Acute Respiratory Distress Syndrome after Trauma: Fat Embolism Syndrome

Jessica O’Brien
MSIII Radiology Core Clerkship
Beth Israel Deaconess Medical Center
Harvard Medical School
March 19, 2010
Our patient is a 20 yo female, who sustained a massive right lower extremity injury after a motor vehicle accident
- Air-flighted from outside hospital due to extensive soft tissue de-gloving with exposed tibia
- Patient reported brief loss of consciousness during event

In the ER, she was stabilized and evaluated...
Index Patient: Fractures on Lower Extremity Plain Film

Findings:

- Compound
- Comminuted
- Mid-diaphyseal
- Tibia and Fibula
- Fractures

Frontal Right Tib/Fib XR
Findings:
Low lung volumes
No pleural effusion
No pneumothorax
Index Patient: Chest CT

Findings:
Normal lung parenchyma
Low lung volumes
No pleural effusion
No pneumothorax
Index Patient: Summary of Radiographic Findings of Initial Presentation

- R Tib/Fib XR: Tib-fib fractures
- No other acute process on:
  - CXR
  - CT C-Spine
  - CT Head
  - CT Trauma Torso series, including Chest, Abdomen, Pelvis

- Patient underwent emergent surgery:
  - Irrigation and debridement of laceration
  - Intramedullary nailing of right open tibia-fibula fracture
  - VAC application
Index Patient: Interim History
24 hours after admission

- Patient developed dyspnea and non-productive cough
  - Febrile to 102.8
  - Tachycardic to 150
  - O2 sats 80% on RA → 95% with face-mask

- Physical exam was notable for inspiratory crackles at bases

- Patient was evaluated with CTA
Index Patient: Chest CTA

Axial C+ Chest CTA

Please evaluate and proceed to next slide.
Index Patient: Ground Glass Opacities on Chest CT

Bilateral multifocal ground glass opacities, mostly at periphery
Consolidative areas at bases
No pulmonary embolism
Index Patient: Comparison of Chest CTs

Admission

Axial C+ Chest CT

Axial C+ Chest CTA

PACS, BIDMC

PACS, BIDMC

33 hours later

Rapid development of multifocal ground glass opacities within 33 hours
Index Patient: Ground Glass Opacities on Sagittal CT

Development of multifocal ground glass opacities in all lobes within 33 hours
Let’s move on to discuss ground glass opacities.
Ground Glass Opacities: Definition and Differential

- Definition: semi-transparent opacities that allow pulmonary vasculature to be visualized
  - When describing lung findings, this terminology is reserved for Chest CT

- Nonspecific
  - Interstitial
  - Alveolar
  - Mixed

- DDx is broad
  - Fluid: pulmonary edema
  - Blood: contusion, hemorrhage
  - Pus: infectious pneumonia, pneumonitis
  - Cells: malignancy
  - Other: fibrosis
Ground Glass Opacities: Narrowed Differential Diagnosis s/p Trauma

- Pulmonary Hemorrhage/Contusion
- Aspiration pneumonitis
- Pulmonary edema
  - Cardiogenic
  - Noncardiogenic
- Fat embolism
- Pneumonia (later onset)
  - Super-infection
  - Hospital-acquired
  - Ventilator-associated
Let’s return to our patient, 48 hours after admission.
Index Patient: Interim History
48 hours after admission

- Patient’s respiratory status worsens
  - Episodes of dyspnea and tachycardia
  - Continues to spike fevers despite broad antibiotic coverage

- New onset headache

- Acute confusion and hypoxia
  - Emergent intubation
  - ABG: paO2 = 50
Index Patient: Development of ARDS

- Our patient continued to require mechanical ventilation

- PaO2 remained low despite ventilation and PEEP
  - Indicated significant intra-pulmonary shunt

- Ratio of PaO2 to FiO2 ranged from 97-158

- Our patient was diagnosed with Acute Respiratory Distress Syndrome
Index Patient: Frontal CXR at 48 hours after Admission

Please evaluate and proceed to next slide.
Index Patient: Alveolar Opacities on Frontal CXR

Findings:
Widespread patchy pulmonary opacities → alveolar
  Left > Right

Endotracheal tube tip at orifice of right main bronchus

No cardiomegaly

 Appropriately placed NG tube
Index Patient: Chest CT at 76 hours after Admission

Please evaluate and proceed to next slide.
Index Patient: Consolidation on Chest CT

Axial C+ Chest CT

Ground glass opacities

Increased areas of consolidation
Let’s discuss Acute Respiratory Distress Syndrome.
Acute Respiratory Distress Syndrome: Definition and Diagnosis

- ARDS: syndrome of acute and persistent lung inflammation with increased pulmonary vascular permeability, resulting in severe hypoxemia

- 4 Diagnostic Features:
  1. **Acute onset**
     - Develops over 4 to 48 hours, persists for days to weeks
  2. **Radiograph appearance of bilateral infiltrates consistent with pulmonary edema**
  3. **PaO2/FiO2 ≤ 200 mmHg**
     - Regardless of level of PEEP
  4. **Noncardiogenic**
     - No evidence of elevated L atrial pressure or pulmonary capillary wedge pressure < 18 mmHg
Acute Respiratory Distress Syndrome: Pathophysiology

- Injury to alveolar epithelial cells
  ± capillary endothelial cells
  \[\downarrow\]
- Inflammation with neutrophils
  \[\downarrow\]
- Expression of leukocyte adhesion molecules
  Release of multiple cytokine mediators, proteases, oxidants
  \[\downarrow\]
- Contribute to increased vascular and alveolar permeability
  \[\downarrow\]
- Increased fluid movement from capillaries to interstitium in excess of lymphatic reabsorption
  \[\downarrow\]
- Alveolar edema

Breakdown of the alveolar epithelial barrier allows leakage of edema fluid into the alveolar space. Arrows represent lymphatic movement; small circles represent protein.
Acute Respiratory Distress Syndrome: Causes

- Aspiration
  - Gastric
  - Near drowning
  - Hydrocarbons
- Toxic gas inhalation
  - Smoke
- Bilateral PNA
  - Viral
  - Bacterial
  - Pneumocystis jiroveci
- Sepsis
- Trauma
- DIC
- Embolism
  - Fat
  - Amniotic fluid
- Transfusion
- Drugs
- Pancreatitis
- Neurogenic
Acute Respiratory Distress Syndrome: Causes After Trauma

- Bilateral lung contusion/pulmonary hemorrhage
- Extensive aspiration
- Fat embolism
- Sepsis
- Massive traumatic tissue injury
- Iatrogenic
  - Drugs, transfusion-related
Acute Respiratory Distress Syndrome: Radiographic Appearance

- **Chest X-Ray**
  - Bilateral alveolar infiltrates
  - If not present initially, must develop within 24 hours
  - Normal heart size, unless prior heart disease and cardiomegaly unrelated to present problem

- **CT**
  - Multi-focal ground glass opacities
  - Progresses to consolidation
  - Usually begins in dependent-regions and periphery before becoming diffuse
  - Pleural effusions common, usually small

- **Acute development**
Companion Patient #1: Acute Respiratory Distress Syndrome on CXR

Findings:
- Bilateral alveolar opacities
- No cardiomegaly
Companion Patient #2: Acute Respiratory Distress Syndrome on CT

Findings:
- Multi-focal ground glass opacities
- Consolidations
  Greater in dependent areas

This companion patient developed ARDS from sepsis after pneumococcal pneumonia.
Our patient was felt to have developed ARDS from Fat Embolism Syndrome.

Let’s move on to discuss Fat Embolism Syndrome.
Fat Embolism Syndrome: Definitions

- Fat emboli: Presence of fat droplets within the systemic and pulmonary circulation with or without clinical sequelae.

- Fat embolism syndrome: Clinical sequelae that manifests 24-72 hours after initial insult.
  1. Respiratory distress
  2. Mental status changes
  3. Petechial rash

- Causes of Fat Embolism Syndrome:
  - Trauma-related
    - Long bone and pelvic fractures
    - Orthopedic procedures
    - Liposuction
  - Nontrauma-related very rare
    - Pancreatitis, bone tumor lysis, lipid infusion
Fat Embolism Syndrome: Pathogenesis

Two Hypotheses:

1.) Mechanical Obstruction:
   - Fat emboli obstruct pulmonary and systemic vasculature
   - Does not explain symptom-free interval following acute insult

2.) Toxic Intermediates:
   - Fat emboli are degraded into free fatty acids
     → FFAs are very toxic to lungs
   - Explains symptom-free interval
   - Supported by animal studies of FFAs initiating ARDS in mice

Fat Embolism Syndrome: Diagnosis

- Diagnosis remains elusive
  - Incidence is unknown, ranges from 0.25% to 35% in post-trauma patients
  - Complicated by authors’ use of different diagnostic criteria

- 3 Sets of Diagnostic Criteria

- Often indistinguishable from Acute Respiratory Distress Syndrome
Fat Embolism Syndrome: Original Diagnostic Criteria

- Gurd and Wilson (FES = 1 major + 4 minor + fat microglobulinemia)
  - Major criteria:
    - Respiratory insufficiency
    - Cerebral involvement
    - Petechial rash
  - Minor criteria
    - Pyrexia
    - Tachycardia
    - Retinal changes
    - Jaundice
    - Renal changes (anuria or oliguria)
    - Thrombocytopenia (a drop of >50% of the admission thrombocyte value)
    - High erythrocyte sedimentation rate
    - Fat microglobulinemia

- Petechial rash considered pathognomonic in appropriate clinical setting but only present in 20-50% of cases

- Presence of fat globules in sputum, urine, or wedged PA catheter is now not considered to be necessary to confirm diagnosis

Fat Embolism Syndrome: New Diagnostic Criteria

- Fat embolism index (FES = 5 or more points) in appropriate clinical setting
  - Diffuse petechiae (5 points)
  - Alveolar infiltrates (4 points)
  - Hypoxemia (<70 mm Hg) (3 points)
  - Confusion (1 point)
  - Fever 38°C
  - Heart rate >120/min
  - Respiratory rate >30/min

- Lindeque criteria (FES = femur fracture ± tibia fracture + 1 feature)
  - A sustained PaO2 <60 mm Hg
  - A sustained PaCO2 >55 mm Hg) or pH <7.3
  - A sustained respiratory rate >35/min even after adequate sedation
  - Increased work of breathing judged by dyspnea, use of accessory muscles, tachycardia, and anxiety

- All sets of diagnostic criteria have unknown specificity and sensitivity

Let’s evaluate our patient for Fat Embolism Syndrome.
Index Patient: Diagnosis of Fat Embolism Syndrome

- Our patient was evaluated with the Fat Embolism Index Criteria:
  - No diffuse petechiae = 0 points
  - Alveolar infiltrates = 5 points
  - Hypoxemia < 70 mm Hg = 3 points
  - Confusion = 1 point
  - Fever > 38°C = 1 point
  - Tachycardia > 120/min = 1 point
  - Tachypnea > 30/min = 1 point

- Total points on Fat Embolism Index = 12 points

- She satisfied the Fat Embolism Index (> 5 points) for the diagnosis of Fat Embolism Syndrome
Let’s continue to examine the radiographic findings of Fat Embolism Syndrome.
Fat Embolism Syndrome: Radiographic Appearance of Pulmonary Findings

- Nonspecific
  - Indistinguishable from ARDS
  - Also can progress to ARDS

- Chest X-Ray
  - Bilateral alveolar infiltrates

- CT
  - Multi-focal ground glass opacities
  - May progress to consolidations
  - Pleural effusions uncommon, usually small
  - Evidence of obstructive fat emboli in vasculature is extremely rare and not recently reported
Companion Patient #3: Fat Embolism Syndrome on CXR

Findings:
Bilateral alveolar infiltrates

A/P CXR
Companion Patient #4: Fat Embolism Syndrome on Chest CT

Axial C+ Chest CT

Multi-focal ground glass opacities

Malagari K et al. Chest 2003;123:1196-1201
Let’s conclude by returning to our patient.
At the time of this publication, our patient was felt to have Acute Respiratory Distress Syndrome secondary to Fat Embolism Syndrome. This is because:
- Satisfied ARDS Diagnostic Criteria
- Satisfied Fat Embolism Index Criteria
- Further work-up for Fat Embolism Syndrome, such as the presence of fat microglobinemia, was not pursued
- Multiple infectious work-ups were negative

Our patient received supportive management, which included:
- Mechanical Ventilation with PEEP

She made a full recovery 15 days later.
Many Thanks To:

- Adam Jeffers
- Paul Spirn
- Gillian Lieberman
- Maria Levantakis
References

Akhtar S. Fat embolism. *Anesthesiol Clin* 2009 Sep;27(3):533-50


Hansen-Flaschen J, Siegel MD. Acute respiratory distress syndrome: Definition; epidemiology; diagnosis; and etiology. *UpToDate* 2009.


Seigel MD. Acute respiratory distress syndrome: Pathophysiology; clinical manifestations; prognosis; and outcome. *UpToDate* 2009