Imaging 2: Screening for Coronary Artery Disease with CT and MR

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EBT Scan Configuration
Step and shoot modality

50%–70% RR interval
Helical/ Spiral/ Multidetector CT
Helical/ Spiral/ Multidetector CT

Start of spiral scan

Path of continuously rotating x-ray tube and detector

Direction of continuous patient transport

0,0,0 t,s

2–4 slices
8–16 slices
16–32 slices
32–64 slices
64 x 2 slices
256 slices
320 slices
## CT techniques: technical aspects

<table>
<thead>
<tr>
<th>Test</th>
<th>Radiation dose</th>
<th>CT angiography</th>
<th>CTA dose modulation</th>
<th>Lung CT</th>
<th>Abdomen/Pelvis</th>
<th>Body scan</th>
<th>Virtual colon</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stress MIBI</td>
<td>6 mSv</td>
<td>8-13 mSv</td>
<td>1-1.5 mSv</td>
<td>8 mSv</td>
<td>10 mSv</td>
<td>12 mSv</td>
<td>8-14 mSv</td>
</tr>
<tr>
<td>LC spine</td>
<td>1.3 mSv</td>
<td>5-8 mSv</td>
<td>-</td>
<td>1.5 mSv</td>
<td>2 mSv</td>
<td>2.6 mSv</td>
<td>2-3 mSv</td>
</tr>
<tr>
<td>Barium Enema</td>
<td>7 mSv</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dental X-ray</td>
<td>0.7 mSv</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chest X-Ray</td>
<td>0.04 mSv</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cardiac Catheterization</td>
<td>2.5 - 10 mSv</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- An effective dose of 10 mSv maybe associated with an increase in fatal cancer 1/2000
- 50% of a person radiation exposure is due to medical testing

Adapted from Cardiac CT Imaging-Diagnosis of Cardiovascular Disease Springer2006
Cardiac CT has several diagnostic capabilities applicable of many facets of CAD worth the radiation exposures:

1. Non contrast enhanced can identify and quantify **coronary calcification** (marker of total burden)

2. Contrast enhanced studies can **define ventricular volumes, ejection fraction, wall motion defects and wall thickening, coronary lesions**
Types of Vascular Calcification in CKD

**Atherosclerosis**
- Patchy lesions
- Related to lipids
- Older persons
- Elastic and muscular arteries

**Uremic arteriolopathy:**
- Linear lesions
- Disturbances in mineral metabolism
- Young and old persons
- CKD, DM
- Muscular arteries

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**Atherosclerosis**
- Atherosclerotic atherosclerotic plaque
- Arterial stenotic lesion
- Ischaemia

**Atheriosclerosis**
- Modification of arterial wall properties
  - Arterial stiffness (↑ PWV; ↑PP)
  - Afterload • LVH
  - Coronary perfusion • Angor
The Agatston Score

Calcified plaque area = A; density = D

- Density = 130–200; coefficient 1
- Density = 201–300; coefficient 2
- Density = 301–400; coefficient 3
- Density >401; coefficient 4

Agatston score = A \times D_{\text{coef}}

Reported variability: 10–40%
Calcium Volume Score

DA \times (1-d) + (DB \times d)

DA, density in A
DB, density in B

• 130 HU included (orange)
• 130 HU excluded (red)

Reported variability: 8–10%

Callister TQ et al. Radiology 1998;208:807–14
Variability of Agatston and Volume Score on Electron Beam Tomography in CARE-2 Trial

Performance of a diagnostic test

Degree of ‘positivity’ on test
### Performance of a diagnostic test

#### Table: Performance of a diagnostic test

<table>
<thead>
<tr>
<th>Disease</th>
<th>Present</th>
<th>Absent</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>(true positive)</td>
<td>B (false positive)</td>
</tr>
<tr>
<td>C</td>
<td>(false negative)</td>
<td>D (true negative)</td>
</tr>
</tbody>
</table>

#### Diagram:

- **FALSE NEGATIVES**
- **FALSE POSITIVES**
- **NON-CASES**
- **CASES**

#### Healthy artery

- Risk factors assessment

#### Disease

- Stenosis
- Non stenotic lesion
- Vascular calcification

#### Testing methods:

- Angiography
- Other risk factor assessment
Cardiac CT
Coronary Artery Calcium Scoring

Adapted from Cardiac CT Imaging-Diagnosis of Cardiovascular Disease Springer 2006
Studies examining the relationship between CACS and acute coronary syndrome in the ED setting

<table>
<thead>
<tr>
<th>Study</th>
<th>Year</th>
<th>N</th>
<th>CAC=0 (%)</th>
<th>Sn (%)</th>
<th>Sp (%)</th>
<th>PPV (%)</th>
<th>NPV (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Laudon et al.</td>
<td>1999</td>
<td>105</td>
<td>59 (59)</td>
<td>100</td>
<td>63</td>
<td>30</td>
<td>100</td>
</tr>
<tr>
<td>McLaughlin et al</td>
<td>1999</td>
<td>134</td>
<td>48 (36)</td>
<td>100</td>
<td>38</td>
<td>8</td>
<td>100</td>
</tr>
<tr>
<td>Georgiu et al</td>
<td>2001</td>
<td>192</td>
<td>76 (40)</td>
<td>97</td>
<td>55</td>
<td>48</td>
<td>97</td>
</tr>
<tr>
<td>Hoffman et al</td>
<td>2009</td>
<td>368</td>
<td>197 (54)</td>
<td>97</td>
<td>59</td>
<td>18</td>
<td>99.5</td>
</tr>
<tr>
<td>Nabi et al</td>
<td>2010</td>
<td>103</td>
<td>625 (61)</td>
<td>93.8</td>
<td>62.4</td>
<td>7.4</td>
<td>99.7</td>
</tr>
</tbody>
</table>
Relationship between CACS results and the incidence of abnormal SPECT.

![Diagram showing the relationship between CACS results and abnormal SPECT incidence.](image)
Coronary Calcium as a Predictor of Coronary Events in Four Racial or Ethnic Groups

Major coronary events (myocardial infarction and death from coronary heart disease). The differences among all curves are statistically significant (P<0.001)
Comparison of Prognostic Usefulness of Coronary Arterial Calcium in Men versus Women (Results from a Meta- and Pooled Analysis Estimating All-Cause Mortality and Coronary Heart Disease Death or Myocardial Infarction)

Bellasi et al, Am J Cardiol 2007
Risk-Adjusted Survival (All-Cause Mortality) by Calcium Score Subsets

Follow-up (Years)

Cumulative Survival

<10
11–100
101–400
401–1,000
>1,000

Shaw LJ et al. Radiology 2003;228:826–33
Incremental Value of CAC Over Traditional Risk Factors for ALL-Cause Mortality

Shaw LJ et al. Radiology 2003;228:826–33

P<0.001
Cox Survival Analysis of Time to Acute MI for Patients with >15% △ from Baseline Calcium Volume Score

CAC Score prevalence in CKD Patients

Baseline CAC Score is a Predictor of Morbidity and Mortality in CKD Patients

Table 2. Occurrence of cardiovascular events, hospitalization, start of dialysis, and mortality during the 2-year follow-up according to the baseline CAC scores

<table>
<thead>
<tr>
<th>Event</th>
<th>CAC &gt; 10 (n = 56)</th>
<th>CAC ≤ 10 (n = 61)</th>
<th>P</th>
<th>CAC ≥ 400 (n = 25)</th>
<th>CAC &lt; 400 (n = 92)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cardiovascular events [n (%)]</td>
<td>10 (18%)</td>
<td>5 (8%)</td>
<td>0.16</td>
<td>7 (28%)</td>
<td>8 (8%)</td>
<td>0.017</td>
</tr>
<tr>
<td>Hospitalization [n (%)]</td>
<td>14 (25%)</td>
<td>5 (8%)</td>
<td>0.02</td>
<td>10 (40%)</td>
<td>9 (9%)</td>
<td>0.001</td>
</tr>
<tr>
<td>Start of dialysis [n (%)]</td>
<td>11 (19%)</td>
<td>9 (14%)</td>
<td>0.62</td>
<td>5 (20%)</td>
<td>15 (16%)</td>
<td>0.76</td>
</tr>
<tr>
<td>Mortality [n (%)]</td>
<td>4 (7%)</td>
<td>0</td>
<td>0.05</td>
<td>4 (16%)</td>
<td>0</td>
<td>0.002</td>
</tr>
</tbody>
</table>

Baseline CAC Score is a Predictor of All-cause Mortality in CKD Patients

Baseline CAC Score is a Predictor of All-cause Mortality in CKD Patients

<table>
<thead>
<tr>
<th>Baseline CAC</th>
<th>Alive</th>
<th>dead</th>
<th>Event rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;400</td>
<td>92</td>
<td>0</td>
<td>-</td>
</tr>
<tr>
<td>&gt;400</td>
<td>21</td>
<td>4</td>
<td>16%</td>
</tr>
</tbody>
</table>

Sensitivity = 100% (95%CI 51-100)
Specificity = 81.4% (95%CI 73-87)
PPV = 16.0% (95%CI 6-34)
NPV = 100% (95%CI: 96-100)
Baseline CAC Score is a Predictor of All-Cause Mortality in Dialysis Patients

Is CAC Score a Useful Predictor of Survival Mortality in Dialysis Patients


<table>
<thead>
<tr>
<th>Baseline CAC</th>
<th>Alive</th>
<th>dead</th>
<th>Event rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>2</td>
<td>16</td>
<td>11.1%</td>
</tr>
<tr>
<td>1-100</td>
<td>9</td>
<td>39</td>
<td>18.7%</td>
</tr>
<tr>
<td>101-400</td>
<td>9</td>
<td>19</td>
<td>32.1%</td>
</tr>
<tr>
<td>&gt;400</td>
<td>30</td>
<td>42</td>
<td>41.7%</td>
</tr>
</tbody>
</table>

Sensitivity=96.0%(95%CI 86.5-98.9)
Specificity=13.8% (95%CI 8.7-21.2)
PPV=32.4% (95%CI 25.4-40.3)
NPV=88.9% (95%CI 67.2-96.9)
CAC Score: take home messages

• The amount of CAC correlates to the extent of atherosclerosis plaque burden

• CAC is an interesting tool for risk stratification purposes

• Calcification is neither a sign of stability nor a sign of instability of an individual plaque and its presence is not associated with the likelihood of an individual lesion to rupture

• There is a weak correlation between the the amount of CAC and the angiographic severity of luminal stenosis

• The absence of CAC makes the presence of luminal stenosis unlikely however it does not rule out coronary stenosis especially in symptomatic, young individuals
### Performance of a Diagnostic Test

<table>
<thead>
<tr>
<th>Test cut-off</th>
<th>% of Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Negative</td>
<td>DISEASED</td>
</tr>
<tr>
<td>Positive</td>
<td>NON-DISEASED</td>
</tr>
</tbody>
</table>

#### Disease Presence Table

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<tr>
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<td>A</td>
<td>(true positive)</td>
</tr>
<tr>
<td>Negative</td>
<td>C</td>
<td>(false negative)</td>
</tr>
</tbody>
</table>
CT Angiography (CTA)

• Permits the visualization of the coronary artery lumen and detection of coronary artery stenoses

• In contrast to “calcium screening” it allows visualization and, to some extent, quantification and characterization of non-calcified plaque deposits

• It requires excellent image quality without artifacts (high spatial and temporal resolution)

• Image quality is strongly dependent on HR (it is usually required to lower HR <65 bpm)

• Image acquisition is substantially more elaborate than coronary calcium imaging
CT Angiography (CTA)

• IV injection of contrast is required (60-100 mL)

• Patients selection:
  • sinus rhythm
  • ability to breath holding
  • low HR
  • severe obesity
In individuals with low to intermediate risk for coronary artery disease:

- Sensitivity: 95-99%
- Specificity: 64-83%
- Negative predictive value: 97-99%
- Positive predictive value: 64-86% (overestimation of stenoses and image artifacts often results in false positive interpretations)

Budoff et al J Am Coll Cardiol 2008: 52: 1724-1732
Meijboom et al J Am Coll Cardiol 2008:52:2135-2144-1475
CTA performs best in patient group who are not at high likelihood of CAD. In a study of 291 patients with 56% prevalence of coronary artery stenoses as well as 20% of patients with previous MI and 10% with prior revascularization:

- Sensitivity: 95-99% --> 85%
- Specificity: 64-83% --> 90%

However, a very low event rate has been demonstrated in the absence of stenoses by CTA in patients with stable angina or acute chest pain.

Rubbinshtein et al Circulation 2007;115:1762-1768
Meijboom et al J Am Coll Cardiol 2007;50:1469-1475
Aim: evaluate whether the presence of CKD can provide additional prognostic information for CV events in patients undergoing CTA

- 885 patients with suspected CAD underwent CTA. Patients were stratified according to GFR as moderate CKD (<60 ml/min) or no CKD (>60 ml/min).
- Obstructive stenosis if greater/equal than 50%
- Median follow-up: 896+353 days
- Outcome of interest: non-fatal MI, cerebrovascular accident and all-cause of mortality

Submitted to the Nuclear Cardiology Meeting, Spring 2011
CT angiography (CTA)? What is its role in CKD?

Results:

• Obstructive CAD is more common in moderate CKD (47% vs 32%; p<0.01)

• Higher annualized CV event rate is two fold higher in CKD patients (1.2% vs 2.5%)

• Multivariate models demonstrated that both moderate CKD (HR 2.39, 95%CI 1.08-5.26, p=0.03) and obstructive CAD (HR 2.75, 95%CI 1.38-5.49, p<0.001) were independent predictors of CV events after adjustment for age, gender, CV risk factors
Conclusion:

• Higher incidence of obstructive CAD by CTA in CKD patients

• Moderate CKD is associated with CV events and provided additional prognostic information over age, gender, CV risk factors and the presence of obstructive CAD on CTA
CT Angiography (CTA): Assessment of Coronary Atherosclerotic Plaque

**Non-calcified plaques** can be identified with CTA:

- Compared to IVUS sensitivity and specificity between 80-90%
- Limited agreement between techniques
- Inter-observer variability 30% for plaque quantification
  - Left descending coronary artery 17±10%
  - Circumflex 29±13%
  - Right coronary artery 32±10%

Pflederer et al Rafa 2007; 179:953-957
CT Angiography (CTA): Assessment of Coronary Atherosclerotic Plaque

Prognostic implication of Non-Obstructive Plaque:

• Ostrom et al. Reported the presence of non-obstructive plaque in all 3 coronaries was associated with increased risk of death (Relative Risk 1.77)

• Min et al. Demonstrated that the presence of coronary atherosclerotic plaque in at least 5 coronary artery segments was associated with increased mortality

Ostrom et al J Am Coll Cardiol 2008; 52:1335-1343
Min et al J Am Coll Cardiol 2007; 50:1161-11170
CT Angiography (CTA): Assessment of Coronary Atherosclerotic Plaque

Prognostic implication of specific plaque parameters

N=1059

Positive remodelling
Low computed tomography attenuation

Motoyama et al J Am Coll Cardiol 2009; 54:49-57
CT Angiography (CTA): Take Home Messages

• Substantial inter-observer variability

• Requires high quality images

• Substantially higher radiation dose compared to calcium screening (12 mSv)

• Requires injection of contrast

• Prognostic implication of specific plaque parameters(?)

Clinical use of coronary CTA to detect plaque in asymptomatic individuals should be discouraged
Cardiovascular Magnetic Resonance Imaging

Wall motion

Gadolinium enhanced scan.
Perfusion deficit

Cardiomyopathy

Cardiac CT Imaging-Diagnosis of Cardiovascular Disease Springer 2006
Cardiovascular Magnetic Resonance Imaging

• Useful for proximal coronary artery disease
• Useful for assessing the patency and stenoses of coronary artery bypass grafts
• It allows for plaque characterization

Issues:
• Cardiac, coronary and respiratory motion
• Assessment of small caliber vessels

• Lack of data in CKD patients
Thanks for your attention