Optimal Method for Stenosis Assessment with CT

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Vice Chairman of Radiology UBC

Disclosures

Speaker’s bureau: GE Healthcare and Edwards LifeSciences
Grant Support- CIHR, GE Healthcare
Advisory Board- GE Healthcare, Vital Images and Edwards LifeSciences
Equity Stakeholder- TC3
Is there a severe anatomic stenosis?

CCTA Findings:
- >70% stenosis LAD
- 25-49% stenosis LCx
- <25% stenosis RCA
Three (3) Prospective Multicenter Studies

<table>
<thead>
<tr>
<th></th>
<th>Sensitivity</th>
<th>Specificity</th>
<th>PPV</th>
<th>NPV</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACCURACY</td>
<td>84</td>
<td>83</td>
<td>48</td>
<td>99</td>
</tr>
<tr>
<td>N=230, Stable Chest Pain; No known CAD; No exclusion (CACS, HP, BMI); CAD prevalence 13%</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Core64</td>
<td>85</td>
<td>90</td>
<td>91</td>
<td>83</td>
</tr>
<tr>
<td>N=291, Stable Chest Pain; No known and Known CAD; Exclusion CACS&gt;600; CAD prevalence 56%</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Meijboom</td>
<td>99</td>
<td>64</td>
<td>85</td>
<td>97</td>
</tr>
<tr>
<td>h=360, Acute and Stable Chest Pain; No known CAD; CAD prevalence 68%</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Budoff et al. JACC 2008; Miller et al. NEJM 2008; Meijboom et al. JACC 2009

Diagnosis of obstructive CAD

<table>
<thead>
<tr>
<th>Test</th>
<th>Sensitivity</th>
<th>Specificity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exercise ECG treadmill¹</td>
<td>68%</td>
<td>77%</td>
</tr>
<tr>
<td>Exercise Echo treadmill²</td>
<td>86%</td>
<td>81%</td>
</tr>
<tr>
<td>Dobutamine Echo treadmill²</td>
<td>~85%</td>
<td>~85%</td>
</tr>
<tr>
<td>Exercise nuclear treadmill³</td>
<td>87%</td>
<td>73%</td>
</tr>
<tr>
<td>Pharmacologic nuclear³</td>
<td>89%</td>
<td>75%</td>
</tr>
<tr>
<td>Cardiac CTA⁴</td>
<td>95%</td>
<td>83%</td>
</tr>
</tbody>
</table>

1. ACC/AHA 2002 Guideline Update for Exercise Testing
2. ACC/AHA/ASE 2003 Guideline Update for the Clinical Application of Echocardiography
3. ACC/AHA/ASNC Guidelines for the Clinical Use of Cardiac Radionuclide Imaging
4. ACCURACY study, presented at 2008 ACC Scientific Sessions
Tips from Dr Achenbach - Data Acquisition

Rule-outs/normal coronary arteries can usually be evaluated even at higher heart rates. Especially in difficult cases:

Low heart rates maximize accuracy.

Calcium

Evaluation of calcified segments: Careful multiplanar reconstruction
Calcium

For evaluation of calcified segments: Careful multiplanar reconstruction

Calcium

evaluation of calcified segments: Careful multiplanar reconstruction
The diagnostic performance of CCTA is improving with each generation of technology

- **Dual-source CT**
  - Improved temporal resolution
  - 75 ms resolution

- **320-slice MDCT**
  - Improved volume coverage
  - Whole heart acquisition in 1 beat

- **High Definition CT**
  - Improved spatial resolution
  - Enhanced calcified plaque and metal imaging
  - Reduced radiation

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**Single source vs. Dual source CCTA**

200 patients with suspected CAD randomized to SSCT vs. DSCT. Sub-randomization for HR control vs. no HR control. For sensitivity of detection of obstructive stenosis, SSCT improved with HRT (78% vs. 57%, p=0.04); DSCT unaffected by HRC (87% vs. 93%, p=NS).

Source: Achenbach et al. JACC Img 2008
High Definition CCTA

Multicenter (4 sites) study of 70 consecutive patients undergoing CCTA by HDCT and ICA. Obstructive CAD prevalence 48%. Median Estimated Effective Dose of 2.3 mSv

Source: Min et al. JCCT 2009

Heydari et al. CJC 2011
Dual Energy CCTA

- Prospective gating only (increased available padding to 300 msec)
- 64 x .625 mm
- 0.5 sec switching 80 to 140 kV
- Iterative Reconstuction
- Projection Based Monochromatic and material decomposition images fully available

Potential Advantages of Projection Based Dual NRG CCTA

- 77 yr old male
  - New chest pressure
  - + Family History CAD
- CCTA 9/13/2011
  - Prospective gating; CCTA DLP
  - 350 mGy-cm
  - CS 1301
  - >50% LAD disease, dense calcified plaque distal to 2nd diagonal
- Rapid kVp Switching Dual Energy CCTA 9/20/2011
  - Prospective gating; CCTA
  - DLP 394 mGy-cm
  - Less calcium blooming
Rd d
R
reduced blooming

50% stenosis

Conventional 120 kVp CCTA
Exam 9/13/2011

GSI CCTA
65 keV MC Images
Exam 9/20/2011

40 keV 90 keV
50 keV 100 keV
60 keV 110 keV
70 keV 120 keV
80 keV 130 keV
Disclosures

• Research Support:
  – NHLBI (R01HL115150-01)
  – U01 HL105907-02 [Contract])
  – QNRF (NPRP 09-370-3-089)
  – GE Healthcare (significant)
  – Philips Healthcare (modest)
  – Vital Images (modest)

• Equity Interest:
  – TC3
  – MDDX
  – Cedars-Sinai Medical Center

• Medical Advisory Board:
  – GE Healthcare
  – Arineta

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60 y/o with atypical angina scheduled to undergo intra-abdominal surgery

• Symptoms: 60 YM atypical angina and associated with shortness of breath; under “a lot of stress”; exercises regularly
• CAD risk factors: Dyslipidemia, Diabetes, FH, HTN
• Medications: Aspirin, Beta blocker, Diuretic, Ezetimibe, HMG CoA reductate inhibitor
• Other factors: BMI 29; ECG- Normal Sinus Rhythm

• A CCTA is performed...
How Severe is the Stenosis and What Should be done?

Limitations of CCTA

- Stenosis severity by CCTA demonstrates an unreliable relationship to lesion-specific ischemia—with the majority of obstructive stenosis detected by CCTA not causal of ischemia
- CCTA cannot predict global myocardial perfusion
Perfusion Imaging

Coronary anatomy is a poor predictor of the hemodynamic significance of CAD

Frequency of Ischemia in Vessels with $\geq 50\%$ Stenosis by CTA

(Ischemia Matters

Cedars-Sinai Nuclear Registry
10,627 patients
No CAD
1.9 yr cardiac death


% Myocardium Ischemic
Courage Nuclear Sub-study

1. Improvements in angina class
2. Less reliance on nitrates for symptom relief
3. Greater anti-ischemic benefit of PCI was with more severe ischemia at baseline.
4. If > 5% reduction in ischemia in either group, there was a trend for reduced rate of death or MI (NS)

Shaw et al., Circulation 2008; 117:1283-1291.

Rationale for Stress CT

- The physiologic significance of many lesions identified by coronary CT angiography is unknown.

- A single test that combines both the anatomical information of CTA along with the physiological significance provided by myocardial perfusion would be beneficial.
Stress CT Protocol

Scout Images
Test Bolus

Stress Perfusion → Rest Scan → Delayed Enhancement

Adenosine

Contrast

Stress perfusion, coronary CTA, function

Data

Blankstein Blankstein R et al. – JACC 2009;54:1072-84
R et al. – JACC 2009;54:1072-84

CT Perfusion (stress) → Coronary CT Angiography

Stress SPECT MPI

Rest
### Studies utilizing cardiac computed tomography perfusion (CTP) imaging as compared with (MPI)

<table>
<thead>
<tr>
<th>First Author, Year of Publication</th>
<th>Per Vessel</th>
<th>Number of vessels (Subjects)</th>
<th>Sensitivity</th>
<th>Specificity</th>
<th>Positive Predictive Value</th>
<th>Negative Predictive Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kurata et al, 2008 (34)</td>
<td></td>
<td>36 (12)</td>
<td>21.22 (0.95)</td>
<td>9.12 (0.64)</td>
<td>21.26 (0.81)</td>
<td>9.10 (0.90)</td>
</tr>
<tr>
<td>Kudo et al, 2009 (35)</td>
<td></td>
<td>42 (14)</td>
<td>7.6 (0.82)</td>
<td>27.34 (0.76)</td>
<td>7.14 (0.50)</td>
<td>27.38 (0.66)</td>
</tr>
<tr>
<td>George et al, 2009 (25)</td>
<td></td>
<td>120 (40)</td>
<td>42.6 (0.70)</td>
<td>31.0 (0.52)</td>
<td>42.71 (0.59)</td>
<td>31.49 (0.63)</td>
</tr>
<tr>
<td>Blomloet et al, 2009 (26)</td>
<td></td>
<td>102 (34)</td>
<td>71.37 (0.84)</td>
<td>52.83 (0.60)</td>
<td>71.46 (0.71)</td>
<td>52.56 (0.60)</td>
</tr>
<tr>
<td>Hu et al, 2010 (37)</td>
<td></td>
<td>96 (32)</td>
<td>74.79 (0.94)</td>
<td>11.17 (0.65)</td>
<td>74.80 (0.93)</td>
<td>11.16 (0.69)</td>
</tr>
<tr>
<td>Tamamura et al, 2010 (38)</td>
<td></td>
<td>196 (65)</td>
<td>0.87 (0.78 - 0.96)</td>
<td>0.69 (0.56 - 0.82)</td>
<td>0.72 (0.66 - 0.60)</td>
<td>0.33 (0.71 - 0.95)</td>
</tr>
</tbody>
</table>

**TOTAL** 396 (132)

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### CTP vs Stress Perfusion MRI

<table>
<thead>
<tr>
<th>First Author, Year of Publication</th>
<th>Per Vessel</th>
<th>Number of vessels (Subjects)</th>
<th>Sensitivity</th>
<th>Specificity</th>
<th>Positive Predictive Value</th>
<th>Negative Predictive Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ko et al, 2010 - (40)</td>
<td></td>
<td>84 (28)</td>
<td>41.45 (0.91)</td>
<td>28.39 (0.72)</td>
<td>41.52 (0.79)</td>
<td>28.32 (0.88)</td>
</tr>
<tr>
<td>Fanchi et al, 2011† (41)</td>
<td></td>
<td>90 (30)</td>
<td>45.47 (0.90)</td>
<td>41.43 (0.93)</td>
<td>45.47 (0.90)</td>
<td>41.45 (0.93)</td>
</tr>
</tbody>
</table>

**TOTAL** 174 (58)

- Sensitivity: 0.84 (0.89 - 0.89)
- Specificity: 0.85 (0.61 - 1.06)
- Positive Predictive Value: 0.88 (0.72 - 1.05)
- Negative Predictive Value: 0.95 (0.88 - 1.00)
## CTP/ CCTA vs Cath Measured FFR

<table>
<thead>
<tr>
<th>First Author, Year of Publication</th>
<th>Modality for Comparison</th>
<th>Per Vessel</th>
<th>Number of vessels (patients)</th>
<th>Sensitivity</th>
<th>Specificity</th>
<th>Positive Predictive Value</th>
<th>Negative Predictive Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Buehring et al., 2011 * (42)</td>
<td>CCTA CTP vs FFRCCA</td>
<td></td>
<td>56 (53)</td>
<td>27.2 (0.95)</td>
<td>58.6 (0.87)</td>
<td>27.3 (0.75)</td>
<td>58.8 (0.97)</td>
</tr>
<tr>
<td>Kim et al., 2011 † (43)</td>
<td>CCTA CTP vs FFRCCA</td>
<td></td>
<td>56 (42)</td>
<td>22.4 (0.63)</td>
<td>44.4 (0.93)</td>
<td>20.3 (0.97)</td>
<td>44.5 (0.77)</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td></td>
<td></td>
<td><strong>112 (95)</strong></td>
<td><strong>0.93</strong></td>
<td><strong>0.93</strong></td>
<td><strong>0.87</strong></td>
<td><strong>0.88</strong></td>
</tr>
</tbody>
</table>

### Diagnostic Performance of Combined Noninvasive Coronary Angiography and Myocardial Perfusion Imaging Using 320-row Detector Computed Tomography: *The CORE320 Multicenter International Study*

![CORE 320](image)

João A.C. Lima, M.D.
Professor of Medicine and Radiology
Johns Hopkins Hospital

For the CORE320 Investigators
Primary Hypothesis

CTA 50% Stenosis + CTP Perfusion Defect
ICA 50% Stenosis + SPECT Perfusion Defect

Patient Based Results

Incremental Value of Most Severe CTA-CTP over CTA
(Reference Standard: 50% by ICA with SPECT-MPI defect)

- CTA-CTP ROC Area = 0.87
- 95% CI [0.83-0.91]
- 95% CI [0.77-0.86]

Combined Most Severe CTA-CTP and CTA alone vs. Reference Standard (ICA 50% with SPECT-MPI defect)

P<0.001
Summary

• Combined CTA and CTP can detect hemodynamically significant stenosis (50% or greater) by ICA with an associated SPECT-MPI defect.
• CT myocardial perfusion adds to the diagnostic power of CT angiography alone.
• The combination of CTA & CTP in one non invasive examination is useful to identify patients who benefit from revascularization and guide management of CAD.

Incremental Value of Adenosine-induced Stress Myocardial Perfusion Imaging with Dual-Source CT at Cardiac CT Angiography

First, to assess the feasibility of a protocol involving stress-induced perfusion evaluated at computed tomography (CT) combined with cardiac CT angiography in a single examination and second, to assess the incremental value of perfusion imaging performed with cardiac CT angiography in a dual-source technique for the detection of obstructive coronary artery disease (CAD) in a high-risk population.

Purpose:

Materials and Methods:

Institutional review board approval and informed patient consent were obtained before patient enrollment in the study. Thirty-five patients at high risk for CAD were prospectively enrolled for evaluation of the feasibility of
**Case 1: 70-year-old man with diabetes, hypertension, old infarct**

<table>
<thead>
<tr>
<th>Reading</th>
<th>Stress</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1 CTA</td>
<td>Proximal stent restenosis</td>
</tr>
<tr>
<td>Step 2 ct perfusion</td>
<td>Normal perfusion</td>
</tr>
<tr>
<td>Step 3 final call</td>
<td>Non significant stenosis</td>
</tr>
<tr>
<td>Gold standard</td>
<td>Mild proximal stent stenosis</td>
</tr>
</tbody>
</table>

**Case 2: 63 y-o male, history of CAD, episode of syncope. Hypertension and hyperlipidemia**

<table>
<thead>
<tr>
<th>Reading</th>
<th>Stress</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1 CTA</td>
<td>RCA Non interpretable</td>
</tr>
<tr>
<td></td>
<td>LCX Possible stenosis</td>
</tr>
<tr>
<td>Step 2 ct perfusion</td>
<td>RCA Normal perfusion</td>
</tr>
<tr>
<td></td>
<td>LCX Abnormal perfusion</td>
</tr>
<tr>
<td>Step 3 final call</td>
<td>RCA Non-significant stenosis</td>
</tr>
<tr>
<td></td>
<td>LCX Significant stenosis</td>
</tr>
<tr>
<td>Gold standard</td>
<td>RCA Non significant stenosis</td>
</tr>
<tr>
<td></td>
<td>LCX Significant stenosis</td>
</tr>
</tbody>
</table>
What About Lesion Specific Ischemia?

Reference “Gold” Standard for Ischemia: Fractional Flow Reserve (FFR)

- FFR at the time of invasive coronary angiography (ICA) is the only method for specific determination of the hemodynamic significance of coronary artery lesions (lesion-specific ischemia).

- FFR = Ratio of maximal myocardial blood flow through a diseased artery to the blood flow in the hypothetical case that this artery is normal.
- Values ≤0.80 or ≤0.75 considered diagnostic of lesion-specific ischemia.

Assessment of Lesion-specific Ischemia by FFR is the Only Method To Improve Event-free Survival


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**Fractional Flow Reserve–Guided PCI versus Medical Therapy in Stable Coronary Disease**

Bernard De Bruyne, M.D., Ph.D., Nico H.J. Pijls, M.D., Ph.D.,
---

Sven Mehillis-Winkler, M.D., Gilles Roffi, M.D., Ph.D., Niels Wilt, M.D., Ph.D.,
---

Keith G. Oldroyd, M.D., Krzysztof Mavrommatis, M.D., Ganesan Manoharan, M.D.,
---

Peter Verheye, M.D., Ove Enblad, M.D., Nick Cutler, M.B., Ph.D.,
---

Jane B. Johnston, R.N., B.S.N., Peter Jori, M.D., and William F. Faxon, M.D.,
---

for the FAME 2 Trial Investigators

**Primary Outcomes**

- PCI+MT vs. MT: HR 0.32 (0.19-0.53); p=0.001
- PCI+MT vs. Registry: HR 1.29 (0.69-3.39); p=0.61
- MT vs. Registry: HR 4.32 (1.75-10.7); p=0.001
Computational Fluid Dynamics

Computational fluid dynamics (CFD) quantifies fluid pressure and velocity, based on physical laws of mass conservation and momentum balance

- CFD for Patient-Specific Models of Coronary Arteries
  1. Numerical method approximates governing equations
  2. Obtain solution for velocity / pressure at finite (but very large) number of points
  3. Simultaneously solve millions of non-linear equations and repeating process for thousands of time intervals within cardiac cycle

Images courtesy of Prof. Charbel Farhat, Dept. of Aeronautics & Astronautics, Stanford University

An Analogy for Computing FFR\textsubscript{CT} from a Static CT

Flow over a Wing

- Input data:
  - Geometry – from design specs
  - Boundary conditions
    - Velocity of incoming air relative to wing
    - Atmospheric pressure, P=P\textsubscript{atm}
  - Fluid Properties – viscosity and density of air

- Calculated data:
  - Velocity and pressure of air in front of, around, behind wing
  - Lift and drag

Flow through an Artery

- Input data:
  - Geometry – high quality 64 slice CT
  - Boundary conditions
    - Blood pressure
    - Resting coronary flow calculated from myocardial mass
    - Coronary microcirculatory resistance determined from size of feeding vessel
  - Fluid properties – viscosity (from hematocrit) and density of blood

- Calculated data:
  - Velocity and pressure of blood in coronary arteries
  - FFR\textsubscript{CT}

Images courtesy of Prof. Charbel Farhat, Dept Aeronautics, Stanford
Patient-Specific Computation of FFR\textsubscript{CT}

1. **Image-Based Modeling** – Segmentation of patient-specific arterial geometry
2. **Heart-Vessel Interactions** – Allometric scaling laws relate caliber to pressure and flow
3. **Microcirculatory resistance** – Morphometry laws relate coronary dimension to resistance
4. **Left Ventricular Mass** – Lumped-parameter model couples pulsatile coronary flow to time-varying myocardial pressure
5. **Physiologic Conditions** – Blood as Newtonian fluid adjusted to patient-specific viscosity
6. **Induction of Hyperemia** – Compute maximal coronary vasodilation
7. **Fluid Dynamics** – Navier-Stokes equations applied for coronary pressure

Simulating *coronary* blood flow uses similar principles but is even more complicated

**Inputs**
- Accurate coronary geometric models including branching structure and pathology
- Physiologic models personalized using minimal measured data

**Boundary Conditions**
- Heart/vascular interaction
- Aortic impedance
- Time-varying coronary resistance related to intramyocardial pressure
- Models to simulate hyperemia

**Numerical Methods**
- Anisotropic, adaptive, boundary layer mesh generation to reduce computation time
- Tight coupling between heart model and aorta/coronary model
- High performance parallel incompressible flow solver
Case Examples: Obstructive CAD

Case 1
- CT
- LAD stenosis
- FFR 0.65 = Lesion-specific ischemia
- FFRCT 0.62 = Lesion-specific ischemia

Case 2
- CT
- RCA stenosis
- FFR 0.86 = No ischemia
- FFRCT 0.87 = No ischemia

Examples – DISCOVER-FLOW

CCTA
- >50% diameter stenosis
- FFRCT 0.74 = ischemia

Invasive angiography
- >50% diameter stenosis
- FFR 0.74 = ischemia

FFR
- >50% diameter stenosis
- FFR 0.84 = no ischemia

FFRCT
- >50% diameter stenosis
- FFRCT 0.85 = no ischemia
I KNOW A TIGHT LESION WHEN I SEE ONE........
I know a tight lesion when I see one…

LAD FFR
Negative
$FFR_{CT} = 0.83$
Invasive=0.83

LAD FFR
Negative
$FFR_{CT} = 0.81$
Invasive=0.81

LAD FFR
Positive
$FFR_{CT} = 0.72$
Invasive=0.75

LAD FFR
Negative
$FFR_{CT} = 0.93$
Invasive=0.95

LAD FFR
Negative
$FFR_{CT} = 0.84$
Invasive=0.84

LAD FFR
Positive
$FFR_{CT} = 0.74$
Invasive=0.77
What about intermediate stenoses?

Source: Tonino PA et al. J Am Coll Cardiol

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### Angiographic Versus Functional Severity of Coronary Artery Stenoses in the FAME Study

Fractional Flow Reserve Versus Angiography in Multivessel Evaluation

Pim A. L. Tonino, MD,* William F. Fearon, MD,† Bernard De Bruyne, MD, PhD,‡
Keith G. Oldroyd, MD,§ Massoud A. Lee, MD,¶ Peter N. Ver Lee, MD,*¶
Philip A. McCarthy, MD, PhD,¶ Marcel van’t Veer, MSc, PhD,* Nico H. J. Pijls, MD, PhD*°
Eindhoven, the Netherlands; Stanford, California; Aalst, Belgium; Glasgow and London, United Kingdom; Cincinnati, Ohio; and Bangor, Maine

<table>
<thead>
<tr>
<th>% Stenosis by Angiography*</th>
<th>50% to 70% (n = 620, 47%)</th>
<th>71% to 90% (n = 513, 39%)</th>
<th>91% to 99% (n = 96, 15%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>FFR &gt; 0.80</td>
<td>402 (65)</td>
<td>104 (20)</td>
<td>7 (4)</td>
</tr>
<tr>
<td>FFR ≤ 0.80</td>
<td>218 (35)</td>
<td>409 (80)</td>
<td>189 (96)</td>
</tr>
<tr>
<td>Mean FFR for all lesions</td>
<td>0.81 ± 0.12</td>
<td>0.67 ± 0.15</td>
<td>0.52 ± 0.15</td>
</tr>
<tr>
<td>Mean FFR &gt; 0.80</td>
<td>0.89 ± 0.05</td>
<td>0.87 ± 0.05</td>
<td>0.87 ± 0.04</td>
</tr>
<tr>
<td>Mean FFR ≤ 0.80</td>
<td>0.68 ± 0.10</td>
<td>0.62 ± 0.13</td>
<td>0.51 ± 0.13</td>
</tr>
</tbody>
</table>
Moderate vs. Severe Stenosis: Moving Beyond a Binary Approach

Cheng et al. JACC CV Imaging (Jul 2008)

Diagnostic Performance of FFRCT for 30-69% Stenoses by CCTA

<table>
<thead>
<tr>
<th>FFR_{CT}</th>
<th>Accuracy</th>
<th>Sensitivity</th>
<th>Specificity</th>
<th>PPV</th>
<th>NPV</th>
</tr>
</thead>
<tbody>
<tr>
<td>≥ 0.80</td>
<td>83.8</td>
<td>64.9</td>
<td>88.5</td>
<td>60.5</td>
<td>90.0</td>
</tr>
<tr>
<td>CCTA</td>
<td>43.1</td>
<td>85.2</td>
<td>31.2</td>
<td>25.2</td>
<td>88.9</td>
</tr>
</tbody>
</table>

Leipsic et al. RSNA 20
Usefulness of Noninvasive Fractional Flow Reserve Computed from Coronary Computed Tomographic Angiograms for Intermediate Stenoses Confirmed by Quantitative Coronary Angiography

James K. Min, MD*†, Bon-Kwon Koo, MD‡, Andrejs Eglis, MD*, Joon-Hyung Doh, MD‡, David V. Daniels, MD‡, Sandra Jegere, MD‡, Hyo-Soo Kim, MD§, Allison M. Danning, MD†, Tony DeFrance, MD*, Alexandra Lansky, MD*, and Jonathon Leipsic, MD

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Diagnostic performance of $\text{FFR}_{\text{CT}}$ compared to invasive measured FFR for lesions of intermediate stenosis severity

<table>
<thead>
<tr>
<th>$\text{FFR}_{\text{CT}}$</th>
<th>Accuracy (%)</th>
<th>Sensitivity (%)</th>
<th>Specificity (%)</th>
<th>PPV (%)</th>
<th>NPV (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CCTA stenosis $&gt;50%$*</td>
<td>56.1 (43.3-68.3)</td>
<td>90.3 (74.2-98.0)</td>
<td>25.7 (12.5-43.3)</td>
<td>51.9 (37.8-65.7)</td>
<td>75.0 (42.8-94.5)</td>
</tr>
<tr>
<td>$\text{FFR} \leq 0.80$</td>
<td>86.4 (72.6-94.8)</td>
<td>73.9 (51.6-89.8)</td>
<td>88.4 (74.9-96.1)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

35% improvement in overall accuracy with nearly 60% improvement in specificity
Conclusions

• CCTA is an accurate test for the detection and exclusion of obstructive CAD with significant recent advancements

• CT perfusion is a developing tool with promising data from single center studies

• The optimal protocol has yet to be defined

• CORE 320 first multicenter again with promising results but may be vendor specific

Conclusions

FFR_{CT} -
1. Demonstrates high diagnostic performance compared to invasive measured FFR with 6 fold reduction in false positives as compared to CCTA
2. >40% improvement in diagnostic accuracy compared to CCTA
3. Robust discrimination of ischemia-causing lesions
4. Good correlation to invasive FFR

• FFR_{CT} is a new computational method that may be considered for the physiologic assessment of intermediate stenoses identified by CCTA
Awaiting Results from Larger Multicenter Trials

Diagnostic Performance of Combined Noninvasive Coronary Angiography and Myocardial Perfusion Imaging Using 320-MDCT: The CT Angiography and Perfusion Methods of the CORE320 Multicenter Multinational Diagnostic Study

Thank you.
Moderate vs. Severe Stenosis: Moving Beyond a Binary Approach

<table>
<thead>
<tr>
<th>Stenosis Severity</th>
<th>0-24%</th>
<th>25-49%</th>
<th>50-69%</th>
<th>&gt;70%</th>
<th>100%</th>
</tr>
</thead>
</table>

Cheng et al. JACC CV Imaging (Jul 2008)

Pre-Test Likelihood: ACC/AHA Clinical Practice Guidelines

<table>
<thead>
<tr>
<th>Pre-test obstructive CAD probability</th>
<th>Nonanginal CP</th>
<th>Atypical Angina</th>
<th>Typical Angina</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Age (y)</strong></td>
<td>♂ (%)</td>
<td>♂ (%)</td>
<td>♂ (%)</td>
</tr>
<tr>
<td>30-39</td>
<td>4</td>
<td>34</td>
<td>76</td>
</tr>
<tr>
<td>40-49</td>
<td>13</td>
<td>51</td>
<td>87</td>
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<tr>
<td>50-59</td>
<td>20</td>
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</tr>
<tr>
<td>60-69</td>
<td>27</td>
<td>72</td>
<td>94</td>
</tr>
</tbody>
</table>

Table recreated from: Gibbons, et al. ACC/AHA 2002 Guideline Update for the Management of Patients with Chronic Stable Angina.


Chaitman, BR. Circulation 1981;64:360-7