US of the Chest

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Historical perspective

- Initially for cardiac echo
- Subsequent studies → 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 (arrowhead) in the decubitus position. Arrow = membrane.

Empyema:
- a. Chest radiograph demonstrates almost total opacification of the left hemithorax.
- b. CT scan through the mid-chest demonstrates opacification of the left hemithorax and displacement of the heart to the right. The nature of the opacification was not resolved by CT.
- c and d. Longitudinal (c) and transverse sonograms (d) show that the process in the left chest is a complex mass consisting of large anechoic areas separated by thick septa (arrows).

Water-Path Ultrasound of Chest Disease in Childhood

Radiology 1984; 152: 401-408
Pneumonic infiltrate

a. Coned-down film through the right chest and abdomen demonstrates a right pulmonary parenchymal process above the liver, obscuring the right hemidiaphragm. The scattered bony structures are visible within the mass suggesting an extension of an extrinsic mass.

b. Lateral film demonstrates a pulmonary infiltrate with air messaging.

Middle-lobe infiltrate secondary to Kaposi's sarcoma

a. Lateral chest roentgenogram demonstrates a right middle-lobe infiltrate.

b. Tomograms at the level of the right middle lobe reveal a wedge-shaped area of increased opacity (arrow) immediately adjacent to the right heart border, not involving major vessels, suggesting a right middle lobe infiltrate.

Eating area of the right chest wall

a. Chest radiograph taken following section of the fifth through seventh ribs reveals a hyperlucent area on the inferior aspect of the right hemidiaphragm, associated with an apparent pleural mass.

b. Tomograms demonstrate a pleural process arising from the lateral chest wall, associated with pleural fluid. Absence of one rib can be appreciated (arrow), associated with thickening of the subcostal tissues. Beneath the chest wall is a lobulated mass which appears more irregular than post-inflammatory pleural thickening. The solid pulmonary parenchymal component (open arrow) indicates direct invasion of the lung by tumor.
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

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Ultrasound of the pediatric chest
Andrew Mong • Monica Epelman • Kassa Darge
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
  – Thymic window
Disadvantages

- Pediatric chest
  - Aerated lung
    - Requires parenchymal lesion to be superficial
  - Older children
    - Sternum ossified, thymus small
Applications

- Thoracic cage
- Diaphragm
- Mediastinum
- Pleura
- Parenchyma
Thoracic Cage
Usefulness of Sonography in Evaluation of “Breast Lumps” in Children: An Illustrated Review

Archana Malik MD, Monica Epelman MD, Teresa Victoria MD PhD, Diego Jaramillo MD MPH, Kassa Darge MD PhD

The Children’s Hospital of Philadelphia
- 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
- 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
### Anterior chest wall masses: “Pseudo” breast lumps

#### NORMAL VARIANTS
- Prominent anterior convexity of rib or costal cartilage
- Prominent asymmetric costochondral junction
- Tilted sternum
- Subcutaneous/Parachondral nodule

#### CHEST WALL LESIONS
- Phlegmon/Collection
- Lymph node
- Hemangioma
- Hematoma
- Costochondritis
- Lipoma
- Lipoblastoma
Normal variant:
Prominent anterior convex rib
Normal variant: Tilted sternum

Abnormal

Normal

Rib
Lung
Pleural reflection
Normal variant:
Asymmetric costochondral junction
Chest wall collection
VP shunt disruption
Chest wall hemangioma
Chest wall post-op hematoma
Diaphragm
M-mode sonography of diaphragmatic motion: description of technique and experience in 278 pediatric patients
<table>
<thead>
<tr>
<th></th>
<th>Abnormal M-US</th>
<th>Normal M-US</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abnormal chest radiograph</td>
<td>62 (true positive)</td>
<td>11 (false positive)</td>
<td>73</td>
</tr>
<tr>
<td>Normal chest radiograph</td>
<td>118 (false negative)</td>
<td>69 (true negative)</td>
<td>187</td>
</tr>
<tr>
<td>Total</td>
<td>180</td>
<td>80</td>
<td>260</td>
</tr>
</tbody>
</table>
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 sympathetich tone and enhanced sympaticoadrenal discharge
  - Children → FTT

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

- **Intermittent hypoxemia**
  - ↑pulmonary vasoconstriction
  - ↑pulmonary artery Pressure
  - Pulmonary HTN
  - Cor pulmonare
Pathophysiology - complications

- Desaturations
- Hypercapnia with pulmonary hypertension
- Systemic hypertension
- Arrhythmias
Pathophysiology

Infants are more severely affected than older children and adults with ↑morbidity:

- **Diaphragmatic contraction is less efficient in infants** → more circular thorax, horizontal orientation of the ribs, and greater compliance of the rib cage
- Paralyzed diaphragm → ascends into the thorax → **reduction of vital capacity**, especially in the recumbent position
- Small caliber of the bronchial tree → easier to become occluded
- Increased mediastinal mobility
- Accessory muscles of respiration (intercostals) → poorly developed and adequate ventilation is almost totally dependant on diaphragmatic function
Clinical conditions suspicious for diaphragmatic dysfunction:

- Unexplained difficulties in weaning a patient from mechanical ventilation
- Persistent elevated hemidiaphragm on chest radiographs
- Unexplained respiratory distress or dependence on oxygen supplementation
- Signs of respiratory distress
- Asymmetric breathing pattern
- Paradoxical movement of the epigastrium
- Recurrent pneumonia
- Recurrent unilateral lung collapse
- Tachypnea / polypnea
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 😞
Diagnosis cont.

• Assessment of VC in sitting and supine positions

• Real time US “alone”:
  – Direct assessment, +/- “sniff” test
  – Indirect assessment:
    • Measurement of renal excursion
    • Measurement of cranio-caudal displacement of the left branches of the portal vein
Purpose

• To describe our experience with M-US for the assessment and quantitative evaluation of diaphragmatic motion in a large series of children

• To describe the sonographic technique
Materials & methods

- Retrospective analysis
- 371 exams - 742 hemidiaphragms
  - 278 consecutive patients
- 3 days old–17 years old
  - mean age: 1 y 10m
- September 1999-December 2003
Technique

• Initial conventional B-mode US:
  - Evaluation of upper quadrants and lower chest in longitudinal and transverse planes
  - Midline transverse subxiphoid 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
<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</td>
<td>sharp/rounded</td>
<td>&gt; 4-5mm</td>
</tr>
<tr>
<td>Paralysis</td>
<td>paradoxical</td>
<td>rounded</td>
<td>variable</td>
</tr>
<tr>
<td>Paresis/dysfunction</td>
<td>normal</td>
<td>rounded/flat</td>
<td>&lt; 4-5mm</td>
</tr>
</tbody>
</table>

## Results: associated clinical conditions

<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>
**Results: classification**

- **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**
Advantages of US over fluoroscopy:

- Visualization of all portions of each hemidiaphragm – not just anterior third
- Lack of radiation exposure
- Portability
- Evaluation of adjacent pathology
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 → more “objective” evaluation
- Better for comparison with contralateral hemidiaphragm
- Particularly helpful in tachypnea
- More helpful for comparison on F/U studies
In conclusion:

US with B-mode and M-mode is the modality of choice to assess diaphragmatic motion as it can easily differentiate normal motion from dysfunction and paralysis, and allows comparison of changes in follow-up studies. It also allows some degree of prognostication since some authors have postulated that immobility of the affected hemidiaphragm carries a better prognosis than paradoxical motion.
Mediastinum
Technique

- **IMAGING PLANES** - Coronal, axial, sagittal
- **WINDOW** - Transabdominal, Transthoracic
  - Loculations: require evaluation of the *entire* chest
- **PATIENT POSITION**
  - Supine and Upright
    - Determines loculation vs. free flowing
    - Identify appropriate site for thoracentesis
Pneumonia
US exam performed subsequently
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!