Objective

- To understand basic technical background of dual-energy CT imaging
- To understand potential thoracic applications of dual-energy CT including
  - Perfusion assessment of lung diseases
  - Xenon-enhanced ventilation imaging
  - Nodule assessment

Contents

- Basic Concept / Physical Background
- Basic theory for DS-DECT analysis
- Thoracic applications
  - Contrast enhanced DE lung perfusion
  - Xenon enhanced lung ventilation
  - Virtual non-contrast image: SPN Study

DECT: Concept

- The process of acquiring X-ray transmission measurements with two different effective X-ray energies with CT.
  - Using two X-ray beams of known effective energies it is possible to extract additional information on tissue composition.
- Two important modes of X-ray / tissue interaction in the diagnostic X-ray range
  - Compton scattering: dependent on the X-ray energy and the electron density
  - Photoelectric absorption: increases rapidly with atomic number and decreases rapidly with increasing photon energy.

Two Different Energy Setting with DSCT

How do typical materials look like?

- higher CT-value at 80kV: iodine, bone, metal ...
- higher CT-value at 140kV: fat, plastic, uric acid ...
- (almost) same CT-value: water, soft tissue, blood ...
DECT-DSCT Workflow

- Scanner
  - raw data A (140kV)
  - raw data B (80kV)
- Images A
  - Weighted average
- Images B
- Diagnostic image
- Dual Energy Viewer
- Results 1
- Results 2

Extraction of Contrast Material
- Calculate contrast image
- Generate virtual non-contrast image and contrast material map

Examplary contrast material map:
- Various concentrations of iodine

Perfusion Dual Energy CT
- A-tube: 140 kVp, 50 eff.mAs
- B-tube: 80 kVp, 210 eff.mAs
- Two tubes run simultaneously
- Single scanning after injection of contrast media
- Average image
- CT Angiography
- Post-processing
- Fusion image
- Iodine image
- Parenchymal perfusion

Perfusion CT: Clinical Applications
- Pulmonary embolism
  - Diagnosis / Severity assessment
- Preop. evaluation of lung cancer: prediction of postoperative lung function
- Assessment of perfusion in diffuse lung diseases: emphysema, bronchiectasis
- Others
  - Congenital PA anomaly
  - Primary Pulmonary hypertension

Acute Pulmonary Embolism

Infarction
APE: Severity Assessment

- 30 patients with acute PE
- Scoring system
  - Angiographic score
  - Perfusion score
    - Segment based 0-2 scores
  - RV/LV diameter ratio
- Correlation between scoring systems, readers

Chae EJ, Seo JB, AJR, in press

Assessment of Perfusion Defect with DECT in APE: Conclusions

- Proposed perfusion scoring system showed reliable correlation with angiographic occlusion score and RV/LV ratio in severity assessment.
- There were perfusion-angiography mismatched lesions in some patients, which could represent the disturbance of microcirculation or normal perfusion in area of partial occlusion. This interesting observation implies that combined assessment of perfusion and vascular occlusion may be necessary for further understanding of severity and proper management.

Chae EJ, Seo JB, AJR, in press

Correlations with RVD

- Correlation mean P score or mean CTA score with RVD

<table>
<thead>
<tr>
<th>P score</th>
<th>CTA score</th>
<th>Correlation with RVD</th>
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<tbody>
<tr>
<td>Reader 1</td>
<td>30 ± 10 %</td>
<td>39 ± 21 %</td>
</tr>
<tr>
<td>Reader 2</td>
<td>30 ± 10 %</td>
<td>39 ± 19 %</td>
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</tbody>
</table>

r = 0.69, p < 0.001

Chae EJ, Seo JB, AJR, in press

Congenital PA Hypoplasia

Assessment of Perfusion in COPD with DECT

Other Obstructive Lung Diseases

Swyer James Syndrome

Bronchiectasis

Lee CW, Seo JB, unpublished data
Xenon Ventilation CT

• Contrast material: Xenon Gas
  – Similar Atomic Number (54) with Iodine (53): K edge similar to iodine
  – CT Density of Airspace Containing Xe Increases Linearly with Xe Concentration

Dual-source Dual-energy CT

• Extraction of Xe component from lung parenchyma
• Escape from influence of background lung density

Normal vs. Bronchiectasis

Chae EJ, Seo JB, Radiology 2008

Xenon CT: Clinical Implications

• Direct Visualization of Local ventilation
  – Assessment of regional ventilation in various diseases: COPD, asthma, various bronchiolitis
  – Severity assessment of ventilation defect in asthma

• Superior to Ventilation Scan
  – Ventilation + High-resolution CT
  – Quantification

Asthma
Xenon Ventilation DECT in Asthmatics

- Results of 22 patient study
  - No significant adverse effect of xenon gas
  - Ventilation defect was shown in 16/22 pts
  - Defect group: lower FEV1/FVC, DLco, increased FRC, thicker airway wall
  - Significant correlation with defect score and PFT

- Conclusion: Xenon ventilation imaging using DECT may be useful in functional assessment of asthmatics

Chae EJ, Seo JB, RSNA 2009

Xenon Ventilation CT: Summary

- Dual-energy CT after inhalation of xenon gas is a new, safe ventilation imaging modality.

- Xenon ventilation DECT imaging may provide further insights into the pathophysiology of obstructive lung diseases by combining ventilation and detailed anatomic information.

DECT study for SPN

- Virtual Non-enhanced Image ≈ Non-enhanced Scan
  - Iodine image ≈ Degree of enhancement
  - Potential benefits
    - Avoid additional non-enhanced scan
    - Reduce measurement error

Virtual Non-contrast Image

- Advantage over single-energy CT
  - No need for non-contrast imaging
  - Reduction of radiation
  - Accurate measurement of enhancement

Result: Calcification

<table>
<thead>
<tr>
<th></th>
<th>SPN</th>
<th>Lymph nodes</th>
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<tbody>
<tr>
<td>Real</td>
<td>20</td>
<td>45</td>
</tr>
<tr>
<td>Virtual</td>
<td>17 (85.0%)</td>
<td>44 (97.8%)</td>
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</table>
Iodine Extraction

- Degree of Enhancement on SPN [HU(post) – HU(pre)] vs. Iodine value on DECT
  - Excellent correlation (ICC=0.91, p<0.01)
- Diagnostic accuracy for determining malignancy (threshold: 20HU)

<table>
<thead>
<tr>
<th>Iodine value</th>
<th>Sensitivity</th>
<th>Specificity</th>
<th>Accuracy</th>
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<tbody>
<tr>
<td>Degree of Enhancement</td>
<td>92%</td>
<td>70%</td>
<td>82.2%</td>
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<tr>
<td>72%</td>
<td>70%</td>
<td>71.1%</td>
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Chae EJ, Song JW, Seo JB, Radiology 2008

Summary

- DECT is a new emerging imaging technique in clinical radiology.
- There are many useful clinical thoracic applications with DECT.
- With introduction of 2nd DSCT, several limitations of DECT were overcome.

Chae EJ, Song JW, Seo JB, Radiology 2008

References