MYOCARDIAL PERFUSION COMPUTED TOMOGRAPHY
PhD course in Medical Imaging

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CORONARY CT ANGIOGRAPHY (CTA)

- Accurate method in the assessment of possible cardiac symptoms
  - caused by coronary stenosis
- Non-invasive
- High sensitivity and negative predictive value
### SYSTEMATIC REVIEWS 2007-2012

**CTA DETECTION OF SIGNIFICANT CORONARY STENOSIS**

<table>
<thead>
<tr>
<th></th>
<th>Abdulla 2007 64-MDCT</th>
<th>Stein 2008 64-MDCT</th>
<th>Sun 2008 64-MDCT</th>
<th>Peach 2011 ≥ 64-MDCT</th>
<th>Pontone 2012 ≥ 4-MDCT</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensitivity %</td>
<td>98</td>
<td>98</td>
<td>97</td>
<td>98</td>
<td>90</td>
<td>90-98</td>
</tr>
<tr>
<td>Specificity %</td>
<td>91</td>
<td>88</td>
<td>88</td>
<td>82</td>
<td>96</td>
<td>82-96</td>
</tr>
<tr>
<td>PPV %</td>
<td>93</td>
<td>93</td>
<td>94</td>
<td>91</td>
<td>9</td>
<td>69-94</td>
</tr>
<tr>
<td>NPV %</td>
<td>97</td>
<td>96</td>
<td>95</td>
<td>99</td>
<td>99</td>
<td>95-99</td>
</tr>
</tbody>
</table>

• CCTA effectively identify significant CAD (high sensitivity)
• Best at excluding significant coronary artery stenosis (high NPV).
CORONARY CT ANGIOGRAPHY (CTA) CHALLENGES

- Irregular heart rate
- Rapid heart rate
- Calcified plaques
- Coronary stents
- Body weight
- Radiation dose
CORONARY CT ANGIOGRAPHY (CTA) CHALLENGES

- Stenosis evaluation
  A. Grading
  B. Hemodynamic information
CORONARY CT ANGIOGRAPHY (CTA) CHALLENGES

- Stenosis evaluation
  A. Grading
CORONARY CT ANGIOGRAPHY (CTA) CHALLENGES

- Stenosis evaluation
  A. Grading
    - Calcifications;
      especially heavy calcification in a small area
    - The specificity of CTA decreases with increasing CACS, while the sensitivity remains high independent of that.

CORONARY CT ANGIOGRAPHY (CTA) CHALLENGES

• Stenosis evaluation
  B. Hemodynamic information

Only anatomical information. No hemodynamic information of the lesion or of its ability of inducing ischemia
→ Additional testing
  – Stress echocardiography
  – Nuclear myocardial perfusion tests
  – MR myocardial perfusion imaging
  – Fractional flow reserve
MYOCARDIAL CT PERFUSION (CTP)

- Detection of myocardial ischemia
- Combined with coronary anatomical information
  - Feasibility established
  - Validation needed
  - Investigational research tool

→ Improve diagnostic accuracy of CCTA

W/L 300/150
MYOCARDIAL CT PERFUSION (CTP) 
FARMACHOLOGICAL STRESSING

• Vasodilatation and hyperemia in a normal myocardium.
• Relative hypoperfusion in a pathological myocardium.
MYOCARDIAL CT PERFUSION (CTP) FARMACHOLOGICAL STRESSING

- Vasodilatation and hyperemia in a normal myocardium.
- Relative hypoperfusion in a pathological myocardium.
MYOCARDIAL CT PERFUSION (CTP) 
FARMACHOLOGICAL STRESSING

• Adenosine T½ < 10 s  
  (Dipuridamole T ½ h or Regadenoson T½ min)
• Total infusion time 5-6 min
• Moderate increase in heart frequency (mean increase of 20 bpm)  
  Dobutamine/adrenergic substances are not used.
• Adverse effects:
  – Dyspnea  - Tachycardia
  – Chest pain - AV-block
  – Flushing - Hypotension
  - Bronkospasme
MYOCARDIAL CT PERFUSION (CTP) CT SCAN PROTOCOL

CACS  CCTA/Rest CTP  4 min  Stress CTP

Contrast media  Adenosin  Contrast media
MYOCARDIAL CT PERFUSION (CTP) IMAGE INTERPRETATION

• QUALITATIVE
  – Visual detection of hypo-perfused areas of the myocardium (darker areas)

• SEMI-QUANTITATIVE
  1. Attenuations density (AD)
  2. Perfusion index (PI)
  3. Transmural perfusion ratio (TPR) (Polar maps)

• QUANTITATIVE
  – Absolute myocardial blood flow (ml/min/g)
MYOCARDIAL CT PERFUSION (CTP) QUALITATIVE INTERPRETATION

A. **Inducible ischemia:** hypoattenuated defects seen only at stress with normal rest perfusion.

B. **Infarct** with hypoattenuation at rest, with some recovery of hypoattenuation during stress secondary to relative hyperenhancement of scar.

C. **Infarct** with hypoattenuation at rest and almost complete normalization of hypoattenuation in area of infarct because of enhancement of scar.

D. **Infarct** with hypoattenuation at rest that hyperenhances with stress perfusion imaging.

E. **Peri-infarct ischemia:** hypoattenuation at rest that partially or fully recovers with stress, associated with inducible ischemia at the periphery of the infarct.

*Mehra, JCC 2011*
MYOCARDIAL CT PERFUSION (CTP)
SEMI-QUANTITATIV INTERPRETATION

1. ATTENUATION DENSITY

Attenuation Density = Mean Myocardial HU – Baseline HU
MYOCARDIAL CT PERFUSION (CTP) SEMI-QUANTITATIV INTERPRETATION

2. PERFUSION INDEX

Perfusion Index is calculated for each segment:

\[
\text{Perfusion Index} = \frac{\text{Mean Myocardial AD}}{\text{Mean LV AD}}
\]

Myocardium

LV Blood Pool

Courtesy Toshiba
MYOCARDIAL CT PERFUSION (CTP)
SEMI-QUANTITATIV INTERPRETATION

3. TRANSMURAL PERFUSION RATIO

- In areas with obstructive coronary artery disease the subendocardium is affected first.

- Abnormal TPR < 0.99 *

MYOCARDIAL CT PERFUSION (CTP) CORRELATION BETWEEN CTA AND CTP

Diagram showing segments of the heart with labels for LAD, LCX, RCA, anterior wall, septal wall, lateral wall, and inferior wall.
MYOCARDIAL CT PERFUSION (CTP) LIMITATIONS

• Main limitations
  
  – Artifacts
    ▪ Motion and beam hardening
  
  – Radiation exposure
    ▪ Equivalent to rest/stress SPECT-MPI
  
  – Contrast load

• Ko, Journal of Cardiovascular Computed Tomography (2011) 5, 345–356
MYOCARDIAL CT PERFUSION (CTP) ARTIFACTS

1. Motion artifacts

2. Beam hardening artifacts

3. Reconstruction artifacts (cone-beam artifacts)

4. Misalignment artifacts

64/128 MDCT: When the heart is scanned through multiple heart beats – heart positions and/or contrast attenuation might differ due to time delay.
MYOCARDIAL CT PERFUSION (CTP) PERFORMANCE

  - Prospective, multicenter, multinational study
  - Designed to assess the diagnostic performance of combined 320-row CTA and myocardial CT perfusion imaging (CTP) in comparison with the combination of invasive coronary angiography and singlephoton emission computed tomography myocardial perfusion imaging (SPECT-MPI).

- CTA alone was a limited predictor of myocardial ischemia compared with SPECT, with a sensitivity, specificity, positive (PPV) and negative predictive value (NPV) of 56%, 75%, 56%, and 75%

- CTP was a better predictor of myocardial ischemia, with a sensitivity, specificity, PPV, and NPV of 72%, 91%, 81%, and 85%

- CTP was an excellent predictor of myocardial ischemia on SPECT-MPI in the presence of stenosis (50% on CTA), with a sensitivity, specificity, PPV, and NPV of 100%, 81%, 50%, and 100%

- The radiation dose for the comprehensive cardiac CT protocol and SPECT were 13.8 ± 2.9 and 13.1 ± 1.7; respectively (P=0.15)
A 63-year old lady with hypertension presented for evaluation of atypical chest pain since several months

- ECG revealed T wave inversions in the anteroseptal leads
- Bicycle exercise stress testing was inconclusive
- The patient refused invasive evaluation – non-invasive CT was ordered
CT PROTOCOL

CACS
- 120 kV
- 150 mA
- 75% R-R

CCTA/Rest CTP
- 100 kV
- 140 mA
- 70-80% R-R
- Scan length 12 cm

Stress CTP
- 100 kV
- 140 mA
- 75-95% R-R
- Scan length 10 cm

Scan length 10 cm

Patient BMI 20 kg/m²
Heart rate rest 52 bpm/stress 62 bpm

Adenosin
Iomeron 350

Scan length 12 cm
### CORONARY CALCIUM SCORE

<table>
<thead>
<tr>
<th>Region</th>
<th>Calcium Score (Agatston)</th>
<th>Volume (mm$^3$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>LM</td>
<td>24</td>
<td>18</td>
</tr>
<tr>
<td>RCA</td>
<td>119</td>
<td>106</td>
</tr>
<tr>
<td>LAD</td>
<td>14</td>
<td>10</td>
</tr>
<tr>
<td>CX</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>PDA</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Other1</td>
<td>---</td>
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</tr>
<tr>
<td>Other2</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Other3</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Total</td>
<td>157</td>
<td>134</td>
</tr>
</tbody>
</table>

**Total Calcium Score 157**

![Graph showing coronary calcium scores in asymptomatic women (Hoff 2001)](image-url)
CORONARY CT ANGIOGRAPHY

- Right dominant system
- Atherosclerosis, but no significant stenosis
- A small left descending artery (LAD)
CORONARY CT ANGIOGRAPHY

Left descending artery
CORONARY CT PERFUSION

- Rest and stress perfusion both demonstrate a fixed apical defect
- No residual ischemia
INVASIVE CORONARY ANGIOGRAPHY

• Confirmed absence of significant disease eligible for revascularization

A Right coronary artery

B Left coronary artery
### RADIATION DOSE

<table>
<thead>
<tr>
<th>Imaging sequence</th>
<th>Dose Length Product</th>
<th>Effective radiation dose</th>
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</thead>
<tbody>
<tr>
<td>CACS</td>
<td>61.4 mGy.cm</td>
<td>0.86 mSv</td>
</tr>
<tr>
<td>Planning and bolus-tracking</td>
<td>11.2 mGy.cm</td>
<td>0.15 mSv</td>
</tr>
<tr>
<td>sequences</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CTCA</td>
<td>34.3 mGy.cm</td>
<td>0.48 mSv</td>
</tr>
<tr>
<td>Stress CTP</td>
<td>26.2 mGy.cm</td>
<td>0.37 mSv</td>
</tr>
</tbody>
</table>

Effective radiation dose was calculated using the conversion factor $k = 0.014 \text{ mSv.mGy}^{-1}.\text{cm}^{-1}$.

$1.00 \text{ mSv}$
MYOCARDIAL CT PERFUSION (CTP) SUMMARY

- A combined anatomical and functional assessment in patient suspected coronary artery disease.

- Increased diagnostic accuracy of Cardiac CT for the identification of significant coronary artery disease.

- Assessment of functional importance of borderline coronary stenosis.