April 2002

Radiographic Manifestations of ARDS and its Sequelae

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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

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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

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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

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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

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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 ≤ 18 mmHg or absence of clinical evidence of left atrial hypertension
  - $PaO_2/FiO_2 \leq 200$
  - $PaO_2/FiO_2 \leq 300$ = Acute Lung Injury
- Incidence between 10 and 75 per 100,000
- Mortality approx. 35%, down from 50 – 60% over the last 15 years

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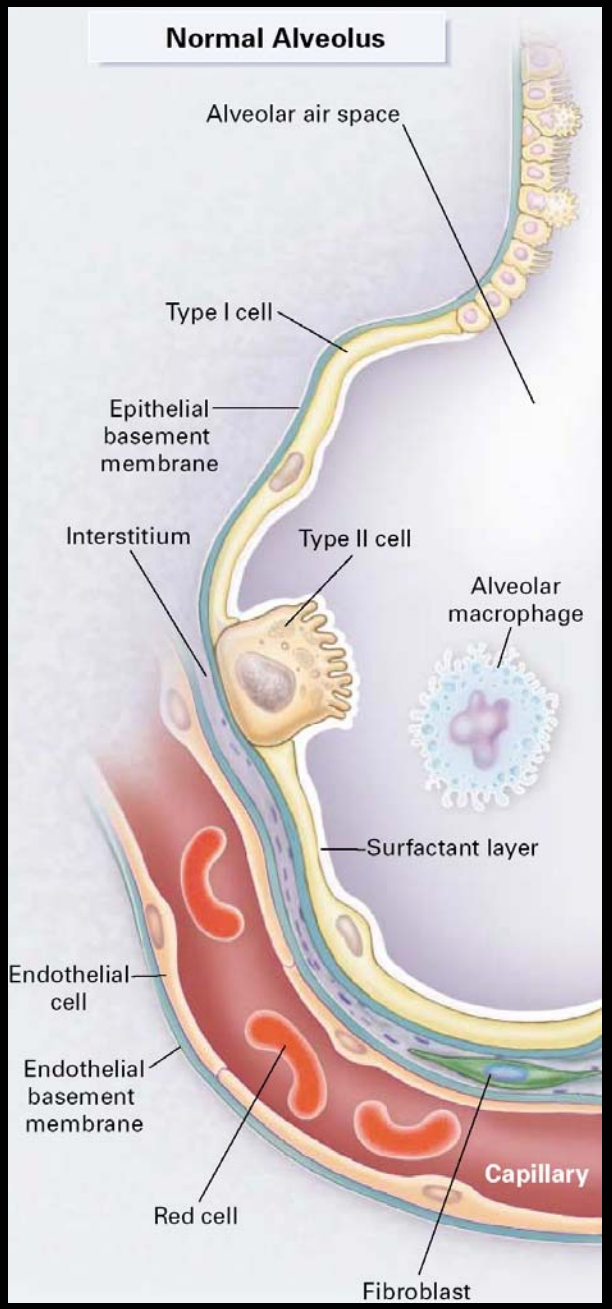
Normal Pulmonary Capillary Circulation

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



Source: Ware LB, Matthay MA. "The Acute Respiratory Distress Syndrome" *The New England Journal of Medicine*. May 2000; **342** (18): 1334-1349.

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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

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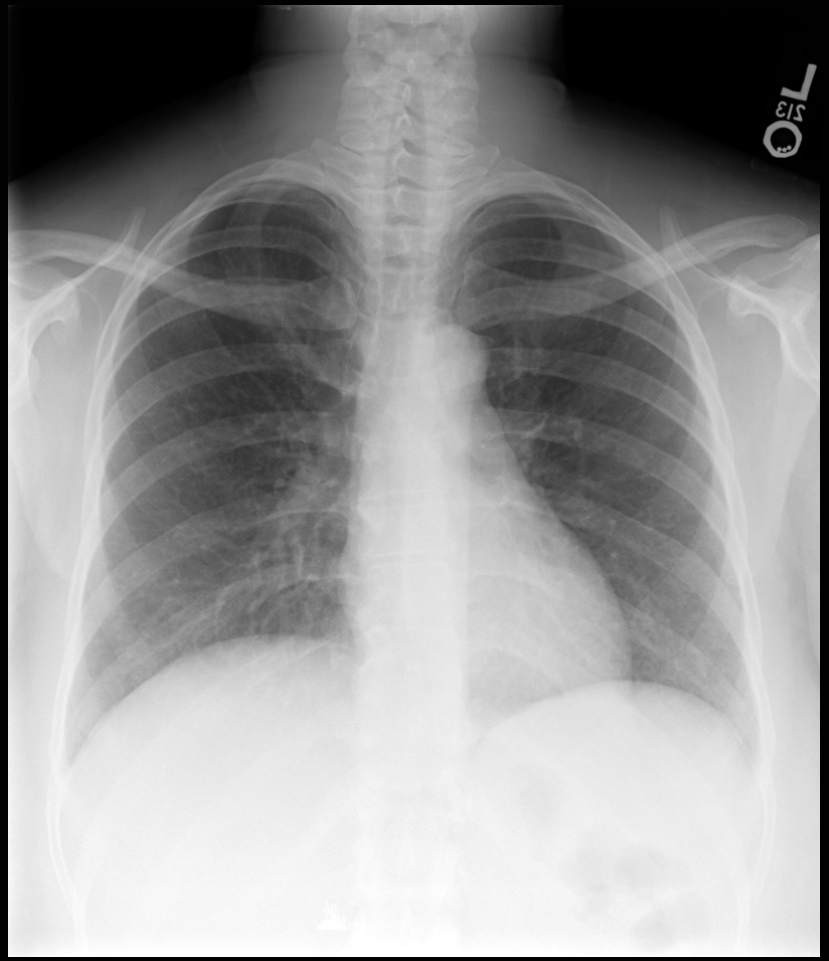
Patient presentation: AY

- 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



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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 O_2 sats in the 80's on a non-rebreather

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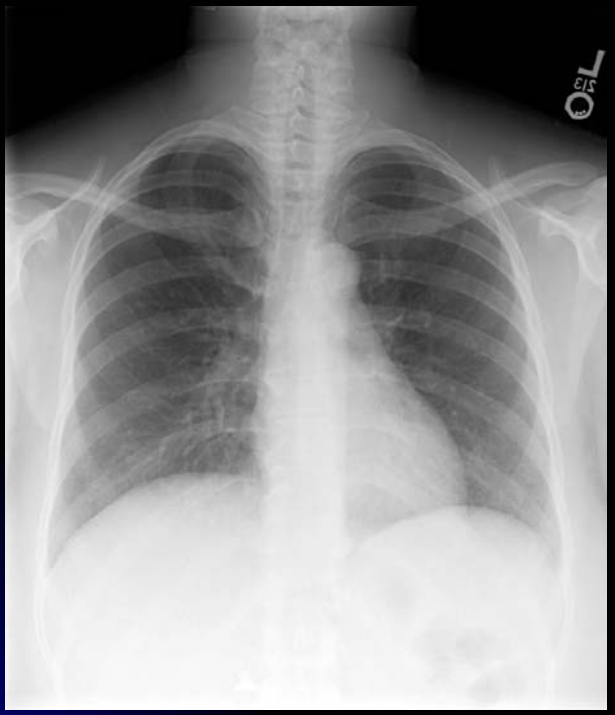
AY: Chest X-rays



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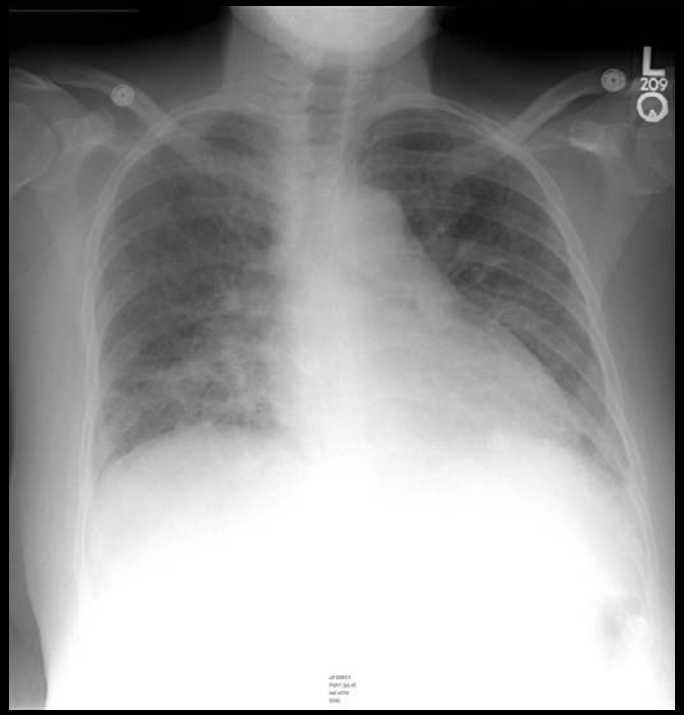
Baseline PA



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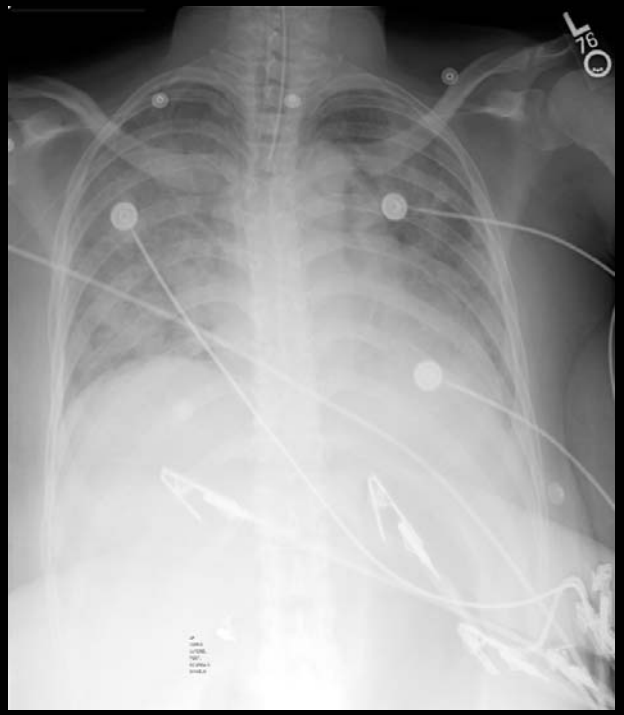
Portable AP 6:50 AM



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Portable AP 9:23 AM

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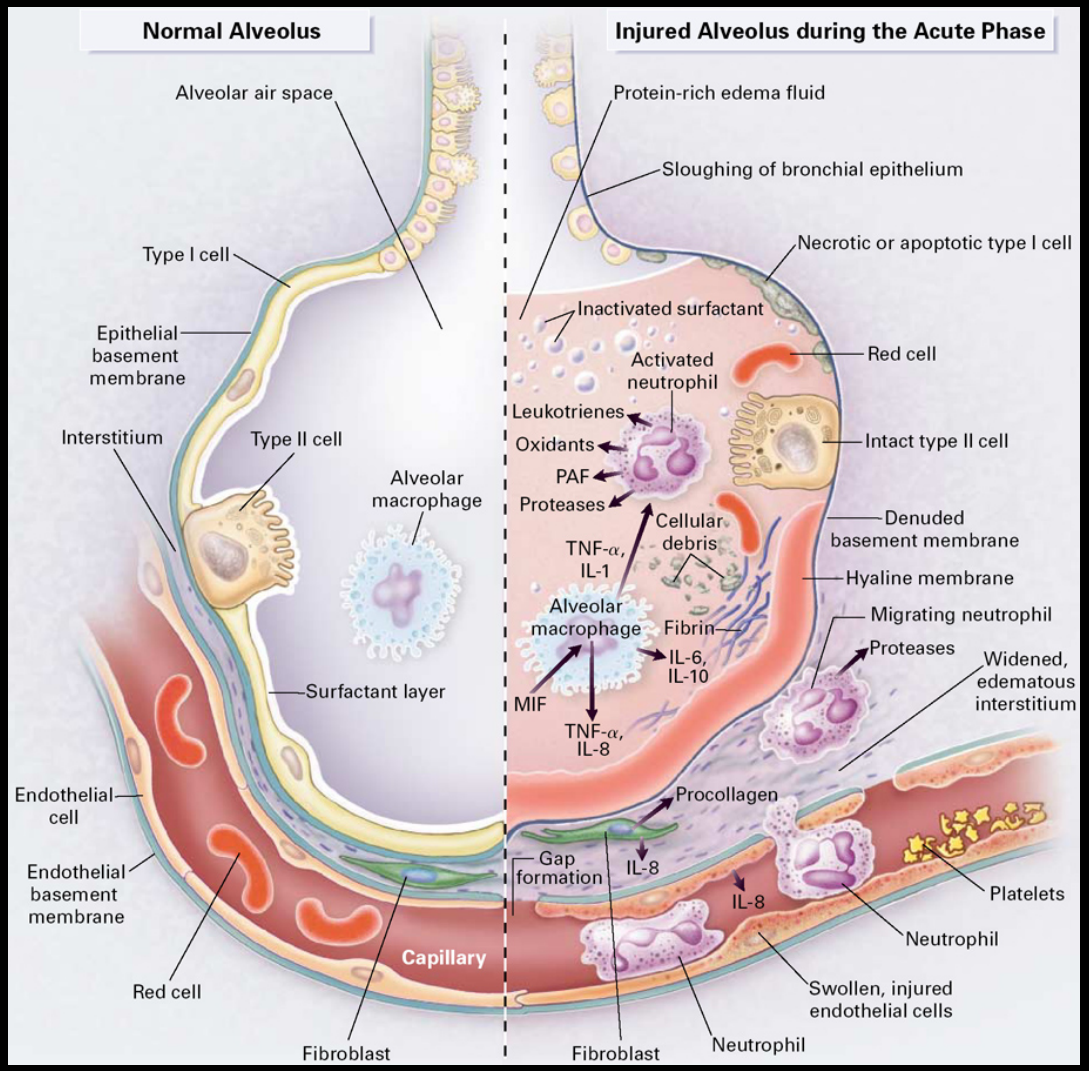
Pathophysiology of ARDS

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



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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%)

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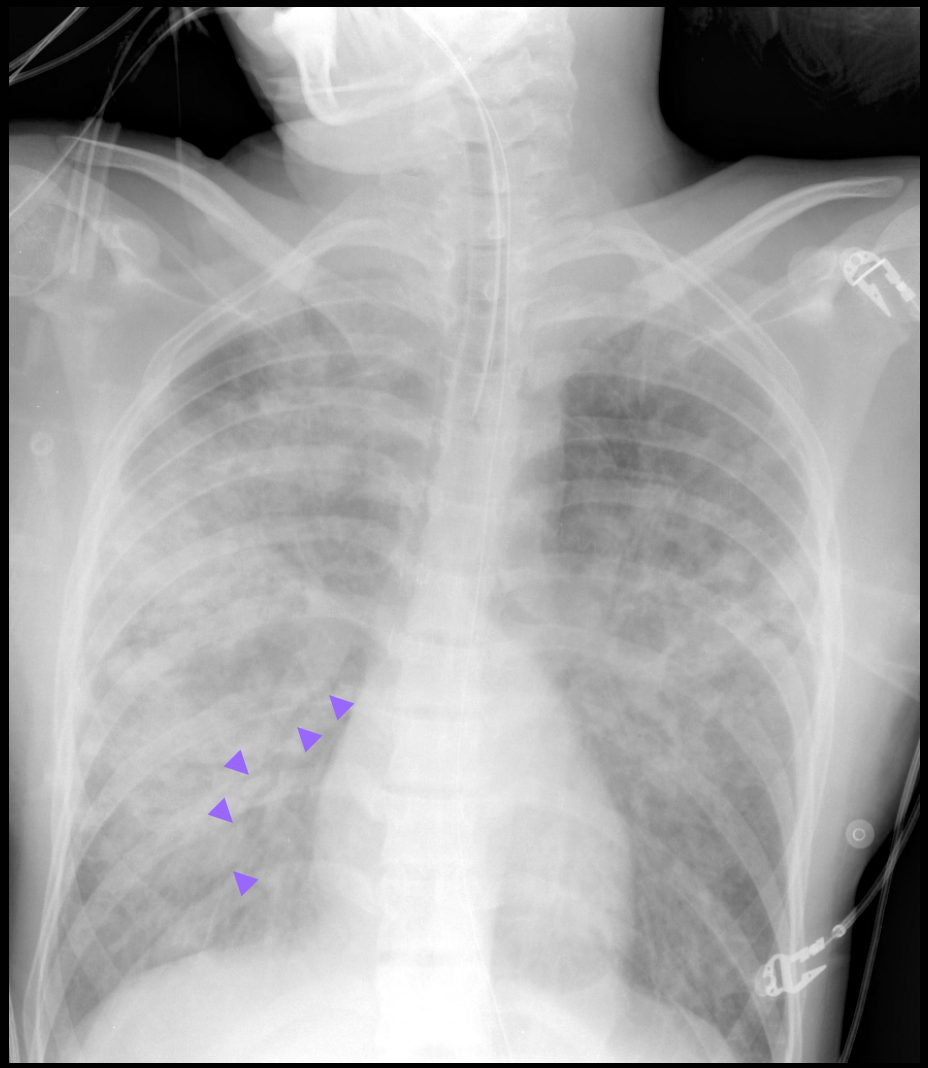
DF: Initial Chest X-ray

- Diffuse patchy bilateral opacities
- Relatively Symmetric
- Involves both central and peripheral lung
- Air bronchograms



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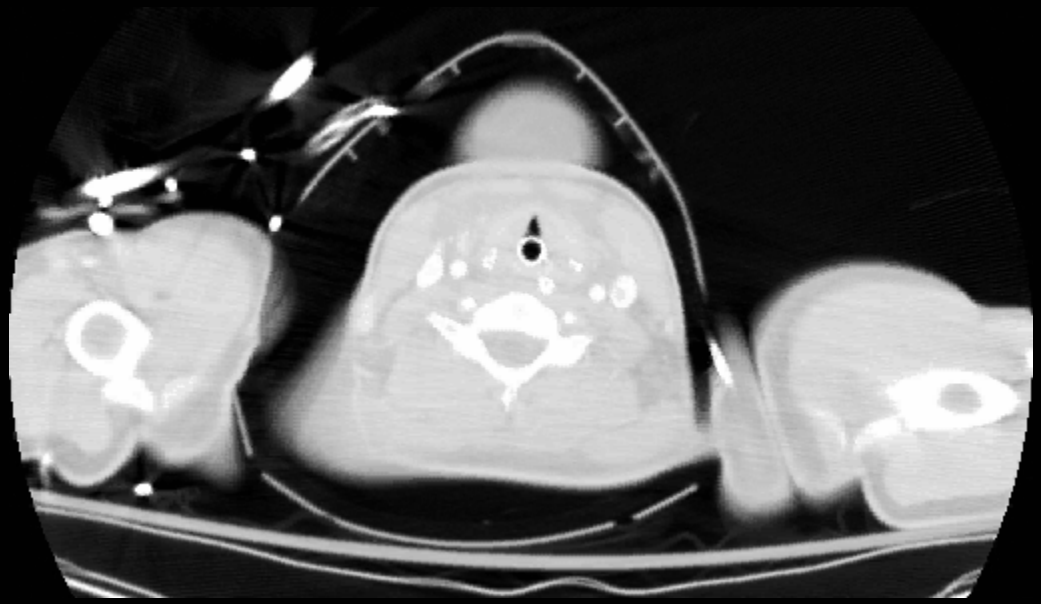
DF: Initial CT



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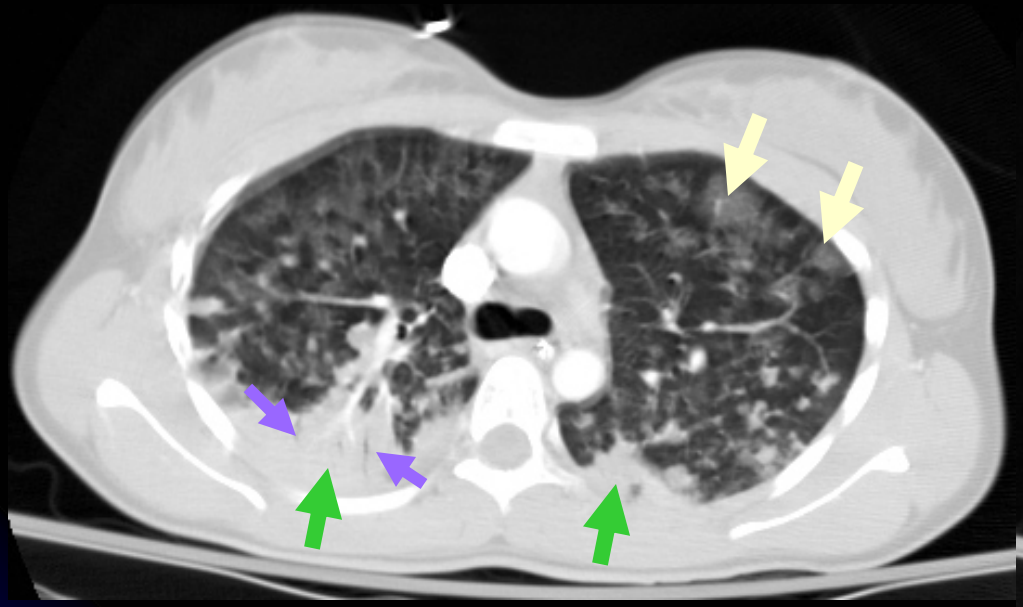
DF: Initial CT

Level of carina



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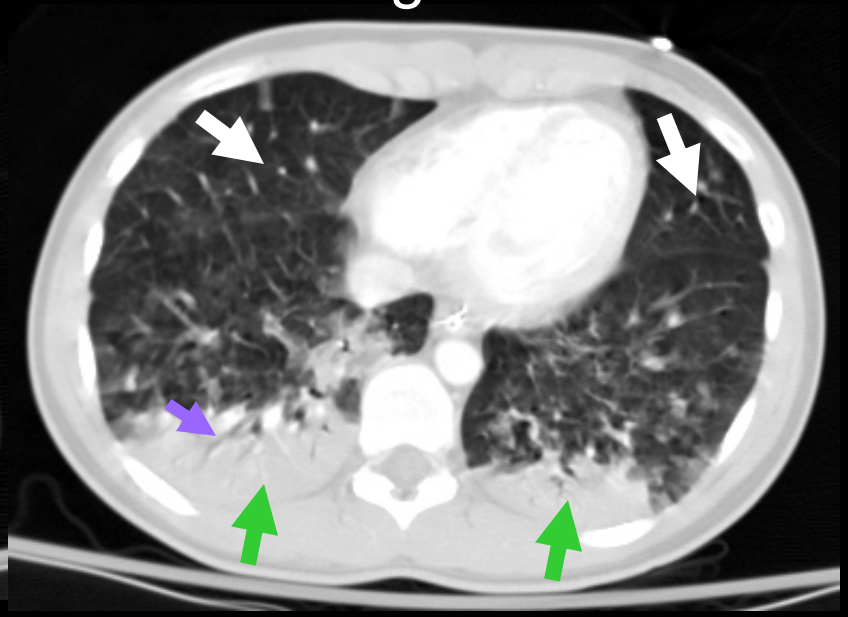
Lung bases



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- Dependent areas of dense consolidation
- Air bronchograms
- Patchy areas of “ground glass” opacification
- Areas of relatively normal appearance

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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

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DF: Near-drowning

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AY: Acute pancreatitis

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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 $Q_f = k\,[(P_c + \pi_i)-(P_i + \pi_p)]$
  - Increased pulmonary capillary pressure ($\uparrow P_c$)
    - CHF
  - Decreased plasma oncotic pressure ($\downarrow \pi_p$)
    - Hypoalbuminemia
  - Increased capillary permeability ($\uparrow k$)
    - ARDS

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ARDS vs. CHF

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

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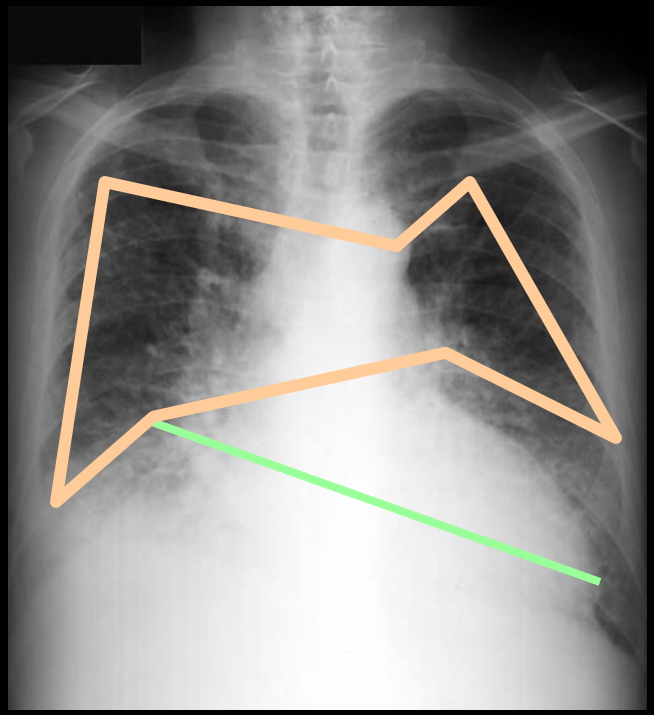
- Favors CHF:
  - Clinical history
  - Changes from day to day
  - "Bat-winged" pattern
  - Cardiomegally
  - Kerley lines



BIDMC teaching files

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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

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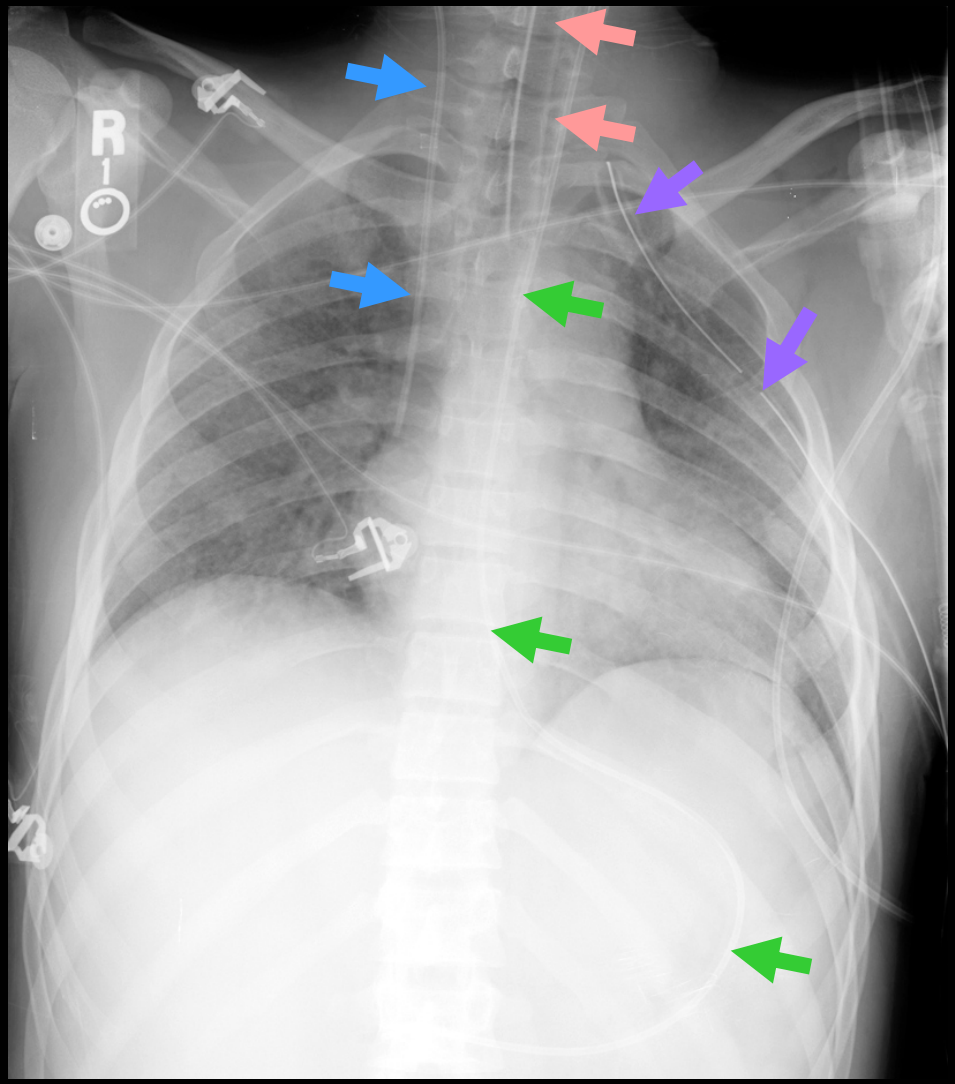
Patient Presentation: LC (Lines and tubes)

- 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



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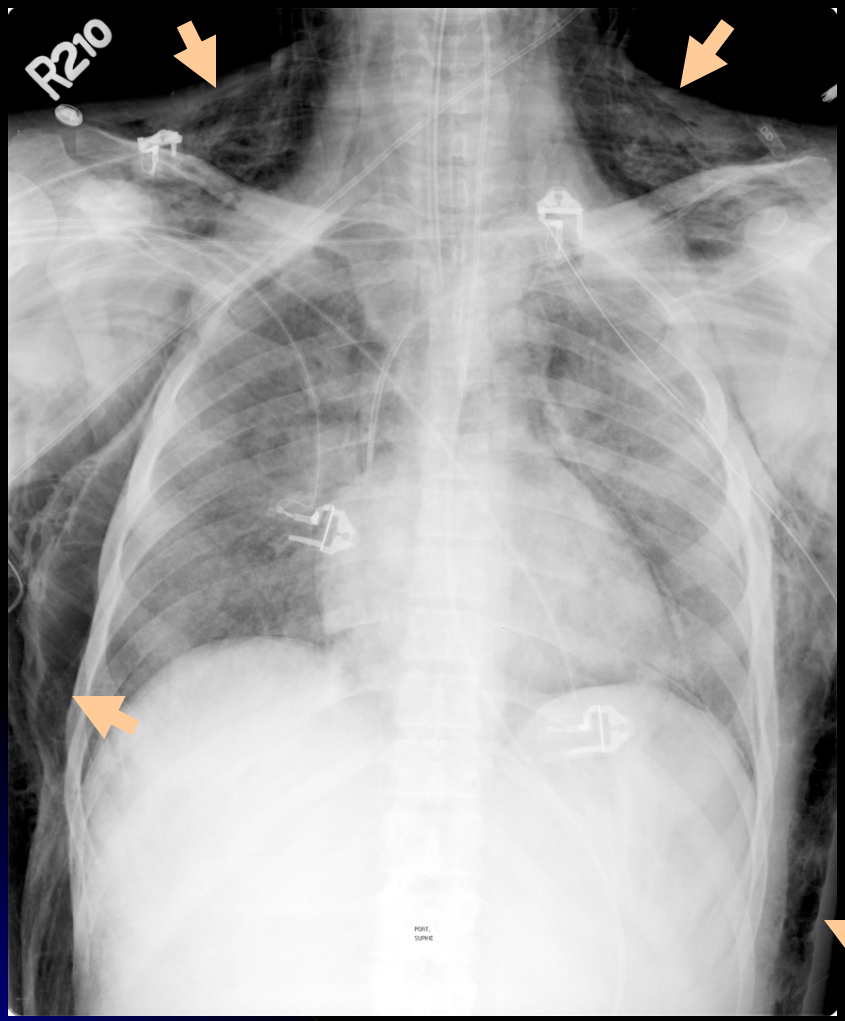
LC: Aberrant Air in the Chest



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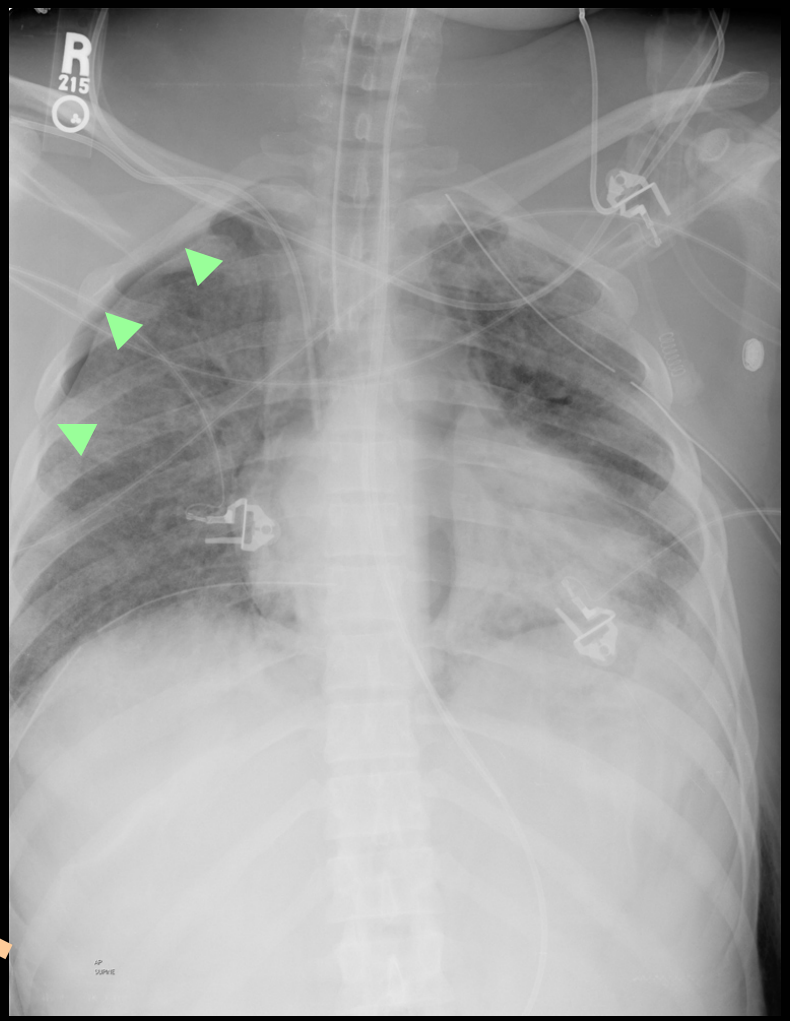
Subcutaneous emphysema (HD 5)



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Pneumothorax (HD 11)

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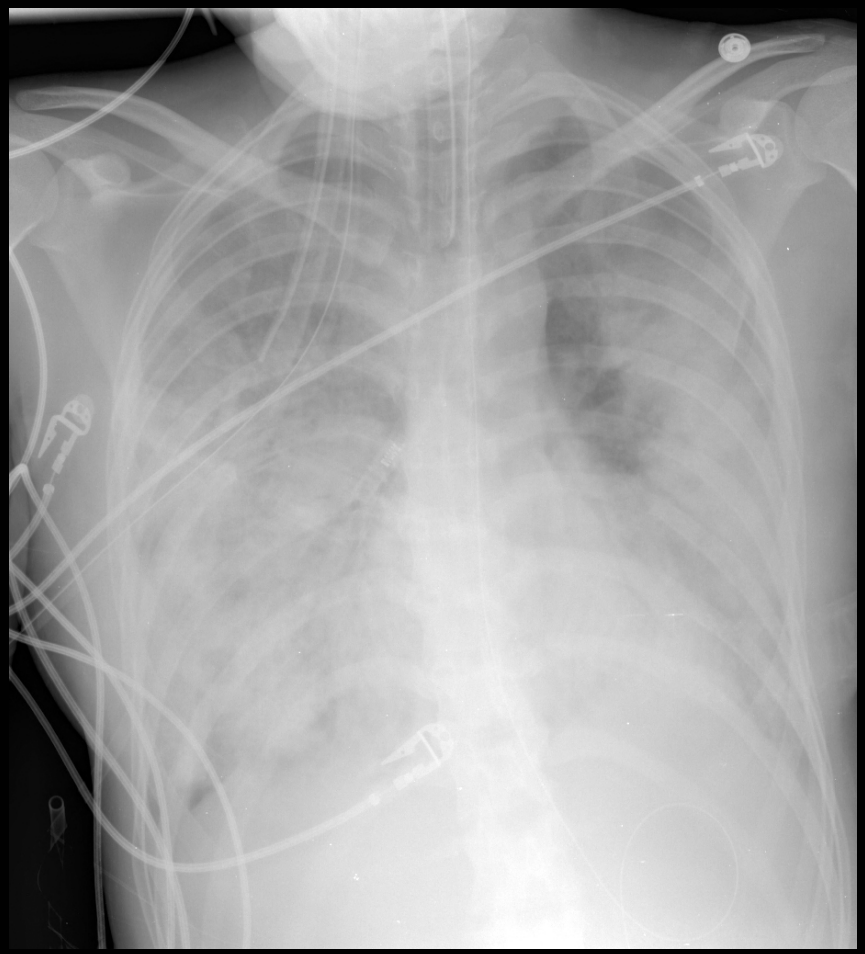
DF: Hospital Course

- Respiratory distress worsened
- Patient placed on ECMO on HD 7
- On ECMO for 17 days



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DF: High Resolution CT

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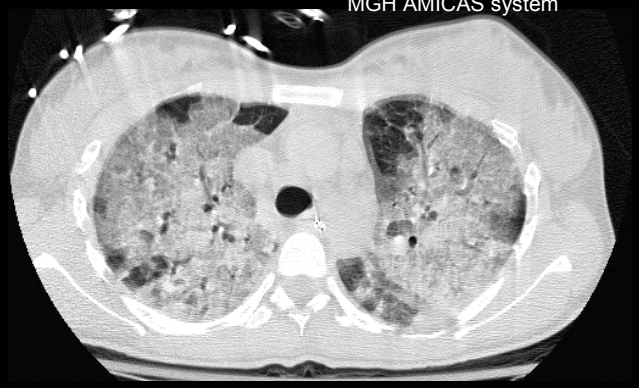

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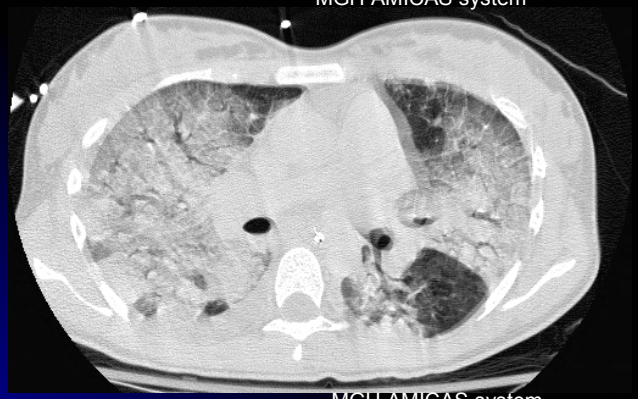

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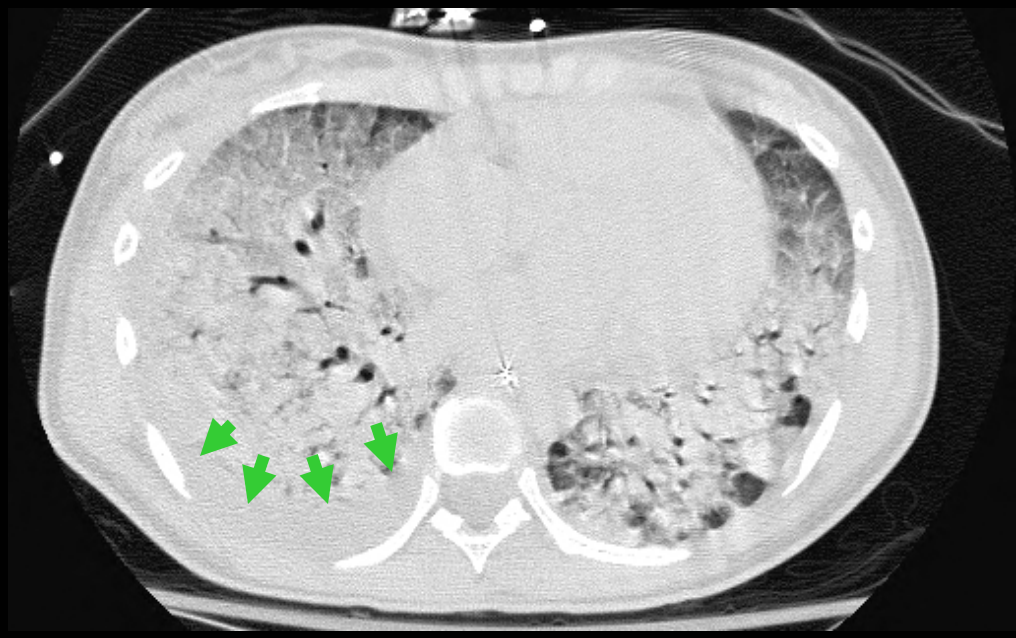

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Pleural Effusion
(Visible on CT but not on supine AP view)

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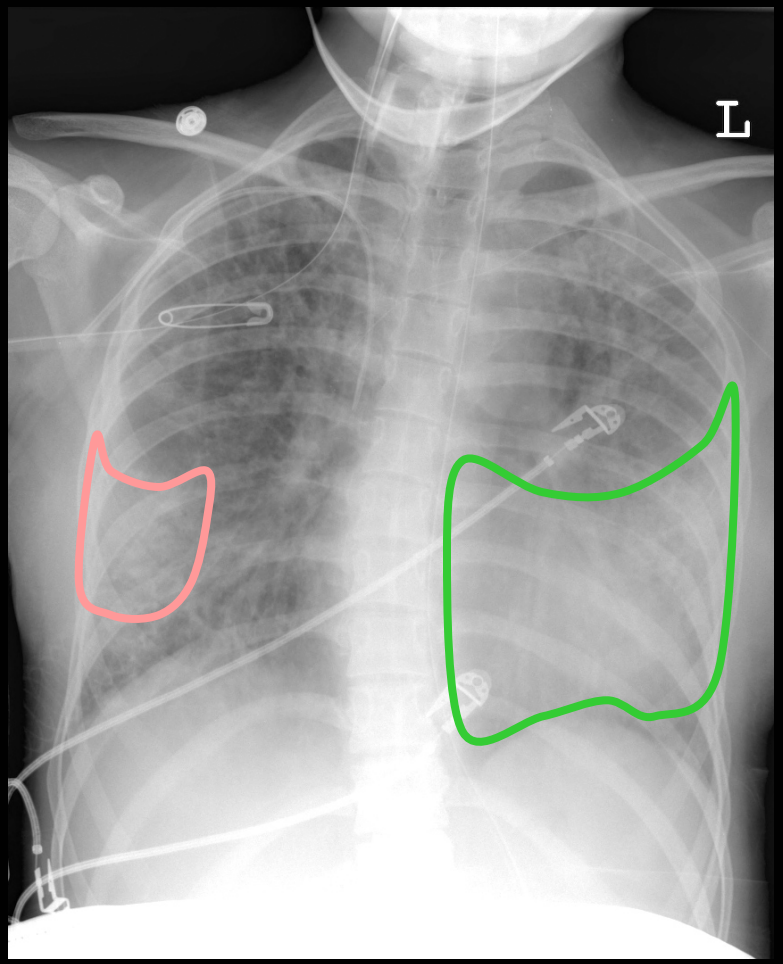
DF: Persistent Hypoxia

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



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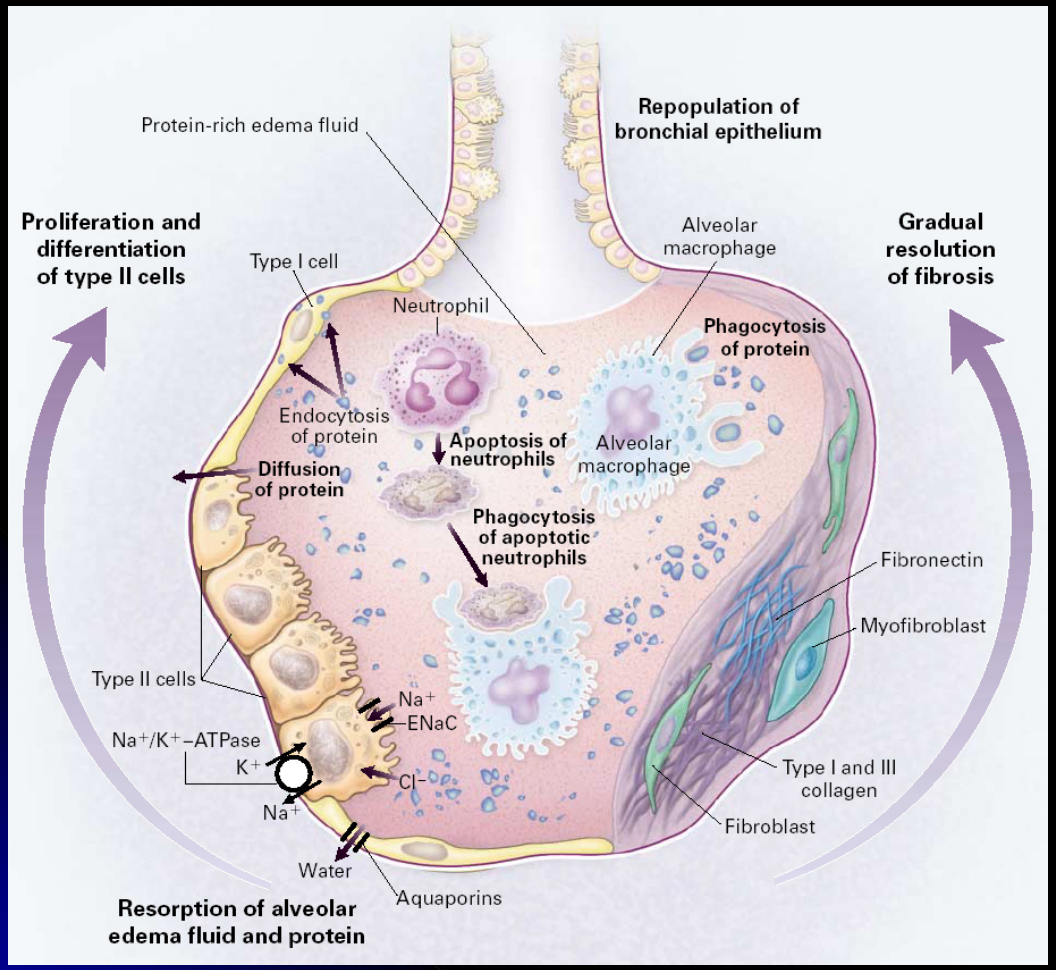
Resolution of ARDS



- 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

Source: Ware LB, Matthay MA. "The Acute Respiratory Distress Syndrome" *The New England Journal of Medicine*. May 2000; **342** (18): 1334-1349.

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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 exhertional dyspnea but no other long-term symptoms
- Returned to work as an administrative assistant

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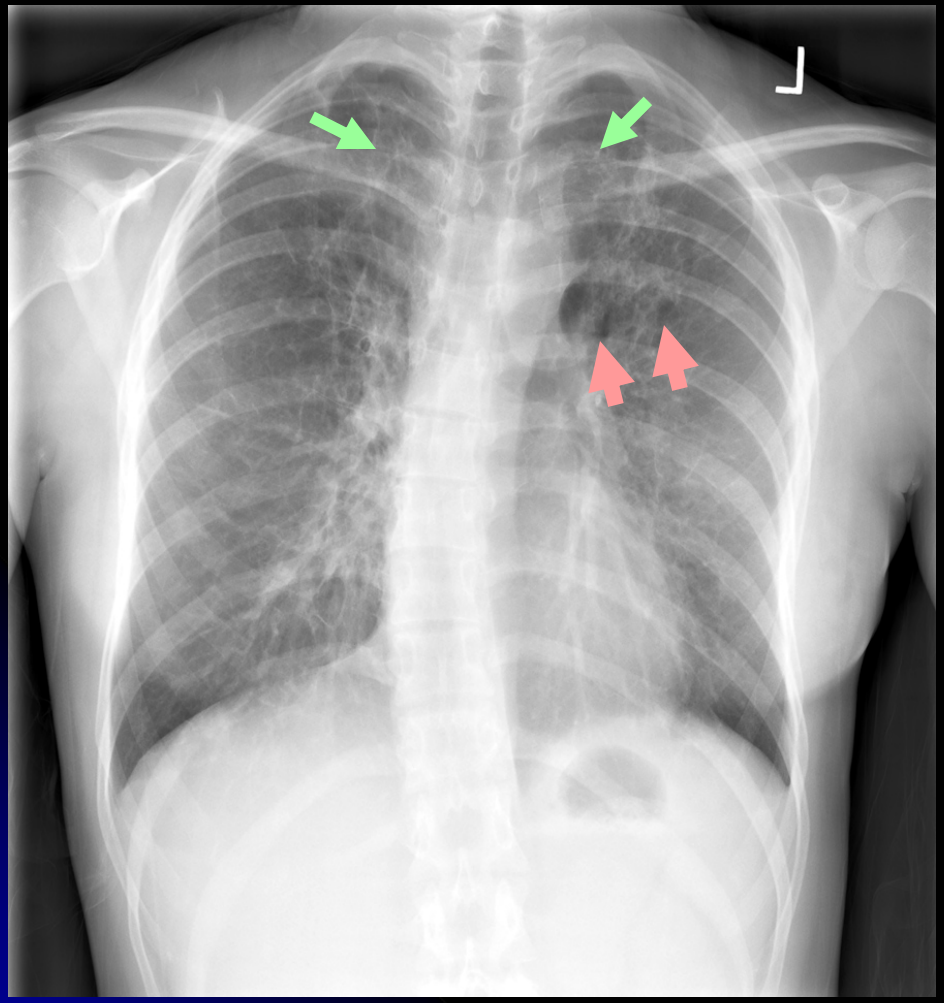
DF: Follow-up Chest X-ray



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

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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

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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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Acknowledgements

- Christopher Taylor, MD
- Phillip Boiselle, MD
- David Sher, HMS III
- Larry Barbaras and Cara Lyn D'amour, our Webmasters
- Gillian Lieberman, MD
- Pamela Lepkowski

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Thank you

- HMS Core radiology clerkship, April/May 2002