Update on Digital Chest Radiography

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Disclosures

- Consultant for Riverain Medical
- Minor stockholder in Hologic, Inc.
- License and royalty fees from University of Chicago (UCTech)
Advances in Imaging Plate Technology

- **CR:**
  - Powder phosphors
  - Dual reading CR
  - Needle phosphors

- **DR:**
  - CSI- photodiode/TFT detectors
  - Amorphous selenium detectors
Advances in Imaging Plate Technology

- **CR:**
  - Powder phosphors
  - Dual reading CR
  - Needle phosphors

- **DR:**
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  - Amorphous selenium detectors

Schaefer-Prokop, C et al, European Radiology 2008 18:1818-1830
Advantages of Newer Detectors

- Increased Dose Efficiency
- Improved Image Quality
Advantages of Newer Detectors

- **Enhanced Workflow**
  - Image > Console ~2 secs
    - Tube adjustment/repeat
  - Image > PACS
Advances in Detectors and Software

- CR versus DR
- Dual Energy Subtraction
- Bone Suppression Imaging
- Temporal Subtraction
- Tomosynthesis
- Dynamic Radiography
- Computer-aided Detection
- **CR (Computed Radiography):**
  Digital radiography that uses storage (photostimulable) phosphor as a detector
  Scanned by a laser to extract the signal

- **DR (Direct digital Radiography):**
  Digital radiography that uses a “flat panel” TFT direct read-out detector
  Previously tethered by a cable, now can transmit image at bedside for portable XR
Adenocarcinoma
Missed Lung Cancers

- **Size:** 0.6 – 3.4 cm (mean 1.6)
- **Location:** Upper lobes 80% +
- **Conspicuity:** Overlapping bones in 95% +

Modified from Li et al. *January 2008 Radiology, 246, 273-280.*
Missed Lung Cancers

- Size: 0.6 – 3.4 cm (mean 1.6)
- Location: Upper lobes 80% +
- Conspicuity: Overlapping bones in 95% +

Enhancement and CADe for CXR

- Dual Energy Subtraction
- Bone Suppression Imaging
- Temporal Subtraction
- Tomosynthesis
- Dynamic Radiography
- Computer-aided Detection
Dual Energy CXR - Single Exposure Technique

X Ray Source

Copper filter

1st CR plate → 2nd CR plate

Single exposure ES uses two detectors separated by a filter

Patient
Dual Energy CXR - Single Exposure Technique

X Ray Source

Copper filter

1st CR plate

2nd CR plate

Single exposure ES uses two detectors separated by a filter
Single exposure ES uses two detectors separated by a filter. 1st CR plate and 2nd CR plate.

X Ray Source

Copper filter

Patient

First plate records full energy spectrum for standard image.

Second plate records high energy photons.

Weighted subtraction gives soft tissue and bone images.
Sequential Exposure ES

X Ray Source

Detector Plate

First exposure at 60 Kv for calcium detection

Second exposure at 120 Kv for standard image and soft tissue

Weighted subtraction gives soft tissue and bone images
Dual Energy Chest Radiography
Dual Energy Chest Radiography
Dual Energy Chest Radiography
Standard CXR
Calcified Granuloma
Standard CXR
Calcified pleural plaques
Pericardial Calcification

Standard CXR

Bone Image
Skeletal Metastases

Bone Image

Standard CXR
Clinical Advantages of Dual Energy Radiography

- Improved detection of pulmonary nodules
- Improved rejection of false positives
- Improved detection/characterization of calcified pleural/cardiac lesions
- Improved detection of bone metastases
Missed Lung Cancers: Observer Test

- All cases of lung cancer seen at U of Chicago 2001-2004
- Available CXRs reviewed
- 20 missed cancers in 19 pts imaged with dual energy CXRs
ROC Curves for 6 Observers

Observers with ES (Az = 0.82)

Observers without ES (Az = 0.71)
Enhancement and CADe for CXR

- Dual Energy Subtraction
- Bone Suppression Imaging
- Temporal Subtraction
- Tomosynthesis
- Dynamic Radiography
- Computer-aided Detection
Bone Suppression Imaging

Standard CXR
Bone Suppression Imaging

Standard CXR

BSI CXR
Bone Suppression Imaging

Standard CXR

BSI CXR
Bone Suppression Imaging

Standard CXR

BSI CXR
Bone Suppression Imaging

Standard CXR

BSI CXR

DES CXR
Average Radiologist Accuracy with Standard vs BSI vs Dual Energy CXRs
Bone Suppression Imaging

• Provides many of the benefits of Dual Energy CXRs except calcium detection.

• Provides a software-only solution that can be applied to all digital CXRs, including bedside exams without specialized equipment.
Enhancement and CADe for CXR

- Dual Energy Subtraction
- Bone Suppression Imaging
- Temporal Subtraction
- Tomosynthesis
- Dynamic Radiography
- Computer-aided Detection
Previous and Current CXRs
Previous and Current CXRs

Iterative Warping of Previous CXR
Previous and Current CXRs

Iterative Warping of Previous CXR

Subtraction
Temporal Subtraction

Benefits

- Improved detection for pulmonary, pleural, mediastinal disease

Limitations

- Misregistration artifacts can be confusing
Enhancement and CADe for CXR

- Dual Energy Subtraction
- Bone Suppression Imaging
- Temporal Subtraction
- Tomosynthesis
- Dynamic Radiography
- Computer-aided Detection
3D Radiography (Tomosynthesis)

- 61-71 projection images
- Continuous 20-40 degree tube movement
- 69 plane reconstruction; 5 mm spacing
- 11 second acquisition
- Radiation exposure = 1 - 3 CXRs

Slide courtesy James T. Dobbins III, PhD, H Page McAdams, MD, Devon J Godfrey, PhD; Duke University
# Thoracic Tomosynthesis

<table>
<thead>
<tr>
<th>Sensitivity</th>
<th>3-5mm</th>
<th>5-10 mm</th>
<th>&gt;10 mm</th>
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</thead>
<tbody>
<tr>
<td><strong>CXR</strong></td>
<td>7%</td>
<td>20%</td>
<td>53%</td>
</tr>
<tr>
<td><strong>Tomo</strong></td>
<td>53%</td>
<td>71%</td>
<td>90%</td>
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</table>


**Sahlgrenska University Hospital Experience:**

- Tomosynthesis had 3x sensitivity of CXR for nodules
- Limitations: Motion artefacts, subpleural nodules

24 February 2010
Enhancement and CADe for CXR

- Dual Energy Subtraction
- Bone Suppression Imaging
- Temporal Subtraction
- Tomosynthesis
- **Dynamic Radiography**
- Computer-aided Detection
Dynamic Chest Radiography with a Flat-Panel Detector (FPD)

Rie Tanaka, PhD, S. Sanada, PhD, M. Fujimura, MD, N. Okazaki, MD, T. Kobayashi, MD, T. Matsui, O. Matsui, MD
Graduate School of Medicine, Kanazawa University, JAPAN
Computerized Method for Visualizing Respiratory Changes in Pixel Values

Fusion images
Normal subject (24M)

Inter-frame difference

Decreased air

Rie Tanaka, PhD, S. Sanada, PhD, M. Fujimura, MD, N. Okazaki, MD, T. Kobayashi, MD, T. Matsui, O. Matsui, MD
Graduate School of Medicine, Kanazawa University, JAPAN
Bullous Emphysema

Nonuniform

Uniform

Rie Tanaka, PhD, S. Sanada, PhD, M. Fujimura, MD,
N. Okazaki, MD, T. Kobayashi, MD, T. Matsui, O. Matsui, MD
Graduate School of Medicine, Kanazawa University, JAPAN
Dynamic Chest Radiography

- Can detect abnormal regional ventilation
- Has potential to show abnormal regional perfusion
- Non-invasive and simple to perform

Evaluation of Regional Pulmonary Airflow with a Dynamic Flat-Panel Detector

R. Tanaka et al. RSNA 2006
Enhancement and CADe for CXR

- Dual Energy Subtraction
- Bone Suppression Imaging
- Temporal Subtraction
- Tomosynthesis
- Dynamic Radiography
- Computer-aided Detection
Computer Aided Detection
Results with Missed Lung Cancers: CADe (V1.1) Applied to 34 CXRs

- All Missed Cancers: 35% marked
- Average False Marks rate: 5.9 per case
- 95% of FPs due to normal anatomy
## Improvement in CAD Accuracy since 2006: Results with a 50-Case Database

<table>
<thead>
<tr>
<th></th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
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<tbody>
<tr>
<td>CAD</td>
<td>V 1.0</td>
<td>V 3.0</td>
<td>V 4.0</td>
<td>V 5.0</td>
<td></td>
</tr>
<tr>
<td>Sensitivity</td>
<td>54 %</td>
<td>62 %</td>
<td>58 %</td>
<td>67 %</td>
<td></td>
</tr>
<tr>
<td>Average False Marks</td>
<td>5.6</td>
<td>2.9</td>
<td>2.2</td>
<td>2.0</td>
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</tr>
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</table>
### Improvement in CAD Accuracy since 2006: Results with a 50-Case Database

<table>
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<tr>
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<th>2011</th>
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</thead>
<tbody>
<tr>
<td>CAD</td>
<td>V 1.0</td>
<td>V 5.2</td>
</tr>
<tr>
<td>Sensitivity</td>
<td>54 %</td>
<td>83 %</td>
</tr>
<tr>
<td>Average False</td>
<td>5.6</td>
<td>0.48</td>
</tr>
<tr>
<td>Marks</td>
<td>2.9</td>
<td>2.2</td>
</tr>
</tbody>
</table>
Sensitivity

False Marks

CAD performance 2006 - 2011

Sensitivity

False Marks

2006

2011
Primary Adenocarcinoma
False Positive due to Healed Rib Fracture
Recent Improvements in CXR CAD

- Increased sensitivity
- Greatly reduced false positive rate
- Nearly 50% of false positives are now due to focal benign opacities
Future CAD Systems

- Higher sensitivity and specificity
- Seamless integration into PACS
- Increasingly broad application and acceptance of CAD in various types of exams and pathology
Conclusions

- Enhanced Radiography can improve diagnostic accuracy without impairing workflow
Conclusions

- Enhanced Radiography and CADe can improve diagnostic accuracy, even for experienced radiologists.
- Because most cases are negative, these methods can also potentially increase productivity.