Breathing – Lung Ultrasound

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Lecture Goals

- Pneumothorax
- Pleural Fluid
- Thoracentesis
- Alveolar and interstitial fluid
- New ideas?

A decision tree utilizing lung ultrasonography to guide diagnosis of severe dyspnea

Pneumothorax

Background

- Pneumothorax is a common complication of trauma, emphysema, and procedures
  - 15-50% of patients with chest trauma
  - 6% of mechanically ventilated ICU patients
  - 2.5-30% of thoracenteses
  - 0.1-3% of central line placements
- Up to 1/3 of pneumothoraces are not detected on initial CXR in trauma patients
Background

- Rapid diagnosis key in critical patients
  - Hemodynamically unstable
  - Short of breath
  - Positive pressure ventilation
- Signs and symptoms of pneumothorax may be subtle, misleading
- Supine AP chest x-ray insensitive for pneumothorax
  - Up to 1/3 of pneumothoraces are not detected on initial CXR in trauma patients

Does this patient have a pneumothorax?

- Lung sliding or comet tail on US?
  - No pneumothorax
- Lung sliding, comet tail absent?
  - Pneumothorax

<table>
<thead>
<tr>
<th>Authors</th>
<th>Patients</th>
<th>Standard</th>
<th>Sens</th>
<th>Spec</th>
<th>PP</th>
<th>NP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blaivas '05</td>
<td>176 blunt trauma patients</td>
<td>CT, chest tube</td>
<td>98</td>
<td>99</td>
<td>98</td>
<td>99</td>
</tr>
<tr>
<td>Rowan '02</td>
<td>27 ED trauma getting CT</td>
<td>CT</td>
<td>100</td>
<td>94</td>
<td>92</td>
<td>100</td>
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<tr>
<td>Dulchavsky '01</td>
<td>382 trauma patients</td>
<td>CT</td>
<td>94</td>
<td>100</td>
<td>95</td>
<td>99.4</td>
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<tr>
<td>Lichtenstein '99</td>
<td>115 ICU patients</td>
<td>CXR, CT</td>
<td>100</td>
<td>96.5</td>
<td>89</td>
<td>100</td>
</tr>
<tr>
<td>Lichtenstein '95</td>
<td>111 hemithoraces in ICU</td>
<td>CXR, CT</td>
<td>95.3</td>
<td>91.1</td>
<td>67</td>
<td>100</td>
</tr>
</tbody>
</table>

Sens: sensitivity
Spec: specificity
PP: positive predictive value
NP: negative predictive value

Technique

- High-frequency linear transducer (5-10 MHz)
- 3rd-4th intercostal space, longitudinal orientation
  - Anterior axillary line below nipple also works well
- Locate acoustic shadow of ribs
- Note pleural line
  - Hyperechoic line between and below two ribs
- Normal lung exhibits:
  - Lung sliding at the pleural line
  - Comet-tail artifact

Technique

- High-frequency linear transducer
- (5-10 MHz)
The comet tail artifact
Imaging

Technique

- Power Doppler - lung slide

Technique

- M-mode lung slide

Technique

- M-mode + PTX
Summary

• Pneumothorax characterized by:
  – Absence of pleural lung sliding
    • Back-and-forth motion
    • Greatest movement at bases, least at apices
    • Requires real-time video, M-Mode, or power Doppler to document
  – Absence of comet-tail artifacts
    • Caused by reverberation of sound waves between hyperechoic parietal and visceral pleura

Pitfalls

• Loss of lung sliding or comet tail from other conditions may mimic pneumothorax
  – Bullous emphysema
  – Pleural adhesions
  – Extensive pneumonia
• Subcutaneous emphysema may inhibit thoracic ultrasound

Pleural Effusions and Thoracentesis

• Morison’s or splenorenal space
• Longitudinal orientation of probe with marker to patient’s head
• Normal lung tissue – mirror image artifact above diaphragm
• Anechoic above diaphragm - fluid

What is a Mirror image?

Actual Path: Calculated Path:

Mirror Image
Pleural fluid

Thoracentesis

- Identify area of maximal fluid
- Measure depth to fluid pocket using calipers
- Two dimensional localization for needle insertion
- Depth to fluid is maximal needle insertion

Literature

- Mayo PH et al Chest 125(3); 2004:1059-62
  - 232 thoracenteses performed in ICU patients receiving mechanical ventilation
  - 3 pneumothoraces
- Jones PW et al Chest 123(2); 2003:418-23
  - 941 thoracenteses performed by IR staff
  - 2.5% incidence of pneumothoraces

Technique

- Review the CXR
- Map out effusion
  - Identify the largest & most accessible pocket of fluid
- Note location of diaphragm, spleen, liver
- Measure depth from surface to parietal pleura

Direct Intercostal Approach
Comet-tail Technique

- Relies on microreflections of ultrasound beam in thickened interlobular septae
- Correlated with extravascular lung water

A-lines

B-lines

B-lines
Background
Published lung ultrasound techniques

- Lichtenstein et al.
  - Three areas divided into two regions. AIS more than two/three B lines between two ribs in one longitudinal scan. Positive = any artifact. Negative = no artifact.

- Agricola et al.
  - Scanning from second to fourth intercostal space, from parasternal to midaxillary line, sum all b-lines seen for comet tail score
  - Positive = “multiple” comet-tail images either disseminated over anterolateral lung surface or lateral (limited only to lateral surface)

- Volpicelli et al.
  - Scanning in eight regions of chest, AIS 1. more than three B lines per area 2. more than one area per side 3. must be bilateral

CHF vs COPD

<table>
<thead>
<tr>
<th>Ultrasound</th>
<th>Pulmonary Edema</th>
<th>COPD</th>
<th>Normal Lungs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diffuse B-lines</td>
<td>have a Sens = 100%, Spec = 92% in the diagnosis of pulmonary edema when compared with COPD.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Localized anterior location</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Localized posterior location</td>
<td>0</td>
<td>13</td>
<td>20</td>
</tr>
<tr>
<td>Absence of comet-tail artifact</td>
<td>0</td>
<td>9</td>
<td>58</td>
</tr>
</tbody>
</table>

Total

40 | 26 | 80


New Ideas?
Pneumonia

- Air is a barrier to ultrasound
- Normal lungs do not image well
- When lung consolidation occurs:
  - Airspace gets consolidated
  - Behaves more like a solid than a gas
  - Hepatization

- Alveolar consolidation was defined as a tissue-like pattern visible at the chest wall, arising from the pleural line and devoid of centrifugal inspiratory dynamics.

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Diaphragmatic Injury

Questions?

Thank you.