Dual Energy CT of the Liver

Vassilios Raptopoulos, MD
Dual Energy CT (DECT)

- Different materials attenuate x-rays differently when different energy is applied.
- Attenuation is greater when energy is closer to \( K \) edge of the material.
- Iodine attenuation: 80kVp > 140 kVp

Coursey C A et al. Radiographics 2010;30:1037
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<table>
<thead>
<tr>
<th>Substance</th>
<th>K Edge (keV)</th>
<th>Atomic Number (Z)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydrogen</td>
<td>0.01</td>
<td>1</td>
</tr>
<tr>
<td>Carbon</td>
<td>0.28</td>
<td>6</td>
</tr>
<tr>
<td>Nitrogen</td>
<td>0.40</td>
<td>7</td>
</tr>
<tr>
<td>Oxygen</td>
<td>0.53</td>
<td>8</td>
</tr>
<tr>
<td>Calcium</td>
<td>4.00</td>
<td>20</td>
</tr>
<tr>
<td>Iodine</td>
<td>33.20</td>
<td>53</td>
</tr>
<tr>
<td>Barium</td>
<td>37.45</td>
<td>56</td>
</tr>
<tr>
<td>Gadolinium</td>
<td>50.20</td>
<td>64</td>
</tr>
</tbody>
</table>

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Dual Energy CT

- Material density reflects energy-related attenuation characteristics
- Use of Different Energies (kVp)
  - 80 kVp imaging can enhance Iodine
    - Vessels, Hyper-enhancing lesions, Hyperemia
    - Potential to improve lesion detection
- Synchronous Dual Energy
  - 80-140 kVp can reconstruct specific materials
    - Fat - Water - Iodine – Calcium
    - Decrease beam-hardening & pseudoenhancement
Dual-source (ds) – Single-source (ss)

dsDECT – 2 tubes
80 kVp & 140 kVp
Uses Image data

ssDECT – Single tube
Rapid energy alternation
Uses Projection data
Virtual monochromatic images &
Material Images (e.g. Iodine, Water)
Energy and flux at conventional CT
Photons with broad range of energies
The maximum energy of the beam
Expressed as kilovolt peak (kVp)

ssDECT with a monochromatic display
Mathematical model to create
computer monochromatic images of
different energies reported as
kiloelectron-volt (keV)

Silva A C et al. Radiographics 2011;31:1031-1046
ssDECT with Material Imaging

60 keV

77 keV

Iodine

Water
DECT lesion characterization
Liver cyst

 Silva A C et al. Radiographics 2011;31:1031-1046
ssDECT- Lesion characterization
metastasis from breast ca

Water

60 keV

77 keV

C-

Iodine

Iso-dense on Water & High energy (enhancing)
Hypo-dense on Iodine & Low energy (hypo-enhancing)
Tissue Characterization with asynchronous DECT

- Fatty liver
- Sequential scanning of liver w/ 80kVp & 140 kVp
- Greater change in fatty liver attenuation than other tissues
  - moderately proportional to % of fat in tissue
- Mean $\Delta$ between 80 & 140 kVp (13 HU): 23H $\Rightarrow$ 10H
  - reverse from iodine

Change in attenuation between low & high kVp

Raptopoulos V et al
AJR 1991:157:721
Iodine in CT of the liver

- Arterial phase scanning improves detection of hyper-vascular neoplasms in the liver
  - Hollett MD et al (Stanford) AJR 1995;164:879

- Late arterial phase for detecting hypervascular HCC
  - Ichikawa T et al (Yamnashi U) AJR 2002; 179:751
Liver Cirrhosis & HCC

Detection/Characterization of small lesions may be challenging

Arterial hyper-enhancement – Portal Venous & 3m delay washout
Low kVp is more sensitive in detecting hyper-vascular lesions but with decrease in subjective image quality.

Asynchronous Sequential DECT (asDECT)

C - 120 kVp
PV - 120 kVp
Art - 80 kVp
3m - 120 kVp
asDECT
HCC in right lobe

C - 120 kVp

Art - 80 kVp

PV - 120 kVp

3m - 120 kVp
asDECT
Shunting & fibrosis in left lobe

C - 120 kVp
Art - 80 kVp
PV - 120 kVp
3m - 120 kVp
asDECT: Other Clinical Uses

Hyper-vascular metastasis (neuro-endocrine tumors)
asDECT: Other Clinical Uses

Cholangio-carcinoma – delayed enhancement
Low energy scanning can improve detection

10 min
80 kVp
asDECT can improve detection less than characterization

Hyperemia at resection margin vs. recurrence
asDECT can improve detection less than characterization

Hyperemia at radiofrequency ablation margin vs. recurrence
Poly- vs Mono-chromatic Imaging

Polychromatic 80 kVp (↑↑ Contrast & ↑ Noise)

Monochromatic ssDECT 60 keV (↑↑ Contrast & ↓ Noise)

Silva A C et al. Radiographics 2011;31:1031-1046
Poly- vs Mono-chromatic Imaging

80 kVp

60 keV
Poor image quality of 80 kVp scanning in obese patients

Patient weight > 200 Lbs
Beam Hardening and streak artifact reduction

Virtual monochromatic beam and metal artifact reduction software can reduce artifact from gold Radiotherapy fiducial markings

**Conclusions**

- Single source and dual source synchronous DECT scanners are now commercially available.
  - The advantages of one over the other are not clearly defined.
- Dual Energy CT has potential to improve lesion detection and characterization.
- Value in Screening for HCC in patients with cirrhosis.
- May play role in fatty liver disease, evaluation of hyperemia and fibrosis.
Conclusions

- DECT may decrease need for non-contrast scanning
- DECT may reduce beam hardening artifacts and can help with surgical clips
- Low energy scanning and asDECT can be helpful in lesion detection but have severe limitations in image quality and lesion characterization