Cardiac CT - Coronary Calcium Basics
Workshop II (Basic)

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No significant disclosures

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Some of the techniques discussed may be experimental

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WFU GCRC M01-RR07122
Workshop Outline

- Objective - learn how to measure calcified coronary plaque CT
- Cardiac CT “hardware”
- Cardiac CT “software”
- Discuss future standardization process
Set of Axial CT images or “slices”
## Report Pixels

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**ID:** D5S9603  
**Exam 117 Series 3 Image 31**

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**WW:** 400  **WL:** 40

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Key Factors Cardiac CT - Image Quality

- Gantry speed
- Scan mode
- Tube
- Detector Configuration

- Temporal Resolution
- Scan time
- Gating Method
- Radiation Exposure
- Signal to Noise
- Spatial Resolution
EMI Clinical CT system
MDCT 4, 8, 16, 32, 64 -- volume?
MDCT - basics think “Angio Suite”

Diagram showing a CT scan setup with a tube, detector, and CT couch.
Gantry Speed = Time to make 360 degree rotation

<table>
<thead>
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<th>Gantry Speed [sec]</th>
<th>Cardiac image “time”</th>
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<tr>
<td>(year introduced)</td>
<td>(Axial partial scan recon)</td>
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<tr>
<td>1 (1996)</td>
<td>800 msec</td>
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<td>0.8 (1998)</td>
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<td>0.5 (2000)</td>
<td>305 msec</td>
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<tr>
<td>0.4 (2003)</td>
<td>240 msec</td>
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<td>0.37 (2004)</td>
<td>225 msec</td>
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<tr>
<td>C100-eSpeed (85-03)</td>
<td>50 / 100 msec</td>
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Cardiac Scan Mode
Axial (cine) = stationary couch
Helical = moving couch (pitch)

• Determines ECG gating method
• Impacts radiation dose
• Impact spatial & temporal resolution
<table>
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<th>Radiation (tube on time)</th>
<th>Axial (Cine)</th>
<th>Helical-Cardiac</th>
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<tr>
<td></td>
<td>1 - 1.5 mSv</td>
<td>&gt; 3-15 mSv</td>
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<td>(6-8 secs)</td>
<td>(&gt;20 secs)</td>
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<tr>
<td>resolution (z- &amp; temporal)</td>
<td>+++</td>
<td>++++</td>
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<td>(? MDCT16-64)</td>
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<td>Robustness (?idiot proof)</td>
<td>high</td>
<td>Some limits</td>
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<tr>
<td>Clinical application</td>
<td>Established CAC</td>
<td>CTA / Function</td>
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Detectors - E Speed
MDCT = Multiple Slices Configurations

2 x 0.0625 mm

8 x 1.25 mm

8 x 2.5 mm
Cardiac Gating & Scan Modes

• Cardiac Gating
  – Prospective (triggered on R wave)
  – Retrospective (post-processing)

• Scan modes
  – Axial / Cine (step and shoot)
  – Helical / Helical Multi-sector
ECG – Prospective (Triggering)
MDCT - Helical / Spiral
MDCT - Axial / sequential / cine
Prospective Scanning

- Lower Dose
- Multi-slice acquisition in a single cardiac cycle
- Less system overhead
- Does not support overlap recon

Graphic courtesy of General Electric Medical Systems & modified by Dr. Carr
Retrospective Gating
Retrospective Gating

Single Sector Reconstruction Method - SnapShot Segment

Graphic courtesy of General Electric Medical Systems & modified by Dr. Carr
Multi-Sector Image Reconstruction:

Improving Effective Temporal Resolution

4 sectors: ~ 65 msec on LightSpeed Plus/Ultra

Graphic courtesy of General Electric Medical Systems
Single Slice Cardiac CT

Heartbeat

1 2 3 4 5 6 7 8
Multi-Detector CT (MDCT)
4 Channels
MDCT (4 slices x 2.5 mm)
Single R-R interval
MDCT (16 levels x 1.25 mm)
Single R-R interval
<table>
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<tr>
<th>Mode images/rr</th>
<th>Thickness slice [mm] slab [mm]</th>
<th>Slabs needed for 120mm</th>
<th>Breathhold time [sec]</th>
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Patient Preparation & Instructions

• Prior to study (tell clinic staff to remind at scheduling)
  – No caffeine products before scan
  – Will have to change into gown (optional)
  – Beta blockers not indicated for calcium scoring

• Immediate pre-scan
  – Change into hospital gown
  – Easier if opens in front (placing ECG leads)
  – Safety checks which are routine at your institution (i.e. LMP, pregnancy etc..)
Where to scan? - Landmarks
“Take a deep breath in <pause>
blow it all the way out <pause>
Take a deep breath in <pause>
blow it all the way out <pause>
Take a deep breath in and hold it.

******Scan 8-20 seconds*****

Breath and relax”
Breath holding Instructions

- Instruction after greeting patient
- Prepare patient by indicating there will be several times they are asked to hold their breath – some short (the scouts) and some longer
- Instruction & observation during scout images
Breathing Instruction
– why longer than the scan?

• End inspiration.
  – Pushes liver down – less beam attenuation
  – Valsalva lowers heart rate.
  – Easier to do than end expiration.
  – Blowing off C0₂ (hyperventilation) - easier to hold breath!

• Pre-recorded voice if available.
ECG – Setup

• Arms overhead
• Reposition leads if necessary
• Make sure amplitude (i.e. size) is OK per your CT scanner instructions
• Trigger at 50% RR
  – (alternate 75% RR)
ECG lead Placement
- several options
ECG positioning

“White is Right (white lead)–
Smoke (black) over Fire (red) (left side)

• Identifiable R-wave
• Trouble shooting
  – Reposition leads / electrodes
  – check connections
  – Move closer to the heart
Movie clip
Measuring Coronary Calcium

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WW: 400 WL: 40
EBCT and CAC

- Agaston and Janowitz et. al. developed Total Calcium Score (TCS)
- System for scoring amount of calcified plaque:
  - area of plaque $\times$ weighting factor = lesion score
  - weighting based on brightest pixel in lesion
  - sum of lesion scores = vessels score
  - sum of vessel scores = total calcium score (TCS)
EBCT - Conventional (AJ) scoring

- **CT #**  wt. factor
- 0-129     ===> 0
- 130-199   ===> 1
- 200-299   ===> 2
- 300-399   ===> 3
- >400      ===> 4

- (area) x wt. Factor = lesion score
CT image to quantitative data
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**Plaque 1**

**Plaque 2**

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Conventional Scoring (Agatston)

• Plaque 1
  – Number pixels above 130 threshold = 5
  – Highest CT# = 249
  – Weight = 2
  – $5 \times 2 = 10$

• Plaque 2
  – Number pixels above 130 threshold = 5
  – Highest CT# = 346
  – Weight = 3
  – $5 \times 3 = 15$
Variability in 1 Pixel by 1 H.U. can Double the Agatston Score

- **Scan 1**
  - CAC area = 10
    - all pixels in lesion > 130 CT#
    - brightest pixel \( \text{CT#} = 199 \); wt factor = 1
    - \( 10 \times 1 = 10 \) lesion score

- **Scan 2**
  - CAC area = 10
    - all pixels in lesion > 130 CT#
    - brightest pixel \( \text{CT#} = 200 \); wt factor = 2
    - \( 10 \times 2 = 20 \)
CT Calcified Plaque Area

- Pixel dimensions (2D: height x width [mm$^2$]):
  - 350 mm fov
  - 512 rows and columns
  - $350 / 512 = 0.68$ mm

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CT Calcified Plaque Volume

- Voxel (volume element = ht x wt x depth)
  - Slice thickness = 2.5 mm
  - Voxel volume calculation
  - $0.68 \text{ mm} \times 0.68 \text{ mm} \times 2.5 \text{ mm} = 1.16 \text{ mm}^3$
Volume = 0.68 mm \times 0.68 mm \times 2.5 mm = 1.16 \text{ mm}^3
Plaque Volume by CT

- Plaque 1 = Plaque 2
  - # pixels >= 130 = 5
  - # pixels >= 90 = 6
- Plaque Volume @ 130 threshold
  - 5 pixels x 1.16 = 5.8 mm$^3$
- Plaque Volume @ 90 threshold
  - 6 pixels x 1.16 = 6.9 mm$^3$
MDCT - Improved Spatial Resolution

2.5 mm slices 1.25 mm slices
2.5 mm slices

1.25 mm slices

LAD

Great Coronary vein

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Calibration of CT Systems
Calcified Plaque Mass [mg]
CT Technique – Coronary Calcium State of the Art - 2004

- Axial (Cine) mode
- 2.5 mm slice collimation
- Prospective ECG gating/triggering @ 50% RR
- KVp 120, 50 - 100 mAs
- Maximize scan speed (temporal resolution)
  - 0.4-0.5 sec gantry rotation
  - partial scan reconstruction
- Dose ~ 1 mSv
Weight and mAs

If the weight is **less than 100 kg / 220 lbs**
Set mAs = 50-100
{know how your system calculates mas}

If the weight is **100 kg / 220 lbs or greater**
Set mAs = 25% increase

Objective - image noise & calcium score independent of patient size
Conclusions
MDCT Calcified Plaque

• MDCT-4 or greater
• 0.5 second gantry (or faster)
• Prospective gating (Axial scan mode) for non-contrast Coronary Calcium Scan
• ECG gated helical scan for CT coronary angiography - ramp mA
• Future hybrid protocols likely prior to introduction of volume CT.