Laryngeal Ultrasound: What can we see?

Julina Ongkasuwan, MD, FAAP, FACS
Adult and Pediatric Laryngology
Outline

Historical Perspective
Principles of Ultrasound
Vocal Fold Mobility in Infants
Laryngeal Lesions
Historical Perspective

• 1880 Pizoelectric effect
• WWI to WWII SONAR (SOund Navigation And Ranging)
• 1935 RADAR (RAdio Detection And Ranging)
• 1930’s Medical therapy and ablation
• 1940 Diagnostic tool 1.2MHz
• 1949 A-mode ultrasound
• 1953 B-mode ultrasound
• 1953 Echocardiogram
• 1960’s OB applications
• 1970 The American Society of Ultrasound Technical Specialists aka Society of Diagnostic Medical Sonography

Surgeon performed ultrasound

Surgeon-Performed Ultrasound
Its Use in Clinical Practice
Grace S. Rozycki, MD, FACS

Ultrasonography for the endocrine surgeon: A valuable clinical tool that enhances diagnostic and therapeutic outcomes
Mira Milas, MD, Antonia Stephen, MD, Eren Berber, MD, Kristin Wagner, MD, Jodiann Miskulin, MD, and Allan Siperstein, MD, Cleveland, Ohio, Boston, Mass, and Charlotte, NC

MANAGEMENT OF NONDIAGNOSTIC THYROID FINE-NEEDLE ASPIRATION BIOPSY: SURVEY OF ENDOCRINOLOGISTS
Israel B. Orija, MD, MRCP, Amir H. Hamrahian, MD, and S. Sethu K. Reddy, MD, FRCPC, FACP, FACE, MBA

Parathyroid Adenoma Localization: Surgeon-Performed Ultrasound Versus Sestamibi
David L. Steward, MD; Gregory P. Danielson, MD; Chad E. Afman, MD; Jeffrey A. Welge, PhD
Evaluation of the American College of Surgeons Thyroid and Parathyroid Ultrasound Course: Results of a Web-Based Survey

Giriraj K. Sharma, MD, MS; Robert A. Sofferman, MD; William B. Armstrong, MD

Position Statement: Surgeon Performed Neck Ultrasound

Position Statement: Reimbursement

The AAO-HNS supports surgeons performing ultrasound of the head and neck, including ultrasound-guided fine needle aspiration for diagnostic purposes. Neck ultrasound is not an extension of the physical exam, but rather a discrete diagnostic procedure.

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Principles of Ultrasound

[Image of ultrasound transducer and wave diagram]

http://www.vaultrasound.com/educational-resources/ultrasound-physics/transducers/
Principles of Ultrasound

<table>
<thead>
<tr>
<th>Medium</th>
<th>Velocity (m/s)</th>
<th>Acoustic Impedance ((10^6 \text{ Rayls}))</th>
<th>Attenuation Coefficient (dB/cm at 1MHz)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air</td>
<td>331</td>
<td>0.0004</td>
<td>1.64</td>
</tr>
<tr>
<td>Water</td>
<td></td>
<td>0.002</td>
<td></td>
</tr>
<tr>
<td>Blood</td>
<td></td>
<td>0.18</td>
<td></td>
</tr>
<tr>
<td>Fat</td>
<td>1450</td>
<td>1.34</td>
<td>0.63</td>
</tr>
<tr>
<td>Brain</td>
<td>1541</td>
<td></td>
<td>0.6</td>
</tr>
<tr>
<td>Liver</td>
<td>1549</td>
<td>1.65</td>
<td>0.5-0.94</td>
</tr>
<tr>
<td>Kidney</td>
<td>1561</td>
<td>1.63</td>
<td>1.0</td>
</tr>
<tr>
<td>Muscle</td>
<td>1585</td>
<td>1.71</td>
<td>1.3-3.3</td>
</tr>
<tr>
<td>Soft Tissue</td>
<td>1540</td>
<td></td>
<td>0.54</td>
</tr>
<tr>
<td>Bone</td>
<td>3000-5000</td>
<td>7.8</td>
<td>5</td>
</tr>
</tbody>
</table>

http://www.vaultrasound.com/educational-resources/ultrasound-physics/sound-basics/
Artifacts

- Air Artifact
- Acoustic shadowing
- Acoustic enhancement
- Reverberation
- Refraction
- Comet-tail
- Mirror-image
- Ghosting
- Beam-width
- Ring-down
- Speed displacement

Outline

Historical Perspective
Principles of Ultrasound
Vocal Fold Mobility in Infants
Laryngeal Lesions
Vocal fold movement impairment (VFMI)

• Neuronal injury
  – 8.8-58.7% after infant aortic arch surgery
  • TCH – 27%
  – 12-22% after adult aortic surgery
  • BCM - 32% extent I/II aortic repair (unpublished data)
  – Thyroidectomy 1-2%

• Mechanical fixation
  – Posterior glottic stenosis, Cricoarytenoid joint fixation

• Morbidity of VFMI
  – Stridor (infants)
  – Aspiration
  – Impaired pulmonary toilet
  – Increased length of stay

Dewan K et al. *Laryngoscope*; 122:2781-2785.
Background

- Morbidity of FNL
  - Epistaxis 1%
  - Bradycardia 2%
  - Physiologic shifts
    • BP, pulse, O₂ sat

- Congenital heart disease
  • De Oliveira: Early circulatory collapse in 24% of children after Norwood
    - 64% mortality rate for those patients

References:
Background

• Limitations of Flexible Nasolaryngoscopy (FNL)
  – Extensive movement
  – Excess secretions
  – Retroflexed or omega epiglottis
  – Floppy arytenoids

• Intrarater reliability vocal fold mobility in infants
  – Normal vs. VFMI $\kappa = 0.6667$
  – Paresis vs. paralysis $\kappa = 0.4937$
• Intra-rater reliability ranged from moderate to perfect agreement ($\kappa = 0.4783$-1)
Cry volume in vocal fold paralysis

- 42 NICU and CVICU post-extubation infants
  - 21 with and 21 without VFMI
- Smartphone app
  - Sound Meter (ver 1.6), Smart Tools Co.
  - 12 inches from patient’s head
  - Peak measurements x3 (in dB) while patient crying

<table>
<thead>
<tr>
<th></th>
<th>Normal</th>
<th>VFMI</th>
<th>p</th>
<th>Correlation to dB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender (female)</td>
<td>13</td>
<td>7</td>
<td>0.066</td>
<td>0.219</td>
</tr>
<tr>
<td>Age at scope (days)</td>
<td>30</td>
<td>33</td>
<td>0.219</td>
<td>0.406</td>
</tr>
<tr>
<td>Duration intubation (days)</td>
<td>4.43</td>
<td>5.60</td>
<td>0.094</td>
<td>0.796</td>
</tr>
<tr>
<td>Volume (dB)</td>
<td>85.72</td>
<td>76.60</td>
<td>0.0058</td>
<td></td>
</tr>
</tbody>
</table>
Infant with normal vocal fold mobility after extubation
Results

• Receiver Operating Characteristic Curve

Cry volume vs. VFMI
Area under the ROC = 0.721

Cry volume vs. Aspiration
Area under the ROC curve = 0.583
## Results

<table>
<thead>
<tr>
<th>Mean Cry Volume (dB)</th>
<th>Vocal Fold Movement Impairment</th>
<th>Aspiration</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Sensitivity (%)</td>
<td>Specificity (%)</td>
</tr>
<tr>
<td>60</td>
<td>4.76</td>
<td>100</td>
</tr>
<tr>
<td>65</td>
<td>14.28</td>
<td>100</td>
</tr>
<tr>
<td>70</td>
<td>47.61</td>
<td>95.23</td>
</tr>
<tr>
<td>75</td>
<td>47.61</td>
<td><strong>90.48</strong></td>
</tr>
<tr>
<td>80</td>
<td>57.14</td>
<td>71.42</td>
</tr>
<tr>
<td>85</td>
<td>71.42</td>
<td>57.14</td>
</tr>
<tr>
<td>90</td>
<td><strong>90.47</strong></td>
<td>33.33</td>
</tr>
<tr>
<td>95</td>
<td>95.24</td>
<td>19.05</td>
</tr>
</tbody>
</table>
History of Laryngeal Ultrasound

- **1987**
  - 5MHz probe

- **Adults: Laryngeal Ultrasound (LUS) vs. FNL**
  - Sensitivities 67% - 93.3%
  - Specificities from 89% - 97.8%

  - Hu et al. 2010 (6-13MHz)
    - visualization of endolarynx
      - > age 60 years 38.1%
      - <18 years 100%

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Calcification

• Based on CT
  – Thyroid cartilage calcifies by 1.5% to 4% per year.
  – Posterolateral to anteromedial direction
  – mean patient age thyroid cartilage denser than soft tissue (300 HU)
    • 40 yrs (standard deviation 7.71)

• Frequency?
  – 12-5 MHz vs 9-3 MHz

• Other factors?
  – Gender
  – Race
  – BMI

Wenaas AE, Tran B, Ongkasuwan J. The progression of thyroid cartilage calcification as it relates to the utilization of laryngeal ultrasound. Laryngoscope. 2016 Apr;126(4):913-7
Vocal Fold Mobility in Infants

• LUS vs. FNL in Children
  – E. Friedman, 1997 (7MHz)
    • Agreement 87% to 94%
    • Weighted kappa values between 0.75 to 0.91
  – Vats et al., 2004 (7.5MHz)
    • LUS vs. FNL in infants <12 mo age
    • Concordance rate 77.7%

Purpose

• #1
  – Compare LUS to FNL in recently extubated post-surgical CVICU neonates and the ability to identify VFMI
• #2
  – Compare the physiologic impact of FNL versus LUS on blood pressure, pulse, and oxygen saturation
• #3
  – Determine LUS measurements that can determine mobility
Methods

• 46 consecutive CVICU post-op infants
  – 23 with and 23 without VFMI

• Exclusion criteria
  – FNL could not be performed or was non-diagnostic
  – Tracheotomy
  – Inability to extend the neck

• GE Logic E9 ultrasound, 51 mm length 15 MHz linear probe
• LUS reviewed by 2 pediatric radiologists blinded to mobility
## Results

<table>
<thead>
<tr>
<th>Variable</th>
<th>Asymmetry (N = 23)</th>
<th>Symmetry (N = 23)</th>
<th>P-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Age (days)</strong></td>
<td>38.5 ± 59.2</td>
<td>97 ± 319</td>
<td>0.93</td>
</tr>
<tr>
<td><strong>Days on Ventilator</strong></td>
<td>4.57 ± 2.33</td>
<td>5.74 ± 8.08</td>
<td>0.3</td>
</tr>
<tr>
<td><strong>Type of Surgery</strong></td>
<td></td>
<td></td>
<td>0.073</td>
</tr>
<tr>
<td>Aortic arch repair</td>
<td>12 (60.0)</td>
<td>8 (40)</td>
<td></td>
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<tr>
<td>Norwood</td>
<td>4 (50.0)</td>
<td>4 (50.0)</td>
<td></td>
</tr>
<tr>
<td>PDA ligation</td>
<td>1 (100)</td>
<td>0 (0)</td>
<td></td>
</tr>
<tr>
<td>other</td>
<td>7 (41.2)</td>
<td>10 (58.8)</td>
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</tr>
<tr>
<td><strong>Gender</strong></td>
<td></td>
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<td>0.77</td>
</tr>
<tr>
<td>Female</td>
<td>12 (54.6)</td>
<td>10 (45.5)</td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>11 (45.8)</td>
<td>13 (54.2)</td>
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<tr>
<td><strong>O2 support</strong></td>
<td></td>
<td></td>
<td>0.46</td>
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<tr>
<td>No</td>
<td>6 (66.7)</td>
<td>3 (33.3)</td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>17 (46.0)</td>
<td>20 (54.0)</td>
<td></td>
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</tbody>
</table>
Results #1

• Identification of VFMI
  – Intra-rater reliability for LUS $\kappa=0.94$
  – Inter-rater reliability LUS $\kappa=0.78$
  – LUS vs. FNL $\kappa=0.78$

<table>
<thead>
<tr>
<th></th>
<th>Sensitivity</th>
<th>Specificity</th>
<th>Positive Predictive Value</th>
<th>Negative Predictive Value</th>
<th>95% Confidence Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.83</td>
<td>0.95</td>
<td>0.95</td>
<td>0.84</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
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<td></td>
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<td>0.75</td>
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<td>1</td>
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<td>0.73</td>
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<td>1</td>
</tr>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.63</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
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<td></td>
<td>0.95</td>
</tr>
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</table>
Results #2

- Physiologic Impact

<table>
<thead>
<tr>
<th>Change in</th>
<th>FNL</th>
<th>LUS</th>
<th>P-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>SBP</td>
<td>6.7 (14.8)</td>
<td>4.8 (11.1)</td>
<td>0.55</td>
</tr>
<tr>
<td>DBP</td>
<td>8.8 (12.8)</td>
<td>3.6 (9.2)</td>
<td>0.01</td>
</tr>
<tr>
<td>HR</td>
<td>16.0 (20.1)</td>
<td>8.1 (12.3)</td>
<td>0.004</td>
</tr>
<tr>
<td>O₂ Sat</td>
<td>-3.3 (6.3)</td>
<td>-0.2 (4.1)</td>
<td>0.001</td>
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</tbody>
</table>
Results #3

- Measurements

<table>
<thead>
<tr>
<th>Label</th>
<th>Asymmetry (N = 23)</th>
<th>Symmetry (N = 23)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>glottic angle</td>
<td>35.7 ± 15.6</td>
<td>40.1 ± 13.8</td>
<td>.23</td>
</tr>
<tr>
<td>interarytenoid angle abd</td>
<td>141 ± 14.7</td>
<td>144 ± 12</td>
<td>.53</td>
</tr>
<tr>
<td>Right VF-AA angle abd</td>
<td>120 ± 22.8</td>
<td>121 ± 17.9</td>
<td>.72</td>
</tr>
<tr>
<td>Right VF-AA angle add</td>
<td>88.6 ± 24</td>
<td>85.8 ± 17.7</td>
<td>.11</td>
</tr>
<tr>
<td>Left VF-AA angle abd</td>
<td>94.5 ± 37.2</td>
<td>108 ± 36.1</td>
<td>.019</td>
</tr>
<tr>
<td>Left VF-AA angle add</td>
<td>95.9 ± 8.58</td>
<td>92.4 ± 5.57</td>
<td>.2</td>
</tr>
</tbody>
</table>
Results #3

- Measurements

Table VII: VF-AA angle in abduction $\leq 120^\circ$ as predictor of asymmetry on FNL

<table>
<thead>
<tr>
<th></th>
<th>Sensitivity</th>
<th>Specificity</th>
<th>Positive Predictive Value</th>
<th>Negative Predictive Value</th>
<th>95% Confidence Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.91</td>
<td>0.68</td>
<td>0.75</td>
<td>0.88</td>
<td></td>
</tr>
</tbody>
</table>

|                     |             |             |                          |                            | 0.70 | 0.98 |
|                     |             |             |                          |                            | 0.45 | 0.85 |
|                     |             |             |                          |                            | 0.55 | 0.89 |
|                     |             |             |                          |                            | 0.62 | 0.98 |
Outline

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Principles of Ultrasound
Vocal Fold Mobility in Infants
Laryngeal Lesions
Background

• FNL
  • Causes changes in heart rate, blood pressure, and oxygen saturation
  • 25% of adults report gagging
  • 10% have dyspnea
  • For children: 2 or more adults to restrain the child

• Rigid transoral 70 degree laryngoscopy
  • 18% 3 year olds
  • 66% of 6 and up

Ongkasuwan J, Ocampo E, Tran B. Laryngeal ultrasound and vocal fold movement in the pediatric cardiovascular intensive care unit. Laryngoscope 2016.
Laryngeal Ultrasound and Vocal Fold Lesions

• **Adults**
  - Rubin et al. (5-10 MHz probes, 29 patients)
  - Sirikci et al. (5MHz probe, 14 patients)
    • Lesions > 2mm in size that project into the lumen

• **Pediatric**
  - Bisetti et al. (7.5-12MHz probe)
    • 16 children (mean age 7.5 years) cysts, nodules could be seen
  - Bryson et al. (probe type not specified)
    • 8 children (mean age 10.25 years) RRP
      – discrete, hyperechoic lesions


Purpose

• #1
  – Compare LUS to FNL to identify vocal fold nodules vs. normal
• #2
  – Determine if ultrasound can be used to reliably measure nodule size and depth
Methods

• 46 patients
  – 23 with vocal fold nodules on laryngoscopy
  – 23 normals

• Exclusion criteria
  – Laryngoscopy could not be performed or was non-diagnostic
  – Tracheotomy
  – Inability to extend the neck

• GE Logic E9 ultrasound, 51 mm length 15 MHz linear probe
• LUS reviewed by 2 pediatric radiologists blinded to nodule status
Results

• #1
  – Compare LUS to FNL to identify vocal fold nodules
• #2
  – Determine if ultrasound can be used to reliably measure nodule size and depth

TABLE II. Sensitivity and Specificity.

<table>
<thead>
<tr>
<th></th>
<th>Sensitivity (95% CI)</th>
<th>Specificity (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>LUS vs. strobe*</td>
<td>100 (85-100)</td>
<td>87 (66-97)</td>
</tr>
<tr>
<td>Radiologist 1</td>
<td>100 (82-100)</td>
<td>74 (51-89)</td>
</tr>
<tr>
<td>Radiologist 2</td>
<td>96 (76-99)</td>
<td>100 (82-100)</td>
</tr>
</tbody>
</table>

TABLE III. Consistency of Vocal Fold Nodules Measurements on Laryngeal Ultrasound.

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Pearson Correlation Coefficient</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Right AP</td>
<td>0.075</td>
<td>.75</td>
</tr>
<tr>
<td>Right lateral</td>
<td>0.280</td>
<td>.23</td>
</tr>
<tr>
<td>Left AP</td>
<td>-0.123</td>
<td>.61</td>
</tr>
<tr>
<td>Left lateral</td>
<td>0.313</td>
<td>.18</td>
</tr>
</tbody>
</table>

AP = anterior-posterior.
Discussion

• Small size studies
• No real time physiologic data
• Have not determined if it can distinguish between various lesions
• Cannot assess laryngeal closure

• High resolution can be used for young children
• ? May need lower resolution for 40’s and up
QUESTIONS?