Imaging ischemic heart disease: Role of CCTA

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Overview

- Definitions
- Exclusion/Detection CAD
- Perfusion
- Triple Rule Out
Overview

• Definitions

• Exclusion/Detection CAD

• Perfusion

• Triple Rule Out
**Framingham Risk-Score**

- **Age**
- **Total cholesterol**
- **HDL**
- **Blood pressure**
- **Diabetes**
- **Smoking**

**Definitions**

**Framingham Risk-Score**

- **Age**
- **Total cholesterol**
- **HDL**
- **Blood pressure**
- **Diabetes**
- **Smoking**

**Step 1**

<table>
<thead>
<tr>
<th>Years</th>
<th>LDL Pts</th>
<th>Chol Pts</th>
</tr>
</thead>
<tbody>
<tr>
<td>30-34</td>
<td>-1</td>
<td>[1]</td>
</tr>
<tr>
<td>35-39</td>
<td>0</td>
<td>[0]</td>
</tr>
<tr>
<td>40-44</td>
<td>1</td>
<td>[1]</td>
</tr>
<tr>
<td>45-49</td>
<td>2</td>
<td>[2]</td>
</tr>
<tr>
<td>50-54</td>
<td>3</td>
<td>[3]</td>
</tr>
<tr>
<td>55-59</td>
<td>4</td>
<td>[4]</td>
</tr>
<tr>
<td>60-64</td>
<td>5</td>
<td>[5]</td>
</tr>
<tr>
<td>65-69</td>
<td>6</td>
<td>[6]</td>
</tr>
<tr>
<td>70-74</td>
<td>7</td>
<td>[7]</td>
</tr>
</tbody>
</table>

**Step 2**

<table>
<thead>
<tr>
<th>LDL - C (mg/dL)</th>
<th>LDL Pts</th>
<th>Chol Pts</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;100</td>
<td>-2.59</td>
<td>3</td>
</tr>
<tr>
<td>100-129</td>
<td>2.60-3.36</td>
<td>0</td>
</tr>
<tr>
<td>130-159</td>
<td>3.37-4.14</td>
<td>0</td>
</tr>
<tr>
<td>160-166</td>
<td>4.15-4.92</td>
<td>1</td>
</tr>
<tr>
<td>&gt;160</td>
<td>&gt;5.77</td>
<td>2</td>
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</table>

**Step 3**

<table>
<thead>
<tr>
<th>HDL - C (mg/dL)</th>
<th>HDL Pts</th>
<th>Chol Pts</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;35</td>
<td>&lt;0.90</td>
<td>2</td>
</tr>
<tr>
<td>35-44</td>
<td>0.91-1.16</td>
<td>1</td>
</tr>
<tr>
<td>45-49</td>
<td>1.17-1.29</td>
<td>0</td>
</tr>
<tr>
<td>50-59</td>
<td>1.30-1.55</td>
<td>0</td>
</tr>
<tr>
<td>&gt;50</td>
<td>&gt;1.56</td>
<td>1</td>
</tr>
</tbody>
</table>

**Step 4**

<table>
<thead>
<tr>
<th>Blood Pressure (systolic, mmHg)</th>
<th>Systolic (mmHg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;120</td>
<td>0 [0] pts</td>
</tr>
<tr>
<td>120-129</td>
<td>0 [0] pts</td>
</tr>
<tr>
<td>130-139</td>
<td>1 [1] pts</td>
</tr>
<tr>
<td>140-159</td>
<td>2 [2] pts</td>
</tr>
<tr>
<td>&gt;160</td>
<td>3 [3] pts</td>
</tr>
</tbody>
</table>

**Step 5**

<table>
<thead>
<tr>
<th>Diabetes</th>
<th>LDL Pts</th>
<th>Chol Pts</th>
</tr>
</thead>
<tbody>
<tr>
<td>No</td>
<td>0</td>
<td>[0]</td>
</tr>
<tr>
<td>Yes</td>
<td>2</td>
<td>[2]</td>
</tr>
</tbody>
</table>

**Step 6**

<table>
<thead>
<tr>
<th>Smoker</th>
<th>LDL Pts</th>
<th>Chol Pts</th>
</tr>
</thead>
<tbody>
<tr>
<td>No</td>
<td>0</td>
<td>[0]</td>
</tr>
<tr>
<td>Yes</td>
<td>2</td>
<td>[2]</td>
</tr>
</tbody>
</table>

**Step 7**

<table>
<thead>
<tr>
<th>Adding up the points</th>
<th>LDL Pts</th>
<th>Chol Pts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LDL-C or Chol</td>
<td></td>
<td></td>
</tr>
<tr>
<td>HDL - C</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Blood Pressure</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diabetes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Smoker</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Point total</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Step 8**

<table>
<thead>
<tr>
<th>LDL Pts</th>
<th>CHD Risk</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;3</td>
<td>1%</td>
</tr>
<tr>
<td>-2</td>
<td>2%</td>
</tr>
<tr>
<td>-1</td>
<td>[&lt;=1%]</td>
</tr>
<tr>
<td>0</td>
<td>[0%]</td>
</tr>
<tr>
<td>1</td>
<td>[1%]</td>
</tr>
<tr>
<td>2</td>
<td>[2%]</td>
</tr>
<tr>
<td>3</td>
<td>[3%]</td>
</tr>
<tr>
<td>4</td>
<td>[4%]</td>
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<tr>
<td>5</td>
<td>[5%]</td>
</tr>
<tr>
<td>6</td>
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<td>7</td>
<td>[7%]</td>
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<td>8</td>
<td>[8%]</td>
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<tr>
<td>9</td>
<td>[9%]</td>
</tr>
<tr>
<td>10</td>
<td>[10%]</td>
</tr>
<tr>
<td>11</td>
<td>[11%]</td>
</tr>
<tr>
<td>12</td>
<td>[12%]</td>
</tr>
<tr>
<td>13</td>
<td>[13%]</td>
</tr>
<tr>
<td>&gt;14</td>
<td>[14%]</td>
</tr>
<tr>
<td>&gt;15</td>
<td>[15%]</td>
</tr>
</tbody>
</table>

**Step 9**

**Comparative Risk**

<table>
<thead>
<tr>
<th>Age (years)</th>
<th>10 Yr CHD</th>
<th>10 Yr CHD</th>
<th>Low*</th>
</tr>
</thead>
<tbody>
<tr>
<td>30-34</td>
<td>3%</td>
<td>1%</td>
<td>2%</td>
</tr>
<tr>
<td>35-39</td>
<td>5%</td>
<td>4%</td>
<td>3%</td>
</tr>
<tr>
<td>40-44</td>
<td>7%</td>
<td>4%</td>
<td>4%</td>
</tr>
<tr>
<td>45-49</td>
<td>11%</td>
<td>8%</td>
<td>4%</td>
</tr>
<tr>
<td>50-54</td>
<td>14%</td>
<td>10%</td>
<td>6%</td>
</tr>
<tr>
<td>55-59</td>
<td>15%</td>
<td>13%</td>
<td>7%</td>
</tr>
<tr>
<td>60-64</td>
<td>21%</td>
<td>20%</td>
<td>9%</td>
</tr>
<tr>
<td>65-69</td>
<td>25%</td>
<td>22%</td>
<td>11%</td>
</tr>
<tr>
<td>70-74</td>
<td>30%</td>
<td>28%</td>
<td>14%</td>
</tr>
</tbody>
</table>

* Hard CHD events exclude angina pectoris

**Low risk was calculated for a person the same age, optimal blood pressure, LDL-C 100-129 mg/dL, or cholesterol 160-199 mg/dL, HDL-C 45 mg/dL, for men or 55 mg/dL, for women, non-smoker, no diabetes

CHD risk – low (<10%)

- Age-specific risk below average
- Absolute risk of CHD event in the next 10 years <10%

CHD risk – intermediate (10-20%)

- Average risk or higher
- 10-year risk 10-20%

CHD risk – high (>20%)

- Diabetes in a patient > 40a; PAOD or another coronary risk
- Absolute 10-year risk > 20%
## Pre-Test Probability

Table 4. Pretest Probability of Coronary Artery Disease by Age, Gender, and Symptoms*

<table>
<thead>
<tr>
<th>Age (y)</th>
<th>Gender</th>
<th>Typical/Definite Angina Pectoris</th>
<th>Atypical/Probable Angina Pectoris</th>
<th>Nonanginal Chest Pain</th>
<th>Asymptomatic</th>
</tr>
</thead>
<tbody>
<tr>
<td>30–39</td>
<td>Men</td>
<td>Intermediate</td>
<td>Intermediate</td>
<td>Low</td>
<td>Very low</td>
</tr>
<tr>
<td></td>
<td>Women</td>
<td>Intermediate</td>
<td>Very low</td>
<td>Low</td>
<td>Very low</td>
</tr>
<tr>
<td>40–49</td>
<td>Men</td>
<td>High</td>
<td>Intermediate</td>
<td>Intermediate</td>
<td>Low</td>
</tr>
<tr>
<td></td>
<td>Women</td>
<td>Intermediate</td>
<td>Low</td>
<td>Very low</td>
<td>Very low</td>
</tr>
<tr>
<td>50–59</td>
<td>Men</td>
<td>High</td>
<td>Intermediate</td>
<td>Intermediate</td>
<td>Low</td>
</tr>
<tr>
<td></td>
<td>Women</td>
<td>Intermediate</td>
<td>Low</td>
<td>Very low</td>
<td>Very low</td>
</tr>
<tr>
<td>60–69</td>
<td>Men</td>
<td>High</td>
<td>Intermediate</td>
<td>Intermediate</td>
<td>Low</td>
</tr>
<tr>
<td></td>
<td>Women</td>
<td>High</td>
<td>Intermediate</td>
<td>Intermediate</td>
<td>Low</td>
</tr>
</tbody>
</table>

*No data exist for patients <30 or >69 years, but it can be assumed that prevalence of CAD increases with age. In a few cases, patients with ages at the extremes of the decades listed may have probabilities slightly outside the high or low range. High indicates >90%; intermediate, 10%–90%; low, <10%; and very low, <5%.
Pre-Test Probability of Coronary Artery Disease

- Very Low - < 5% probability of CAD
- Low - < 10% probability of CAD
- Intermediate – 10 – 90% probability of CAD
- High - > 90% probability of CAD
ACCF/SCCT/ACR/AHA/ASE/ASNC/SCAI/SCMR 2010 Appropriate Use Criteria for Cardiac Computed Tomography. A Report of the American College of Cardiology Foundation Appropriate Use Criteria Task Force, the Society of Cardiovascular Computed Tomography, the American College of Radiology, the American Heart Association, the American Society of Echocardiography, the American Society of Nuclear Cardiology, the Society for Cardiovascular Angiography and Interventions, and the Society for Cardiovascular Magnetic Resonance

CARDIAC COMPUTED TOMOGRAPHY WRITING GROUP, Allen J. Taylor, Manuel Cerqueira, John McB. Hodgson, Daniel Mark, James Min, Patrick O'Gara and Geoffrey D. Rubin

Circulation published online Oct 25, 2010;
DOI: 10.1161/CIR.0b013e3181fcae66
Circulation is published by the American Heart Association. 7272 Greenville Avenue, Dallas, TX 75231
Copyright © 2010 American Heart Association. All rights reserved. Print ISSN: 0009-7322. Online ISSN: 1524-4539

Taylor AJ et al, Appropriate use of cardiac CT. J Am Coll Cardiol. 2010 Nov 23;56(22):1864-94
Score 7 to 9
**Appropriate** test for specific indication (test *is* generally acceptable and *is* a reasonable approach for the indication).

Score 4 to 6
**Uncertain** for specific indication (test *may* be generally acceptable and *may* be a reasonable approach for the indication). (Uncertainty also implies that more research and/or patient information is needed to classify the indication definitively.)

Score 1 to 3
**Inappropriate** test for specific indication (test *is not* generally acceptable and *is not* a reasonable approach for the indication).
### Table 1. Detection of CAD in Symptomatic Patients Without Known Heart Disease*

<table>
<thead>
<tr>
<th>Indication</th>
<th>Appropriate Use Score (1–9)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Nonacute Symptoms Possibly Representing an Ischemic Equivalent</strong></td>
<td></td>
</tr>
<tr>
<td>Pretest Probability of CAD</td>
<td>Low</td>
</tr>
<tr>
<td>1. ECG interpretable AND Able to exercise</td>
<td>U (5)</td>
</tr>
<tr>
<td>2. ECG uninterpretable OR Unable to exercise</td>
<td>A (7)</td>
</tr>
<tr>
<td><strong>Acute Symptoms With Suspicion of ACS (Urgent Presentation)</strong></td>
<td></td>
</tr>
<tr>
<td>3. Definite MI</td>
<td>I (1)</td>
</tr>
<tr>
<td>4. Persistent ECG ST-segment elevation following exclusion of MI</td>
<td>U (6)</td>
</tr>
<tr>
<td>5. Acute chest pain of uncertain cause (differential diagnosis includes pulmonary embolism, aortic dissection, and ACS [“triple rule out”])</td>
<td>U (6)</td>
</tr>
<tr>
<td><strong>Pretest Probability of CAD</strong></td>
<td>Low</td>
</tr>
<tr>
<td>6. Normal ECG and cardiac biomarkers</td>
<td>A (7)</td>
</tr>
<tr>
<td>7. ECG uninterpretable</td>
<td>A (7)</td>
</tr>
<tr>
<td>8. Nondiagnostic ECG OR Equivocal cardiac biomarkers</td>
<td>A (7)</td>
</tr>
</tbody>
</table>

*Note: All indications are for CTA unless otherwise noted. A indicates appropriate; I, inappropriate; and U, uncertain.
Table 2. Detection of CAD/Risk Assessment in Asymptomatic Patients Without Known CAD

<table>
<thead>
<tr>
<th>Indication</th>
<th>Noncontrast CT for CCS</th>
<th>Coronary CTA</th>
<th>Coronary CTA Following Heart Transplantation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Global CHD Risk Estimate</td>
<td>Low</td>
<td>Intermediate</td>
</tr>
<tr>
<td>9. Family history of premature CHD</td>
<td></td>
<td>A (7)</td>
<td></td>
</tr>
<tr>
<td>10. Asymptomatic No known CAD</td>
<td></td>
<td>I (2)</td>
<td>A (7)</td>
</tr>
<tr>
<td></td>
<td>Coronary CTA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11. Asymptomatic No known CAD</td>
<td></td>
<td>I (2)</td>
<td>I (2)</td>
</tr>
<tr>
<td></td>
<td>Coronary CTA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12. Routine evaluation of coronary arteries</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

A indicates appropriate; I, inappropriate; and U, uncertain.
Overview

- Definitions
- Exclusion/Detection CAD
- Perfusion
- Triple Rule Out
Recommended Indications for Coronary CTA

- Patients with atypical chest pain and inconclusive stress-test, if there is a low or low/intermediate risk of CAD.

- Patients with inconclusive stress-test with few or absent symptoms, if there is a low or low/intermediate risk of CAD.

- Patients with chest pain in rest without ECG-signs and enzymes.
CAD – Exclusion

- male patient, 55 y/o
- acute onset of atypical chest pain
- intermediate pre-test probability
- emergency department: regular ECG, negative enzymes
- CT: Exclusion of CAD
Recommended Indications for Coronary CTA

- Patients with chest pain in rest without ECG-signs and enzymes.
CAD – Exclusion

LAD (CPR)  LAD (CPR)
CAD – Exclusion

CX (CPR)  
RCA (CPR)
CAD – Exclusion

RCA (CPR)
CAD – Exclusion

CAD exclusion by CTA
No invasive angiography!!
• male patient, 53 y/o

• intermediate risk of CAD

• inconclusive treadmill test, negative enzymes

• Patient → CTA: Exclusion/Detection of CAD
Recommended Indications for Coronary CTA

- Patients with inconclusive stress-test with few or absent symptoms, if there is a low or low/intermediate risk of CAD.
CAD – Detection

RCA

LAD

LCX

Significant LAD stenosis
CAD – Detection
Detection of CAD → CA → LAD-Stent
## low-dose CTA for exclusion of CAD

<table>
<thead>
<tr>
<th>Author</th>
<th>Year</th>
<th>n</th>
<th>Scanner type</th>
<th>Heart rate (bpm)</th>
<th>Non-assessable segments</th>
<th>Sensitivity (%)</th>
<th>Specificity (%)</th>
<th>PPV (%)</th>
<th>NPV (%)</th>
<th>Radiation dose (mSv)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pontone</td>
<td>2009</td>
<td>80</td>
<td>64-slice</td>
<td>≤ 65</td>
<td>4%</td>
<td>99</td>
<td>86</td>
<td>86</td>
<td>99</td>
<td>5.7 ± 1.5 (3.8)</td>
</tr>
<tr>
<td>Scheffel</td>
<td>2008</td>
<td>120</td>
<td>DS 64</td>
<td>≤ 70</td>
<td>2%</td>
<td>100</td>
<td>96</td>
<td>97</td>
<td>100</td>
<td>2.5 ± 0.8</td>
</tr>
<tr>
<td>Stolzmann</td>
<td>2008</td>
<td>100</td>
<td>DS 64</td>
<td>≤ 70</td>
<td>4%</td>
<td>100</td>
<td>93</td>
<td>95</td>
<td>100</td>
<td>2.6 ± 0.8</td>
</tr>
<tr>
<td>Dewey</td>
<td>2010</td>
<td>30</td>
<td>320-slice</td>
<td>≤ 65</td>
<td>1 patient</td>
<td>100</td>
<td>94</td>
<td>92</td>
<td>100</td>
<td>4.2</td>
</tr>
</tbody>
</table>

**Step-and-Shoot or prospective ECG-gating**

**High-pitch**

Courtesy of Prof. Dr. H. Alkadhi
## Literature

### Multicenter Studies

<table>
<thead>
<tr>
<th>Author</th>
<th>Year</th>
<th>n</th>
<th>Scanner type</th>
<th>Vendor</th>
<th>Sensitivity</th>
<th>Specificity</th>
<th>PPV</th>
<th>NPV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Miller</td>
<td>2008</td>
<td>291</td>
<td>64-slice</td>
<td>Toshiba</td>
<td>85%</td>
<td>90%</td>
<td>91%</td>
<td>83%</td>
</tr>
<tr>
<td>Budoff</td>
<td>2008</td>
<td>230</td>
<td>64-slice</td>
<td>GE</td>
<td>95%</td>
<td>83%</td>
<td>64%</td>
<td>99%</td>
</tr>
<tr>
<td>Meijboom</td>
<td>2008</td>
<td>360</td>
<td>64-slice</td>
<td>Siemens/Phillips/Toshiba</td>
<td>99%</td>
<td>64%</td>
<td>86%</td>
<td>97%</td>
</tr>
</tbody>
</table>

Courtesy of Prof. Dr. H. Alkadhi
Example: ACS exclusion

- male patient, 53 y/o
- acute chest pain
- emergency department: regular ECG, no enzymes
- elevated D-Dimer
- exclusion/detection of CAD → CTA
Presence of coronary artery stenosis does not prove the ACS as reason for the chest pain.
Overview

- Definitions
- Exclusion/Detection CAD
- Perfusion
- Triple Rule Out
56a male
Emergency department, instable AP
6:00
Troponin negative
Regular ECG

Myocardial septal ischemia, occlusion of a septal branch

- 82y/o male patient
- acute chest pain
- heavy calcifications
- suspicion of 70% stenosis RCA
- suspicion of >90% stenosis CX

Complete reversible ischemia

Feuchtnner  Circulation CV Imag 2011
CT-Perfusion

128-DSCT: stress MPI
100 kV / 320 mAs

Adenosine
3 min

CA 1

STRESS
high-pitch CTA (3.4)

CA 2

REST
High-pitch or prosp. if HR>65 bpm

5 min

0.9 mSv + 1.6 mSv

2.5 mSv

Feuchtn er Circulation CV Imag 2011
CT-Perfusion

- 76 patients – chest pain – emergency department
- rest CTA + CT-perfusion compared to SPECT
- Perfusion/patient: Sens 92%, Spez 95%, PPV 80%, NPV 98%
- CTA: accuracy 92%, PPV 67%, NPV 95%
- CT-perfusion + CTA: PPV 67% → 90%
- False positive results are reduced with CTA!

Feuchten GM et al. Heart 2012
CT-Perfusion

• CT-Perfusion
• New tool for Cardiac Imaging
• One Stop Shop –
  • Morphology
  • Function
  • Relevance of a stenosis
  • Viability
• When?
  • Stenosis 40 – 70% → relevance?
  • Heavy calcifications
  • stents

Feuchtner GM et al. Heart 2012
<table>
<thead>
<tr>
<th>ACS – differential diagnosis</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Heart</strong></td>
</tr>
<tr>
<td>Rhythmic changes</td>
</tr>
<tr>
<td>Pericarditis</td>
</tr>
<tr>
<td>Myocarditis</td>
</tr>
<tr>
<td>Aortic dissection</td>
</tr>
<tr>
<td><strong>Lung</strong></td>
</tr>
<tr>
<td>PE</td>
</tr>
<tr>
<td>Pleuritis</td>
</tr>
<tr>
<td>Pneumothorax</td>
</tr>
<tr>
<td><strong>Skeleton</strong></td>
</tr>
<tr>
<td>Rib fracture</td>
</tr>
<tr>
<td>Spine</td>
</tr>
<tr>
<td><strong>GI</strong></td>
</tr>
<tr>
<td>GI-pathologies</td>
</tr>
</tbody>
</table>
Overview

• Definitions
• Exclusion/Detection CAD
• Perfusion
• Triple Rule Out
ACS – algorithm of diagnosis

Initial symptom - pain

Suspicion of ACS

ST-elevation
- enzymes +
  - STEMI

no ST-elevation
- enzymes +
  - NSTEMI
- enzymes -
  - ???

Myocardial infarction
Definitions

Acute Chest Pain

- USA: 2006 6.4 million patients with acute chest pain in the emergency department (all patients 119 millions)
- Main task: to rule out ACS
- 10 Billion $ / a
- 15 – 25 % ACS
- 2% - 8% ACS not detected: mortality 25%
- Non-diagnosed MI – main reason for emergency medicine malpractice proceedings in the USA
- Many admissions to avoid malpractice-problems
triage decision critical

A diagnostic test for rule out or detection of ACS would be extremely helpful

cardiac CTA ??????
Exclusion or detection of

acute coronary syndrome (ACS) or

other reasons for chest pain (pulmonary embolism, dissection, ...)

Sens 100%
Spez 100%
NPV 100%
PPV 100%

Idea of Triple Rule Out
The Perfect Test

- CTA of the coronaries - evaluated and valuable
- CTA of the pulmonary arteries – “goldstandard”
- CTA of the aorta – “goldstandard”
- Triple-Rule-Out protocol ??
CTA in acute chest pain

ACS – no differential diagnosis

- Rule out or detect CAD
- Dedicated CCTA protocol
- Heart rate < 65bpm – Flash
- Heart rate > 65bpm - Sequence

ACS + DD

- TRO-protocol
Examination protocols

Triple Rule Out

CTA pulmonary arteries, CTA aorta und CTA coronaries
Additionally chest-CT, bone-CT, uU abdominal-CT, staging-CT,.....
What we don’t want to have...
Examination protocols

Triple Rule Out - protocol

- DSCT 2x32x0.6
- 120kV/330mAs, 330ms Rot.time, pitch 0.2 – 0.5
- Tube Current Modulation and MinDose
- 110ml CM, 4ml/sec, bolus-triggering A. asc., 30ml NaCl
- Retrospective ECG-triggering
- Reconstruction 10% steps 0-90% (wall motion!)

Schertler T et al., Acad Radiol 2009; 16
Examination protocols

Triple Rule Out - protocol

- 125 patients
- Mean heart rate 72 bpm (42 – 137 bpm)
- Mean scan time: 12.6 s (9.5 – 18.1 s)
- Mean dose: 16.6 mSv (12 – 20 mSv)
- Diagnostic image quality
  - Aorta 100%
  - Pulmonary arteries 99%
  - Coronaries 95%

Schertler T et al., Acad Radiol 2009; 16
Examination protocols

Triple Rule Out - protocol

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Schertler T et al., Acad Radiol 2009; 16
Examination protocols

Triple Rule Out – radiation dose

- DSCT (conventional spiral scan): 16 - 20mSv
- Rest-Stress-Szinti $^{99m}$Tc: bis zu 20mSv
- $^{201}$TI-Scan: bis zu 40mSv
- Conventional angio: 5-10mSv

For routine application radiation dose too high

Bastarrika G et al, AJR 2009; 193
Examination protocols

Flash-technique

- high pitch spiral-technique
- 2 tubes
- pitch up 3.4
- table feed 45cm/sec!
- conventional low pitch spiral – pitch 0.2
### Examination protocols

**Triple Rule Out – protocol**

- 30 patients: Chest CT protocol
- 31 patients: Low pitch spiral protocol
- 31 patients: High pitch spiral protocol („Flash-technique“)

**CM protocol TRO:**
- 120 mL CM, flow rate of 5 mL/s
- saline chaser bolus 100 mL at 5 mL/s
- Test bolus of 15 mL contrast agent, trigger level ascending aorta

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Sommer W et al., Saving Dose in Triple-Rule-Out Computed Tomography Examination Using a High-Pitch Dual Spiral Technique. Invest Radiol 2010 45:64-71
Examination protocols

Triple Rule Out – protocol

Sommer W et al., Saving Dose in Triple-Rule-Out Computed Tomography Examination Using a High-Pitch Dual Spiral Technique. Invest Radiol 45:64-71
Examination protocols

Triple Rule Out – protocol

**TABLE 1.** Comparison of the Patients Who Underwent the High-Pitch Dual Spiral Chest Pain Protocol and the Controls Who Were Previously Scanned With a Conventional Chest Pain Protocol, Using Retrospective Gating Technique

<table>
<thead>
<tr>
<th></th>
<th>Patients</th>
<th>Controls</th>
<th>(P)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (yr)</td>
<td>65 ± 14</td>
<td>63 ± 15</td>
<td>0.72</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>73 ± 13</td>
<td>74 ± 13</td>
<td>0.67</td>
</tr>
<tr>
<td>Heart rate (bpm)</td>
<td>66 ± 17</td>
<td>69 ± 15</td>
<td>0.71</td>
</tr>
<tr>
<td>Scan time (sec)</td>
<td>0.7 ± 0.1</td>
<td>15 ± 3</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Non-diagnostic exams</td>
<td>4</td>
<td>1</td>
<td>0.12</td>
</tr>
<tr>
<td>Non-diagnostic coronary segments</td>
<td>15%</td>
<td>7%</td>
<td>0.11</td>
</tr>
<tr>
<td>Dose (mSv)</td>
<td>4.1 ± 0.8</td>
<td>20.4 ± 5.3</td>
<td>&lt;0.0001</td>
</tr>
</tbody>
</table>

Conclusion: „This protocol can be recommended for patients with unclear chest pain presenting with rhythmic heart rates below 65 bpm“

Sommer W et al., Saving Dose in Triple-Rule-Out Computed Tomography Examination Using a High-Pitch Dual Spiral Technique. Invest Radiol 45:64-71
Examination protocols

Triple Rule Out – radiation dose

- Flash-Scan: 1.2 – 4.4 mSv
- But: low heart rate necessary (<65 bpm)
- Alternative: prospective sequence scan – dose < 10 mSv
- Dose reduction tools from all vendors available or in development

For routine application radiation dose acceptable
Examination protocols

Triple Rule Out – radiation dose

But

- Strict indication!
- Check pre-test probability before each examination
- Check further consequence of the test
- Avoid uncontrolled increase of TRO examinations!
- Negative example: uncontrolled use of pulmonary artery CTA
Flash Aorta TRO

- **collimation:** 128x0.6
- **120kV (CARE kV on!),** 116 ref. mAs, high pitch (Flash) mode
- Scan-direction cranio-caudal, inspiration
- **Pitch:** 3.2
- **Contrast media:** 90ml, flow 5ml/s, 50ml NaCl – 5ml/s
- Bolus Trigger technique: ROI Ao desc., threshold 150HU, delay 15sec
- **reconstruction:** 1/0.8 und 3/2mm
- HF < 65bpm necessary!!
Are there so many patients with acute chest pain and a heart rate < 65bpm?

NO
Sequence Aorta TRO

- **collimation**: 128x0.6
- Sequence technique – step and shot
- 120kV (CARE kV on!), 320 ref. mAs,
- Scan direction cranio-caudal, inspiration, at least 6 steps (4cm/step)
- **Padding**: HR < 65bpm – full dose at 70%, HR > 65bpm – full dose at 40%
- **Contrast media**: 100ml, flow 5ml/s, 50ml NaCl – 5ml/s
- **Bolus Trigger Technik**: ROI Ao. descendens, threshold 150HU, delay 10sec
- **Recon**: 0.6/0.4mm und 3/2mm, coronal and parasagittal Thin MIP 3/2mm
63y/o male patient – road biker

Dyspnoe after 20 minutes of training → ad TRO

- bilateral pulmonary embolism
- severe CAD
- myocardial scar lateral wall

Courtesy of: Prof. Dr. G. Feuchtner
Triple Rule Out

Progressive Clinical Practice

Triple Rule-out Computed Tomographic Angiography for Chest Pain: A Diagnostic Systematic Review and Meta-Analysis

David Ayaram, MD, M. Fernanda Bellolio, MD, MS, M. Hassan Murad, MD, Torrey A. Laack, MD, Annie T. Sadosty, MD, Patricia J. Erwin, MLS, Judd E. Hollander, MD, Victor M. Montori, MD, MSc, Ian G. Stiell, MD, MSc, and Erik P. Hess, MD, MSc

- 11 studies with 3,539 patients (791 TRO and 2748 non-TRO)
- TRO vs. Non-TRO: no difference in image quality
- TRO: diagnostic accuracy for CAD: Sens 94.3%/Spez 97.4%
- TRO-protocol works in detection/exclusion of CAD

Ayaram D et al., Acad Emerg Med 2013;20:861-71
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Yes, but?
Triple Rule Out

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- TRO vs. Non-TRO: no difference in image quality
- TRO: diagnostic accuracy for CAD: Sens 94.3%/Spez 97.4%
- TRO-protocol works in detection/exclusion of CAD
- TRO: higher radiation dose (+4.84mSv) + more cm (+38ml)
- Prevalence PE/aortic dissection: <1%
→ TRO-protocol not recommended/not necessary
Conclusions

✓ Cardiac CT angiography – standard method with low radiation dose

✓ Exclusion of CAD works excellent with almost 100% NPV

✓ Detection of CAD also works excellent – but PPV limited

✓ CT-perfusion adds functional information → stenosis relevant?

✓ Triple Rule Out
  ✓ technically possible with relatively low radiation dose
  ✓ But: not often necessary
Imaging ischemic heart disease: Role of CCTA

Florian Wolf

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