CT imaging techniques

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Nice 2010
Outline

- Calcium scoring
- CT angiography
  - Acquisition and Patient selection
  - Advances and Dose reduction
- Additional information/ imaging techniques
  - LV function
  - Myocardial perfusion imaging
Hallmark:

• Presence and extent of coronary calcifications as marker for CAD
Calciuim scoring (EBCT/MSCT)

- No contrast
- Images acquired at predefined phase
- 4 x 3mm collimation
- Low radiation dose 1-3 mSv
Calcium scoring (EBCT/MSCT)

<table>
<thead>
<tr>
<th>CAC Score</th>
<th>Calcified Plaque Burden</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>No identifiable atherosclerotic plaque</td>
</tr>
<tr>
<td>1-10</td>
<td>Minimal plaque burden</td>
</tr>
<tr>
<td>11-100</td>
<td>Mild plaque burden</td>
</tr>
<tr>
<td>101-400</td>
<td>Moderate plaque burden</td>
</tr>
<tr>
<td>401-1,000</td>
<td>Extensive plaque burden</td>
</tr>
<tr>
<td>&gt;1,000</td>
<td>Very extensive plaque burden</td>
</tr>
</tbody>
</table>

Region | Agatston | Volume |
--------|----------|--------|
LM      | 0        | 0      |
RCA     | 0        | 0      |
LAD     | 37       | 31     |
CX      | 0        | 0      |
PDA     | 0        | 0      |
Other1  | 0        | 0      |
Other2  | 0        | 0      |
Other3  | 0        | 0      |
Total   | 37       | 31     |
Limitations calcium scoring

- No direct relation between extent calcium and angiographic severity of disease

- extensive calcium without obstruction
- limited calcium with high grade stenosis
- Non-calcified lesions are not visualized...
MSCT coronary angiography

- Direct visualization of the coronary arteries
- Detection of significant CAD (stenosis >50% luminal narrowing)
Rapid development

2000 → 2010

4-slice CT → 16-slice CT → 64-slice CT → 256/320-row CT → Dual-source CT → High-pitch spiral CT

Adapted from G Pundziute
MSCT scanning
Sequential CT scanning
- Prospective triggering
- 1 phase acquired

Spiral CT scanning
- Retrospective gating
- Reconstruction in all phases

- Breath hold of approx 8 seconds
- Collimation 64 x 0.5 mm
- Rotation time: 0.4s or faster
- Contrast agent bolus 4-6 ml/s
- ECG is simultaneously acquired to allow retrospective reconstruction of the data
- 4D dataset

Registration of the ECG
Reconstructed Images gated to ECG

Reconstructed at 75% ; 0.5 mm at 0.3 mm increment
Protocol Issues

- Iodinated contrast
- Radiation
- Temporal resolution relatively limited, images reconstructed over several heartbeats: heart rate should be stable and low
- Breath hold required
Contra-indications for MSCT

**Contrast**
- Known or suspected contrast allergy
- Renal insufficiency

**Radiation**
- Pregnancy
- Age
- Recent imaging with radiation?
Contra-indications for MSCT

Heart rate
- Atrial fibrillation
- High heart rate and contra-indications for beta-blockers

Breath hold
- Not able to hold breath
- Not able to lie still
HR below 60 bpm

- Improved image quality with lower heart rates
- Higher diagnostic accuracy
- More options for dose reduction
- Administration of beta-blockers at HR >60 bpm
Nitroglycerine

With Nitro

Without Nitro

(Klass et al J Comput Assist Tomogr 2009;33: 199Y203)
Estimated radiation dose 64-slice

50 study sites, different vendors, 4% 16-slice

Range of medians: 5.7 to 36.5 mSv

Hausleiter et al ACC 2008/JAMA 2009
Dose saving algorithms

- Automatic exposure control
  adaptation of tube current to pat.'s anatomy
- ECG pulsing
  modulation of tube current to pat.'s ECG
- 100 kV tube voltage
  instead of conventional ≥ 120 kV tube voltage
  adapted to pat’s posture
- Sequential scanning (step and shoot)
  instead of conventional spiral scan technique

Hausleiter et al ACC 2008/JAMA 2009
Automatic exposure control
– 64-slice systems – Hausleiter et al JAMA 2009

Frequency of use

Estimated dose

- Without automatic exposure control
- With automatic exposure control

Frequency of use (%): 62.1 vs. 37.9
Estimated dose (mSv): 15.4 vs. 15.8
ECG pulsing

Maximum output only during diastole
Noisy images during systole
ECG pulsing
– 64-slice systems – Hausleiter et al JAMA 2009

Frequency of use

Estimated dose

- ECG pulsing

<table>
<thead>
<tr>
<th>without</th>
<th>with</th>
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</thead>
<tbody>
<tr>
<td>21.3</td>
<td>78.7</td>
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</table>

<table>
<thead>
<tr>
<th>Estimated dose (mSv)</th>
</tr>
</thead>
<tbody>
<tr>
<td>without</td>
</tr>
<tr>
<td>20.9</td>
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</tbody>
</table>

20% decrease in estimated dose with ECG pulsing.
100 kV tube voltage
– 64-slice systems – Hausleiter et al JAMA 2009

Frequency of use

<table>
<thead>
<tr>
<th>Voltage (kV)</th>
<th>Frequency (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>≥ 120</td>
<td>7.8</td>
</tr>
<tr>
<td>100</td>
<td>92.2</td>
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</tbody>
</table>

Estimated dose

<table>
<thead>
<tr>
<th>Dose (mSv)</th>
<th>Percentage</th>
</tr>
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<tbody>
<tr>
<td>30</td>
<td>50%</td>
</tr>
<tr>
<td>17.4</td>
<td>50%</td>
</tr>
<tr>
<td>8.7</td>
<td>50%</td>
</tr>
</tbody>
</table>

Image quality

<table>
<thead>
<tr>
<th>Quality (%)</th>
<th>Value</th>
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<tbody>
<tr>
<td>≥ 120</td>
<td>2.7%</td>
</tr>
<tr>
<td>100</td>
<td>97.3%</td>
</tr>
</tbody>
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Legend:
- ≥ 120
- 100 kV tube voltage
Retrospective vs prospective

Sequential CT scanning
- Prospective triggering
- 1 phase acquired

Spiral CT scanning
- Retrospective gating
- Reconstruction in all phases

Spiral vs. sequential scanning
– 64-slice systems – Hausleiter et al JAMA 2009

Frequency of use

<table>
<thead>
<tr>
<th>Percentage (%)</th>
<th>Spiral</th>
<th>Sequential</th>
</tr>
</thead>
<tbody>
<tr>
<td>93.8</td>
<td></td>
<td>6.2</td>
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</tbody>
</table>

Estimated dose

<table>
<thead>
<tr>
<th>Dose in mSv</th>
<th>Spiral</th>
<th>Sequential</th>
</tr>
</thead>
<tbody>
<tr>
<td>17.6</td>
<td></td>
<td>5.6</td>
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68% reduction in estimated dose.
Prospective ECG triggering

30 pts
Heart rate 56 +/- 8 bpm;
Dose 2.1 +/- 0.7 mSv
(range: 1.0–3.3)

Sensitivity 100%
Specificity 83%
PPV 90%
NPV 100%
Radiation dose

Good image quality, good diagnostic accuracy at doses even lower than invasive coronary angiography

Herzog et al Heart 2009;95:1656-1661
During computed tomography coronary angiography scanning with prospective ECG-gating (SnapShot Pulse technology), data are acquired with a z-coverage of 40 mm (indicated by white lines).
Coverage in a single heart beat

56 year old male, family history for CAD +++

Prospective ECG-triggering 75%
320-row CT: 1 heart beat
100 kV
Rule out significant CAD at 2.7 mSv
High-pitch spiral CT

Prospective triggering with very fast pitch
128 DSCT, 2 x 128 x 0.6 mm
Entire period of data acquisition 260 ms, placed in diastole
Temp resolution of each slice is 75 ms (0.28s rotation time)

Achenbach S. et al. Eur Heart J 2009
High-pitch spiral CT

Estimated effective dose: 0.89 mSv