Lung ultrasound for childhood pneumonia

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Disclaimer

- Some statements in this presentation are opinions of the author and not those of Fogarty International Center or AB PRISMA.

Conflict of interest:
- Support and collaboration with grants from the Global Health Fellowship, Bill and Melinda Gates foundation
Outline

• Background
• Introduction of lung ultrasound
• Results of our group
• Future directions
• Conclusions
Pneumonia = global health problem

(2) WHO. Global Health Observatory (http://www.who.int/gho/child_health/en/index.html)
EVERY YEAR:

- 150 million cases in <5y
- 20 million requires hospitalization
- 1.1 million children dies
  - More than AIDS, malaria and tuberculosis combined
  - 90-95% in developing countries

Diagnosis

(1) Signs or symptoms of respiratory distress
   Cough, fever, tachypnea, difficulty breathing

(2) Radiologic evidence of an acute pulmonary infiltrate

Limitations
   • Ill-defined classifications
   • Inter-observer variability
   • Requires time, resources, and specialized physicians

Source: (1) Evidence-based care guidelines for medical management of community acquired pneumonia in children 60 days to 17 years of age. www.cincinnatichildrens.org/svc/alpha/h/health-policy/ev-based/pneumonia.htm
Low resource settings

Cough/shortness of breath +
>50 breaths/min in 2-12 m
>40 breaths/min in 1 to 5y

PNEUMONIA

• Limitations
  – Moderate sensitivity and poor specificity
  – Worsens antibiotic resistance
  – Fails to address other respiratory conditions and their life-saving treatments

LUNG ULTRASOUND
Is this a new idea?

- First description
  - Bogin et al. 1970

- Concept and case series in the 1980s
Lung ultrasound

- No gold standard for diagnosis
- LUS advantages to CXR
  - Wider availability
  - Bedside/ Portability
  - Repeatability
  - Safe (No ionizing radiation)
  - Ease of use/learning curve
Procedure

Ellington et al, BMJ Open, 2012
Lung ultrasound: What is normal?

- **A lines**: The *absence* of findings
  - Air does not transmit ultrasound waves
Abnormal causes artifacts

- Lung disease is a disruption of the air/tissue ratio: fluid, pus, blood, fibrosis
Pattern recognition

NORMAL LUNG

CONSOLIDATION

INTERSTITITAL
1. Meta-analysis

Studies with neonates/children with clinical suspicion of pneumonia and/or confirmation with CXR or chest CT scan.

1475 studies identified

- Eight selected for analysis
- Six (75%) in pediatric population
- Two (25%) in neonates

Pereda MA, Chavez MA et al, submitted results
Sensitivity and Specificity

Reali et al. [20]
Liu et al. [21]
Esposito et al. [14]
Shah et al. [15]
Caiulo et al. [22]
El Dien et al. [23]
Iuri et al. [24]
Copetti et al. [13]
Overall

Sensitivity (%)

<table>
<thead>
<tr>
<th>Study</th>
<th>Sensitivity (%)</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reali et al. [20]</td>
<td>93.8%</td>
<td>[86.2%, 98%]</td>
</tr>
<tr>
<td>Liu et al. [21]</td>
<td>100%</td>
<td>[91%, 100%]</td>
</tr>
<tr>
<td>Esposito et al. [14]</td>
<td>97.9%</td>
<td>[88.9%, 99.9%]</td>
</tr>
<tr>
<td>Shah et al. [15]</td>
<td>85.7%</td>
<td>[69.7%, 95.2%]</td>
</tr>
<tr>
<td>Caiulo et al. [22]</td>
<td>98.9%</td>
<td>[93.9%, 100%]</td>
</tr>
<tr>
<td>El Dien et al. [23]</td>
<td>93.2%</td>
<td>[84.7%, 97.7%]</td>
</tr>
<tr>
<td>Iuri et al. [24]</td>
<td>91.7%</td>
<td>[73%, 99%]</td>
</tr>
<tr>
<td>Copetti et al. [13]</td>
<td>100%</td>
<td>[94%, 100%]</td>
</tr>
<tr>
<td>Overall</td>
<td>95.8%</td>
<td>[93.5%, 97.4%]</td>
</tr>
</tbody>
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Specificity (%)

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<tr>
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<td>[80.4%, 99.9%]</td>
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<tr>
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<td>88.5%</td>
<td>[82.4%, 93%]</td>
</tr>
<tr>
<td>Caiulo et al. [22]</td>
<td>100%</td>
<td>[75.3%, 100%]</td>
</tr>
<tr>
<td>El Dien et al. [23]</td>
<td>100%</td>
<td>[15.8%, 100%]</td>
</tr>
<tr>
<td>Iuri et al. [24]</td>
<td>100%</td>
<td>[39.8%, 100%]</td>
</tr>
<tr>
<td>Copetti et al. [13]</td>
<td>100%</td>
<td>[82.4%, 100%]</td>
</tr>
<tr>
<td>Overall</td>
<td>93%</td>
<td>[89.6%, 95.6%]</td>
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</tbody>
</table>

I² = 65.5%

I² = 47.8%

Pereda MA, Chavez MA et al, submitted results
2. Peru Pneumonia Project

Diagnostic validation study in Children 2-59 months old in a tertiary care hospital in Lima, Peru

1062 children were screened

– 230 healthy controls
– 832 (87%) with respiratory symptoms that had CXR available
– 453 (43%) had pneumonia by pediatrician

Ellington et al, BMJ Open, 2012
Ellington et al, preliminary data, Oct 2014
Childhood pneumonia

<table>
<thead>
<tr>
<th>Lung ultrasound Diagnosis</th>
<th>Sensitivity (95% CI)</th>
<th>Specificity (95% CI)</th>
<th>AUC (95% CI)</th>
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<tbody>
<tr>
<td>Pneumonia Diagnosis versus Controls</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chest X Ray Diagnosis</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alveolar/Lobar infiltrate</td>
<td>42.2 (0.38-0.47)</td>
<td>100 (0.99-100)</td>
<td>0.71 (0.68-0.74)</td>
</tr>
<tr>
<td>Lung ultrasound Diagnosis</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Abnormal findings II</td>
<td>79.5 (75.4-83.0)</td>
<td>95.2 (91.4-97.5)</td>
<td>0.87 (0.85-0.90)</td>
</tr>
<tr>
<td>Medium to large consolidation†</td>
<td>28.0 (24.0-32.5)</td>
<td>100 (98.0-100)</td>
<td>0.64 (0.60-0.68)</td>
</tr>
</tbody>
</table>

- 87% agreement between CXR and lung ultrasound

Ellington et al, BMJ Open, 2012
Ellington et al, preliminary data, Oct 2014
Asthma

353 children had asthma by pediatrician
– 206 (58%) had pneumonia diagnosis

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<td></td>
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<td>Chest X Ray Diagnosis</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Alveolar/Lobar infiltrate</td>
<td>45.8</td>
<td>86.5</td>
<td>0.66</td>
</tr>
<tr>
<td>(0.40-0.53)</td>
<td>(0.79-0.92)</td>
<td></td>
<td>(0.61-0.71)</td>
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<td>Lung ultrasound Diagnosis</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Abnormal findings II</td>
<td>83.7</td>
<td>50.4</td>
<td>0.67</td>
</tr>
<tr>
<td>(77.8-88.4)</td>
<td>(41.6-59.1)</td>
<td></td>
<td>(0.62-0.72)</td>
</tr>
<tr>
<td>Medium to large consolidation†</td>
<td>26.1</td>
<td>97.7</td>
<td>0.62</td>
</tr>
<tr>
<td>(20.3-32.8)</td>
<td>(93.0-99.4)</td>
<td></td>
<td>(0.56-0.67)</td>
</tr>
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Ellington et al, BMJ Open, 2012
Ellington et al, preliminary data, Oct 2014
Bronchiolitis

140 children had bronchiolitis by pediatrician
– 29 (21%) had pneumonia diagnosis

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<th>Sensitivity (95% CI)</th>
<th>Specificity (95% CI)</th>
<th>AUC (95% CI)</th>
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</thead>
<tbody>
<tr>
<td>Alveolar/Lobar infiltrate</td>
<td>40.7 (0.23-0.61)</td>
<td>91.3 (0.84-0.96)</td>
<td>0.66 (0.57-0.74)</td>
</tr>
</tbody>
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<th>Chest X Ray Diagnosis</th>
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<td>Abnormal findings ‡</td>
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<td>Medium to large consolidation†</td>
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Ellington et al, BMJ Open, 2012
Ellington et al, preliminary data, Oct 2014
Case 1

CXR - Lung ultrasound -

Ellington et al, BMJ Open, 2012
Ellington et al, preliminary data, Sept 2014
Case 2

CXR +

Lung ultrasound+

Ellington et al, BMJ Open, 2012
Ellington et al, preliminary data, Sept 2014
Case 3

CXR -

Lung ultrasound +

Ellington et al, BMJ Open, 2012
Ellington et al, preliminary data, Sept 2014
### Inter-observer variability

<table>
<thead>
<tr>
<th>Diagnostic method</th>
<th>Kappa</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Chest Radiography</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Overall Agreement</td>
<td>0.37</td>
<td>(0.34-0.40)</td>
</tr>
<tr>
<td>Normal</td>
<td>0.40</td>
<td>(0.37-0.42)</td>
</tr>
<tr>
<td>Interstitial Opacities</td>
<td>0.20</td>
<td>(0.16-0.23)</td>
</tr>
<tr>
<td>Alveolar/Lobar infiltrate</td>
<td>0.51</td>
<td>(0.48-0.58)</td>
</tr>
<tr>
<td><strong>Lung ultrasound</strong></td>
<td></td>
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<tr>
<td>Overall Agreement</td>
<td>0.65</td>
<td>(0.61-0.66)</td>
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<tr>
<td>Abnormal findings II</td>
<td>0.73</td>
<td>(0.70-0.74)</td>
</tr>
<tr>
<td>All size consolidations</td>
<td>0.78</td>
<td>(0.77-0.83)</td>
</tr>
<tr>
<td>Interstitial Findings</td>
<td>0.38</td>
<td>(0.27-0.41)</td>
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*Ellington et al, BMJ Open, 2012
Ellington et al, preliminary data, Oct 2014*
Children with respiratory complaints

Lung ultrasound evaluation

**Group 1**
*Normal lung ultrasound*

1. Pneumonia suspicion: further test (i.e. CXR) or treat.
2. No pneumonia suspicion: lung ultrasound + clinical follow

**Group 2**
*Abnormal lung ultrasound*
(Interstitial infiltrate, small consolidation)

1. Pneumonia suspicion: CXR or treat.
2. No pneumonia suspicion: lung ultrasound + clinical follow

**Group 3**
*Medium to large consolidation*

1. Pneumonia confirmed: Treat
FUTURE STEPS
Specific aims

• Quantify the effect of lung ultrasound as a point-of-care diagnostic approach by trained personnel on:

(1) Reduction in antibiotic use
(2) Subsequent acute care needs
(3) Reduction of Chest X rays (CXR) use.
Study participants

Children < 5 years of age who meet the WHO initial criteria for ALRI (cough and/or difficulty breathing) in acute care centers in Puno, Peru.

Inclusion criteria:

• Child less than 5 years of age.
• Complaints of cough and/or difficulty breathing

Exclusion criteria:

• Self-reported history or signs of chronic lung or heart disease.
Study design

Eligible participants with ALRI

Randomization 1:1

Control Group
- Standard Clinical Evaluation
- Lung Ultrasound not available for decision-making
- Follow-up
  - 1. Antibiotic use
  - 2. Subsequent acute care need

Ultrasound group
- Standard Clinical Evaluation + Lung Ultrasound
- Follow-up
  - 1. Antibiotic use
  - 2. Subsequent acute care need
Future studies

- Lung ultrasound follow-up
- Lung ultrasound: bacterial versus viral
- Lung ultrasound + electronic ascultation
Conclusions

1. Ultrasound is a fast, portable, easy-to-use tool that requires minimal training and resources.

2. Data are promising:
   - Good Sensitivity, Great Specificity
   - High concordance with radiography
   - Good reliability

3. Proposed approach:
   WHO Clinical assessment + Lung ultrasound
Acknowledgement

• William Checkley MD PhD

• Robert Gilman MD DTMH
• “The use of ultrasound in respiratory diseases of the child needs to be encouraged not simply as a valid diagnostic alternative but as a necessary ethical choice.” Mathis G.