Enhanced Detection and Computer-aided Diagnosis for Thoracic Imaging

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Disclosures

- Consultant for Riverain Medical
- Minor stockholder in Hologic, Inc.
- License and royalty fees from University of Chicago (UCTech)
- Research support from Philips Healthcare
Chest Radiography and CT

- CR versus DR
- Dual Energy Subtraction
- Bone Suppression Imaging
- Temporal Subtraction
- Tomosynthesis
- Dynamic Radiography
- CT protocols
- CADe and CADx
- CT vessel suppression
- Machine learning
Advances in Detector Technology

- **CR (Computed Radiography)**:
  - Powder phosphors
  - Dual reading CR
  - Needle phosphors

- **DR (Direct Digital Radiography)**:
  - CSI- photodiode/TFT detectors
  - Amorphous selenium detectors

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

- Increased Dose Efficiency
- Improved Image Quality
- Improved Scatter Rejection

Therefore:

- Opportunity for dose reduction
- Low kVp non-grid technique possible for PCXRs except in very large patients
Advantages of Newer Detectors

- Enhanced Workflow
  - Image > Console ~2 secs
    - Tube adjustment/repeat
  - Image > PACS
No Grid. 85 kVp, 2mAs

8:1 Grid. 115 kVp, 3mAs
Adenocarcinoma
Enhancement and CADe for CXR

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

Water

Linear Attenuation Coefficients

- Photoelectric
- Compton
- Coherent
Dual Energy CXR - Single Exposure Technique

Single exposure ES uses two detectors separated by a filter.

First plate records full energy spectrum for standard image.

Second plate records high energy photons.

Weighted subtraction gives soft tissue and bone images.

X Ray Source

Patient

Copper filter

1st CR plate

2nd CR plate
Dual Energy Chest Radiography
Sequential Exposure ES

X Ray Source

First exposure at 60 Kv for calcium detection

Second exposure at 120 Kv for standard image and soft tissue

Patient

Detector Plate

Weighted subtraction gives soft tissue and bone images
Two Shot Dual Energy Method

- Excellent energy separation
- Efficient detector – low noise
- Misregistration artifact in many cases
- Requires some additional exposure

but

- Total dose need be no more than CR energy subtraction
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

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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

- Standard Image (AUC=0.807)
- With BSI Image (AUC=0.867)
- With DES Image (AUC=0.916)
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

Iterative Warping of Previous CXR

Subtraction
Temporal Subtraction

Current CXR

Temporal 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
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- Tomosynthesis
- Dynamic Radiography
- Computer-aided Detection
3D Radiography (Tomosynthesis)

- 71 projection images
- Continuous 20-40 degree tube movement
- 69 plane reconstruction; 5 mm spacing
- Tube movement
- 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

Duke University Experience:

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

Enhancement and CADe for CXR

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

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: flat-panel detector (FPD) based functional X-ray imaging
Rie Tanaka
Enhancement and CADe for CXR

- Dual Energy Subtraction
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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>2017</th>
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<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>
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<tr>
<td>Average False</td>
<td>5.6</td>
<td>0.48</td>
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<tr>
<td>Marks</td>
<td>2.9</td>
<td>2.0</td>
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</table>
CAD performance 2006 - 2014

Sensitivity vs False Marks

- Red line: Sensitivity
- Green line: False Marks

Year:
- 2006
- 2011
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
Enhancements for Thoracic CT

- Thin section contiguous axial sections
- Coronal, sagittal recon.
- MIPs, MINIPs
- CAD
Standard Thoracic CT Protocol,
University of Chicago 2017
Histoplasmosis

3 mm slab

10 mm MIP
Axial and Coronal Slabs
SLT with emphysema in native lung (MINIP)
UIP with Traction Bronchiectasis
RUL Bronchus Variant
Surface Rendering and Virtual Bronchoscopy
Emphysema: Quantitative Analysis

<table>
<thead>
<tr>
<th></th>
<th>Total Lung</th>
<th>Right Lung</th>
<th>Left Lung</th>
<th>Trachea</th>
</tr>
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<tbody>
<tr>
<td>Volume ( \text{cm}^3 )</td>
<td>4879.14</td>
<td>2584.53</td>
<td>2294.61</td>
<td>44.37</td>
</tr>
<tr>
<td>Emphysema ( \text{cm}^3 )</td>
<td>1771.49</td>
<td>1102.69</td>
<td>660.60</td>
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<tr>
<td>Ratio (%)</td>
<td>36.31</td>
<td>42.67</td>
<td>29.14</td>
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</table>

Total Lung

Mean: -904.979
SD: 88.6234
CAD for Chest CT

- Nodules
Nodule Tracking and Comparison

STANDARD CHEST PROTOCOL/ThoraxLUNGS
9/10/2007 8:45:31 AM
Supine

120 kVp
Thickness: 3 mm
CNR: 500/1700

Volume growth: 58.4
Axial LD growth: 21.8
Width growth: 12.2
Elapsed time (days): 56
Doubling time (days): 94

Volume (mm³): 42.7
Axial LD (mm): 3.0
Width (mm): 3.8
Max density (HU): 140

Axial Zoom Prior Coronal Prior Sagittal Axial Zoom Current Coronal Current Sagittal

Surface Histogram Surface Histogram Coronal Zoom Sagittal Zoom Surroundings

MEDIAN LMS Lung
Current Status of Nodule CAD for CT (2017)

- Good sensitivity for $\geq 4$mm solid nodules (70-90%)
- Acceptable false positive rate (3-4 per case)
- Increased radiologist accuracy
Detection of Non-Solid Nodules
Detection of Non-Solid Nodules
CAD for Chest CT

Detection

- Embolism
- Nodules
CAD for Pulmonary Embolism

- Sensitivity range 85% to 90% per patient
- False positives from 3 to 4 per case
- Accuracy depends on image quality
- Potential to estimate clot burden
CT Vessel Suppression
CT Vessel Suppression
CT Vessel Suppression
Future Directions

- Big Data
- Convolutional Neural Networks
- Machine Learning
- Cognitive computing
Uber Self Driving Car
CLOUD VISION API
Derive insight from images with our powerful Cloud Vision API

Labels

<table>
<thead>
<tr>
<th>Label</th>
<th>Score</th>
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<tbody>
<tr>
<td>Vacation</td>
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<tr>
<td>Residential Area</td>
<td>70%</td>
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<tr>
<td>Home</td>
<td>69%</td>
</tr>
<tr>
<td>Coast</td>
<td>65%</td>
</tr>
<tr>
<td>Tower</td>
<td>60%</td>
</tr>
<tr>
<td>Cottage</td>
<td>55%</td>
</tr>
<tr>
<td>Walkway</td>
<td>52%</td>
</tr>
<tr>
<td>Sunset</td>
<td>50%</td>
</tr>
</tbody>
</table>

Colors

Safe Search

JSON Response
“In theory, there’s no difference between theory and practice. But in practice, there is”.

Yogi Berra
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 reducing productivity