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# Fat Embolism Syndrome

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## Abstract

Fat embolism syndrome (FES) is a clinical syndrome characterized by signs and symptoms resulting from fat emboli and typically occurs after trauma, orthopaedic surgeries and non-traumatic conditions like acute pancreatitis. Literature reports an incidence of FES of up to 19% in prospective studies. Fat embolism refers to the presence of fat globules in pulmonary microcirculation and is often asymptomatic. The clinical syndrome of FES is characterized by systemic manifestations resulting from fat emboli which may manifest with a triad of lung, brain, and skin involvement in about 24–72 hours of asymptomatic period. The pathophysiology of fat embolism syndrome remains unclear. Two theories have been hypothesized: mechanical(disruptive) and biochemical(production of toxic metabolites). Universal agreement on the definition of FES is lacking. FES presents with nonspecific signs and symptoms;common to other critical illnesses and is often a diagnosis of exclusion. The clinical criteria proposed by Gurd and Wilson are popular. Biochemical tests and imaging may be of value in supporting the diagnosis. Treatment for FES is essentially supportive care in ICU. Principles of treatment include maintenance of adequate oxygenation, ventilation, hemodynamics, and organ perfusion. It may be prevented by early fixation of large bone fractures.

**Keywords:** fat embolism syndrome (FES), long bone fractures, clinical criteria, imaging studies, supportive care, early fixation

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## 1. Introduction

The term “fat embolism” (FE) is often loosely used to describe both fat embolization (of insignificant clinical relevance) and the clinical syndrome of fat embolism syndrome (FES) [1].

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The term “fat embolism” may be defined as the presence of fat globules in the pulmonary microcirculation irrespective of its clinical relevance, while the clinical syndrome of FES is characterized by the clinical signs and symptoms (systemic manifestations) resulting from fat emboli [2] and must be differentiated from the pathophysiological phenomenon of fat embolization [3].

## 2. History

Fat embolism was described as early as 1862 by Zenker. Warthin [4] opined that fat embolism from traumatic lipemia was not rare and the most frequent cause of death following long bone fractures in the absence of infection.

More data on FES came forth in the early twenty-first century from wounded soldiers involved in armed conflict across the world. A series of 1000 combats injured in the World War II reported the incidence of FES to be 0.8%. In Vietnam, cases of arterial hypoxemia among wounded soldiers were attributed to FES and also reported a few classic presentations of FES [3].

## 3. Pathophysiology

The pathophysiology of development of fat embolism syndrome is still unclear. However, two theories were hypothesized for its mechanism: mechanical and biochemical. Either the disrupted fat globules from bone marrow or adipose tissues enter into the bloodstreams (mechanical) or any sequel that leads to the production of toxic metabolites in the blood (biochemical) can give rise to a conundrum of clinical features that characterize the fat embolism syndrome. It is also likely that either the mechanisms exist in tandem or one gives rise to the other in the production of FES.

### 3.1. Mechanical theory

In the twentieth century, it was suggested that following a trauma, fat particles from the bone marrow and adipose tissues enter into the disrupted venules and travel to the pulmonary circulation or enter into the systemic circuit via arteriovenous shunts. The echocardiographic finding of echogenic material passing into the right heart during an orthopedic procedure contributed to this mechanical theory [5].

### 3.2. Biochemical theory

However, the mechanical theory does not explain the development of FES after a delay of 2–3 days postinjury. There are many biochemical mechanisms involved in the progression of fat embolism syndrome; the most widely accepted is the release of free fatty acids into the plasma following trauma, sepsis, and/or systemic inflammation. Acute phase reactants,

like C-reactive proteins, lead to lipid agglutination that tend to cause Acute respiratory distress syndrome (ARDS) in animal models, dysfunction of cardiac contractility and increase in plasma lipase concentration, which are the features of FES. These free fatty acids migrate to other organs, causing multiorgan failure [6]. This theory also helps in understanding the development of nontraumatic fat embolism syndrome.

#### 4. Incidence

Fat Embolism is common in trauma patients, particularly those with pelvic or long bone fractures [3]. Most literature reporting incidence of FES involves orthopedic or trauma patients with retrospective studies reporting an incidence of below 1%, while prospective studies have reported a much higher incidence of 11–19% [7]. Autopsy studies reported a much higher incidence of Fat embolism. One study demonstrated pulmonary fat emboli in 82% of trauma patients at autopsy [8]. Up to 67% of trauma patients without clinical features of fat embolism syndrome were shown to have circulating fat globules [3].

Fat emboli with a diameter of more than 20  $\mu\text{m}$  have been shown to occur in up to 90% of patients with long bone fractures. Another study concluded that more than 90% of patients with long bone fractures had embolism with fat droplets more than 20  $\mu\text{m}$  in diameter [9].

Gurd proposed that the clinical syndrome of fat embolism can be differentiated from a mere presence of fat emboli at autopsy in patients with no prior clinical features. Gurd suggested that a distinction can be made between the clinical syndrome of fat embolism and demonstration of fat embolism on autopsy with no prior clinical features of the syndrome [10].

Bulger et al. studied the incidence of FES at a level I trauma center over a 10-year period, reporting an incidence of 0.9% among patients with long bone fractures [11]. More recent data from the National Hospital Discharge Survey in USA looking at 21,538,000 patients with long bones and pelvic fractures reported a diagnosis of FES in 0.12% of the patients [12].

#### 5. Etiology and risk factor

The development of FES is frequently associated following an orthopedic trauma, with highest occurrence in closed and/or multiple long bone fractures, particularly of lower limb bones like femur. Aggressive nailing of the medullary canal poses increased risk of FES. Vigorous nailing of medullary cavity during intramedullary nailing and increase in gap between nail and cortical bone puts the patient at high risk of developing FES [6].

Furthermore, younger populations of 10–40 years and men more often than women are at high risk. Fat embolism has been reported in other nontraumatic conditions like pancreatitis, liposuction, bone marrow transplant, sickle cell disease, and liver disease. Nontraumatic causes of fat embolism syndrome include bone marrow transplant, pancreatitis, liposuction, alcoholic liver disease, and sickle cell crisis [13].

## 6. Clinical features

The phenomenon of fat embolism (fat droplets in circulation) is often undiagnosed in clinical practice. The clinical syndrome of FES tends to present with signs and symptoms similar to other critical illness and is mostly a diagnosis of exclusion. Fat embolism, which is a mere presence of fat emboli in circulation, may frequently go undiagnosed [10], while fat embolism syndrome presents with nonspecific clinical features common to other critical illnesses and is often a diagnosis of exclusion.

The fulminating form may present with sudden cardiovascular collapse and right ventricular failure subsequent to pulmonary and systemic fat embolization. More often, it is characterized by a more gradual onset of hypoxemia, neurological symptoms and a petechial rash about 12–36 hours after an injury [7].

Fat emboli could travel through the systemic vasculature resulting in a multiorgan disease involving lungs, brain, skin, retina, kidneys, liver, and heart.

The most common manifestations among patients with FES are of pulmonary system. Pulmonary manifestations though of varying severity are the most common finding in patient with fat embolism syndrome. Bulger et al. reported hypoxemia in 96% of the cases, and 44% of the patients with FES required mechanical ventilation [11]. Patients may develop dyspnea and tachypnea and a more severe syndrome indistinguishable from Acute respiratory distress syndrome (ARDS) may develop.

Nonspecific neurological symptoms including lethargy, restlessness or a decrease in Glasgow Coma Scale (GCS) may suggest cerebral edema subsequent to FES [14]. Severe neurological deterioration with cerebral edema has been reported with FES [15].

Skin involvement characterized by a petechial rash manifests in up to 60% of patients and usually affects oral mucous membranes, neck and axilla skin folds and conjunctiva. Dermal manifestations with a petechial rash pathognomonic of FES usually involves the conjunctiva, oral mucous membranes and skin folds of the neck and axillae and occurring in up to 60% of patients with FES [7].

## 7. Diagnosis

### 7.1. Gurd's and Wilson's criteria

Universal agreement on a standard definition of FES is lacking. There is a lack of universally accepted definition of FES [3]. The major and minor criteria proposed by Gurd and Wilson (**Table 1**) in 1970 are still popular [10]. It required one major criterion plus four minor criteria's in addition to fat macroglobulinemia for a diagnosis of FES.

### 7.2. Schonfeld’s criteria

Other authors later adapted these criteria and proposed the combinations of major and minor features needed for a diagnosis. Schonfeld et al. proposed (**Table 3**) a quantitative measure to diagnose FES; a score of more than 5 is required to diagnose FES [3].

### 7.3. Lindeque’s criteria

Lindeque proposed criteria for diagnosis of fat embolism syndrome based on respiratory changes alone [16]. A positive diagnosis of FES was proposed if atleast one of the criteria are met (**Table 2**).

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1. Major criteria
    - a. Petechial rash
    - b. Respiratory insufficiency
    - c. Cerebral involvement
  2. Minor criteria
    - a. Tachycardia
    - b. Fever
    - c. Retinal changes
    - d. Jaundice
    - e. Renal signs
    - f. Thrombocytopenia
    - g. Anemia
    - h. High ESR
    - i. Fat macroglobinemia
- 

**Table 1.** Gurd’s and Wilson’s criteria (with permission from Dr. Nissar Shaikh) [6].

	Scores
Petechiae	5
X-Ray chest diffuse infiltrates	4
Hypoxemia	3
Fever	1
Tachycardia	1
Tachypnea	1
Confusion	1

**Table 2.** Lindeque’s criteria (with permission from Dr. Nissar Shaikh) [6].

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Sustained  $pO_2 < 8$  kpa

Sustained  $pCO_2 > 7.3$  kpa

Sustained respiratory rate  $> 35$  per min, in spite of sedation

Increase work of breathing, dyspnea, tachycardia, anxiety

**Schonfeld's criteria**

Petechiae 5

Chest X-ray changes (diffuse alveolar infiltrates) 4

Hypoxaemia ( $Pao_2 < 9.3$  kPa) 3

Fever ( $>38^\circ C$ ) 1

Tachycardia ( $>120$  beats  $min^{-1}$ ) 1

Tachypnoea ( $>30$  bpm) 1

Cumulative score  $>5$  required for diagnosis

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**Table 3.** Schonfeld's criteria (with permission from Dr. Nissar Shaikh) [6].

## 8. Investigations

Diagnosis must be made on the basis of clinical findings but biochemical changes may be of value to support in diagnosis.

In the initial stages, a blood gas analysis is imperative, which will show hypoxia with  $paO_2$  of less than 60 mmHg and hypocapnia within the first 24–48 hours. Also, there will be an unexplained increase in the pulmonary shunt fraction and an alveolar to arterial oxygen tension difference. These are highly suggestive of a diagnosis of FES.

Nonspecific findings include anemia, thrombocytopenia, hypofibrinogenemia and high erythrocytes sedimentation rate. Cytological examination of urine, blood, sputum, and pulmonary capillary blood may detect fat globules in patients with FES; however, these tests are rarely done in the immediate period as they lack sensitivity and their absence does not rule out fat embolism [6].

### 8.1. Imaging studies

#### 8.1.1. Chest X-ray

Various nonspecific findings have been reported on chest X-ray though none of them is diagnostic. Numerous radiological findings have been described but none is diagnostic of fat embolism syndrome. The chest X-ray is often normal initially but in some patients bilateral fluffy shadows can be seen with worsening respiratory insufficiency (**Figure 1**).



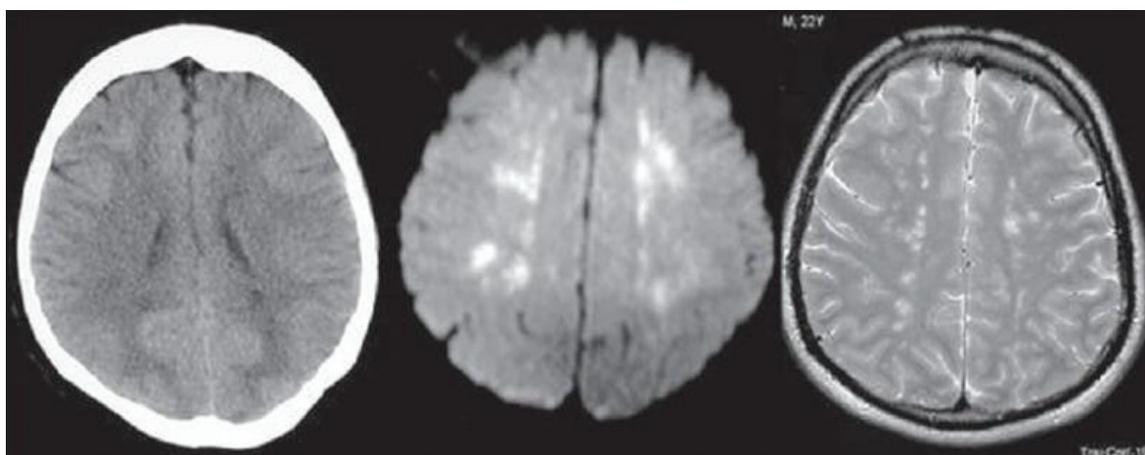
**Figure 1.** AP radiograph of the chest showing bilateral basal air space-filling lesions (consolidation in a patient of FES) (with permission from Dr. Nissar Shaikh) [6].

#### 8.1.2. Ventilation – perfusion scan (V/Q)

V/Q scans may demonstrate a mottled pattern of subsegmental perfusion defects with a normal ventilatory pattern.

#### 8.1.3. CT – computerized tomography chest and head

Spiral CT scan of the chest may show focal areas of ground glass opacification with interlobular septal thickening. Normal findings or diffuse petechial hemorrhages of white matter may be seen on CT scan of brain. CT Head may be normal or reveal diffuse white-matter petechial hemorrhages consistent with microvascular injury. This will also rule out other causes for deterioration in consciousness level (**Figure 2**).



**Figure 2.** CT image showing minimal hypodense changes in periventricular region, which are more evident in MRI DWI and T2WI as areas of high signals (with permission from Dr. Nissar Shaikh) [6]. (Produced with permission) Constellation of findings along with clinical data is characteristic for FES.

#### 8.1.4. MRI of brain

It may reveal high-intensity T2 signal which correlates with the degree of neurological impairment found clinically.

### 9. Treatment

Treatment is largely supportive care in a unit equipped with intensive care capabilities. Maintaining adequate oxygenation, ventilation, and organ perfusion are the essential goals of treatment. Principles of treatment include maintenance of adequate oxygenation and ventilation, hemodynamics, and perfusion. Correction of hypoxemia to maintain normal oxygen tension may require simple measures like oxygen supplementation or mechanical ventilation and Positive end expiratory pressure (PEEP) depending on the clinical context. Shock in patients with FES can worsen the lung injury and hence restoration of intravascular volume with balanced salt solutions or albumin is often required. Albumin administration not only expands the intravascular volume but may also mitigate the extent of lung injury as a result of its binding with fatty acids. Vasopressors to maintain the hemodynamics may be required. It has been proposed that heparin by enhancing lipase activity may augment the clearance of lipids from blood circulation. Treatment modalities including corticosteroids and anticoagulation have unfortunately not been shown to improve the morbidity or mortality. Other medications including alcohol and dextran have also been shown to be ineffective [2, 6].

### 10. Prognosis

Fat embolism occur in around 90% of all trauma patient, but FES accounts for less than 5% of patients having long bone fracture [17, 18]. The unstable form of FES presents as acute respiratory failure, cor pulmonale, and/or embolic event, leading to death within a few hours of injury. This is seen more often among high-risk patients and those with a background of multiple comorbidities.

It is hard to predict the extent of FES as it is often subclinical and the outcome of patients are generally favorable [6]. Mortality rate is less than 10% at present as there have been significant improvements in supportive care. Neurological deficits and pulmonary manifestations usually resolve completely over time [18].

### 11. Prevention

Studies have shown early fixation of fractures involving long bones is important in decreasing the incidence of fat embolism syndrome and may prevent it [6, 19, 20]. Preventing significant increase in intraosseous pressure in orthopedic surgeries may reduce embolization

of fat droplets and thereby reduce the incidence of FES. It has been suggested that plate fixation and external fixation results in less emboli and less severity of lung injury than surgical fixation with intramedullary nailing [6]. Prophylactic use of corticosteroids may have a beneficial effect in preventing fat embolism syndrome [21]. Wong et al. suggested monitoring with continuous pulse oximetry in patients with long bone fractures for early identification of desaturation [22]. This would allow early initiation of appropriate oxygen supplementation and other measures, possibly reducing the systemic complications of fat embolism syndrome [6].

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## References

- [1] Robinson CM. Current concepts of respiratory insufficiency syndromes after fracture. *The Journal of Bone and Joint Surgery (Br)*. 2001;**83**(B):781-791
- [2] Kosova E, Bergmark B, Piazza G. Fat embolism syndrome. *Circulation*. 2015;**131**:317-320
- [3] Talbot M, Schemitsch EH. Fat embolism syndrome: history, definition, epidemiology. *Injury*. 2006;**37**(Suppl 4):S3-S7
- [4] Warthin AS. Traumatic lipemia and fatty embolism. *International Clinics* 4:171, 1913
- [5] Sulek CA, Davies LK, Enneking FK, et al. Cerebral microembolism diagnosed by transcranial Doppler during total knee arthroplasty: Correlation with transesophageal echocardiography. *Anesthesiology*. 1999;**91**(3):672-676
- [6] Sheikh N. Emergency management of fat embolism syndrome. *Journal of Emergencies Trauma and Shock*. 2009;**2**(1):29-33
- [7] Mellor A, Soni N. Fat embolism. *Anaesthesia*. 2001;**56**:145-154
- [8] Eriksson EA, Pellegrini DC, Vanderkolk WE, et al. Incidence of pulmonary fat embolism at autopsy: an undiagnosed epidemic. *The Journal of Trauma and Acute Care Surgery*. 2011;**71**(2):312-315
- [9] Weisz G. M. Fat embolism. *Current problems in surgery*. Chicago (Ill.): Year Book Publisher Nov. 1974
- [10] Gurd AR, Wilson RI. The fat embolism syndrome. *The Bone and Joint Journal*. 1974;**56B**(3):408-416

- [11] Bulger EM, Smith DG, Maier RV, et al. Fat embolism syndrome: A 10-Year Review. *Archives of Surgery*. 1997;**132**(4):435-439
- [12] Stein PD, Yaekoub AY, Matta F, et al. Fat embolism syndrome. *The American Journal of the Medical Sciences*. 2008;**336**(6):472-477
- [13] Akhtar S. Fat embolism. *Anesthesiology Clinics*. 2009;**27**(3):533-550
- [14] Kwiatt ME, Seamon MJ. Fat embolism syndrome. *International Journal of Critical Illness and Injury Science*. 2013;**3**(1):64-68
- [15] Meeke RI, Fitzpatrick GJ, Phelan DM. Cerebral edema and fat embolism syndrome. *Intensive Care Medicine*. 1987;**13**:291-292
- [16] Lindeque BG, Schoeman HS, Dommissie GF, et al. Fat embolism and the fat embolism syndrome. A double-blind therapeutic study. *The Journal of Bone and Joint Surgery (Br)*. 1987;**69**(1):128-131
- [17] Palmovic V, McCarroll JR. Fat embolism in trauma. *Archives of Pathology*. 1965;**80**(6):630-635
- [18] Habashi NM, Andrews PL, Scalea TM. Therapeutic aspects of fat embolism syndrome. *Injury*. 2006;**37**(Suppl 4):S68-S73
- [19] Behrman SW, Fabian TC, Kudsk KA, et al. Improved outcome with femur fractures: Early vs. delayed fixation. *The Journal of Trauma*. 1990;**30**:792-797
- [20] Svennisngsen S. Prevention of fat embolism syndrome in patients with femoral fractures-immediate or delayed operation fixation. *Annales Chirurgiae et Gynaecologiae*. 1987;**76**(3):163-166
- [21] Bederman SS, Bhandari M, McKee MD, Schemitsch EH. Do corticosteroids reduce the risk of fat embolism syndrome in patients with long-bone fractures? A meta-analysis. *Canadian Journal of Surgery*. 2009;**52**:386-393
- [22] Wong MW. Continuous pulse oximeter monitoring for inapparent hypoxemia after long bone fractures. *The Journal of Trauma*. 2004;**56**(2):356-362