Current applications of Cardiac Imaging: Computed Tomography

Learning objective: Learn the role of cutting edge imaging modalities in CAD patients

Philipp A Kaufmann, MD
Professor and Director of Cardiac Imaging
SPECT/PET/CT/MR
University Hospital Zurich, Switzerland
Disclosures

• Institutional contract with GE Healthcare
Cornerstones for evaluating the clinical role of a procedure

Clinical validity of diagnostic procedures

• Diagnosis
• Prognosis
• Outcome
Cornerstones for evaluating the clinical role of a procedure

Clinical validity of diagnostic procedures

• Diagnosis
• Prognosis
• Outcome
Ischemic cascade

- SPECT MPI
- Ado-Perf CMR
- Dobu-stress CMR
- Stress Echo
- Exercise

Perfusion → Metabolism → Relaxation → Contractility → ST-alterations → Angina pectoris

Duration and intensity of stress
Diagnosis of coronary atherosclerosis

NON INVASIVE

ECG
ECHO
SPECT
PET
Cardiac CT

INVASIVE

Intracoronary Ultrasound
Coronary Angiography

Atherosclerotic vs ischemic CAD (modified from R.Erbel)
Cardiac computed tomography: indications, applications, limitations, and training requirements

Report of a Writing Group deployed by the Working Group Nuclear Cardiology and Cardiac CT of the European Society of Cardiology and the European Council of Nuclear Cardiology

Stephen Schroeder¹*, Stephan Achenbach², Frank Bengel³, Christof Burgstahler¹, Filippo Cademartiri⁴,⁵, Pim de Feyter⁶, Richard George⁷, Philipp Kaufmann⁸, Andreas F. Kopp⁹, Juhani Knuuti¹⁰, Dieter Ropers², Joanne Schuijf¹¹, Laurens F. Tops¹¹, and Jeroen J. Bax¹¹
Table 2  Diagnostic performance of 64-slice computed tomography and dual-source computed tomography for the detection of significant coronary stenosis (luminal diameter >50%) on a per-patient basis

<table>
<thead>
<tr>
<th>Author</th>
<th>Number of patients</th>
<th>Not evaluable (%)</th>
<th>Sensitivity (%)</th>
<th>Specificity (%)</th>
<th>PPV (%)</th>
<th>NPV (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leschka et al.</td>
<td>67</td>
<td>0</td>
<td>100 (47/47)</td>
<td>100 (20/20)</td>
<td>100 (47/47)</td>
<td>100 (20/20)</td>
</tr>
<tr>
<td>Leber et al.</td>
<td>59</td>
<td>23.7 (14/59)</td>
<td>88 (22/25)</td>
<td>85 (17/20)</td>
<td>88 (22/25)</td>
<td>85 (17/20)</td>
</tr>
<tr>
<td>Raff et al.</td>
<td>70</td>
<td>0</td>
<td>95 (38/40)</td>
<td>90 (27/30)</td>
<td>93 (38/41)</td>
<td>93 (27/29)</td>
</tr>
<tr>
<td>Mollet et al.</td>
<td>52</td>
<td>1.9 (1/52)</td>
<td>100 (38/38)</td>
<td>92 (12/13)</td>
<td>97 (38/39)</td>
<td>100 (12/12)</td>
</tr>
<tr>
<td>Ropers et al.</td>
<td>84</td>
<td>3.6 (3/84)</td>
<td>96 (25/26)</td>
<td>91 (50/55)</td>
<td>98 (25/30)</td>
<td>98 (50/51)</td>
</tr>
<tr>
<td>Schuijf et al.</td>
<td>61</td>
<td>1.6 (1/61)</td>
<td>94 (29/31)</td>
<td>97 (28/29)</td>
<td>97(29/30)</td>
<td>93 (27/29)</td>
</tr>
<tr>
<td>Ehsara et al.</td>
<td>69</td>
<td>2.9 (2/69)</td>
<td>98 (59/60)</td>
<td>86 (6/7)</td>
<td>98 (59/60)</td>
<td>86 (6/7)</td>
</tr>
<tr>
<td>Nikolaou et al.</td>
<td>72</td>
<td>5.6 (4/72)</td>
<td>97 (38/39)</td>
<td>79 (23/29)</td>
<td>96 (38/44)</td>
<td>96 (23/24)</td>
</tr>
<tr>
<td>Weustink et al.</td>
<td>77</td>
<td>0</td>
<td>99 (76/77)</td>
<td>87 (20/23)</td>
<td>96 (76/79)</td>
<td>95 (20/21)</td>
</tr>
<tr>
<td>Leber et al.</td>
<td>90</td>
<td>2.2 (2/90)</td>
<td>95 (20/21)</td>
<td>90 (60/67)</td>
<td>94 (20/27)</td>
<td>96 (60/61)</td>
</tr>
<tr>
<td>Total</td>
<td>701</td>
<td>3.8 (27/701)</td>
<td>98 (394/404)</td>
<td>90 (263/293)</td>
<td>93 (794/424)</td>
<td>95 (633/273)</td>
</tr>
</tbody>
</table>

95% CI, 95% confidence interval; NPV, negative predictive value; PPV, positive predictive value.

*Exclusion of patients with stents.
Diagnostic Performance of 64-Multidetector Row Coronary Computed Tomographic Angiography for Evaluation of Coronary Artery Stenosis in Individuals Without Known Coronary Artery Disease

Matthew J. Budoff, MD,* David Dowe, MD,† James G. Jollis, MD,‡ Michael Gitter, MD,§ John Sutherland, MD,‖ Edward Halamiri, MD,¶ Markus Scherer, MD,‖ Rave Rellinger, MD,**

Diagnostic Accuracy of 64-Slice Computed Tomography Coronary Angiography

W. Bob Meijboom, MD,*† Matthijs F. L. Meijjs, MD,§ Joanne D. Schuijf, MD, Maarten J. Cramer, MD, PhD,§ Nico R. Mollet, MD, PhD,† Carlos A. G. van Koen Nieman, MD, PhD,† Jacob M. van Werkhoven, MD,§ Gabija Pundziute, Annick C. Weustink, MD,‡ Alexander M. de Vos, MD,§ Francesca Pugliese, Benno Rensing, MD, PhD,‖ Wouter Jukema, MD, PhD,‡ Jeroen J. Bax, MD, Mathias Prokop, MD, PhD,¶ Pieter A. Doevendans, MD, PhD,§ Myriam G. M. H. Gabriel P. Krestin, MD, PhD,‡ Pan J. de Feyter, MD, PhD†

Diagnostic Performance of 64-Slice Computed Tomography Coronary Angiography by 64-Row CT

Julie M. Miller, M.D., Carlos E. Rochitte, M.D., Marc Dewey, M.D., Armin Arbab-Zadeh, M.D., Hiroyuki Niinuma, M.D., Ph.D., Ilan Gottlieb, M.D., Narinder Paul, M.D., Melvin E. Clouse, M.D., Edward P. Shapiro, M.D., John Hoe, M.D., Albert C. Lardo, Ph.D., David E. Bush, M.D., Albert de Roos, M.D., Christopher Cox, Ph.D., Jeffery Brinker, M.D., and João A.C. Lima, M.D.
### Diagnostic Performance of 64-Multi-Slice Coronary Computed Tomographic Angiography Without Known Coronary Artery Disease

<table>
<thead>
<tr>
<th>Sensitivity</th>
<th>Specificity</th>
<th>PPA</th>
<th>NPA</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Segmental</strong></td>
<td>n = 1807</td>
<td>84%</td>
<td>92%</td>
</tr>
<tr>
<td><strong>Patient</strong></td>
<td>n = 230</td>
<td>94%</td>
<td>83%</td>
</tr>
</tbody>
</table>

### Diagnostic Accuracy of 64-Slice Computed Tomography Coronary Angiography

<table>
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<th>Specificity</th>
<th>PPA</th>
<th>NPA</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Segmental</strong></td>
<td>n = 5297</td>
<td>88%</td>
<td>90%</td>
</tr>
<tr>
<td><strong>Patient</strong></td>
<td>n = 360</td>
<td>94%</td>
<td>83%</td>
</tr>
</tbody>
</table>

### Diagnostic Performance of Coronary Angiography

<table>
<thead>
<tr>
<th>Sensitivity</th>
<th>Specificity</th>
<th>PPA</th>
<th>NPA</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Segmental</strong></td>
<td>n = 866</td>
<td>76%</td>
<td>93%</td>
</tr>
<tr>
<td><strong>Patient</strong></td>
<td>n = 291</td>
<td>85%</td>
<td>90%</td>
</tr>
</tbody>
</table>

**Diagnostic Performance of 64-Multislice Computed Tomographic Angiography Without Known Coronary Artery Disease**

Matthew J. Budoff, MD,* David Dowe, MD,† James G. Jallis, MD,‡ Michael Gitter, MD,§ John Sutherland, MD,‖ Edward Halamek, MD,¶ Markus Scherer, MD,# Rave Bellinger, MD,**

**Sensitivity** | **Specificity** | **PPA** | **NPA**
---|---|---|---
Segmental | n = 1807 | 84% | 92% | 36% | 99%
Patient | n = 230 | 94% | 83% | 48% | 99%

---

**Diagnostic Accuracy of 64-Slice Computed Tomography Coronary Angiography**

W. Bob Meijboom, MD,* Matthijs F. L. Meijs, Maarten J. Cramer, MD, PhD,§ Nico R. Moller, Koen Nieman, MD,|| Annick C. Weusten, Benno Rensing, Mathias Prokop, Gabriel P. Krestin, PD||

**Sensitivity** | **Specificity** | **PPA** | **NPA**
---|---|---|---
Segmental | n = 5297 | 88% | 90% | 47% | 99%
Patient | n = 360 | 94% | 83% | 48% | 99%

---

**Diagnostic Performance of Coronary Angiography**

Julie M. Miller, MD,∗ Armin Arbab-Zadeh, M.D.,†† Narinder Paul, M.D.,* John Hoe, M.D.,† Albert de Roos, M.D.**

**Sensitivity** | **Specificity** | **PPA** | **NPA**
---|---|---|---
Segmental | n = 866 | 76% | 93% | 82% | 89%
Patient | n = 291 | 85% | 90% | 91% | 83%
Diagnostic Performance of 64-Multidetector Coronary Computed Tomographic Angiography

- Segmental: n = 1807
  - Sensitivity: 84%
  - Specificity: 92%
  - PPA: 36%
  - NPA: 99%

- Patient: n = 230
  - Sensitivity: 94%
  - Specificity: 83%
  - PPA: 48%
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Diagnostic Accuracy of 64-Slice Coronary Computed Tomographic Coronary Angiography

- Segmental: n = 5297
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  - Sensitivity: 94%
  - Specificity: 83%
  - PPA: 48%
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Diagnostic Performance of Coronary Angiography

- Segmental: n = 866
  - Sensitivity: 76%
  - Specificity: 93%
  - PPA: 82%
  - NPA: 89%

- Patient: n = 291
  - Sensitivity: 85%
  - Specificity: 90%
  - PPA: 91%
  - NPA: 83%

25% CAD prevalence

68% CAD prevalence

56% CAD prevalence
2013 ESC guidelines on the management of stable coronary artery disease

The Task Force on the management of stable coronary artery disease of the European Society of Cardiology

Task Force Members: Gilles Montalescot* (Chairperson) (France), Udo Sechtem* (Chairperson) (Germany), Stephan Achenbach (Germany), Felicita Andreotti (Italy), Chris Arden (UK), Andrzej Budaj (Poland), Raffaele Bugiardini (Italy), Filippo Crea (Italy), Thomas Cuisset (France), Carlo Di Mario (UK), J. Rafael Ferreira (Portugal), Bernard J. Gersh (USA), Anselm K. Gitt (Germany), Jean-Sebastien Hulot (France), Nikolaus Marx (Germany), Lionel H. Opie (South Africa), Matthias Pfisterer (Switzerland), Eva Prescott (Denmark), Frank Ruschitzka (Switzerland), Manel Sabaté (Spain), Roxy Senior (UK), David Paul Taggart (UK), Ernst E. van der Wall (Netherlands), Christiaan J.M. Vrints (Belgium).
Table 12  Characteristics of tests commonly used to diagnose the presence of coronary artery disease

<table>
<thead>
<tr>
<th>Test</th>
<th>Diagnosis of CAD</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Sensitivity (%)</td>
</tr>
<tr>
<td>Exercise ECG (a, 91, 94, 95)</td>
<td>45–50</td>
</tr>
<tr>
<td>Exercise stress echocardiography(96)</td>
<td>80–85</td>
</tr>
<tr>
<td>Exercise stress SPECT(96, 99)</td>
<td>73–92</td>
</tr>
<tr>
<td>Dobutamine stress echocardiography(96)</td>
<td>79–83</td>
</tr>
<tr>
<td>Dobutamine stress MRI(100)</td>
<td>79–88</td>
</tr>
<tr>
<td>Vasodilator stress echocardiography(96)</td>
<td>72–79</td>
</tr>
<tr>
<td>Vasodilator stress SPECT(96, 99)</td>
<td>90–91</td>
</tr>
<tr>
<td>Vasodilator stress MRI(98, 100-102)</td>
<td>67–94</td>
</tr>
<tr>
<td><strong>Coronary CTA</strong>(c, 103-105)</td>
<td><strong>95–99</strong></td>
</tr>
<tr>
<td>Vasodilator stress PET(97, 99, 106)</td>
<td>81–97</td>
</tr>
</tbody>
</table>

CAD = coronary artery disease; CTA = computed tomography angiography; ECG = electrocardiogram; MRI = magnetic resonance imaging; PET = positron emission tomography; SPECT = single photon emission computed tomography.

\(a\) Results without/with minimal referral bias.

\(b\) Results obtained in populations with medium-to-high prevalence of disease without compensation for referral bias.

\(c\) Results obtained in populations with low-to-medium prevalence of disease.
Causes of poor image quality

- Good: 455/494
- Poor: 14/494
- Moderate: 25/494
- Motion: 7/14
- Calcium: 5/14
- Low contrast-to-noise: 2/14

Causes of false positives + false negatives

- TP+TN: 474/494
- FP+FN: 20/494
- No artifacts: 1/20
- Motion: 2/20
- Calcium: 17/20

Pugliese et al., Eur Radiol 2006; 16: 575-582
Artifacts in Cardiac CT

Motion
Calcification
Mass
Stair Step Artifact
Mechanical
Beam Hardening

Differential attenuation of the CT X-ray energy spectrum.

X-ray beam spectrum becomes skewed toward higher (“hardened“) energy

Artifact from beam hardening increases as density of the structures increases (metal > bone > soft tissue)
Fig. 1  Comparison of 68 different coronary stents. Longitudinal through-plane reformations of 0.6-mm slice thickness reconstructed using a B46f sharp kernel. Numbering of the stents is as in Table 1.
Fig. 1 Comparison of 68 different coronary stents. Longitudinal through-plane reformations of 0.6-mm slice thickness reconstructed using a B46f sharp kernel. Numbering of the stents is as in Table 1.
Artifacts in Cardiac CT

Calcifications are a problem but.....
Long-term prognosis associated with coronary calcification

Study Design

A cohort of 25,253 consecutive, asymptomatic individuals referred by their primary physician for CAC scanning to assess cardiovascular risk

<table>
<thead>
<tr>
<th>CAC Score</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>44%</td>
</tr>
<tr>
<td>1-10</td>
<td>14%</td>
</tr>
<tr>
<td>11-100</td>
<td>20%</td>
</tr>
<tr>
<td>101-400</td>
<td>13%</td>
</tr>
<tr>
<td>401-1000</td>
<td>6%</td>
</tr>
<tr>
<td>&gt;1000</td>
<td>4%</td>
</tr>
</tbody>
</table>

6.8 ± 3 yrs. follow-up

Assessment of all-cause mortality

Budoff et al. JACC 2007; 49: 1860-70
Excellent longterm predictive value of CACS

χ²=1363, p<0.0001 for variable overall and each category subset.
CACS more predictive than Framingham
Prevalence and Severity of Coronary Artery Disease and Adverse Events Among Symptomatic Patients With Coronary Artery Calcification Scores of Zero Undergoing Coronary Computed Tomography Angiography

Results From the CONFIRM (Coronary CT Angiography Evaluation for Clinical Outcomes: An International Multicenter) Registry

Todd C. Villines, MD,* Edward A. Hulten, MD, MPH,* Leslee J. Shaw, PhD,† Manju Goyal, MD,* Allison Dunning, MS,‡ Stephan Achenbach, MD,§ Mouaz Al-Mallah, MD, MSC,¶ Daniel S. Berman, MD,¶ Matthew J. Budoff, MD,# Filippo Cademartiri, MD, PhD,** Tracy Q. Callister, MD,†† Hyuk-Jae Chang, MD, PhD,‡‡ Victor Y. Cheng, MD,¶ Kavitha Chinnaiyan, MD, §§ Benjamin J. W. Chow, MD,¶¶ Augustin Delago, MD,¶¶ Martin Hadamitzky, MD, ## Jörg Hausleiter, MD, ## Philipp Kaufmann, MD, *** Fay Y. Lin, MD, ††† Erica Maffei, MD, ** Gilbert L. Raff, MD, §§ James K. Min, MD, ††† for the CONFIRM Registry Investigators
Figure 1  Coronary Artery Stenosis on CCTA
Figure 5  Major Adverse Events Stratified by CAC Score and Stenosis
Zero scores have a 95%-99% negative predictive power

- Budoff et al (1851 pts) 95%
- Haberl et al (1764 pts) 99%
- Knez et al (2111 pts) 97%
- Rumberger et al (213 pts) 97%

CACS sensitive for obstructive CAD
Zero scores have a 95%-99% negative predictive power

- Budoff et al (1851 pts) 95%
- Haberl et al (1764 pts) 99%
- Knez et al (2111 pts) 97%
- Rumberger et al (213 pts) 97%

BUT: NPV only 84% in younger patient populations
2013 ESC guidelines on the management of stable coronary artery disease

The Task Force on the management of stable coronary artery disease of the European Society of Cardiology

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Figure 2. For diagnosing coronary artery disease, it appears that computed tomography (CT) will be most useful in patients with a lower pretest likelihood of disease and myocardial perfusion imaging (MPI) most useful in patients with a higher pretest likelihood of disease. Adapted with permission from Tracy Callister, MD. CT Angiography for the Cardiologist. Milwaukee, WI: Wisconsin Heart Hospital; 2005.
Low Diagnostic Yield of Elective Coronary Angiography

Manesh R. Patel, M.D., Eric D. Peterson, M.D., M.P.H., David Dai, M.S.,
J. Matthew Brennan, M.D., Rita F. Redberg, M.D., H. Vernon Anderson, M.D.,
Ralph G. Brindis, M.D., and Pamela S. Douglas, M.D.

Rate of Obstructive CAD

37.6%

397,954 Patients at 663 sites

<table>
<thead>
<tr>
<th>Obstructive CAD (N=149,739)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Multivessel CAD</td>
<td>53.0%</td>
</tr>
<tr>
<td>1-vessel CAD</td>
<td>46.7%</td>
</tr>
<tr>
<td>2-vessel CAD</td>
<td>30.5%</td>
</tr>
<tr>
<td>3-vessel CAD</td>
<td>22.5%</td>
</tr>
</tbody>
</table>

CONCLUSIONS

In this study, slightly more than one third of patients without known disease who underwent elective cardiac catheterization had obstructive coronary artery disease. Better strategies for risk stratification are needed to inform decisions and to increase the diagnostic yield of cardiac catheterization in routine clinical practice.

N ENGL J MED 362;10  NEJM.ORG  MARCH 11, 2010
Europe: 2.7 Mio angio/y, 1.1 Mio PCI/y = 41% intervention rate
59% = 1.6 Mio purely diagnostic caths
Table 1. Pretest Probabilities of ≥50% Diameter Stenotic Coronary Artery Disease in Patients With Chest Pain as Shown in the American College of Cardiology/American Heart Association Guidelines for Management of Chronic Stable Angina

<table>
<thead>
<tr>
<th>Age, y</th>
<th>Nonanginal Chest Pain, %</th>
<th>Atypical Angina, %</th>
<th>Typical Angina, %</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Men</td>
<td>Women</td>
<td>Men</td>
</tr>
<tr>
<td>30–39</td>
<td>4</td>
<td>2</td>
<td>34</td>
</tr>
<tr>
<td>40–49</td>
<td>13</td>
<td>3</td>
<td>51</td>
</tr>
<tr>
<td>50–59</td>
<td>20</td>
<td>7</td>
<td>65</td>
</tr>
<tr>
<td>60–69</td>
<td>27</td>
<td>14</td>
<td>72</td>
</tr>
</tbody>
</table>
Prevalence of CAD is massively overestimated which leads to unnecessary invasive coronary angiographies.
Coronary CTA – Prospective ECG-Triggering

Spiral-CT

40mm coverage/rotation

Husmann et al.
Radiology 2007;245: 567-576

1.3 mSv
Coronary computed tomography angiography with a consistent dose below 1 mSv using prospectively electrocardiogram-triggered high-pitch spiral acquisition

Achebach et al.

Husmann et al.
Radiology 2007; 245:567–576
Image quality of ultra-low radiation exposure coronary CT angiography with an effective dose <0.1 mSv using high-pitch spiral acquisition and raw data-based iterative reconstruction

Annika Schuhbaeck · Stephan Achenbach · Christian Layritz · Jasmin Eisentopf · Franziska Hecker · Tobias Pflederer · Soeren Gauss · Johannes Rixe · Willi Kalender · Werner G. Daniel ·

Eur Radiol
DOI 10.1007/s00330-012-2656-2

62 kg
SAFIRE - Sinogram Affirmed Iterative Reconstruction algorithm (Siemens)

<table>
<thead>
<tr>
<th></th>
<th>Filtered back projection (FBP)</th>
<th>Iterative reconstruction (SAFIRE)</th>
<th>Significance P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aorta signal (HU)</td>
<td>721.9±133.3</td>
<td>711.9±134.7</td>
<td>n.s. (0.88)</td>
</tr>
<tr>
<td>Aorta noise (HU)</td>
<td>158.2±44.7</td>
<td>128.9±46.6</td>
<td>0.02</td>
</tr>
<tr>
<td>LM signal (HU)</td>
<td>734.8±163.6</td>
<td>710.6±148.0</td>
<td>n.s. (0.80)</td>
</tr>
<tr>
<td>LM contrast (HU)</td>
<td>773.9±182.1</td>
<td>728.3±138.3</td>
<td>n.s. (0.48)</td>
</tr>
<tr>
<td>LM SNR</td>
<td>5.0±1.8</td>
<td>6.3±2.7</td>
<td>n.s. (0.15)</td>
</tr>
<tr>
<td>LM CNR</td>
<td>5.2±1.8</td>
<td>6.4±2.4</td>
<td>n.s. (0.11)</td>
</tr>
</tbody>
</table>
Standard image quality at radiation dose <2 mSv
MBIR
Model based iterat. Reconstruction
(GE Healthcare)

ASIR
Adapted statist. iterat. Reconstruction
(GE Healthcare)

ultra low dose: 0.2 mSv
standard: 1.2 mSv

LMA signal: 707 HU
noise: 18 HU
SNR: 40

LMA signal: 602 HU
noise: 36 HU
SNR: 17
MBIR
Model based iterat. Reconstruction (GE Healthcare)

0.19 mSv

ASIR
Adapted statist. iterat. Reconstruction (GE Healthcare)

GE HD 750

1.07 mSv
### Table 3

Appropriate clinical indications for the use of computed tomography coronary angiography and cardiac computed tomography imaging according to an expert consensus document endorsed by several professional societies and published in 2006

<table>
<thead>
<tr>
<th>Detection of CAD with prior test results</th>
<th>evaluation of chest pain syndrome (use of CT angiogram)</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Uninterpretable or equivocal stress test (exercise, perfusion, or stress echo)</td>
<td></td>
</tr>
<tr>
<td>• Intermediate pre-test probability of CAD</td>
<td></td>
</tr>
</tbody>
</table>

Detection of CAD: symptomatic—evaluation of intra-cardiac structures (use of CT angiogram)

- Evaluation of suspected **coronary anomalies**

Structure and function—morphology (use of CT angiogram)

- Assessment of complex congenital heart disease including anomalies of coronary circulation, great vessels, and cardiac chambers and valves
- Evaluation of coronary arteries in patients with new onset heart failure to assess aetiology

- Evaluation of pulmonary vein anatomy prior to invasive radiofrequency ablation for atrial fibrillation
- Non-invasive coronary vein mapping prior to placement of biventricular pacemaker
- Non-invasive coronary arterial mapping, including internal mammary artery prior to repeat cardiac surgical revascularization

Structure and function—evaluation of aortic and pulmonary disease (use of CT angiogram∗)

- Evaluation of suspected aortic dissection or thoracic aortic aneurysm
- Evaluation of suspected pulmonary embolism
Coronary anomalies
Advanced coronary CT angiography: More than anatomy?
Computed Tomography Myocardial Perfusion Imaging With 320-Row Detector Computed Tomography Accurately Detects Myocardial Ischemia in Patients With Obstructive Coronary Artery Disease

Clinical Perspective

by Richard T. George, Armin Arbab-Zadeh, Julie M. Miller, Andrea L. Vavere, Frank M. Bengel, Albert C. Lardo, and João A.C. Lima

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Timeline of a comprehensive cardiac computed tomography (CT) protocol that includes coronary artery calcium scoring (CACS), rest CT angiography and perfusion (CTA), stress CT perfusion (CTP), and delayed enhanced CT (DECT).

55-year-old with exertional chest pressure.

Computed tomography perfusion derived transmural perfusion ratio (TPR) compared with the summed stress score (SSS) measured on single photon emission computed tomography (SPECT) in patients with stenoses ≥50%.

A

B

\[ y = 0.0145 - 0.0409x \]

\[ R^2 = 0.84, \ p = 0.001 \]
Radiation doses in millisievert (mSv) for coronary artery calcium scoring (CACS), rest computed tomography (CT) angiography and perfusion, stress CT perfusion, delayed enhanced CT, rest single photon emission computed tomography (SPECT), and stress SPECT.

Diagnosis of ischemia-causing stenoses obtained via non-invasive fractional flow reserve (DISCOVER-FLOW): a prospective multicentre first-in-man study

Bon-Kwon Koo, Andrejs Erglis, Joon-Hyung Doh, David V Daniels, Sanda Jegere, Hyo-Soo Kim, James K. Min

Seoul National University Hospital, Seoul, South Korea, Pauls Stradins University, Riga, Latvia, Inje University Ilsan Paik Hospital, Goyang, South Korea, Stanford University, Stanford, USA, New York Presbyterian Hospital, New York, USA
Non-invasive FFR (FFR\textsubscript{CT})

**Computational Model based on CCTA**

- 3-D anatomic model from CCTA
- No additional imaging
- No additional medications

**Blood Flow Solution**

- Blood flow equations solved on supercomputer
- Physiologic models:
  - Myocardial demand
  - Morphometry-based boundary condition
  - Effect of adenosine on microcirculation

**Calculate FFR\textsubscript{CT}**

- 3-D FFR\textsubscript{CT} map computed
- FFR\textsubscript{CT} = 0.72
  - (can select any point on model)
Case Examples

CCTA

>50% diameter stenosis

FFR\textsubscript{CT} 0.74 \rightarrow \text{ischemia}

>50% diameter stenosis

FFR 0.74 \rightarrow \text{ischemia}

Invasive angiography

>50% diameter stenosis

FFR 0.84 \rightarrow \text{no ischemia}

FFR 0.84 \rightarrow \text{no ischemia}

FFRCT
FFR vs. CT and FFR\textsubscript{CT}

Reduction of false positives: 70%

CCTA

- True - 40 (25%)
- False - 5 (3%)
- True + 61 (38%)

CT < 50%
(N=45)

CT \geq 50%
(N=114, 71%)

FFR\textsubscript{CT}

- True - 83 (52%)
- True + 51 (32%)
- False - 7 (4%)

FFR\textsubscript{CT} > 0.80
(N=90)

FFR\textsubscript{CT} \leq 0.80
(N=69, 43%)

False + 61 (38%)

False + 18 (11%)

False - 5 (3%)

True - 40 (25%)

JACC 2012
CCTA for low-intermediate CAD pretest probability

Adapted with permission from Tracy Callister, MD. CT Angiography for the Cardiologist. Milwaukee, WI: Wisconsin Heart Hospital; 2005.
Most evidence-based indications for CCTA and cardiac CT

Suspected CAD with
-equivocal stress test OR low probability of CAD (“rule out indication”) AND
- low probability of calcification AND low heart rate (or BB possible)

Suspected coronary anomaly

Matching ischemic territory with culprit vessel in complex anatomy (multivessel/CABG) with hybrid imaging

Calcium scoring for CV risk assessment in asymptomatic patients

Non-coronary: TAVI planning, Carto merge for A fib ablation etc.