possible cause of death such as shock, rhabdomyolysis, and others must be ruled out first. It has been suggested that the subcutaneous tissue injury produces an increased liability to hypovolemic shock because of impaired peripheral vasoconstriction or excessive bleeding. Hypovolemic shock is the most common mechanism of death because of massive blood loss caused by extensive subcutaneous soft tissue injuries.[31] In the present case, there was no evidence of damage to any large- or medium-sized vessel. The total blood loss was less than 10% (500 mL). In addition, the skin and internal organs did not show pallor or petechiae at autopsy. The general signs of shock—low blood pressure, decreased urine output, fast heart rate, and confusion—were not observed during treatment. Before he died, his vital signs such as blood pressure, respiration, and pulse were stable. Thus, there was no direct evidence that the victim had died of hypovolemic shock. We found no obvious symptoms, including nausea, vomiting, confusion, coma, or abnormal heart rate and rhythm. Kidney function was not deteriorating (abnormally elevated or rising creatinine and urea levels, decreased urine output, or reddish brown discoloration of the urine). Thus, there was no proven link between rhabdomyolysis and death in the present case. The deceased was an MA abuser, but the toxicological analysis revealed that the blood MA concentration was 1.05 μg/mL, which was below the lethal level. The right and left coronary arteries had signs of moderate atherosclerosis (grade 3–4), but there were no typical findings of cardiomyopathy or other cardiac lesions. No new or old myocardial infarction was detected. Before his death, physical examination revealed a blood pressure of 118/77 mm Hg, a heart rate of 66 beats per minute, and a respiratory rate of 20 breaths per minute. The electrocardiogram was normal. He did not have a history of heart attack or angina, and, hence, no evidence of coronary heart disease. However, coronary atherosclerosis and MA abuse in combination must be considered as possible causes of death.

CONCLUSIONS

Fat embolism is reported infrequently after trauma without a fracture or with other pathological conditions. When such a case does appear for autopsy, however, it should undergo complete evaluation, including microscopic examination, toxicological analyses, and investigation of the circumstances of death. More importantly, a diagnosis of fat embolism requires special staining procedures to identify the presence of fat globules. Various risk factors, including coronary atherosclerosis and MA abuse, should be considered in combination as possible causes of death. The records and clinical nursing data of the victim also should be obtained and examined.

This case report was presented to remind the forensic science community to consider fat embolism as an immediate cause of death in cases of diffuse subcutaneous tissue injury without osseous fracture. It also reminds clinicians that, when treating such patients, close clinical monitoring is necessary. Attention should also be paid to other relevant clinical factors to prevent the onset or reduce the consequences of PFE.

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