Contemporary Best Practice: How to Integrate Cardiac CT and Nuclear Cardiology in Stable CAD

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CSMC 2013

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Noninvasive Imaging in CAD
Changing Problems for Imaging

• Identify patient in need for specific therapy
  – Prevention
  – Diagnosis
  – Guiding management
Noninvasive Imaging in CAD
Changing Problems for Imaging

• Identify patient in need for specific therapy
  – Prevention
  – Diagnosis
  – Guiding management
• Contain rising costs

Cardiac CT

Strengths
• Non-contrast: proven role of CAC for prevention
• Contrast: CCTA
  – Highest sensitivity and specificity for CAD
  – Strong prognostic value
  – Potential for comprehensive cardiac assessment
  – Function, perfusion, infarct, plaque

Weaknesses
• Densely calcified plaques: nondiagnostic
• Dependence on low HR and regular rhythm
• Iodinated contrast
Myocardial Perfusion SPECT/PET

Strengths
- High technical success rate
- Objective measurements of perfusion and function
- Documented for risk-stratification/management
- Validated for myocardial viability
- Promising new PET tracer in phase II

Limitations
- No detection of early atherosclerosis*
- Frequently underestimates extent of ischemia/CAD

*unless hybrid with routine coronary calcium scanning

Selection of Imaging Tests in Evaluation of Symptomatic Patients with Suspected CAD

Pre-test likelihood of CAD

- Low
- Low-to High-Intermediate (15-85%)
- Intermediate to High (50-100%)

- CAC
- CTA
- Stress SPECT/PET
Nuclear Cardiology and Cardiac CT

- Asymptomatic Prevention
- Symptomatic Diagnosis
- Known disease Intervention

Coronary Calcium as a Predictor of Coronary Events in Four Racial or Ethnic Groups

Unadjusted Kaplan–Meier Survival for Coronary Events by CAC Scores Categories
n=6722, 38.6% white, 27.6% black, 21.9% Hispanic, and 11.9% Chinese. FU 3.9 yrs.

Detrano et al. NEJM 2008;358:1336-45
Comparison of Novel Risk Markers for Improvement in Cardiovascular Risk-Assessment in Intermediate-Risk Subjects

Figure. Receiver Operator Characteristic Curves Showing Area Under the Curve for Incident Coronary Disease and Incident Cardiovascular Disease in Intermediate-Risk MESA Participants

Cardiovascular Events with Minimal vs Absent Coronary Calcification: The Multi-Ethnic Study of Atherosclerosis (MESA)

3415 CAC=0, 508 CAC=1-10, FU 4.1 yrs, 28 all CHD events (MI, cardiac death, resuscitated cardiac arrest, angina and probable angina with revasc.) and 16 hard events


CAC Severity Predicts Stress-Induced Scintigraphic Ischemia

326 M, 85 F, age 58 ±10 yrs, SPECT in median 17 days

0 10 20 30 40 50 Abnormal SPECT (%)

<table>
<thead>
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<th>Abnormal SPECT (%)</th>
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<tr>
<td>0</td>
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<td>46</td>
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</table>

*p<0.001

n = 37  n = 19  n = 76  n = 142  n = 137

He et al, Circulation 2000;101:244-51
Frequency of Ischemia on Myocardial Perfusion SPECT by Coronary Artery Calcium (CAC) Category

![Chart showing frequency of ischemia by CAC category]

- CAC=0 (n=250): 1.6% ischemia ≥5%, 0% ischemia ≥10%
- 1-9 (n=49): 2.4% ischemia ≥5%, 0% ischemia ≥10%
- 10-99 (n=207): 4.5% ischemia ≥5%, 0% ischemia ≥10%
- 100-399 (n=290): 5.2% ischemia ≥5%, 2.1% ischemia ≥10%
- 400-999 (n=248): 8.9% ischemia ≥5%, 2.4% ischemia ≥10%
- ≥1000 (n=151): 19.9% ischemia ≥5%, 8.6% ischemia ≥10%

* p<0.0001 for trend for Ischemia ≥5%, Ischemia ≥10%

Berman et al, JACC 2004;44:923-30

Nuclear Cardiology and Cardiac CT
Screening for Subclinical Atherosclerosis

- CT coronary calcium: effective
  - Class IIa ACC/AHA prevention guidelines (2010)
- Coronary CTA: uncertain role at present
- Limited role for nuclear cardiology
- Stress imaging documented as useful for guiding management when CCS is high (~10%)
Nuclear Cardiology and Cardiac CT

- Asymptomatic Prevention
- Symptomatic Diagnosis
- Known disease Intervention

ACC National Cardiovascular Data Registry
- 397,954 patients with elective cath (663 hospitals)
- 37.6% had obstructive CAD (>70% stenosis)

Patel et al. *NEJM* 2010;362:886-95
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.

- ACC National Cardiovascular Data Registry
- 397,954 patients with elective cath (663 hospitals)
- 37.6% had obstructive CAD (>70% stenosis)

Patel et al. NEJM 2010;362:886-95
Coronary CTA

• Sensitivity and specificity: ~ 95%/90%
• Higher than all other modalities
  – Per patient
  – Per vessel
  – Per segment

• Very unlikely to miss high risk disease
Coronary CTA

• Sensitivity and specificity: ~ 95%/90%
• Higher than all other modalities
  – Per patient
  – Per vessel
  – Per segment
• Very unlikely to miss high risk disease
• Very high negative predictive value for events

Prognostic value of CCTA is widely generalizable

CONFIRM Registry: Coronary CT Angiography EvaluatioN For Clinical Outcomes: An InTeRnational Multicenter Registry (James K. Min, PI)

• Dynamic registry of >32,000 consecutive patients undergoing CCTA
• V.1. 12-centers in 6 countries (US, Canada, Germany, Switzerland, Italy, and S. Korea), Database lock 09/10 – Derivation Cohort
• V.2. 6 add’l sites (Miami, California, Vancouver, New York, Innsbruck, Seoul) – Validation Cohort
Prognostic Value of CCTA CAD Extent / Severity
23,854 patients w/o known CAD (57±13 years), 2.3 year f/u

• Warranty period of normal scan: likely ~ 10 years

Source: Min et al. J Am Coll Cardiol 2011
Comparison of observed Ob-CAD prevalence in MEN to probabilities based on DFC and CASS

Selection of Imaging Tests in Evaluation of Symptomatic Patients with Suspected CAD

Pre-test likelihood of CAD

Low- to High-Intermediate (15-85%)

CTA

Prediction: In SYMPTOMATIC patients:
• CCTA will become a common initial test in intermediate likelihood of CAD:
• ~10% will need further (ischemia) testing
Pre-test likelihood of CAD

Low (< 15%)

Intermediate (15%-85%)

High (>85%)

Symptomatic

CTA

1° Prevention

2° Prevention

Catheterization +/- Revasc.

HUDPET 55 M

- SOB
- Cholesterol, FH early CAD
- Rest ECG: LBBB
- Referred for SPECT MPI
  - No walk adenosine
HUDPET 55 M  #3321-1784

CCTA: normal coronary arteries, CCS 6, HR 63, LVEF 55%

Pre-test likelihood of CAD

Low (<15%)  Intermediate (15%-85%)  High (>85%)

CTA Symptomatic

NL

1° Prevention  2° Prevention  Catheterization +/- Revasc.
RR, a 66y old male

ADENOSINE MYOCARDIAL PERFUSION STUDY

Reason: chest pain
Symptomatic: typical chest pain
Risk factors: hypertension, diabetes
Medication: oral diabetes agents
Height: 71 in. Weight: 146 lbs. Body Mass Index (BMI): 20.4

STRESS TEST RESULTS:
- Type: no walk adenosine
- Rest HR = 62, Peak HR = 96, Peak/Rest HR ratio = 1.5
- Blood pressure: Rest: not achieved, Stress: 132/75
- Symptom during test: chest discomfort occurred at 2 minutes into the infusion
- Resting ECG: left bundle branch block
- Stress ECG: no ST segment depression

NUCLEAR RESULTS:
- Dual isotope gated SPECT (stress sestamibi/supine+prone/rest thallium)
  - Myocardial Perfusion: Total perfusion defect 9% myocardium (9% reversible, 0% fixed)
    - Vessel Reversible
      - LAD medium (anterior, septal)
      - LV enlargement: no, Lung uptake: normal, Visual TID: no, TID ratio: 1.36
    - Myocardial Function:
      - LVEF: 55%
      - EDV: 36 ml/m2
- Resting and adenosine post stress gated SPECT demonstrated dyskinesis in the septal wall with no change during adenosine stress.

CONCLUSION:
- Clinical response: Non-diagnostic
- ECG response: Non-diagnostic [LBBB]
- Perfusion: Prob abnormal (Reversible)
- Function: Abn rest, no change stress

Likelihood of angiographically significant coronary artery disease: Intermediate (30-60%)
- LAD: a medium sized reversible defect in the distal anterior and septal wall.

RR, a 66y old male
Proximal and mid LAD severe stenosis
RR, a 66y old male

Cath done 2 days later…

Non-Invasive Detection of Coronary Artery Disease in Patients with Left Bundle Branch Block using 64-Slice Computed Tomography

Ghostine et al. JACC Vo.44, No. 10, 2006:1929-34

OBJECTIVES
The goal of this study was to evaluate the diagnostic accuracy of 64-slice computed tomography (CT) to identify coronary artery disease (CAD) in patients with complete left bundle branch block (LBBB).

BACKGROUND
Left bundle branch block increases risk of cardiac mortality, and prognosis is primarily determined by the underlying coronary disease. Non-invasive stress tests have limited performance, and conventional coronary angiography (CCA) is usually required.

METHODOLOGY
Sixty-six consecutive patients with complete LBBB and sinus rhythm admitted for CCA were enrolled. Computed tomography was performed 3 ± 3.9 days before CCA. The accuracy of 64-slice CT to detect significant stenosis (>50% lumen narrowing) was compared with quantitative coronary angiography. All segments were analyzed regardless of image quality from coronary calcification or motion artifacts. Results were analyzed by patient and by coronary segment (990) using the American Heart Association 15-segment model.

RESULTS
Lower heart rates were associated with improved image quality. Computed tomography correctly identified 35 of 37 (95%) patients without significant stenosis and 28 of 29 (97%) patients with significant stenosis on CCA. Computed tomography correctly assessed 68 of 94 (72%) significant stenosis. Overall, accuracy, sensitivity, specificity, positive predictive value, and negative predictive value of 64-slice CT for identifying CAD by patient was 95%, 97%, 95%, 97%, and 97%, respectively, and by segment was 97%, 97%, 90%, 91%, and 97%, respectively.

CONCLUSIONS
In a routine clinical practice, 64-slice CT detects with excellent accuracy a significant CAD in patients with complete LBBB. A normal CT in this clinical setting is a robust tool to act as a filter and avoid invasive diagnostic procedures. (J Am Coll Cardiol 2006;48:1929-34) © 2006 by the American College of Cardiology Foundation
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**BACKGROUND**
Left bundle branch block increases risk of cardiac mortality, and prognosis is primarily determined by the underlying coronary disease. Non-invasive stress tests have limited performance, and conventional coronary angiography (CCA) is usually required.

**METHODS**
Sixty-six consecutive patients with complete LBBB and sinus rhythm admitted for CCA were enrolled. Computed tomography was performed 3 ± 3.9 days before CCA. The accuracy of CTA was compared with that of CCA by two experienced radiologists. A 2-mm coronary stenosis was considered significant.

**RESULTS**
97% sensitivity (28/29); 95% specificity (35/37)

coronary segment (990) using the American Heart Association 15-segment model.

Lower heart rates were associated with improved image quality. Computed tomography correctly identified 35 of 37 (95%) patients without significant stenosis and 28 of 29 (97%) patients with significant stenosis on CCA. Computed tomography correctly assessed 68 of 94 (72%) significant stenosis. Overall, accuracy, sensitivity, specificity, positive predictive value, and negative predictive value of 64-slice CT for identifying CAD by patient was 95%, 97%, 95%, 96%, and 93%, respectively, and by segment was 97%, 79%, 99%, 97%, 91%, and 97%, respectively.

**CONCLUSIONS**
In a routine clinical practice, 64 slice CT detects with excellent accuracy a significant CAD patients with complete LBBB. A normal CT in this clinical setting is a robust tool to act as a filter and avoid invasive diagnostic procedures. (J Am Coll Cardiol 2006;48:1929–34) © 2006 by the American College of Cardiology Foundation

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**Pre-test likelihood of CAD**

- **Low (< 15%)**
- **Intermediate (15%-85%)**
- **High (>85%)**

**Symptomatic**

- **CTA**

**NL**

- **ABNL*”

- ***Critical stenosis**

**1° Prevention**

**2° Prevention**

**Catheterization +/- Revasc.**
SAGMAN 67 M #3311-1670

Reason for test: atypical chest pain
Risk factors: hypertension, ↑cholesterol
Medications: statin, beta blocker
Resting ECG: RBBB

SAGMAN 67 M #3311-1670

CCTA: LAD prox: nondiagnostic (calcium), D1 and D2 50-69%, CCS 1212, LVEF 64%, HR 57

LM/LAD/LCX  LAD  RCA
Which of the following would be appropriate?

1. Invasive coronary angiography
2. Stress ECG
3. Myocardial perfusion imaging
4. Stress echo
5. Coronary CTA
Reason for test: uninterpretable coronary CTA

Results of exercise:
- Duration: 8:30
- HR reserve: 89%
- HR: 144 (94% MPHR)
- BP: 162/102 → 170/94
- Clinical response: nonischemic
- ECG response: nonischemic
50-69% LAD Stenoses with Normal SPECT-MPI

Tamarappoo, et al JNC 2010

50-69% First Diagonal Stenosis with Ischemia on SPECT-MPI

Tamarappoo, et al JNC 2010
CCTA Stenosis Severity by CCTA vs Prevalence of ischemia by SPECT-MPI

Tamarappoo, et al JNC 2010

Pre-test likelihood of CAD

Low (<15%)  Intermediate (15%-85%)  High (>85%)

Symptomatic

CTA

NL  ABNL*

*No critical stenosis

1° Prevention  2° Prevention  Catheterization +/- Revasc.
Pre-test likelihood of CAD

- Low (< 15%)
- Intermediate (15%-85%)
- High (>85%)

Symptomatic

- CTA

- NL
- ABNL*
- Equiv

*No critical stenosis

Patient Management Following Coronary CT Angiography

- “negative” study: clear
  - No plaque: assurance
  - Non-obstructive plaque: prevention
- “positive” or uninterpretable study: not clear
Need for Ischemia Testing after CCTA
Most Common Circumstances

- Borderline stenosis (50-69%)
- Non-diagnostic CCTA
  - Dense coronary calcium
  - Other artifact (motion, arrhythmia)
- Myocardial bridge
- Anomalous coronary artery
**Pre-test likelihood of CAD**

- **Low (< 15%)**
  - Symptomatic
    - CTA
  - Asymptomatic Prevention
- **Intermediate (15%-85%)**
  - Symptomatic
    - Stress SPECT/PET
  - Equiv
- **High (>85%)**
  - Symptomatic
  - ABNL*
  - Equiv
  - Equiv
  - *No critical stenosis
  - 1º Prevention
  - 2º Prevention
  - Catheterization +/- Revasc.

---

**Nuclear Cardiology and Cardiac CT**

- Asymptomatic Prevention
- Symptomatic Diagnosis
- Known disease Intervention
Coronary CTA is not useful in many settings

<table>
<thead>
<tr>
<th>Condition</th>
<th>CCTA</th>
<th>MPI</th>
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<tbody>
<tr>
<td>High CAC</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>Renal failure</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>Prior MI</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>Arrhythmia</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>Stents &lt;3 mm</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>Obese</td>
<td>-</td>
<td>+</td>
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</table>

SPECT: Risk Increases as a Function of Stress Perfusion Abnormality

- Men and women
- Sx and Asx
- Diabetics
- Obese
- Renal Failure
- Arrhythmia
- Elderly
- Known CAD
  - MI
  - PCI
  - CABG

Data from over 50,000 patients

*Risk* adjusted or unadjusted

Guidelines for Clinical Use of Cardiac Radionuclide Imaging 2003
**Adjusted† Risk of Cardiac Death vs MPS ischemia**

Revascularization vs Medical Rx

†Adjusted for predictors of revascularization as well as clinical, hx, stress SPECT data

* Adjusted Risk of Cardiac Death vs EF and Ischemia

Revascularization vs Medical Rx


Hachamovitch, et al

* Revascularization: All levels of ischemia

Medical Rx: % ischemic

0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%

Gated SPECT EF

⇒ change in risk with revasc

p<0.001
Ischemia on MPI Predicts Benefit from Revascularization

- Elderly  
  Circulation 2010
- Prior revascularization  
  EHJ 2010
- Prior MI  
  EHJ 2011

Hachamovitch, et al.
**Underestimation of the Extent of CAD by SPECT MPI**

101 consecutive stress MPS pts with LM CAD (≥50% stenosis)  

Berman et al, J Nucl Cardiol 2007:14:521-8

**Myocardial Perfusion SPECT**

**Role in Guiding Patient Management**

**Limitations**

- Cannot detect early atherosclerosis
- May underestimate extent of ischemia/CAD

CAC scanning and ancillary high risk findings help identify high risk patient
RJ 75 F ATA/SOB, DM, no walk adenosine

<table>
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<th>SHORT AXIS</th>
<th>HORIZONTAL LONG AXIS</th>
<th>VERTICAL LONG AXIS</th>
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<td>APICAL</td>
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</table>

CAC 1463 (97th %)
Pre-test likelihood of CAD

Low (< 15%)  Intermediate (15%-85%)  High (>85%)

Stress SPECT/PET

1° Prevention  2° Prevention  Catheterization +/- Revasc.

Pre-test likelihood of CAD

Low (< 15%)  Intermediate (15%-85%)  High (>85%)

Stress SPECT/PET

No/minimal ischemia (<5%)**  Mild-Moderate ischemia (5-10%)  Extensive ischemia (>10%)

1° Prevention  2° Prevention  Catheterization +/- Revasc.
Pre-test likelihood of CAD

Low (< 15%)
Intermediate (15%-85%)
High (>85%)

Stress SPECT/PET

No/minimal ischemia (<5%)
Mild-Moderate ischemia (5-10%)
Extensive ischemia (>10%)

1° Prevention
2° Prevention
Catheterization +/- Revasc.

ancillary high risk markers?
ISCHEMIA Trial

International Study of Comparative Health Effectiveness with Medical and Invasive Approaches

Study Chair: Judith Hochman
Principal Investigator: David Maron

Sponsor: NHLBI; Submitted: February 2010

[Diagram

ISCHEMIA Trial

>10% Ischemia*
LVEF ≥35%

Blinded CCTA to R/0 LM, NCA

RANDOMIZE

8,000 stable CAD patients
3-6 yr. F/U

Cath (Revasc+ OMT)
3-6 yr. F/U

No Cath (OMT)

*SPECT, PET, echo, CMR
Core lab verification
Selection of Imaging Tests in Evaluation of Symptomatic Patients with Suspected CAD

Pre-test likelihood of CAD

- Low
- Low- to High-Intermediate (15-85%)
- Intermediate to High (50-100%)

- CAC
- CTA
- Stress SPECT/PET

Noninvasive Imaging for CAD
Suspected CAD

Pre-test likelihood of CAD

- Intermediate to High (50-100%)

- CAC + Ischemia Testing
Noninvasive Imaging for CAD
Known CAD
Need to consider revascularization

• Extensive data supports:
  • the extent of ischemic myocardium (stress)
  • the extent of dysfunctional but viable myocardium
    (SPECT, echo, PET, CMR)

• Little data supports the application of coronary CTA in this setting
Noninvasive Imaging for CAD
Known CAD
Need to consider revascularization

- Extensive data supports:
  - the extent of ischemic myocardium (stress)
  - the extent of dysfunctional but viable myocardium (SPECT, echo, PET, CMR)

- Little data supports the application of coronary CTA in this setting

Thank you very much
Which of the following would be appropriate?:

1. Invasive coronary angiography
2. Coronary CTA
3. Stress echo
4. No testing
SWIMIC  58 M  #3021-1618

CCTA: LAD, LCX & RCA <25%, LA enlargement, LVEF 76%, CCS 154, HR 68
DAMJAC  64 y/o M

- Sx: atypical chest pain
- Risk Factors: DM, BP, cholesterol
- Rest ECG: non-specific ST-T wave abnl.
- Rb-82 PET requested
Which of the following would be appropriate?:

1. Invasive coronary angiography
2. Coronary CTA
3. Stress echo
4. No testing
**DAMJAC (Rb-PET 4/2/2010)**

**CONCLUSION:**
- **Clinical response:** Nondiagnostic
- **ECG response:** Nondiagnostic (ST-T)
- **Perfusion:** Borderline (Reversible)
- **Function:** Normal

Likelihood of angiographically significant coronary artery disease: intermediate (30-69%).

*diagonal* is a small reversible defect in the anterior wall.

There is borderline transient ischemic dilation (TID) of the left ventricle which suggests more ischemia than is demonstrated by analysis of perfusion defect size. The calcium of score of zero, however, lowers the likelihood that the above is a significant finding. If clinically indicated and renal function is normal, additional testing with coronary CT angiography may be helpful to further evaluate the likelihood of disease and guide patient management.

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**DAMJAC (CCTA 4/5/2010)**

[Diagrams showing coronary anatomy]
FINDINGS:

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<th>Vessels</th>
<th>Proximal</th>
<th>Mid</th>
<th>Distal</th>
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<tr>
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<tr>
<td>PDA</td>
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Additional findings: Right pulmonary vein has common ostium (upper and middle). Possible small bilateral pleural effusions. Atelectasis and scarring at left base.

IMPRESSION:

- Minimal coronary calcification: 0.5, 19th percentile
- Coronary artery calcification: none
- Moderate left ventricular concentric hypertrophy
Teaching Point
CCTA after Equivocal or Discordant Stress MPI results

- When clinical uncertainty exists after MPI in patients without known CAD, coronary CTA can be used to effectively triage re: invasive coronary angiography
HUDPET 55 M

- SOB
- Cholesterol, FH early CAD
- Rest ECG: LBBB
- Referred for SPECT MPI
  - No walk adenosine
Which of the following would be appropriate?:

1. Invasive coronary angiography
2. Coronary CTA
3. Stress echo
4. No testing
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HUDPET 55 M #3321-1784

CCTA: normal coronary arteries, CCS 6, HR 63, LVEF 55%
RR, a 66y old male with A1A; LBBB No CAD risk factors

Cath done 2 days later…
RR, a 66y old male
Proximal and mid LAD severe stenosis

Non-Invasive Detection of Coronary Artery Disease in Patients with Left Bundle Branch Block using 64-Slice Computed Tomography

| OBJECTIVES | The goal of this study was to evaluate the diagnostic accuracy of 64-slice computed tomography (CT) to identify coronary artery disease (CAD) in patients with complete left bundle branch block (LBBB). |
| BACKGROUND | Left bundle branch block increases risk of cardiac mortality, and prognosis is primarily determined by the underlying coronary disease. Non-invasive stress tests have limited performance, and conventional coronary angiography (CCA) is usually required. Sixty-six consecutive patients with complete LBBB and sinus rhythm admitted for CCA were enrolled. Computed tomography was performed 3 ± 3.9 days before CCA. The accuracy of 64-slice CT to detect significant stenosis (>50% lumen narrowing) was compared with quantitative coronary angiography. All segments were analyzed regardless of image quality from coronary calcification or motion artifacts. Results were analyzed by patient and by coronary segment (990) using the American Heart Association 15-segment model. |
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| RESULTS | In a routine clinical practice, 64 slice CT detects with excellent accuracy a significant CAD in patients with complete LBBB. A normal CT in this clinical setting is a robust tool to act as a filter and avoid invasive diagnostic procedures. (J Am Coll Cardiol 2006;48:1929–34) © 2006 by the American College of Cardiology Foundation |

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**METHODS**
Sixty-six consecutive patients with complete LBBB and sinus rhythm admitted for CCA were enrolled. Computed tomography was performed 3 ± 3.9 days before CCA. The accuracy of computed tomography was assessed with 97% sensitivity (28 of 29) and 95% specificity (35 of 37).

**RESULTS**
97% sensitivity (28/29); 95% specificity (35/37)

**CONCLUSIONS**
In a routine clinical practice, 64 slice CT detects with excellent accuracy a significant CAD in patients with complete LBBB. A normal CT in this clinical setting is a robust tool to act as a filter and avoid invasive diagnostic procedures. (J Am Coll Cardiol 2006;48:1929–34) © 2006 by the American College of Cardiology Foundation

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**ROSROB  66 yo M**

- Atypical angina recent onset
- Risk factors: hypertension, diabetes (oral agents)
- Rest ECG: LBBB
- Referred for SPECT MPI
  - No walk adenosine
RR, a 66y old male

ROSROB (SPECT 8/10/2009)
Which of the following would be appropriate?:

1. Invasive coronary angiography
2. Coronary CTA
3. Stress echo
4. No testing

Which of the following would be appropriate?:

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2. **Coronary CTA**
3. Stress echo
4. No testing
Sx and Reason for test: typical chest pain
Hx: no known CAD
Risk factors: none
Resting ECG: Normal
Results of exercise:
  Duration: 7:30  HR reserve: 94%
  HR: 162 (96% MPHR)  BP: 135/70 → 190/70
  Clinical response: nonischemic
  ECG response: ischemic (-2.1 mm H V5,
                  -2.4 mm H III, -2.5 mm H AVF)
MAYCAR 51 F  #3211-1651

CCTA: normal

LAD  LCX  RCA
Comparison of observed Ob-CAD prevalence in MEN to probabilities based on DFC and CASS

Victor Cheng, Circulation 2011
ZAITAS  64 M   #3421-1619

Sx and Reason for test: shortness of breath and atypical chest pain
Hx: Prior MI (1992)
Risk factors: BP
Resting ECG: nonspecific T wave abnormalities

Which of the following would be appropriate?:

1. Stress MPI
2. Coronary CTA
3. Stress echo
4. No testing
Which of the following would be appropriate?:

1. Stress MPI
2. Coronary CTA
3. Stress echo
4. No testing

Results of adenosine stress:
- HR: 63 → 83  HR ratio = 1.32
- BP: not achieved
- Clinical response: non-ischemic
- ECG response: ischemic (-1.3 mm Hg II)
CCTA: LAD 70-89% mid, RCA 100% mid, CCS 965, LVEF 53%, HR 73
Nuclear Cardiology and Cardiac CT
Complementary Roles
Known CAD/CHF

• Little data supports the application of coronary CTA in this setting

• Extensive data supports SPECT/PET:
  • the extent of ischemic myocardium (stress)
  • the extent of dysfunctional but viable myocardium
  • MIBG
Teaching Point
“Complementary Tests”

- When the first test is definitive and matches the clinical setting, the second test is generally not justified.

Nuclear Cardiology and Cardiac CT
Complementary Roles

Asymptomatic (imaging for prevention)
- Coronary calcium scanning

Symptomatic (imaging for diagnosis/intervention)
- Selection of Initial Test Depends on CAD Likelihood
  Limiting symptoms: Direct catheterization
  Lower likelihood: favors CTA first
  Higher likelihood: favors ischemia testing first

Indications for Sequential Imaging
  initial test + clinical evaluation not definitive
• Thank you
HUDPET 55 M

- SOB
- Cholesterol, FH early CAD
- Rest ECG: LBBB
- Referred for SPECT MPI
  - No walk adenosine

Hudpet 51 M
Hudpet 51 M

CCTA: normal coronary arteries, CCS 6, HR 63, LVEF 55%

HUDPET 55 M #3321-1784
Which of the following would be appropriate?:

1. Invasive coronary angiography
2. Coronary CTA
3. Stress echo
4. No testing
RR, a 66y old male

Cath done 2 days later…
RR, a 66y old male
Proximal and mid LAD severe stenosis

Non-Invasive Detection of Coronary Artery Disease in Patients with Left Bundle Branch Block using 64-Slice Computed Tomography

OBJECTIVES
The goal of this study was to evaluate the diagnostic accuracy of 64-slice computed tomography (CT) to identify coronary artery disease (CAD) in patients with complete left bundle branch block (LBBB).

BACKGROUND
Left bundle branch block increases risk of cardiac mortality, and prognosis is primarily determined by the underlying coronary disease. Non-invasive stress tests have limited performance, and conventional coronary angiography (CCA) is usually required.

METHODS
Sixty-six consecutive patients with complete LBBB and sinus rhythm admitted for CCA were enrolled. Computed tomography was performed 3 ± 3.9 days before CCA. The accuracy of 64-slice CT to detect significant stenosis (>50% lumen narrowing) was compared with quantitative coronary angiography. All segments were analyzed regardless of image quality from coronary calcification or motion artifacts. Results were analyzed by patient and by coronary segment (990) using the American Heart Association 15-segment model.

RESULTS
Lower heart rates were associated with improved image quality. Computed tomography correctly identified 35 of 37 (95%) patients without significant stenosis and 28 of 29 (97%) patients with significant stenosis on CCA. Computed tomography correctly assessed 68 of 94 (72%) significant stenosis. Overall, accuracy, sensitivity, specificity, positive predictive value, and negative predictive value of 64-slice CT for identifying CAD by patient was 95%, 97%, 95%, 95%, and 97%, respectively, and by segment was 97%, 97%, 90%, 91%, and 97%, respectively.

CONCLUSIONS
In a routine clinical practice, 64 slice CT detects with excellent accuracy a significant CAD in patients with complete LBBB. A normal CT in this clinical setting is a robust tool to act as a filter and avoid invasive diagnostic procedures. (J Am Coll Cardiol 2006;48:1929-34) © 2006 by the American College of Cardiology Foundation

Ghostine et al. JACC Vo.44, No. 10. 2006:1929-34
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Spectrum of CAD

Risk Factors  Symptoms  Known Disease

CTA

NL  ABNL*

*Critical stenosis

1° Prevention  2° Prevention  Catheterization +/- Revasc.
Spectrum of CAD

Risk Factors → Symptoms → Known Disease

CTA → Ischemia Testing

NL → ABNL* → Equiv

*No critical stenosis

1° Prevention → 2° Prevention → Catheterization +/- Revasc.

SAGMAN 67 M 10/2/07 #3311-1670

Atypical chest pain; hypertension; cholesterol
Medications: Statin, beta blocker

LM/LAD/LCX  LAD  RCA
Predictive Value by Five Studies for CTA to Detect Ischemia with MPI Perfusion

Hachamovitch et al. JNC 2007;14:634-44
Relationship between Stenosis Severity by CCTA and Ischemia on SPECT MPI

Tamarappoo et al, J Nucl Card 2010;17:791-802

Symptomatic patient

Need for Ischemia Testing after CCTA
Most Common Circumstances

- Borderline stenosis (50-69%)
- Non-diagnostic CCTA
  - Dense coronary calcium
  - Other artifact (motion, arrhythmia)
- Myocardial bridge
- Anomalous coronary artery
Spectrum of CAD

Risk Factors  Symptoms  Known Disease

Limiting symptoms

1° Prevention  2° Prevention  Catheterization +/- Revasc.

SPECT: Risk Increases as a Function of Stress Perfusion Abnormality

- Men and women
- Sx and Asx
- Diabetics
- Obese
- Renal Failure
- Arrhythmia
- Elderly
- Known CAD
  - MI
  - PCI
  - CABG

Data from over 50,000 patients

*Adjusted or unadjusted

Guidelines for Clinical Use of Cardiac Radionuclide Imaging 2003
**Ischemic on SPECT-MPI Predicts Benefit**

Revascularization vs Medical Rx

†Adjusted for predictors of revascularization as well as clinical, hx, stress SPECT data

*log Hazard Ratio CD*


**Therapeutic Benefit among Patients with <10% Myo Fixed**

n = 11,880
FU 8.7±3.3 yrs

[Hachamovitch et al. EHJ 2011]
Ischemia on MPI Predicts Benefit from Revascularization

- Elderly
- Prior revascularization
- Prior MI

Circulation 2010
EHJ 2011
EHJ 2011

Hachamovitch, et al

Spectrum of CAD

Risk Factors  Symptoms  Known Disease

Ischemia Testing

No/minimal ischemia (<5%)**
Mild-Moderate ischemia (5-10%)
Extensive ischemia (>10%)

1° Prevention  2° Prevention  Catheterization +/- Revasc.
ISCHEMIA Trial

International Study of Comparative Health Effectiveness with Medical and Invasive Approaches

Study Chair: Judith Hochman
Principal Investigator: David Maron

Sponsor: NHLBI; Submitted: February 2010

>10% Ischemia*
LVEF ≥35%

Blinded CCTA to R/0 LM, NCA

RANDOMIZE

Cath (Revasc+ OMT)  No Cath (OMT)

• 8,000 stable CAD patients
• 3-6 yr. F/U

• 3-6 yr. F/U

*SPECT, PET, echo, CMR
Core lab verification
Spectrum of CAD

Risk Factors  Symptoms  Known Disease

CTA/CCS  Ischemia Testing

Equivocal/Discordant  Mild-Moderate ischemia (5-10%)**  Extensive ischemia (>10%)

1° Prevention  2° Prevention  Catheterization +/- Revasc.

CCTA After Inconclusive Stress Testing:
To establish added Dx value of CCTA, and prognostic value for intermediate-term events

Inconclusive or non-diagnostic stress imaging tests (n=199)

- Obstructive CAD, but not stress test parameters, predictive of MACE
- MDs planned ICA in 125 (63.0%), but performed in only 32 (16%) after CCTA

CCTA

>2 yr f/u

No CAD (n=93)
No events

CAD
18 underwent TVR

Source: Abidov et al. JNC 2009
Utilization of Two Studies Covered by Medicare
Percent CCTA vs SPECT-MPI

• Overall: ~2.5%
• CSMC: ~5%

Still has not caught on!
Coronary CTA is not useful in many settings

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<thead>
<tr>
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<th>CCTA</th>
<th>MPI</th>
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<tr>
<td>High CAC</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>Renal failure</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>Prior MI</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>Arrhythmia</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>Stents &lt;3 mm</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>Obese</td>
<td>-</td>
<td>+</td>
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For the Symptomatic Patient, a Calcium Score and a Stress Test Could Be More Useful than a Coronary CT Angiogram

Pre-test likelihood of CAD

- Intermediate to High (50-100%)

- Stress SPECT/PET+CAC
Cardiac imaging in the symptomatic patient guides therapy

- Does the patient have ischemia?
  - Should beta blockers and nitrates be initiated?
  - Should revascularization be considered?
- Are aggressive preventive measures warranted?

Myocardial Perfusion SPECT/PET
Role in Guiding Patient Management

Limitations
- Relative quantitation
  - May miss highest risk disease (balanced reduction)
  - May underestimate extent of ischemia/CAD
- Cannot detect early atherosclerosis
Underestimation of the Extent of CAD by SPECT MPI

101 consecutive stress MPS pts with LM CAD (≥50% stenosis) Berman et al, J Nucl Cardiol 2007:14:521-8

Non-perfusion High Risk Variables on SPECT/PET MPI

- TID
- Increased lung uptake
- Increased RV uptake
- Stress-induced wall motion abnormality
- Fall in LVEF >5%
- Reduced EF (<40%)
Non-perfusion High Risk Variables on SPECT/PET MPI

- TID
- Increased lung uptake
- Increased RV uptake
- Stress-induced wall motion abnormality
- Fall in LVEF >5%
- Reduced EF (<40%)
- High CAC Score

Distribution of CAC Scores in Patients with Normal MPS and Patients with Ischemic MPS

- 1,119 normal MPS
- CAC score
- 76 ischemic MPS studies

Berman et al, JACC, 2004
EISNER Trial: Conclusions

• CAC scanning led to improved risk factor profile
  – greater reduction in systolic BP
  – LDL cholesterol
  – waist circumference
  – weight
• Degree of risk factor modification increased as CAC score increased

Rozanski, et al: J Am Coll Cardiol 2011

Adding CAC to MPI Changes Therapy

• 760 patients having normal Rb-82 PET/CT
• 48% non-zero CAC
• <50% on statins at baseline
• Changes after CAC
  • Any medication p<0.001
  • Statin p<0.001
  • Suggested OMT

Bybee et al JNC 2010
RJ 75 F ATA/SOB, DM, no walk adeno

CAC 1463 (97th %)

RJ 75 F ATA/SOB, DM, no walk adeno

CAC 1463 (97th %)
FO 60 M ATA/SOB, AF, HF, no walk adeno

<table>
<thead>
<tr>
<th>STRESS</th>
<th>REST</th>
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<td><img src="image2.png" alt="Image" /></td>
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CAC 0
Nuclear Cardiology and Cardiac CT

Symptomatic Patient with Suspected CAD

• Either CCTA or ischemic testing approaches are supported by data
• Coronary CTA: increasing role likely
• Ischemia testing: established; particularly useful in settings where CCTA likely to be nondiagnostic
• Ischemia testing + CAC when negative could become increasingly common

Nuclear Cardiology and Cardiac CT

• Asymptomatic Prevention
• Symptomatic Diagnosis
• Known disease Intervention
Nuclear Cardiology and Cardiac CT

- Asymptomatic Prevention
- Symptomatic Diagnosis
- Known disease Intervention
  - High likelihood/post cath/post MI
  - CHF/viability
  - Devices
    - Implantable cardiac defibrillator (ICD)
    - Cardiac Resynchronization therapy (CRT)
Increasing Benefit from Revascularization Is Associated with Increasing Amounts of Myocardial Hibernation (A Substudy of the PARR-2 Trial)

Effect of Revascularization or Medical Therapy

182 (of 207) pts (complete data) with LVEF <35% randomized to PET FU 1 yr for cardiac death, MI, or cardiac repeat hospital stay; ↑ creat ↓ EF also risk predictors

D’Egidio et al. ACCImaging 2009;2:1060-8
Nuclear Cardiology and Cardiac CT

- Asymptomatic Prevention
- Symptomatic Diagnosis
- Known disease Intervention
  - High likelihood/post cath/post MI
  - CHF/viability
  - Devices
    - Implantable cardiac defibrillator (ICD)
    - Cardiac Resynchronization therapy (CRT)

Noninvasive Imaging in CAD: Known Disease

Need to consider revascularization/devices

- Data support stress/viability imaging:
  - the extent of ischemic myocardium
  - the extent of dysfunctional but viable myocardium (SPECT, echo, PET, CMR)
- Less data supports the application of coronary CTA in this setting
Selection of Imaging Tests in Evaluation of Symptomatic Patients with Suspected CAD

Pre-test likelihood of CAD

- **Low**
  - Low-to High-Intermediate (15-85%)
  - Intermediate to High (50-100%)

- CAC
- CTA
- Stress SPECT/PET

Complementary test may be useful if initial test + clinical evaluation not definitive
AGHHAS 61 M #2300-7115

Atypical chest pain
No prior CAD
Risk factors: dyslipidemia, hypertension
ECG: normal
AGHHAS 61 M #2300-7115

Atypical chest pain, dyslipidemia, hypertension
CCTA: critical proximal LAD stenosis

Which of the following would be appropriate?

1. Invasive coronary angiography
2. Stress ECG
3. Myocardial perfusion imaging
4. Stress echo
Which of the following would be appropriate?

1. Invasive coronary angiography
2. Stress ECG
3. Myocardial perfusion imaging
4. Stress echo

AGHHAS  61 M    #2300-7115

CATH results
LAD: subtotal occluded

Disposition: stent to LAD
Selection of Imaging Tests in Evaluation of Symptomatic Patients with Suspected CAD

Pre-test likelihood of CAD

- Low
- Low-to High-Intermediate (15-85%)
- Intermediate to High (50-100%)

- CAC
- CTA
- Stress SPECT/PET