Fat Embolism Syndrome in an Adolescent Before Surgical Treatment of an Isolated Closed Tibial Shaft Fracture

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Abstract

Fat embolism syndrome (FES) occurs most commonly in adults with high-energy trauma, especially fractures of the long-bones and pelvis. Because of unique age-related physiologic differences in the immature skeleton, as well as differences in fracture management in pediatric patients, FES is rare in children. To our knowledge, this is the first case report of FES occurring before surgical fixation of a closed tibial shaft fracture in an adolescent.

A 16-year-old, 109 kg, Caucasian adolescent boy developed FES after closed diaphyseal fractures of the distal tibia and fibula, showing signs of respiratory distress and mental status changes.

The FES resolved with supportive respiratory care and intramedullary nailing of the fracture was done without further respiratory compromise.

FES is uncommon in children and adolescents. A high index of suspicion is required to make the diagnosis promptly and institute appropriate treatment. Intramedullary nailing of a long-bone fracture can be done safely and successfully after resolution of the FES.

Fat embolism syndrome (FES) is rare in pediatric patients; it is approximately 100 times less likely to develop in children and adolescents than in adults.[1] The mortality rate for FES in children ranges from 1% to 15%, somewhat lower than that in adults (10%-20%).[1-12] FES most often occurs after fractures of the long-bones, primarily the femur and pelvis. The development of FES after intramedullary nailing of long-bones in adults is well-described, with identified risk factors of advanced age, polytrauma, prolonged immobilization, and male sex.[1-12] To our knowledge, there have been no documented cases of FES after isolated closed tibial shaft fractures but before operative treatment.

This case report highlights the importance of considering the diagnosis of FES in a child or adolescent with respiratory compromise or mental status changes after a closed long-bone fracture. It also demonstrates that with prompt diagnosis and supportive treatment, the fracture can be safely treated with intramedullary nailing after resolution of the FES.

The patient's guardian provided written informed consent for print and electronic publication of their case report.

Case Report

A 16-year-old, 109 kg Caucasian adolescent boy sustained closed diaphyseal fractures of the distal tibia and fibula when he was tackled during a football game (Figure 1). A splint was applied on the football field, and the patient was transferred by ambulance to the emergency department. On arrival, he was comfortable, awake, alert, and oriented. His respiratory rate was 16, and his

Figure 1. Anteroposterior (A) and lateral (B) radiographs showing closed diaphyseal fractures of the tibia and fibula.

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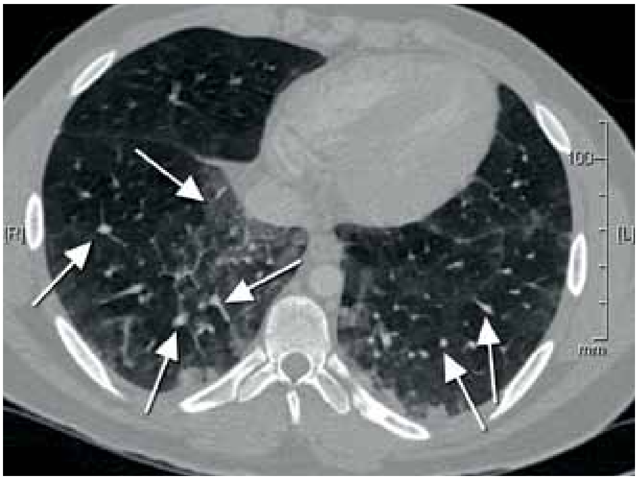

Figure 2. CT scan showing extensive, bilateral ground-glass opacities throughout the lung parenchyma (arrows), as well as areas of consolidation, consistent with fat embolism syndrome.

room air oxygen saturation (SaO_2) was 100%. All leg compartments were soft. The patient was a nonsmoker, on no medications, and had an unremarkable medical history except for resolved early childhood asthma. He did have a history of snoring according to his parents, but he had never had a formal sleep evaluation. His family history was negative for hematologic disorders, blood dyscrasias, and cardiovascular disease.

After evaluation by the orthopedic service, the patient was admitted for limb elevation and observation, with surgical treatment of the fracture planned for the next day. Although closed reduction and casting and external fixation were considered for fracture treatment, intramedullary nailing was determined to be more appropriate because of his age—approaching skeletal maturity—size, and the unstable tibial fracture pattern.

The following morning, approximately 14 hours after fracture, the patient was noted to be somewhat disoriented and lethargic, which was attributed to his narcotic pain medication. His father reported that the patient had snored during the night and was panting. At its lowest point overnight, his room air SaO_2 was 94%. In the operating room, before the induction of anesthesia, the patient experienced increasing respiratory distress and disorientation; he was oriented to person and place but not to time. His room air SaO_2 was 58%, and he required a non-rebreather mask at 15 L/min to maintain an O_2 saturation of 96%. On electrocardiogram (ECG), ST segment depression changes suggestive of ventricular dysfunction were noted.

The procedure was canceled and the patient was transferred to the intensive care unit (ICU) for respiratory stabilization. At that time, his temperature was 37.4°C, blood pressure 137/66 mm Hg, heart rate 90 bpm, and respiratory rate 26 breaths/min. He remained disoriented and in mild respiratory distress. On physical examination, his chest was clear to auscultation bilaterally, no petechial rashes were present, mild edema was present in the left lower extremity distal to the splint, and his leg compartments remained soft. Initial chest radiographs showed no pulmonary pathology.

Because of his respiratory distress and concerns about FES, a computed tomography (CT) scan of the thorax with intravenous contrast was obtained which showed patchy opacities within the lung parenchyma consistent with fat emboli (Figure 2). Transthoracic echocardiogram showed pulmonary hypertension secondary to fat emboli and mild aortic regurgitation with normal systolic function. No septal defects were noted.

The use of the non-rebreather mask at 15 L/min was continued and his SaO_2 was 96%. Intravenous fluids were administered and an albuterol inhaler was used. No high-dose corticosteroids or anticoagulants were given. Follow-up chest radiographs showed changes consistent with FES. Respiratory therapy consisted of incentive spirometry and continuous SaO_2 monitoring. At no point was the patient intubated. After 4 days in the ICU for pulmonary monitoring, the patient was transferred to the inpatient surgical floor for observation and continued respiratory therapy. During the time he was on the inpatient surgical floor, he was noted to have desaturation at night of 70% to 80%. He responded to the use of continuous positive airway pressure (CPAP) and was gradually weaned from this over the next 40 hours to room air only. A repeat echocardiogram 6 days after fracture demonstrated complete resolution of the pulmonary hypertension.

Seven days after fracture, the patient had a room air SaO_2 of 94% and he was cleared for surgery by his pulmonologist based on his clinical examination, ability to maintain normal oxygen saturation on room air, and stable chest radiograph. The tibial fracture was treated with closed reduction and intramedullary nailing; no fixation was used for the fibular fracture. Preoperatively, the tibial intramedullary canal measured 10 mm at the isthmus. The canal was slowly reamed from 9 to 11 mm in 0.5-mm increments, and a 10 mm x 36 cm locked intramedullary was inserted (Figure 3). Operative time was 109 minutes, no tourniquet was used, and there were no complications. The patient was on fractional inspired oxygen (FiO_2) 50%, and he had no ECG changes during the procedure.

After surgery, the patient was transferred to ICU for observation. He never required supplemental oxygen, while maintaining a SaO_2 of 94% or more at all times. He had no shortness of breath, confusion, or respiratory distress. The following day he was transferred to the inpatient surgical floor where he began physical therapy. He was discharged home the next day, 9 days after the fracture. At 6-month follow-up, the tibial and fibular fractures had healed clinically and radiographically (Figure 4); he had resumed athletic activities with no further respiratory problems.

Discussion

Despite advances in medical imaging, the diagnosis of FES remains primarily a clinical one. The typical patient with

FES has sustained a long-bone fracture and then develops a change in sensorium and hypoxemia. Tachycardia, tachypnea, and dyspnea also are clinical manifestations of this disorder. Initially, patients experience respiratory symptoms, which can range from mild distress to complete respiratory failure requiring mechanical ventilation. As hypoxia becomes more severe, neurologic abnormalities such as confusion, loss of consciousness, and even seizures, can occur.[13] Some patients develop a petechial rash caused by dermal capillary occlusion and extravasation of erythrocytes, most often on the head, neck, anterior thorax, subconjunctiva, and axillae.[14,15] Chest radiographs are generally normal early in the disease process.[5,14]

From a physiologic standpoint, FES occurs as fat droplets are forced into the venous system and occlude the microvasculature of the lung, leading to a ventilation-perfusion (VQ) mismatch in which regions of the lung are ventilated but not perfused. These fat droplets usually are generated during reaming or nail placement when an intramedullary nail is used for fixation of a long-bone fracture. As in this case, however, the fat droplets also can be caused by the trauma itself. In addition to a VQ mismatch, occlusion of the pulmonary microvasculature also leads to increased vascular resistance, right-sided hypertension, and, if untreated, ischemic changes to the myocardium. Our patient developed hypoxia and hypoxia-induced delirium, despite increased concentrations of supplemental oxygen, which is consistent with the clinical presentation of FES. His initial ECG and echocardiogram findings of ST segment depression and pulmonary hypertension also are consistent with occlusion of the pulmonary vasculature by fat droplets in FES.

It has been hypothesized that cardiac septal defects, most commonly a patent foramen ovale, can result in direct showering of the brain with fat emboli, leading to neurologic changes including delirium.[16] Increased right heart pressures caused by increased pulmonary vascular resistance may further exacerbate this process.

Recent clinical and cadaver studies, however, have shown no significant difference in the frequency of FES in patients with a patent foramen ovale.[16,17] Our patient had no septal defects noted on echocardiogram, and his mental status changes were attributed to his VQ mismatch alone rather than to brain emboli. While no definite links have been established between obesity and FES, this patient's size (109 kg) and history of sleep apnea may have contributed to FES by decreasing his pulmonary reserve.

Although primarily a clinical diagnosis, the development of FES can be suggested by pulse oximetry when a patient requires progressive higher concentrations of inspired oxygen to maintain a normal blood oxygen concentration. Chest radiographs generally are normal within the first 24 hours of the onset of symptoms, as they were in this patient. Muangman and colleagues[18] reported that the findings on chest radiographs were usually nonspecific and did not appear in half of their 22 patients for at least 24 hours after injury. CT scanning has been shown to be highly effective in making the diagnosis of FES,[19,20] and Arakawa and colleagues[21] showed that the extent of CT abnormalities correlated with arterial oxygen concentration.

The rarity of FES in children has been attributed, at least in part, to the different fat profile of the immature bone marrow, which is low compared with the adult skeleton.[6,14] In addition, the immature skeleton contains a great proportion of the higher temperature melting fats, palmitin and stearin, and less olein, a lower temperature melting fat. Palmitin and stearin, because of their solid nature, are not as likely to produce emboli as is olein.[7] Because this patient was approaching skeletal maturity his bone marrow may have contained more of the liquid fat olein than palmitin and stearin, which predisposed him to develop fat emboli to his lungs.

Figure 3. Anteroposterior (A) and lateral (B) radiographs immediately after locked intramedullary nailing.

Figure 4. Anteroposterior radiograph 6 months postoperatively showing healed tibial and fibular fractures (arrows).

Treatment of FES consists of eliminating the source of the emboli and most commonly involves stabilization of long-bone fractures and cardiopulmonary support. Several adjuvant modalities have been used to decrease the severity of FES, including corticosteroids,[22] nitric oxide,[23] and renin angiotensin inhibitors,[24] but there are no evidence-based recommendations for their use. None of these medications were used in our patient because of the rapid resolution of FES with supplemental oxygen. Mechanical devices designed to ream and aspirate the intramedullary canal during reaming have been hypothesized to decrease the rate of embolization[25]; however, this has not been proven in any human studies. We chose not to use mechanical intramedullary aspiration in this patient because we believed the tibia was already vented by the fracture. We also reamed from the smallest reamer in the smallest increments (0.5 mm) possible to minimize canal pressurization.

The decision to proceed with delayed intramedullary nailing was based on the patient's size and body habitus, and the instability of the fracture. Casting or external fixation would have been difficult in this patient, and we were concerned about continued fat embolization from micromotion of the fracture with less rigid immobilization. The timing of the intramedullary nailing corresponded with the clinical resolution of the FES. Because of the rarity of FES, human studies regarding the optimal timing for treatment of long-bone fractures in patients with FES do not exist to our knowledge.

In a study using a rat model of lung FES, vascular patency after embolism decreased for 96 hours and resolved by 11 days.[26] In a sheep model, animals with FES who had been appropriately resuscitated showed no significant changes in pulmonary function after intramedullary nailing of long-bone fractures.[27] Since no established guidelines exist as to the timing of surgical fracture fixation in patients with FES, we elected to proceed when our patient showed clear improvement in respiratory function, including increased respiratory function, absence of supplemental oxygen, and a stable chest radiograph.

Conclusion

FES occurs most commonly in adults with high-energy trauma, especially fractures of the long-bones and pelvis. Because of unique age-related physiologic differences in the immature skeleton, as well as differences in fracture management in pediatric patients, FES is rare in children. To our knowledge, this is the first case report of FES occurring before surgical fixation of a closed tibial shaft fracture in an adolescent. Because FES is primarily a clinical diagnosis, especially in the early stages, a high index of suspicion must be present when a child or adolescent with a long-bone fracture shows signs of respiratory distress and mental status changes. In this patient, rapid diagnosis and supportive care led to a rapid recovery and may have prevented a potential exacerbation of the FES during acute intramedullary reaming and pressurization of the tibia. Delayed intramedullary nailing after treatment of the FES was successful without further respiratory compromise.

Authors' Disclosure Statement

The authors report no actual or potential conflict of interest in relation to this article.

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