Reading and Interpreting childhood chest radiographs in high tuberculosis/HIV prevalence countries

Challenges in reading childhood TB CXR

Robert Gie

Desmond Tutu Tuberculosis Center
Department of Paediatrics and Child Health
Stellenbosch University
Making a diagnosis

1. History
2. Examination
3. Diagnostic test
4. Diagnosis
Are both the AP and the Lateral readable? 

- Yes
  - Is the CXR normal? 
    - Yes: NORMAL
    - No: Is the diagnosis likely to be TB?
      - Yes: ABNORMAL – LIKELY TB
      - No: UNREADABLE

- No: UNREADABLE
Is interpreting a CXR a challenge?
Challenge 1: Overlap

Abnormal – TB

Abnormal – not TB
2 month old infant with severe respiratory distress
Not responding to treatment
Oxygen dependent
Diagnosis: Pulm Interstitial Glycogenosis (PIG)
Challenge 2
Anatomy
Case 3
Challenges
3. Lateral CXR
Lymphadenopathy on Lateral

- Normal structures (=horseshoe)
- Diverging vessels (=tentacles)
- Lymphadenopathy (=‘doughnut’)
The great pretender
Challenges:
4. Pre-test probability

• Pre-test probability
  – General population prevalence
  – Prevalence in people like the patient in front of you
  – History
  – Examination

➢ Pre-test probability
### Criterion Standard

<table>
<thead>
<tr>
<th>Disease</th>
<th>No disease</th>
</tr>
</thead>
<tbody>
<tr>
<td>Positive test results</td>
<td>a</td>
</tr>
<tr>
<td>Negative test results</td>
<td>c</td>
</tr>
</tbody>
</table>

- **Sensitivity** = \( \frac{a}{a + c} \)
- **Specificity** = \( \frac{d}{b + d} \)
- **Positive predictive value** = \( \frac{a}{a + b} \)
- **Negative predictive value** = \( \frac{d}{c + d} \)

- **Likelihood ratio for disease if test positive** = \( \frac{\text{sensitivity}}{1 - \text{specificity}} \)
- **Likelihood ratio for disease if test negative** = \( \frac{1 - \text{sensitivity}}{\text{specificity}} \)
Challenges:
5. What are the most likely images?

<table>
<thead>
<tr>
<th>TB manifestation</th>
<th>Total (n = 439) n/N (%)</th>
<th>Bacteriological confirmation* n/N (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not TB†</td>
<td>85 (19.4)</td>
<td>0/36</td>
</tr>
<tr>
<td>Intra-thoracic TB‡</td>
<td>307 (69.9)</td>
<td>122/196 (62.2)</td>
</tr>
<tr>
<td>Ghon focus</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Uncomplicated</td>
<td>1/307 (0.3)</td>
<td></td>
</tr>
<tr>
<td>Complicated</td>
<td>3/307 (1.0)</td>
<td></td>
</tr>
<tr>
<td>Primary complex</td>
<td>15/307 (4.9)</td>
<td></td>
</tr>
<tr>
<td>Lymph node disease</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Uncomplicated</td>
<td>147/307 (47.9)</td>
<td></td>
</tr>
<tr>
<td>Complicated</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Compression</td>
<td>25/307 (8.1)</td>
<td></td>
</tr>
<tr>
<td>Consolidation</td>
<td>62/307 (20.6)</td>
<td></td>
</tr>
<tr>
<td>Pleurisy</td>
<td>24/307 (7.8)</td>
<td></td>
</tr>
<tr>
<td>Pericarditis</td>
<td>1/307 (0.3)</td>
<td></td>
</tr>
<tr>
<td>Disseminated</td>
<td>15/307 (4.9)</td>
<td></td>
</tr>
<tr>
<td>Adult-type</td>
<td>14/307 (4.6)</td>
<td></td>
</tr>
<tr>
<td>Extra-thoracic TB</td>
<td>72 (16.4)</td>
<td>33/49 (67.3)</td>
</tr>
<tr>
<td>Peripheral lymphadenitis</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cervical</td>
<td>35/72 (48.6)</td>
<td>27/27 (100)</td>
</tr>
<tr>
<td>Other</td>
<td>1/72 (1.4)</td>
<td>1/1 (100)</td>
</tr>
<tr>
<td>Central nervous system TB</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Meningitis</td>
<td>14/72 (19.4)</td>
<td>1/10 (10.0)</td>
</tr>
<tr>
<td>Tuberculoma</td>
<td>2/72 (2.8)</td>
<td>N/A</td>
</tr>
<tr>
<td>Abdominal TB</td>
<td>1/72 (1.4)</td>
<td>1/1 (100)</td>
</tr>
<tr>
<td>Osteo-articular TB</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spondylitis</td>
<td>4/72 (5.6)</td>
<td>N/A</td>
</tr>
<tr>
<td>Other</td>
<td>7/72 (9.7)</td>
<td>2/7 (28.6)</td>
</tr>
<tr>
<td>Skin</td>
<td>8/72 (11.1)</td>
<td>2/3 (66.7)</td>
</tr>
<tr>
<td>Intra- + extra-thoracic TB§</td>
<td>(25 [5.7])</td>
<td>(17/21 [80.1])</td>
</tr>
</tbody>
</table>
### Challenges:

6. How accurately can we read CXR?

---

**Table 1. Results of chest radiograph assessment by three independent paediatric reviewers, grouped by certainty of tuberculosis diagnosis, South Africa, 2001–2006**

<table>
<thead>
<tr>
<th>Diagnostic certainty</th>
<th>Reviewer 1</th>
<th></th>
<th>Reviewer 2</th>
<th></th>
<th>Reviewer 3</th>
<th></th>
<th>Final classification</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No.</td>
<td>%</td>
<td>No.</td>
<td>%</td>
<td>No.</td>
<td>%</td>
<td>No.</td>
<td>%</td>
</tr>
<tr>
<td>Highly likely to have tuberculosis</td>
<td>16</td>
<td>1.1</td>
<td>29</td>
<td>2.0</td>
<td>171</td>
<td>11.8</td>
<td>271</td>
<td>18.8</td>
</tr>
<tr>
<td>Likely to have tuberculosis</td>
<td>20</td>
<td>1.4</td>
<td>38</td>
<td>2.6</td>
<td>323</td>
<td>22.4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Suspected of having tuberculosis</td>
<td>124</td>
<td>8.6</td>
<td>145</td>
<td>10.0</td>
<td>242</td>
<td>16.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Positive</td>
<td>160</td>
<td>11.1</td>
<td>212</td>
<td>14.6</td>
<td>736</td>
<td>50.9</td>
<td>271</td>
<td>18.8</td>
</tr>
<tr>
<td>Inconclusive</td>
<td>45</td>
<td>3.1</td>
<td>35</td>
<td>2.4</td>
<td>82</td>
<td>5.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Abnormal but not tuberculosis</td>
<td>102</td>
<td>7.1</td>
<td>139</td>
<td>9.6</td>
<td>312</td>
<td>21.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Normal</td>
<td>1038</td>
<td>71.8</td>
<td>778</td>
<td>53.9</td>
<td>59</td>
<td>4.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Negative</td>
<td>1185</td>
<td>82.0</td>
<td>952</td>
<td>65.9</td>
<td>453</td>
<td>31.4</td>
<td>1174</td>
<td>81.2</td>
</tr>
<tr>
<td>Not read</td>
<td>100</td>
<td>6.9</td>
<td>281</td>
<td>19.5</td>
<td>256</td>
<td>17.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>1445</td>
<td>100</td>
<td>1445</td>
<td>100</td>
<td>1445</td>
<td>100</td>
<td>1445</td>
<td>100</td>
</tr>
</tbody>
</table>

*“Highly likely to have tuberculosis”, “likely to have tuberculosis” and “suspected of having tuberculosis” were classified as positive; “inconclusive”, “abnormal but not tuberculosis” and “normal” were classified as negative. Final chest radiograph classification was determined by agreement of at least two reviewers.*
### Table 1  Number (%) of chest x ray views assigned by each viewer to each assessment category

<table>
<thead>
<tr>
<th>Observers</th>
<th>Paediatricians</th>
<th>Primary care doctors</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Viewer 1</td>
<td>Viewer 2</td>
</tr>
<tr>
<td>Assessment</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Absent, confident</td>
<td>41 (13.7)</td>
<td>141 (47.0)</td>
</tr>
<tr>
<td>Absent, equivocal</td>
<td>76 (25.3)</td>
<td>60 (20.0)</td>
</tr>
<tr>
<td>Present, equivocal</td>
<td>95 (31.7)</td>
<td>56 (18.6)</td>
</tr>
<tr>
<td>Present, confident</td>
<td>88 (29.3)</td>
<td>43 (14.3)</td>
</tr>
<tr>
<td>All x rays and views</td>
<td>300</td>
<td>300</td>
</tr>
</tbody>
</table>

Three views per viewer per child.

---

**ORIGINAL ARTICLE**

Diagnostic accuracy of chest radiography in detecting mediastinal lymphadenopathy in suspected pulmonary tuberculosis

G H Swingler, G du Toit, S Andronikou, L van der Merwe, H J Zar

Challenges:
7. How well can we teach childhood TB CXR?

• Previous Courses
  – Pilot course run in September 2011
    • Feedback and course assessment
  – Improved course run in December 2012
    • Pre and post test assessment
    • 27 participants
    • Modest but significant improvement in ability to diagnose TB
Challenge 8
Quality of the CXR

• Is the quality worth acceptable?
• Can we have the CXR accurately read?
• Is doing a lateral CXR worthwhile?
Challenge 9:
Performance of other tests

- Mantoux skin test
- Culture of specimens
- Gene Xpert
Is a CXR useful?

• Most definitely
  – Excludes other underlying pathology
  – Defines patients not responding to treatment
  – Can aid cases of uncertainty as an additional test
  – Can be diagnostic in certain cases

• Conditions that must be met:
  – Good quality CXR
Excludes underlying pathology
Chronic cough, not gaining weight, sputum production.
Patient not responding
TB treated for 5 months (adherent)
Define underlying pathology
2 month old with severe airway obstruction
Highly suggestive CXR’s
Role of the CXR in the diagnosis of TB

• The role of the CXR
  – Exclude other chronic lung disease
  – Evaluate children not responding (wrong diagnosis)
  – Define the underlying cause of the pathology
  – Add diagnostic certainty if TB is suspected
  – Remember:
    • Not a good diagnostic tool with poor sensitivity and specificity
    • Large intra- and inter-reader variability
What we like to achieve?

• Able to identify an acceptable CXR

• Able to identify abnormal CXR’s possibly TB

• Identify the commonest radiological abnormalities on a CXR caused by TB
  Enlarged hilar lymph glands
  Enlarged hilar and paratracheal lymph glands
  Enlarged lymph gland compressing (narrowing) the airways.
  Pneumonic consolidation with lymph gland enlargement.
  Adult type TB
  Miliary TB
  TB pleural effusion
Fig1: Enlarged hilar lymph glands on the right hand side. This is the commonest form of childhood TB. The hilar lymph glands need to be distinguished from hilar blood vessels.
Fig 2: Enlarged hilar and paratracheal lymph glands with pneumatic consolidation of the right middle lobe. On careful inspection narrowing of the R bronchus (Bronchus intermedius can be seen)
Fig 3: Ghon focus (initial infection) of the left lower lobe. In malnourished and HIV infected children the infection in the Ghon focus cannot be contained and a cavity develops.
Fig 4: This is severe (advanced) form of adult type TB in an adolescent. The both upper lobes have consolidation with a number of cavities. These children are sputum smear positive for AFB.
Fig 5: This is a typical example of miliary TB with fine nodules visible in all the lobes of the lung. These children often have accompanying TB meningitis.
Fig 6: A large right sided pleural effusion. This clinical presentation is very uncommon in children younger than 5 years of age.
Challenge 9
Typical vs atypical

• Fundamentally flawed

• About 20% of the radiological pictures are atypical
  • Glands not visible
  • Interstitial lung picture
  • Pneumonic opacification

• Follow-up CXR after 2-4 weeks
How to make the diagnosis of childhood TB?

• Need three elements to make the diagnosis:
  1. Infection
     – Contact
     – Positive skin test
  2. Symptoms of chronic disease
     – Cough
     – Fever
     – Weight loss
  3. Radiological changes *(suspicious of TB)*
  4. Bacteriology
Overall support for the International Maternal Pediatric Adolescent AIDS Clinical Trials (IMPAACT) Network was provided by the National Institute of Allergy and Infectious Diseases (NIAID) of the National Institutes of Health (NIH) under Award Numbers UM1AI068632 (IMPAACT LOC), UM1AI068616 (IMPAACT SDMC) and UM1AI106716 (IMPAACT LC), with co-funding from the Eunice Kennedy Shriver National Institute of Child Health and Human Development (NICHD) and the National Institute of Mental Health (NIMH). The content is solely the responsibility of the authors and does not necessarily represent the official views of the NIH.

Acknowledgements

Pierre Goussard
Colleagues DTTC