Patient Presentation: DF

- DF is 21 year-old female brought in to the ED by EMS for a near drowning
- Was on her way to a wedding when she drove off a 30-foot high bridge
- Fell into brackish, fresh water
- Had a 10 minute submersion time
- Upon extraction, was reported to be vomiting and have an agonal breathing pattern
- EMS was unable to establish an airway
DF: Physical Exam

- **Vitals**
  - Temperature **91.2**, rectally
  - BP: 109/35
  - Pulse: 100
  - Respiratory Rate: **4**
  - $O_2$ Sat: **75% on non-rebreather**

- **HEENT**: notable for some lacerations

- **Chest**: Coarse breath sounds, bilaterally; no flail chest

- **CV**: RRR; pulses 2+ throughout

- **Abd**: NT/ND

- **Neuro**: PERRL, 8 → 7 mm, bil. Moving all extremities

- **Spine**: No tenderness, contusions, or step-offs

- **Skin**: Several lacerations
DF: Radiological Evaluation

- Cross-table C-spine Negative for fractures or dislocations
- Pelvis negative for fractures
- Head CT negative for edema (limited by artifact)
- Portable Chest
Agenda

- ARDS: an introduction
- Normal pulmonary capillary circulation
- Pathophysiology of ARDS
- Radiographic appearance of ARDS
- Differential diagnosis for diffuse alveolar pulmonary infiltrates
- Sequelae of ARDS on radiographs
- Summary
ARDS: an introduction

- ARDS = Acute Respiratory Distress Syndrome
- Consensus criteria (Bernard, et. al., 1994):
  - Acute onset
  - Bilateral Infiltrates on chest radiography
  - Pulmonary artery wedge pressure $\leq 18$ mmHg or absence of clinical evidence of left atrial hypertension
  - $\text{PaO}_2/\text{FiO}_2 \leq 200$
  - $\text{PaO}_2/\text{FiO}_2 \leq 300 = \text{Acute Lung Injury}$
- Incidence between 10 and 75 per 100,000
- Mortality approx. 35%, down from 50 – 60% over the last 15 years
Normal Pulmonary Capillary Circulation

- Fluid is maintained out of the alveolus
- Starling hypothesis describes fluid flow across capillary membrane
- \( Q_f = k \left[ (P_c + \pi_i) - (P_i + \pi_p) \right] \)
  - \( Q_f \) = Fluid movement
  - \( k \) = Filtration constant for capillary membrane
  - \( P_c \) = Capillary hydrostatic pressure
  - \( P_i \) = Interstitial fluid hydrostatic pressure
  - \( \pi_p \) = Plasma oncotic pressure
  - \( \pi_i \) = Interstitial fluid oncotic pressure
- \( P_c \) and \( \pi_i \) favor fluid movement into interstitium
- \( P_i \) and \( \pi_p \) favor fluid movement into capillary
- \( k \) favors increased fluid movement (direction dependent on other coefficients)

Causes of ARDS

- Direct lung injury
  - Pneumonia
  - Aspiration of gastric contents
  - Pulmonary contusion
  - Fat embolus
  - Near-drowning
  - Inhalational injury
  - Reperfusion pulmonary edema

- Indirect lung injury
  - Sepsis
  - Severe trauma with shock
  - Cardiopulmonary bypass
  - Drug overdose
  - Acute pancreatitis
  - Transfusion of blood products
Patient presentation: AY

- AY is a 42 y/o F with fatigue and cervical lymphadenopathy
- Also complained of abdominal pain, nausea and vomiting with constipation
- Outpatient X-ray normal
Clinical Course: AY

• Approx. 3 mo. later, AY presented to the ED with an acute exacerbation of her abdominal pain with radiation to the back
• In the interval, she developed fever, night sweats and 45 lb. weight loss
• CT/MRI revealed extensive lymphadenopathy thought to be lymphoma
• Underwent an endoscopic biopsy
• Developed acute pancreatitis
• Developed respiratory distress, with resps in the 20’s and O₂ sats in the 80’s on a non-rebreather
AY: Chest X-rays

Baseline PA
Portable AP 6:50 AM
Portable AP 9:23 AM
Pathophysiology of ARDS

- Increased capillary endothelium permeability
- Influx of protein-rich fluid into the interstitium
- Alveolar epithelium damage
  - Hyaline membrane production
  - Protein-rich edema fluid floods alveoli
  - No mechanism for removal of edema
  - Reduced surfactant production

Radiographic appearance of ARDS

- Radiographic latent period
  - Few or subtle radiographic findings
- Rapid deterioration: diffuse alveolar pattern pulmonary infiltrate
- Findings are usually:
  - Bilateral (92%)
  - Gravity dependent (86%)
  - Worse at the bases (68%)
  - Pleural effusions (50%)
    - Bilateral (28%)
    - Unilateral (22%)
- Air bronchograms
- Kerley B lines are uncommon
- On CT:
  - Patchy consolidation (42%)
  - Mixed consolidation/ground glass opacification (33%)
  - Homogenous (25%)
DF: Initial Chest X-ray

- Diffuse patchy bilateral opacities
- Relatively Symmetric
- Involves both central and peripheral lung
- Air bronchograms
DF: Initial CT

MGH AMICAS system
DF: Initial CT

- Dependent areas of dense consolidation
- Air bronchograms
- Patchy areas of “ground glass” opacification
- Areas of relatively normal appearance
Pulmonary vs. Extrapulmonary Causes – Appearance on CT

- Favor pulmonary cause:
  - Clinical history
  - Asymmetric findings
  - Mix of consolidation and ground glass opacities
  - Nondependent opacification
  - Presence of cysts

- Favor extrapulmonary cause:
  - Clinical history
  - Symmetric
  - Mostly ground glass opacities
  - Dependent opacification

DF: Near-drowning
AY: Acute pancreatitis
DDx for Diffuse Alveolar Pulmonary Infiltrates

- **Blood**
  - Pulmonary Contusion
  - Pulmonary hemorrhage
  - Goodpasteur’s syndrome

- **Pus**
  - CMV pneumonia
  - PCP pneumonia
  - Herpes pneumonia
  - Overwhelming bacterial pneumonia

- **Cells**
  - Bronchoalveolar carcinoma

- **Fluid**
  \[ Q_f = k \left[ (P_c + \pi_i) - (P_i + \pi_p) \right] \]
  - Increased pulmonary capillary pressure \((\uparrow P_c)\)
    - CHF
  - Decreased plasma oncotic pressure \((\downarrow \pi_p)\)
    - Hypoalbuminemia
  - Increased capillary permeability \((\uparrow k)\)
    - ARDS
ARDS vs. CHF

- Favors ARDS:
  - Clinical history
  - Fairly constant over time
  - Present in periphery
  - No cardiomegally
  - No Kerley lines

- Favors CHF:
  - Clinical history
  - Changes from day to day
  - “Bat-winged” pattern
  - Cardiomegally
  - Kerley lines

MGH AMICAS system

BIDMC teaching files
Sequelae of ARDS

- Lines and tubes
- Pneumothorax from barotrauma
- Pneumomediastinum from barotrauma
- Subcutaneous emphysema from barotrauma
- Pleural effusion
- Atelectasis and collapse from malpositioned ET tube
- Nosocomial pneumonia
- Pulmonary fibrosis
Patient Presentation: LC (Lines and tubes)

- LC is a 25 y/o M transferred from an outside hospital
- Developed ARDS from aspiration and oxycontin and ethanol overdose
- Tubes and lines:
  - ET tube
  - NG tube
  - Chest tube
  - Central line
LC: Aberrant Air in the Chest

Subcutaneous emphysema (HD 5)

Pneumothorax (HD 11)
DF: Hospital Course

- Respiratory distress worsened
- Patient placed on ECMO on HD 7
- On ECMO for 17 days
DF: High Resolution CT

Pleural Effusion
(Visible on CT but not on supine AP view)
DF: Persistent Hypoxia

- ECMO disconnected on HD 24
- Extubated on HD 36
- Persistent high oxygen requirements
- Consolidation in left lower lung field with silhouetting of heart
- Also opacity in right lower lung field
- Pneumonia vs. persistent ARDS
- Broncoscopy revealed MRSA pneumonia
- Treated with vancomycin for 21 days
Resolution of ARDS

- Pulmonary function returns to near normal in most survivors
- Some patients have uncomplicated course and rapid resolution
- Fibrosing alveolitis develops in some patients
  - Collagen is laid down in the alveolar space as early as 7 days after the insult
  - There is remodelling and gradual resolution of fibrosis

DF: Conclusion

- DF was discharged on hospital day 52
- Her $O_2$ saturation at discharge was 100% at room air
- On her presentation at Grand Rounds two months later, she reported some exertional dyspnea but no other long-term symptoms
- Returned to work as an administrative assistant
DF: Follow-up Chest X-ray

- Chest X-ray 6 weeks post discharge
- Alveolar disease largely resolved
- Fibrosis visible throughout especially in upper lung fields
- Emphysematous changes also visible
Summary

- Normal pulmonary fluid balance dictated by the Starling hypothesis
- In ARDS, a pulmonary or extrapulmonary insult results in a breakdown of capillary endothelium and alveolar epithelium
- There is an influx of protein rich edema fluid into the alveolus
- Hypoxia and respiratory distress result
Summary

- Radiographically ARDS typically presents with a bilateral, diffuse, symmetric alveolar pattern with air bronchograms, worse at the bases (initially).
- On CT, patchy consolidation and/or ground glass opacifications is seen; a homogenous appearance is suggestive of an extrapulmonary etiology.
- The DDx is large, and includes blood, pus, cells, and fluid.
- Complications of ARDS visible on chest X-ray include:
  - Pleural effusion
  - Atelectasis and collapse
  - Pneumothorax, pneumomediastinum, and subcutaneous emphysema
  - Pneumonia
  - Pulmonary fibrosis
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