Chest US Review and Update

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• No disclosures
Historical perspective

• Initially for cardiac echo
  • Subsequent studies \(\rightarrow\) non-cardiac applications
    – 1973: Goldberg et al in JCUS
      • 30 mediastinal masses in pts. age 1-84 yrs.
    – 1977: Kangarloo et al in Radiology
      • Juxtadiaphragmatic lesions in children, value of liver window
    – 1980: Haller et al in AJR
      • 28 children - 93% success rate; evaluation of opaque hemithorax, characterizing pleural fluid, guiding drainage, integrity of diaphragm
    – 1984: Claus and Coppens in Ann Radiol
      • Value of thymus as a window for US for mediastinal masses
    – 1984: Miller et al in Radiology
      • “Water path ultrasound of chest disease in childhood”
        – 82 children placed in “Octoson” to expand windows
Diagram of the Octoson, demonstrating the relationship of the patient's chest to the scanning arm and the 8-transducer array (arrow-head) in the decubitus position. Arrow = membrane.
Historical perspective cont.

- 1986: Rosenberg HK in RG
  • Complimentary role of US and CXR in differentiating pediatric chest abnormalities

- 1989: Glasier et al in J Pediatr
  • Modality of choice for opaque chest, mediastinal masses, and pleural disease

- 1993: Ben-Ami TE et al in RCNA
  • Review

- 2005: Coley BD in RCNA
  • Review
A Bedside Ultrasound Sign Ruling Out Pneumothorax in the Critically Ill* Lung Sliding

Daniel A. Lichtenstein, MD, and Yves Menu, MD
**Advantages**

- **Generic**
  - Non invasive, inexpensive, no “contrast”, realtime, Doppler, bedside/portable, some tissue characterization

- **Pediatric**
  - No radiation
  - Paucity of fat
  - Smaller, more superficial structures

- **Pediatric chest**
  - Portable
  - Cartilagenous sternum and ribs
  - Thymic window

**Disadvantages**

- **Pediatric chest**
  - Aerated lung
    - Requires parenchymal lesion to be superficial
  - Older children
    - Sternum ossified, thymus small
  - Problem= we believe that “AIR is the enemy of US”
  - But when pathology is present, air is replaced
  - Both, normal and abnormal lung cause “artifacts”
Problem= we believe that “AIR is the enemy of US”

- But when pathology is present, air is replaced
- Both, normal and abnormal lung cause “artifacts”

Disadvantages

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Applications

• Thoracic cage
• Diaphragm
• Mediastinum
• Pleura & Parenchyma

1- anterior superior
2- anterior basal
3- lateral superior
4- lateral basal
Thoracic Cage
Breast Lumps

- Etiology of breast lumps in children can be clinically challenging
- Anterior chest wall lesions can masquerade as breast lumps due to anatomical relationship between the chest wall and the breast
- Sonography is useful for characterization of these lesions
Technique

- High frequency linear array transducers (7-12 MHz) are useful as the structures evaluated are superficial
- Longitudinal and transverse sections in orthogonal planes
- **Contralateral comparison**
- Compression
- Creating an adequate window
- Making patient comfortable/making friends
- Warm gel
US Normal Chest wall

US transverse section at midline

Sternum is hyperechoic (thick arrow), costal cartilage is hypoechoic (thin arrows)
US Normal Chest wall

US longitudinal section
the costal cartilage is hypoechoic
Prominent anterior convexity of rib or costal cartilage

Prominent asymmetric costochondral junction

Tilted sternum

Subcutaneous/Parachondral nodule

Phlegmon/Collection

Lymph node

Hemangioma

Kaposiform hemangioendothelioma

Hematoma

Costochondritis

Lipoma

Lipoblastoma

NORMAL VARIANTS CHEST WALL LESIONS
Normal variant:
Prominent anterior convex rib
Normal variant:
Prominent anterior convex rib
Normal variant: Tilted sternum
Normal variant: Asymmetric costochondral junction
Asymmetric breast buds

A Rad Right Breast R* Dist 1.07 cm
× Dist 0.558 cm
Fibroadenoma

- Less than 5cm and benign features
- Well-circumscribed
- Ovoid-shaped
- Wider than tall

- Hypoechoic
- Macrolobulated
- High degree of diagnostic confidence
Chest wall hemangioma
Kaposiform hemangioendothelioma
Diaphragm
M-mode sonography of diaphragmatic motion: description of technique and experience in 278 pediatric patients
Background

• Why is this important?
Despite “misleading” benign presentation → high morbidity → 4 main consequences:

**Analogy with obstructive sleep apnea**

- **Sleep fragmentation**
  - Daytime sleepiness
  - Hyperactivity
  - Aggressive behaviour
  - Inverse correlations between memory and learning performance and the severity of OSA

- **Increased work of breathing**
  - Major cardiovascular consequence in adults → Arterial Hypertension → heightened sympathetic tone and enhanced sympaticoadrenal discharge
  - Children → FTT

- **Alveolar hypoventilation**
  - Hypercapnia, particularly while asleep

- **Intermittent hypoxemia**
  - ↑pulmonary vasoconstriction
  - ↑pulmonary artery Pressure
  - Pulmonary HTN
  - Cor pulmonare
<table>
<thead>
<tr>
<th>Condition</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cardiac surgery</td>
<td>133</td>
</tr>
<tr>
<td>Heart transplant</td>
<td>12</td>
</tr>
<tr>
<td>Chest surgery</td>
<td>8</td>
</tr>
<tr>
<td>Lung transplant</td>
<td>4</td>
</tr>
<tr>
<td>Brachial plexus injury</td>
<td>78</td>
</tr>
<tr>
<td>Abnormality on CXR</td>
<td>12</td>
</tr>
<tr>
<td>Abdominal surgery</td>
<td>7</td>
</tr>
<tr>
<td>Neurological disease</td>
<td>4</td>
</tr>
<tr>
<td>Myopathy</td>
<td>2</td>
</tr>
<tr>
<td>Trauma</td>
<td>2</td>
</tr>
<tr>
<td>Spinal surgery</td>
<td>1</td>
</tr>
<tr>
<td>Neck surgery</td>
<td>1</td>
</tr>
</tbody>
</table>

Epelman M et al Pediatr Radiol 2005
Diagnosis

• CXR → non-specific → may or may not show elevation of hemidiaphragm

• Fluoroscopy → “gold standard”
  – May show conflicting results 😞
  – Radiation exposure 😞
  – Need to transport patient to fluoroscopy unit 😞
  – Need of an assistant to observe the phases of respiration 😞
  – Visualization least mobile anterior third of diaphragm on A-P view 😞
  – Potential misinterpretation if paralysis is bilateral 😞
Technique

• Initial conventional B-mode US:
  – Evaluation of upper quadrants and lower chest in longitudinal and transverse planes
  – Midline transverse subxyphoid plane
**Technique**

- M-mode US:
  - Interrogation of each hemidiaphragm in the longitudinal plane
  - Recording of at least 4 respiratory cycles during spontaneous respiration
  - If patient is mechanically ventilated → temporary disconnection & recordings in both situations

**Technique**

- Normal excursion:
  - Diaphragmatic motion towards the transducer on inspiration
  - Excursion exceeds 4-5mm
  - Difference of excursion between hemidiaphragms less than 50%
- Decreased excursion
- Paradoxical motion
- Absent motion
### Table 2—Right Diaphragmatic Excursions and Limit Values in Men and Women*

<table>
<thead>
<tr>
<th>Variables</th>
<th>Men, cm</th>
<th>Women, cm</th>
<th>p Value</th>
</tr>
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<tbody>
<tr>
<td>Quiet breathing</td>
<td>$1.8 \pm 0.3 \ (1.1–2.5)$</td>
<td>$1.6 \pm 0.3 \ (1–2.2)$</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Voluntary sniffing</td>
<td>$2.9 \pm 0.6 \ (1.8–4.4)$</td>
<td>$2.6 \pm 0.5 \ (1.6–3.6)$</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Deep breathing</td>
<td>$7 \pm 1.1 \ (4.7–9.2)$</td>
<td>$5.7 \pm 1 \ (3.6–7.7)$</td>
<td>&lt; 0.001</td>
</tr>
</tbody>
</table>

*Data are presented as mean ± SD (5th to 95th percentile).

### Table 3—Left Diaphragmatic Excursions and Limit Values in Men and Women*

<table>
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</thead>
<tbody>
<tr>
<td>Quiet breathing</td>
<td>$1.8 \pm 0.4 \ (1–2.6)$</td>
<td>$1.6 \pm 0.4 \ (0.9–2.4)$</td>
<td>0.002</td>
</tr>
<tr>
<td>Voluntary sniffing</td>
<td>$3.1 \pm 0.6 \ (1.9–4.3)$</td>
<td>$2.7 \pm 0.5 \ (1.7–3.7)$</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Deep breathing</td>
<td>$7.5 \pm 0.9 \ (5.6–9.3)$</td>
<td>$6.4 \pm 1 \ (4.3–8.4)$</td>
<td>&lt; 0.01</td>
</tr>
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*Data are presented as mean ± SD (5th to 95th percentile).
<table>
<thead>
<tr>
<th>Direction</th>
<th>Transition between inspiration and expiration</th>
<th>Excursion in mm, absolute value</th>
<th>Difference from contralateral side</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td>normal sharp/rounded</td>
<td>&gt; 4-5mm</td>
<td>&lt; 50%</td>
</tr>
<tr>
<td>Paralysis</td>
<td>paradoxical rounded</td>
<td>variable</td>
<td>variable</td>
</tr>
<tr>
<td>Paresis/dysfunction</td>
<td>normal rounded/flat</td>
<td>&lt; 4-5mm</td>
<td>&gt;50%</td>
</tr>
</tbody>
</table>

## Technique

<table>
<thead>
<tr>
<th>Age</th>
<th>1-14 months</th>
<th>2.5 – 5 years</th>
<th>7-10 years</th>
<th>12-15 years</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Right (mm)</strong></td>
<td>6.4 (+/- 2.1)</td>
<td>10 (+/- 2.3)</td>
<td>11.6 (+/- 2.7)</td>
<td>13.1 (+/- 2.5)</td>
</tr>
<tr>
<td><strong>Left (mm)</strong></td>
<td>6.6 (+/- 1.7)</td>
<td>9.5 (+/-2)</td>
<td>10.6 (+/- 2.6)</td>
<td>11.9 (+/- 2.2)</td>
</tr>
</tbody>
</table>

400 healthy volunteers

4 days later

3 months later
Addition of M-US:

- Allows precise measurement of absolute distance of diaphragmatic displacement
- Permits continuous recording of diaphragm displacements, with measurements of:
  - Amplitude
  - Duration
  - Velocity
- Allows quantification of motion \(\rightarrow\) more “objective” evaluation
- Better for comparison with contralateral hemidiaphragm
- Particularly helpful in tachypnea
- More helpful for comparison on F/U studies
Mediastinum
8 y.o. M with T lymphoblastic lymphoma

~ 1 yr later...
Pleural line and A lines
B lines
B Lines

- Vertically oriented comet-tail artifacts
- Originate from irregularities at the lung-pleura interface
- Move with lung sliding
- Obscure A lines
- Up to 3 per interspace → Normal
- More than 3 → nonspecific markers of several lung disorders (pulm edema, interst lung dz, RDS, TTN, etc)
- Absent with pneumothorax

Newborn with TTN

Image courtesy of Dr. M. Soudack  
Tel Aviv, Israel
Pleural line – M mode

- Pleural line – echogenic
- Soft tissues – echogenic. Lines between pleural line and transducer (no motion)
- Normal lung sliding → grainy or sandy appearance

Seashore sign
Strong interface between pleura/pneumothorax → extensive reverberation artifacts → "barcode or stratosphere" sign → deeper reverberation artifacts lines

Pneumothorax: barcode or stratosphere sign
Pneumothorax—M mode

M-mode ultrasound for the detection of pneumothorax during helicopter transport
Matthew Lyon MD, Stephen A. Shiver MD*, Perry Walton DO

Pneumothorax: barcode or stratosphere sign
3 y.o. F with a Hx of SCD, fever, cough, dyspnea
Dynamic air bronchogram = pneumonia – PPV 97%

Beware!
Conclusion

• Back to the future

• To stay...
  
  ...The beautiful images provided by current CT and MR imaging techniques are aesthetically seductive, but it should be remembered that US often provides the clinically needed information at lesser cost, without sedation or radiation exposure...

  » From Coley B, RCNA 2005
Thank you for your attention!

Special Thanks to my IR colleagues: 
Drs. Craig Johnson and Fab Weber