Objectives:

1. Understand the determinants of pleural fluid formation.
2. Interpret pleural fluid studies to distinguish between transudates and exudates.
3. Correctly correlate specific pleural fluid findings suggestive of underlying congestive heart failure, uncomplicated pneumonia, empyema, malignancy, pulmonary embolism, cirrhosis, tuberculosis and chylothorax.
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6. Recognize tension pneumothorax as a cause of shock.
7. Know the treatment options available for managing pneumothorax including observation, oxygen therapy, chest tube placement, and surgery.

Outline:

- Brief Anatomy/Physiology Review
- Pleural Effusions
  - Classification
  - Treatment Options
- Pneumothorax
Pleural Anatomy & Physiology

- Normally, less than 10cc fluid
- Pleural Effusion = Excess Pleural Fluid Accumulation
- Only parietal pleural is innervated
- Blood Supply (confusing at best)
  - Visceral Pleura:
    - Arterial supply is from the bronchial and pulmonary arteries
    - Venous drainage is through the pulmonary veins (to LA)
  - Parietal Pleura:
    - Arterial supply is from intercostals off the aorta
    - Venous drainage is through the IVC (to RA)

LV RV

SVC = Superior Vena Cava; IVC = Inferior Vena Cava; RA = Right Atrium; RV = Right Ventricle;
PA = Pulmonary Artery; PV = Pulmonary Vein; LA = Left Atrium; LV = Left Ventricle

Left Heart Failure leads to Pulmonary Edema and/or Pleural Effusions and/or Both

Which predominates (edema vs effusion) is unpredictable.
Pulmonary Hypertension leads to Cor Pulmonale
(not pulmonary edema or effusions)

Note: Since the parietal pleura drains into the IVC/RA, PHTN
might WORSEN an effusion caused by left heart failure but
PHTN won’t cause an effusion independently.

Pleural Anatomy & Physiology
- Normally, less than 10cc fluid
- Only parietal pleural is innervated
- Arterial supply is systemic
- Venous drainage is to the left atrium
- Sub-atmospheric pleural pressure (Ppl)
  ~ -5 cm H2O at mid-thorax resulting from the
  - Elastic Recoil of the lung pulling in
    and the
  - Elastic Recoil (ER) of the chest wall pulling out

\[
P_{Atm} \geq P_{Lung \ ER} + P_{Chest \ Wall \ ER} + P_{PL} + P_{Alv}
\]
Pleural Fluid Formation

\[ Q = K [(P_{\text{cap}} - P_{\text{pl}}) - R(\pi_{\text{cap}} - \pi_{\text{pl}})] \]

- **Q** = Rate of Fluid Formation
- **K** = Filtration Coefficient of the pleura
- **P_{\text{cap}}** and **P_{\text{pl}}** = the capillary and pleural Hydrostatic Pressures
- **R** = Solute Reflection Coefficient of the pleura
- **\pi_{\text{cap}}** and **\pi_{\text{pl}}** = the capillary and pleural Oncotic Pressures

Causes of EXCESS pleural fluid formation:

\[ Q = K [(P_{\text{cap}} - P_{\text{pl}}) - R(\pi_{\text{cap}} - \pi_{\text{pl}})] \]

- ↑ **K** - Infection/Inflammation/Cancer
- ↑ **P_{\text{cap}}** - LV failure
- ↓ **P_{\text{pl}}** - Atelectasis
- ↓ **\pi_{\text{cap}}** - NS, Cirrhosis, Malnutrition
- Direct entry of ascitic fluid, blood, lymph, gastric fluid

Pleural Effusions

Definition:
- Excessive fluid accumulation in the pleural space

Symptoms:
- None
- Pain
- Dyspnea
- Respiratory Failure
Pleural Effusions

Physical Exam Signs:
- Dullness to Percussion
- Decreased Breath Sounds and Tactile Fremitus
- Egophony

CXR:
- "blunting of the angle"
- "meniscus"
- "white-out"
  - with shift of mediastinum away
- "lateral decubitus" shows "layering"
- "loculations"
Meniscus

Massive Effusion
Complete Atelectasis

"White Out"

Massive Effusion
Complete Atelectasis
Lateral Decubitus

Effusion “layers out”

Loculations

Loculations
**Evaluation of Effusions**

- **H & P**
- **Thoracentesis**
  - Diagnostic
  - $\sim 50cc$
  - Therapeutic
    - for relief of symptoms
    - ? post-thoracentesis pulmonary edema (> 1.5L)

---

**Transudates vs Exudates**

<table>
<thead>
<tr>
<th>Transudates (normal pleura)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\uparrow P_{ap}$</td>
</tr>
<tr>
<td>$\downarrow P_g$</td>
</tr>
<tr>
<td>$\downarrow \pi_{ap}$</td>
</tr>
<tr>
<td>- LV failure</td>
</tr>
<tr>
<td>- Atelectasis</td>
</tr>
<tr>
<td>- Low Albumin</td>
</tr>
<tr>
<td>- Nephrosis, Cirrhosis, Malnutrition</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Exudates (&quot;leaky&quot; pleura)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\uparrow K$</td>
</tr>
<tr>
<td>- Infection</td>
</tr>
<tr>
<td>- Inflammation</td>
</tr>
<tr>
<td>- Cancer</td>
</tr>
<tr>
<td>- Direct entry of ascitic fluid blood, lymph, GI secretions</td>
</tr>
</tbody>
</table>

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**Transudates vs Exudates**

**Light’s Criteria for exudates:**
- $\frac{TP_{pl}}{TP_{serum}} > 0.5$, or
- $\frac{LDH_{pl}}{LDH_{serum}} > 0.6$, or
- $LDH_{pl} > 200$ (or 2/3 upper normal)

**Revised Criteria:**
- $LDH_{pl} > 200$ (or 2/3 upper normal), or
- $\text{Cholesterol}_{pl} > 45$

*Either one criteria classifies the effusion as an exudate.*

$pl = $ pleural; $TP = $ Total Protein; $LDH = $ Lactate Dehydrogenase
Cholesterol?

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Sensitivity</th>
<th>Specificity</th>
<th>PPV</th>
<th>NPV</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Protein ratio</td>
<td>81.4%</td>
<td>87.6%</td>
<td>99.7%</td>
<td>70.4%</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>LDH ratio</td>
<td>86%</td>
<td>94.7%</td>
<td>97.4%</td>
<td>75%</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>pf LDH</td>
<td>100%</td>
<td>97.8%</td>
<td>94.8%</td>
<td>100%</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>pf CHOL*</td>
<td>97.7%</td>
<td>100%</td>
<td>100%</td>
<td>95%</td>
<td>&lt;0.0001</td>
</tr>
</tbody>
</table>

*pf CHOL
- Cutoffs vary between 43 and 65
- Role in “diuresed heart failure”

pf = Pleural Fluid

Adapted from Pulm Med, 2013, Volume 2013

Transudates vs Exudates

Q. Why do we care?
A. Helps construct a differential diagnosis.

Transudative Effusions
- CHF
- Cirrhosis
- Nephrotic Syndrome
- Atelectasis
- Hypothyroidism
- Pulmonary Embolism (15%)
- Peritoneal Dialysis
Exudative Effusions

- Cancer
- Infections (Empyema)
- Parapneumonic Effusions
- Pulmonary Embolism (85%)
- Connective Tissue Diseases
- Esophageal Rupture
- Drug Induced Disease
- Post-MI
- Post-Pericardiotomy
- Uremia
- Asbestos
- Meig’s Syndrome
- Yellow Nail Syndrome
- Hemothorax
- Chylothorax

Additional Pleural Fluid Tests

- **pH**
  - normally, slightly higher than serum due to active transport of bicarbonate
  - low pH may be seen with Infection (empyema), Malignancy, and Esophageal Rupture
- **Glucose**
  - low in RA, TB, Cancer, Empyema

More Tests

- **Cell Count**
  - Total WBC
    - not very important unless frank pus
    - differential normally mainly macrophages
    - lots of poly’s suggests acute infection
    - lots of lymphs suggests TB or fungus
    - more than 5% mesothelial cells speaks against TB
  - Total RBC
    - "Hematocrit" > 1/2 peripheral = hemothorax
Even More Tests

- Cytology
  - sensitivity only 60%
- Gram Stain
- Culture & Sensitivities
- ADA (adenosine deaminase) = TB
- Amylase
  - pancreatitis and/or esophageal rupture

Patterns:

- **TB:**
  - Exudative, lymphocytic, < 5% mesothelial cells, + ADA, PPD may be negative early
- **Malignant Effusions:**
  - Exudative, lymphocytic, RBCs, +/- low pH/Glucose, Large
- **Pulmonary Effusions:**
  - 85% are small, unilateral, and exudative; +/- bloody
- **Esophageal Rupture:**
  - Left sided, low pH, high amylase
- **Endometriosis:**
  - Bloody, +/- associated with Pneumothoraces/Hemoptysis
- **"Hepatic" Effusions:**
  - Underlying cirrhosis, transudative, R > L sided, rapid re-accumulation
- **"Milky" Effusions:**
  - Chylous (Triglycerides > 110)
  - Malignancy, Trauma, Mediastinal Disease (ruptured thoracic duct)
  - Pseudochylous (Triglycerides >100 AND Chol > 300)
  - Chronic Inflammatory Conditions (breakdown of cell walls)
  - Empyema

Final Classification

- **Transudates**
- **Exudates**
  - "Uncomplicated"
  - "Complicated" Exudates
    - very low pH and/or glucose
    - very high LDH
    - at risk of becoming an empyema
- **Empyema**
  - + Gram Stain
  - + Culture
  - + Pus
Treatment

- Transudates: Treat the Cause
- Exudates
  - "Uncomplicated": Treat the Cause
  - "Complicated": Serial Thoracenteses, Chest Tube, +/- Thrombolytics
- Empyema
- Loculations
- Multiple Loculations/ Pleural Peel

*Video-Assisted Thoracoscopic Surgery

Pleurodesis?

- Definition:
  - Chemical or mechanical irritation of the visceral and parietal pleura to create adhesion and obliteration of the pleural space
- Why?
  - Prevents re-accumulation of fluid
- How?
  - Chemical: talc, bleomycin, doxycycline
  - Mechanical: gauze via VATS

Pneumothorax

- Definition:
  - air in the pleural space
- Mechanisms:
  - Alveolar air escapes into the pleural space
  - Air enters via a hole in the chest wall into the pleural space

*VATS* Video-Assisted Thoracoscopic Surgery
Pneumothorax

The Result:
- Air enters the pleural space until $P_{pl} = P_{atm}$
- Lung Collapses Inward
- Chest Wall Expands
- If ball-valve* mechanism, may develop supra-atmospheric $P_{pl}$ with "tension"
  $\rightarrow$ decreased venous return and hypotension

* Air enters the pleura during inspiration through a flap that closes during expiration, trapping ever more air/pressure in the pleural space.

Symptoms:
- Often Asymptomatic
- Chest Pain
- Dyspnea
- Cough
- Shock (if tension)

Physical Exam:
- Unilateral Hyperinflation
- Decreased Breath Sounds and Tactile Fremitus
- Hyper-resonance ("tympanic")

CXR
- Hyperlucent lung fields
- Lack of "lung markings"
- Thin white pleural line
- Shift of mediastinum if tension
Classification

- Spontaneous vs Traumatic/Iatrogenic
- Primary vs Secondary
Treatment

- Observation
  - +/- supplemental FiO₂
  - Room Air + Pneumothorax Space:
  - PmaxO₂ = 159 mmHg (Pₐ x FIO₂)
  - PmaxN₂ = 600 mmHg
  - Capillaries lining the PTx space:
    - PcapO₂ = 40 mmHg
    - PcapN₂ = 550 mmHg
  - Capillaries on 100%FIO₂:
    - PcapO₂ = 40 mmHg
    - PcapN₂ = 0 mmHg

Increased Gradient for Reabsorption

Minimal Gradient for Reabsorption

- Needle/Syringe Drainage
- "Chest Tube"
- Small Bore
- Large Bore
- +/- "suction"
- VATS/Thoracotomy

Only if small, asymptomatic, and no underlying lung disease
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