Chest Radiography for prevalence surveys & active case detection

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Chest Radiography – Technologies and their use in prevalence surveys

Chest Radiography in the field

Prepared for WHO/STB/TBS

Guiding documents for planning, policy making, implementing and optimizing use of radiography in field conditions, particularly for prevalence surveys and for active case detection of TB
Chest Radiography – Technologies and their use in prevalence surveys

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For World Health Organization (WHO/STB/TBS)

Chest Radiography in the field

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Aspects covered

- Basics of radiography (field vs. indoor)
- Appropriate settings / prerequisites
- Costing
- Available technologies, comparison
- Manpower needs
- Criteria for selection
- Recommended specifications
- Interpretation, radiation protection
- Practical tips
- References for specific areas
CXR in TB/TB-HIV

- “Chest radiographs should be performed in all potential recipients – WHO Global TB Programme and UNAIDS, meeting report, 1998
- CXR plays an important role in Dx of TB in PLHIV and can also be an entry-point to Dx non-TB chest diseases –WHO, SN & EP TB, Recommendations for HIV-prevalent and resource-constrained settings, 2007
Recommendations (same document)

- CXR presentations of TB in HIV patients are now well characterized (A-IV)
- ... significant role in shortening delays in Dx..... should be performed early...(A-II)
- Limitations like non-availability, difficulty in interpretation, need to be addressed (A)
- Research needed to identify innovative ways to enhance ability.......and to evaluate novel imaging techniques that might replace conventional radiography (A)
Case definition

- **Sputum positive**
  - 2 sputum smear positive results
  - 1 sputum smear + CXR s/o TB
  - 1 sputum smear + culture positivity

- **Sputum negative**
  - Sputum negative, culture +
  - 2 negative smears, CXR s/o TB

- **Not definite case** (but active TB suggested by CXR)
Basics of Radiography

- Generation
- Recording
- Displaying

- X-ray generator
- X-ray tube
- X-ray table or stand
- Processing facility
Early Experiments in Transportation
Options

- Conventional Radiography
- Conventional Radiography – automatic film processing
- Computed Radiography
- Direct Digital Radiography
  - Indirect
  - Direct
Conventional Radiography

- Time tested
- Cheap – initial cost, consumable-offset*
- Simple
- Durable, sturdy, low maintenance
- Archival, Reproducibility
- Dark Room
- Throughput time
Conventional + Autoprocessor

- Darkroom obviated
- Manpower
- Throughput
- Cost
- Sensitivity, Durability, Maintenance
- Water quality
- Temperature
Digital Radiography*

- Analog to Digital conversion or Direct

- Advantages
  - Economical*: cost of films & chemicals, dark room
  - Archival: data archiving, documentation, storage space
  - Communicable: electronic transmission
  - Robust & consistent
  - Flexible: post processing possible

- Disadvantages
  - Infrastructure needs
  - Interfacing
  - Over interpretation mimics
Radiation – CR/ DR/ Film Screen, *Trade off & repeat rates, overall low in DI*
- Cost
- Techniques – Film Digitizer, Digital Camera/Video
Techniques

- Computed Radiography (CR)
  - Indirect digital
  - Photostimulator Storage Phosphor to acquire image (IP)
  - CR Reader
  - Digital electronics/workstation for display & storage
- Direct & Direct Digital Radiography (DR, DDR)
  - Conversion of x-rays to direct signal capture
  - FPD - Thin Film Transistors (TFT – amorphous Se / Si, CsI)
  - Total electronic image capture
  - Photons - Pixel - Display
CR Image acquisition

1. X-ray Exposure
   Patient
   X-ray system
   Exposed
   Phosphor plate

2. Image Reader

3. Image Scaling

4. Image Record

5. Computed Radiograph
Phosphor Plate Cycle

- Phosphor Plate: "PSP"
- Plate Exposure: "Create Latent Image"
- Plate Readout: "Extract Latent Image"
- Plate Erasure: "Remove Residual Signal"

Image Acquisition

- Latent Image Produced
- Patient Information

CR QC Workstation

DICOM / PACS

CR Reader

- Latent Image Extracted

Display / Archive

Laser Film Printer
Cost, Retrofit
Convenience, No Darkroom/chemicals
Flexibility

Cost
Cumbersome, Multistep process
Durability
Labour intensive
DR Image acquisition
- Array of light sensitive detectors covered with light emitting x-ray phosphor
- Light generated by x-rays converted into charge
- Charge stored in capacitors
- Processing with read out of TFT array
- NO USER INTERVENTION
- Flat panel detector systems – FPD
- Charge coupled device systems – CCD & CMOS
- Slot scanning type systems
- Photon counting type systems
FPD- X-ray convertor material on TFT matrix
Each element has capacitor & switching transistor
Read out from each detector
CCD & CMOS: X-ray conversion to visible light using scintillators or phosphors -> channelled by mirrors/prisms

Slot scanning systems: Like CT Scannograms

Photon counting systems: Like slot scanning but use crystalline Se as scintillate. High DQE and SNR
Post processing - Data
Post processing - Display

Tissue-selective Images
- Soft - tissue Only
- Bone Only

Dual Energy Image Pair
- Low kVp
- High kVp
Limitations
<table>
<thead>
<tr>
<th>Attribute</th>
<th>CR</th>
<th>DR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Positioning</td>
<td>++++</td>
<td>++</td>
</tr>
<tr>
<td>Replacement of FSR</td>
<td>++++</td>
<td>-</td>
</tr>
<tr>
<td>System cost</td>
<td>+++</td>
<td>+</td>
</tr>
<tr>
<td>Patient throughput</td>
<td>+</td>
<td>+++</td>
</tr>
<tr>
<td>Ease of use</td>
<td>+</td>
<td>++++</td>
</tr>
<tr>
<td>PACS compatibility</td>
<td>++</td>
<td>+++</td>
</tr>
</tbody>
</table>
Nutshell

- **CR**: Retrofit advantage
  - Cost advantage
  - Quality comparable
- **DR**: Superior quality and throughput
  - Good for higher average number of case

5 year horizon for CR rule at the moment
Proposed algorithm for selection
Teleradiology

- Teleradiology is the transmission of images and associated data between locations for the purpose of primary interpretation or consultation and/or clinical review
  - Local benefits: Faster, 24x7 reporting
  - Regional: Linking of centres for resource sharing
  - National: Increased capacity, sharing of expertise, reaching the unreached
Not an alternative to local capacity building
Pre requisite : local expertise for service delivery
Bridging a gap or for expert opinions
Picture Archiving and Communication System (PACS)
Computer Aided Diagnosis

- Information, Knowledge, Wisdom
- Success in Mammography, Nodule detection in CT
- Assist tool – not for interpretation
- Not a substitute for education and training
- Tried for pulmonary nodules, ILD
- Complexities: A vs D, segmentation, QA, standard positioning
Inter Observer variability
222 images, 20 radiologists
Standard definitions
Agreement possible
TB – smaller / older studies
RADIATION!

- Deterministic – dose related
- Stochastic – not dose related

No “safe” level* – should be understood in the context of benefit versus risk
## A Perspective: Other Risks People Take

<table>
<thead>
<tr>
<th>Activity</th>
<th>Deaths/10,000/year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Smoking (all causes)</td>
<td>30</td>
</tr>
<tr>
<td>Mining</td>
<td>6.0</td>
</tr>
<tr>
<td>Construction</td>
<td>3.9</td>
</tr>
<tr>
<td>Cardiac Cath (all causes)</td>
<td>3.3</td>
</tr>
<tr>
<td>Driving a car (avg, one year)</td>
<td>2.4</td>
</tr>
<tr>
<td>Boating</td>
<td>0.5</td>
</tr>
<tr>
<td>AP lumbar spine</td>
<td>0.06</td>
</tr>
<tr>
<td>Chest X-ray Exam (AP +Lat)</td>
<td>0.02</td>
</tr>
</tbody>
</table>
Pregnancy & Radiography

- Advice from HPA – RCR

For most Dx (incl. CXR) associated risk of childhood CA are very low and acceptable when compared with natural risk.

Radiation doses resulting from Dx procedures present a negligible risk of induced hereditary disease in descendants of the unborn child.
ACR Guidelines

Some procedures (incl. CXR in 1\textsuperscript{st} & 2\textsuperscript{nd} trimester) render so low exposures that pregnancy status need not be considered for a “medically indicated” exam, as long as good radiation practice is ensured.

3\textsuperscript{rd} trimester: with good technique exposure remains very low.

No risk of deterministic effect < 50mGy.
Occupational Exposure Risks

- Occupational radiation exposure mostly scatter from patient
- At 1 meter, occupational exposure (if no apron is worn) is 0.1% of that which enters the patient
- Minimizing patient dose minimizes your dose
- Occupational Protection: *The Cardinal Rules:*
  - Time
  - Distance
  - Shielding
## Where does exposure come from: Population Exposure

<table>
<thead>
<tr>
<th>Exam</th>
<th>% of Exams</th>
<th>Number of Exams</th>
<th>mR per Exam</th>
<th>Population Exposure (R)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Port Chest</td>
<td>10</td>
<td>15,000</td>
<td>12</td>
<td>180</td>
</tr>
<tr>
<td>PA Chest</td>
<td>15</td>
<td>24,000</td>
<td>18</td>
<td>432</td>
</tr>
<tr>
<td>Body CT</td>
<td>17</td>
<td>28,000</td>
<td>1600</td>
<td>44,800</td>
</tr>
<tr>
<td>Head CT</td>
<td>8</td>
<td>12,000</td>
<td>8000</td>
<td>96,000</td>
</tr>
<tr>
<td>GI Fluoro</td>
<td>2.5</td>
<td>4,000</td>
<td>7500</td>
<td>30,000</td>
</tr>
<tr>
<td>Spec/Card</td>
<td>8</td>
<td>13,000</td>
<td>50,000</td>
<td></td>
</tr>
</tbody>
</table>

650,000
## Radiology Exposures and Doses

<table>
<thead>
<tr>
<th>Examination</th>
<th>Technique (kVp/mAs)</th>
<th>Entrance Skin Exposure (mrad)</th>
<th>Mean Marrow Dose (mrad)</th>
<th>Gonad Dose (mrad)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Skull</td>
<td>76/50</td>
<td>200</td>
<td>10</td>
<td>&lt;1</td>
</tr>
<tr>
<td>Chest</td>
<td>110/3</td>
<td>10</td>
<td>2</td>
<td>&lt;1</td>
</tr>
<tr>
<td>Cervical spine</td>
<td>70/40</td>
<td>150</td>
<td>10</td>
<td>&lt;1</td>
</tr>
<tr>
<td>Lumbar spine</td>
<td>72/60</td>
<td>300</td>
<td>60</td>
<td>&lt;1</td>
</tr>
<tr>
<td>Abdomen</td>
<td>74/60</td>
<td>400</td>
<td>30</td>
<td>125</td>
</tr>
<tr>
<td>Pelvis</td>
<td>70/50</td>
<td>150</td>
<td>20</td>
<td>150</td>
</tr>
<tr>
<td>Extremity</td>
<td>60/5</td>
<td>50</td>
<td>2</td>
<td>&lt;1</td>
</tr>
<tr>
<td>CT (head)</td>
<td>125/300</td>
<td>3000</td>
<td>20</td>
<td>50</td>
</tr>
<tr>
<td>CT (pelvis)</td>
<td>124/400</td>
<td>4000</td>
<td>100</td>
<td>3000</td>
</tr>
</tbody>
</table>
THANK YOU!