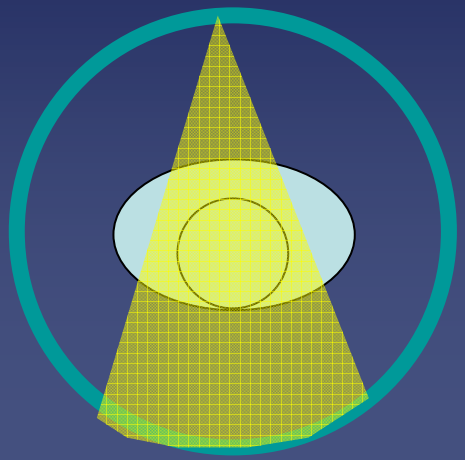
# CT and MR: Concepts & Application of These Complementary Techniques

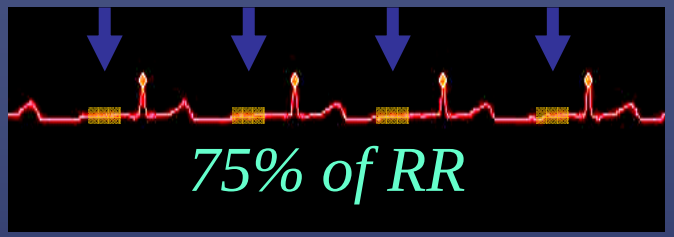
3rd Annual Imaging & Physiology Summit
November 20-21, 2009 Seoul, Korea

Wm. Guy Weigold, MD, FACC

Washington Hospital Center
Cardiovascular Research Institute
Washington, DC

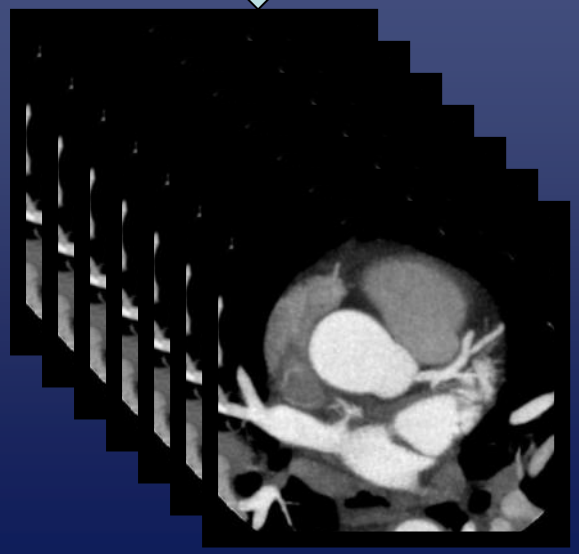
# Cardiac CT Technique: ECG-Gating



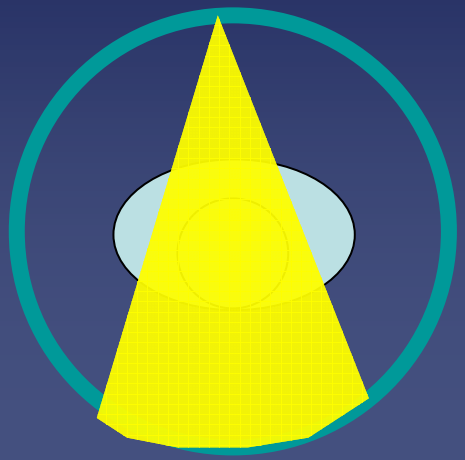


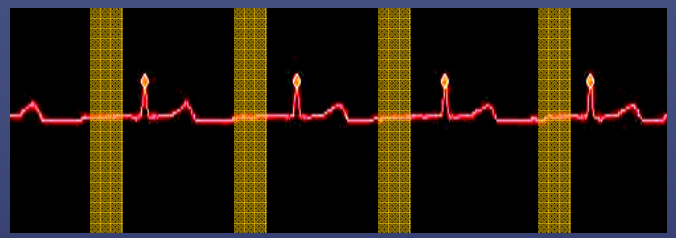

75% of RR

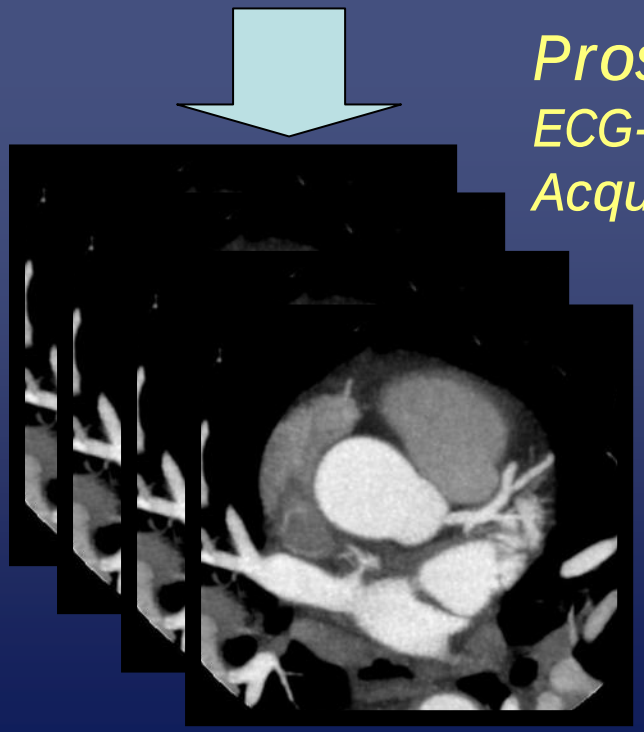
***Retrospective Reconstruction***



# Prospective Cardiac CT: X-Ray Tube Mostly Off

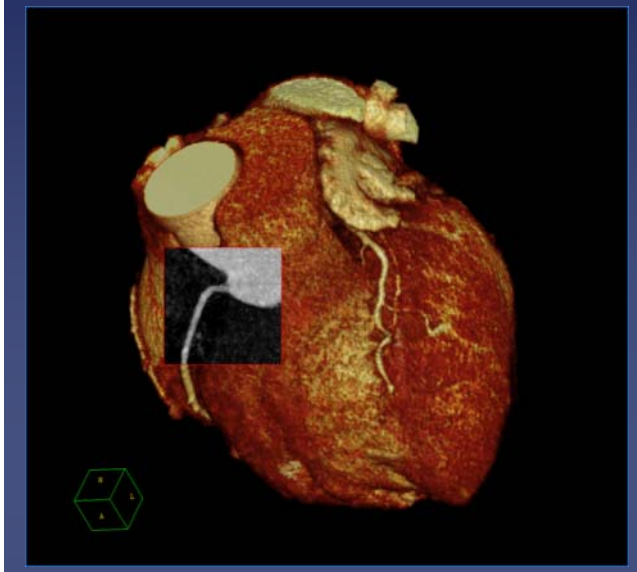






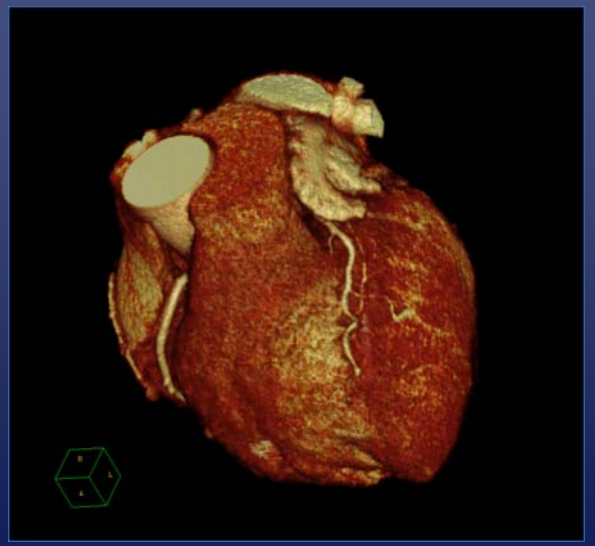
*Prospective*
*ECG-Triggered*
*Acquisition*

# Same Image Quality…Much Lower Radiation Exposure




2-4 mSv

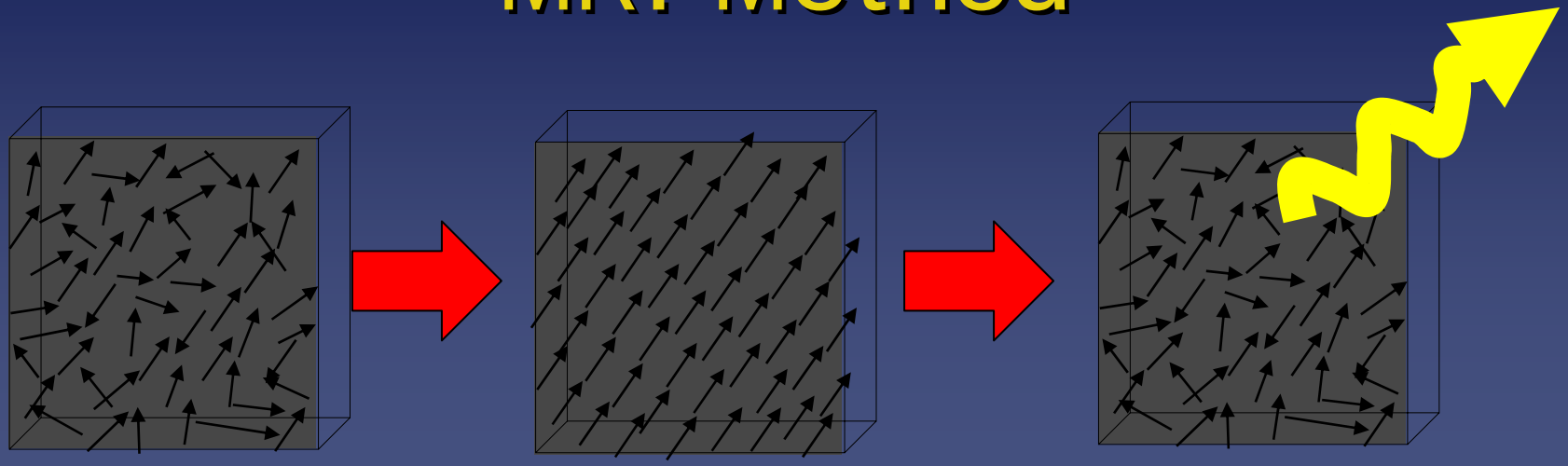
(lower than standard chest CT)

# General Pros and Cons of CT

- CCT Pros:
  - Fast: single 5-10 second acquisition
  - Excellent spatial resolution (0.4mm)
  - True volume acquisition & isotropic voxels
- CCT Cons:
  - Requires intravenous contrast
  - Radiation
  - “One-shot” (one-chance) acquisition

# MR: Method



- Uses magnetic dipole moment of protons
- Application of external magnetic field aligns axes of dipole moments of protons(longitudinal magnetization)
- An electromagnetic wave (radiofrequency pulse) forces the longitudinal magnetization of the protons into the x-y plane
- After the pulse, recovery of longitudinal magnetization, and decay of transverse magnetization, occurs

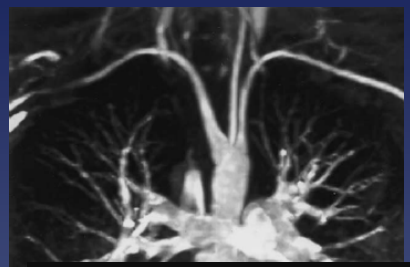
# General Pros and Cons of CMR

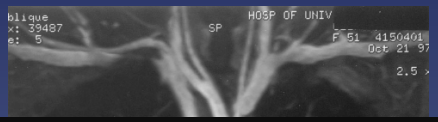
- CMR Pros:
  - (Usually) no significant contrast toxicity
  - No ionizing radiation
  - Can repeatedly reacquire data
  - Excellent tissue characterization
- CMR Cons:
  - Longer total acquisition time
  - Some patients claustrophobic
  - Metal implants
  - Typically not a volume acquisition

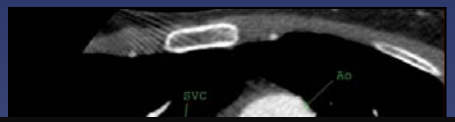
# Capabilities of Cardiac CT and MR

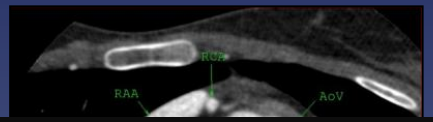
- General cardiovascular structures
  - Aorta (dissection, aneurysm)
  - Pulmonary arteries (PE) and veins
  - Heart chambers (enlargement, hypertrophy, masses) and pericardium
  - Congenital heart disease (cardiac chambers and great vessels)
- Myocardium
  - Ventricular contractility
  - Perfusion
  - Scar / Viability
- Coronary arteries (and veins)

# Congenital Heart Disease Imaging

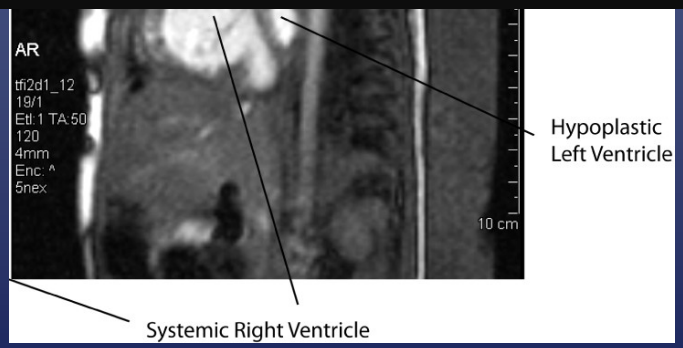


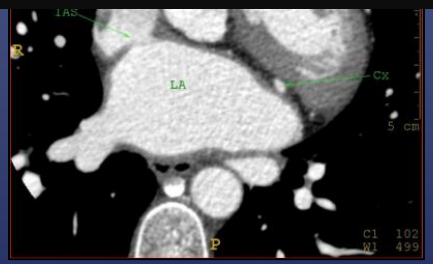



- Good results from either CT or MR
  - Flow quantification by MR
  - Simultaneous coronary anatomy from CT
  - Radiation concerns in pediatric population
  - ICD's a concern for MR



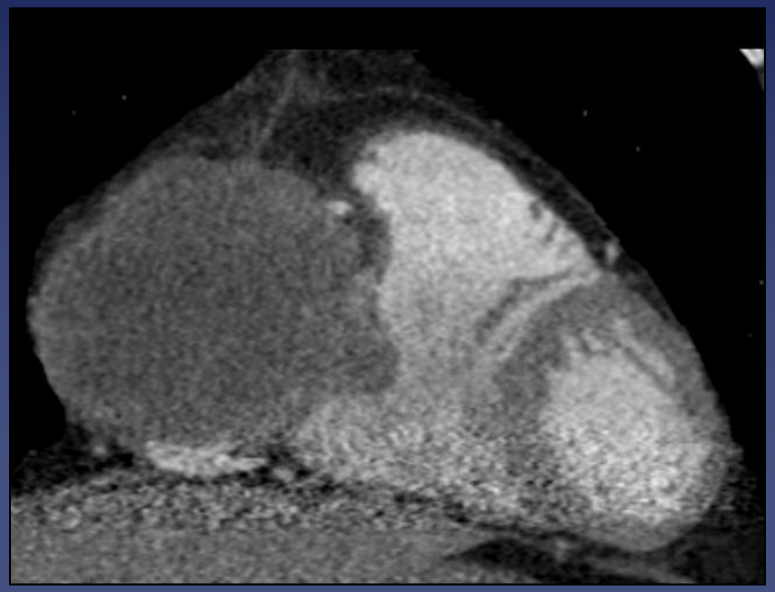


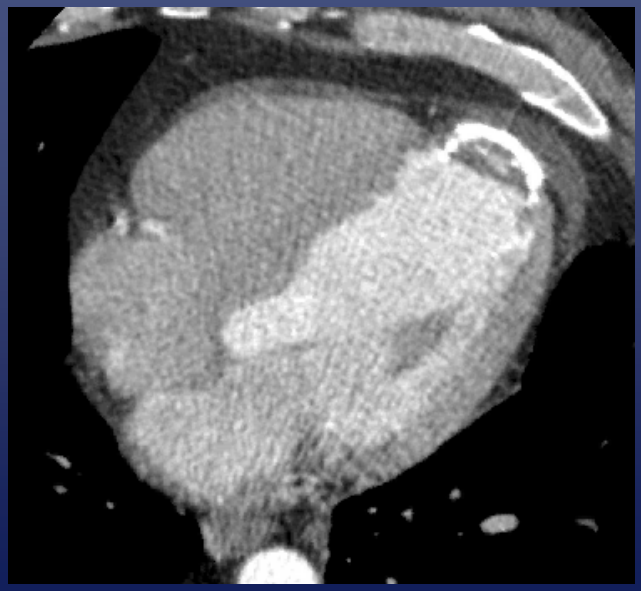
Greil GF et al JACC 2002;39:335-41

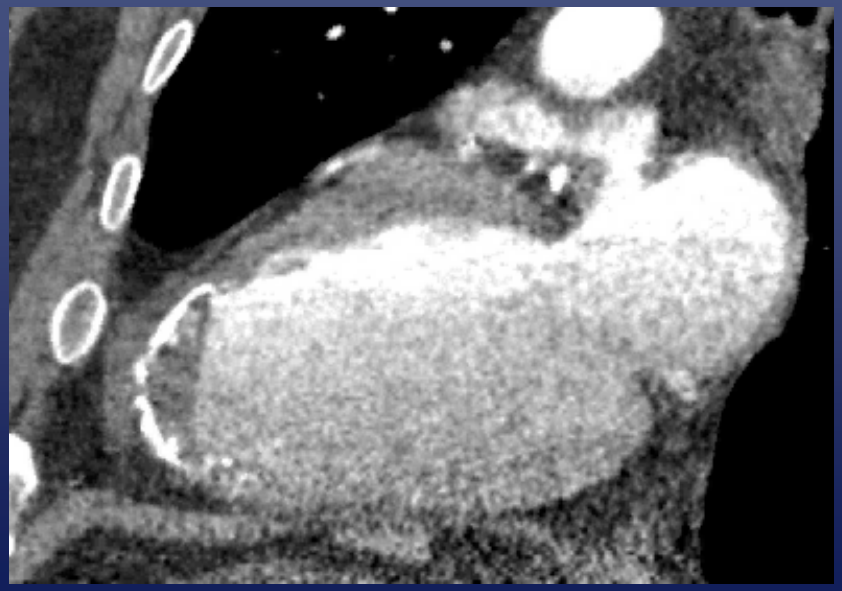
Greil GF et al JACC 2002;39:335-41

Lim DS...Kramer CM. JCMR 2008;10:34

# Intra-cardiac masses

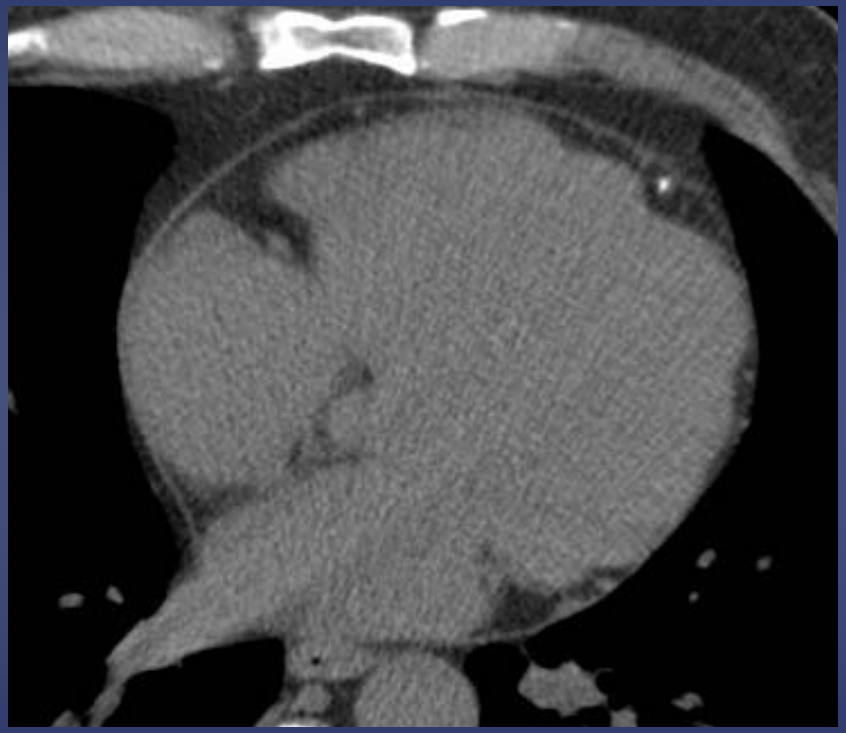


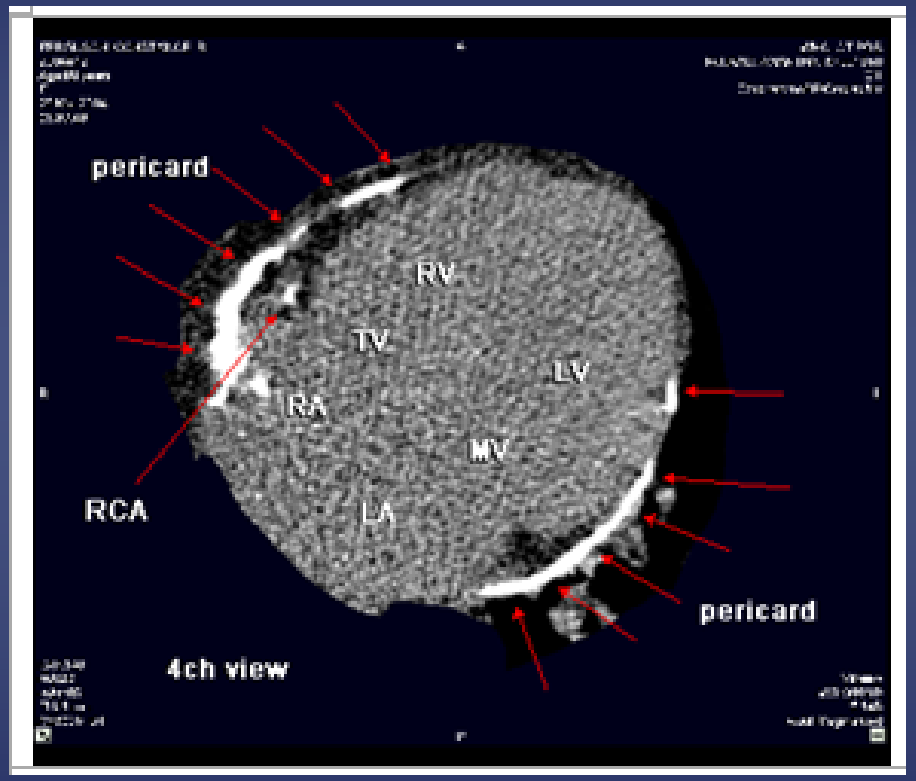




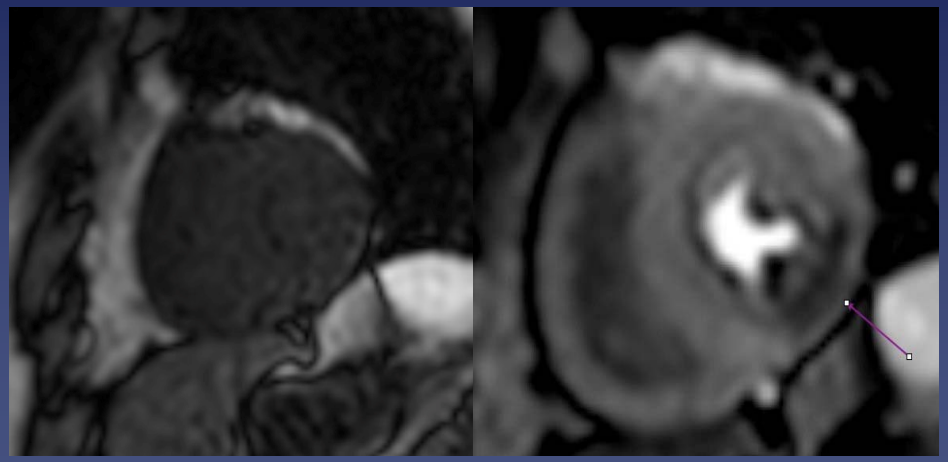
# Normal vs. Calcified (Constrictive) Pericardium

(contrast is not required)

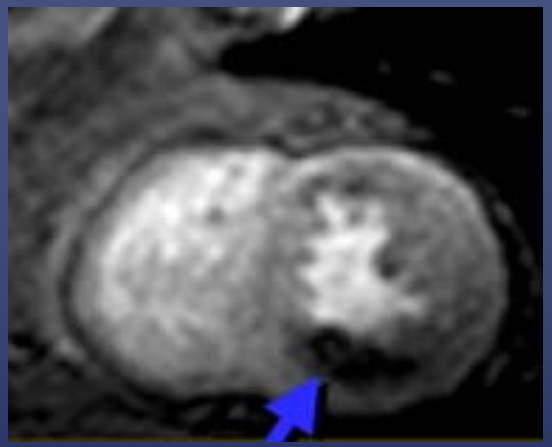




# Ischemia Detection: Adenosine Cardiac MR



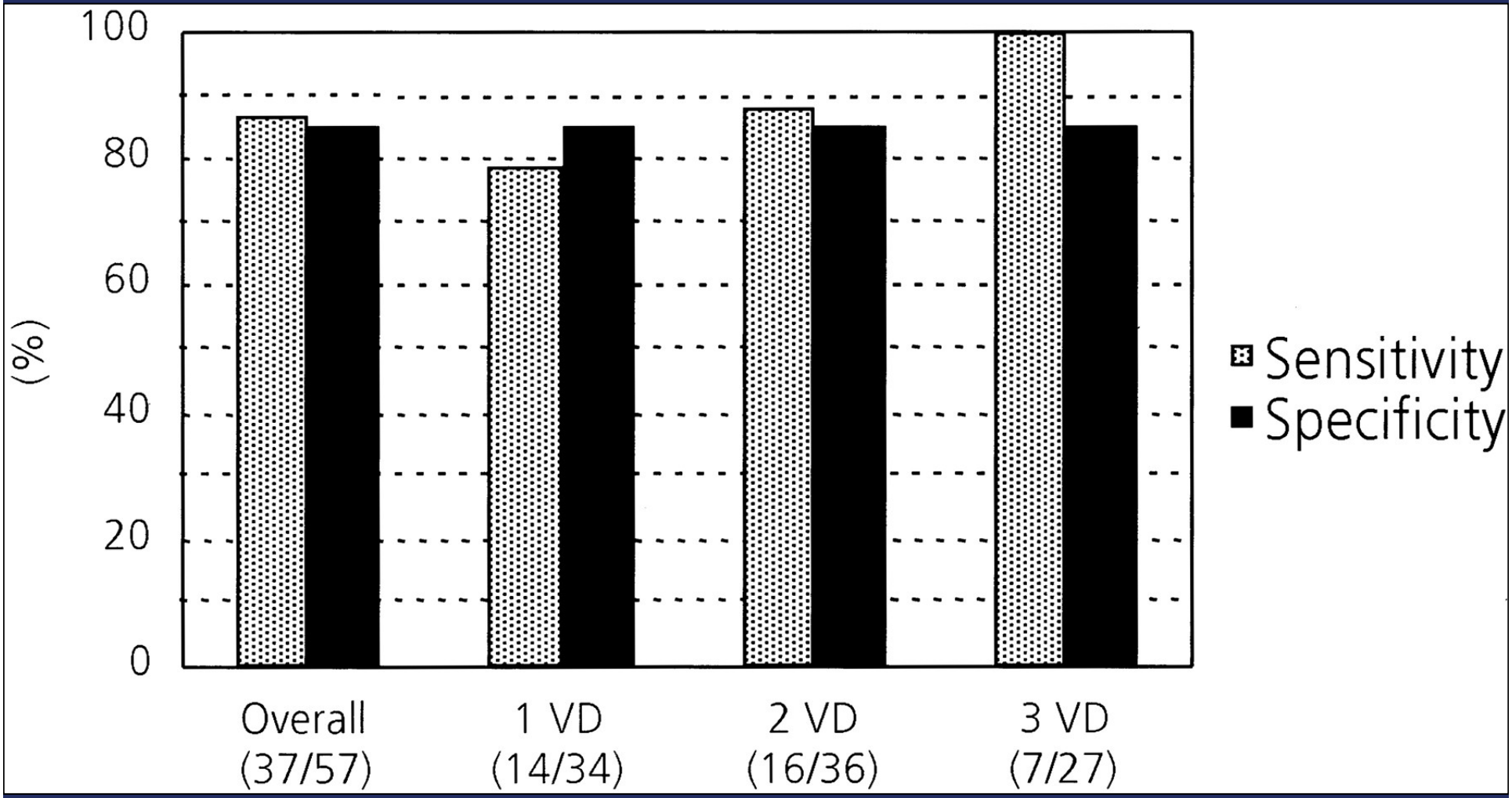
Inferolateral adenosine-induced perfusion defect



Small inferior inducible defect

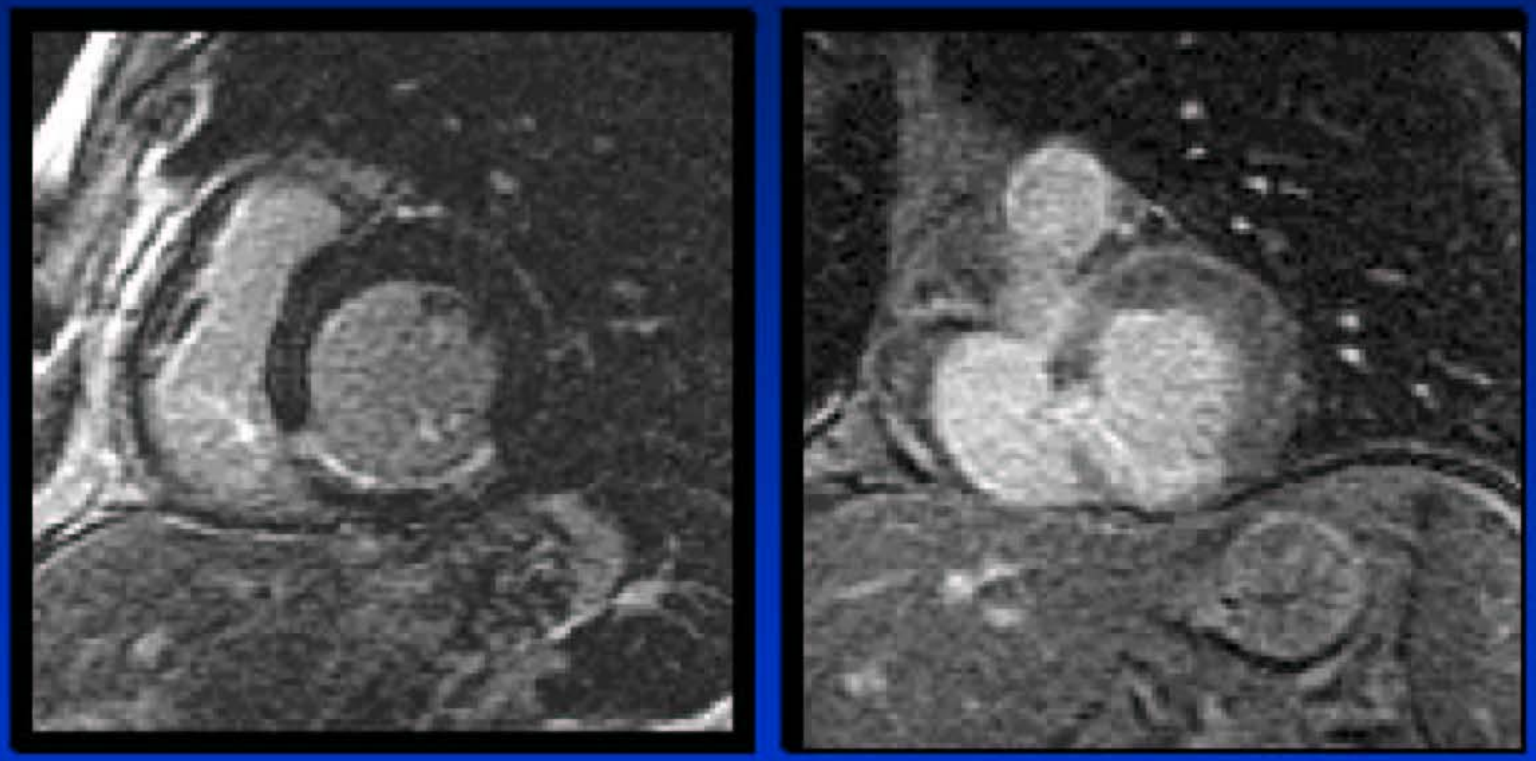
Large (multi-vessel) defect

# Sensitivity and Specificity of MR Perfusion to detect >50% stenosis by QCA.




Schwitter et al. Circulation 2001;103:2230-35

# Delayed Gd-DTPA enhanced MRI

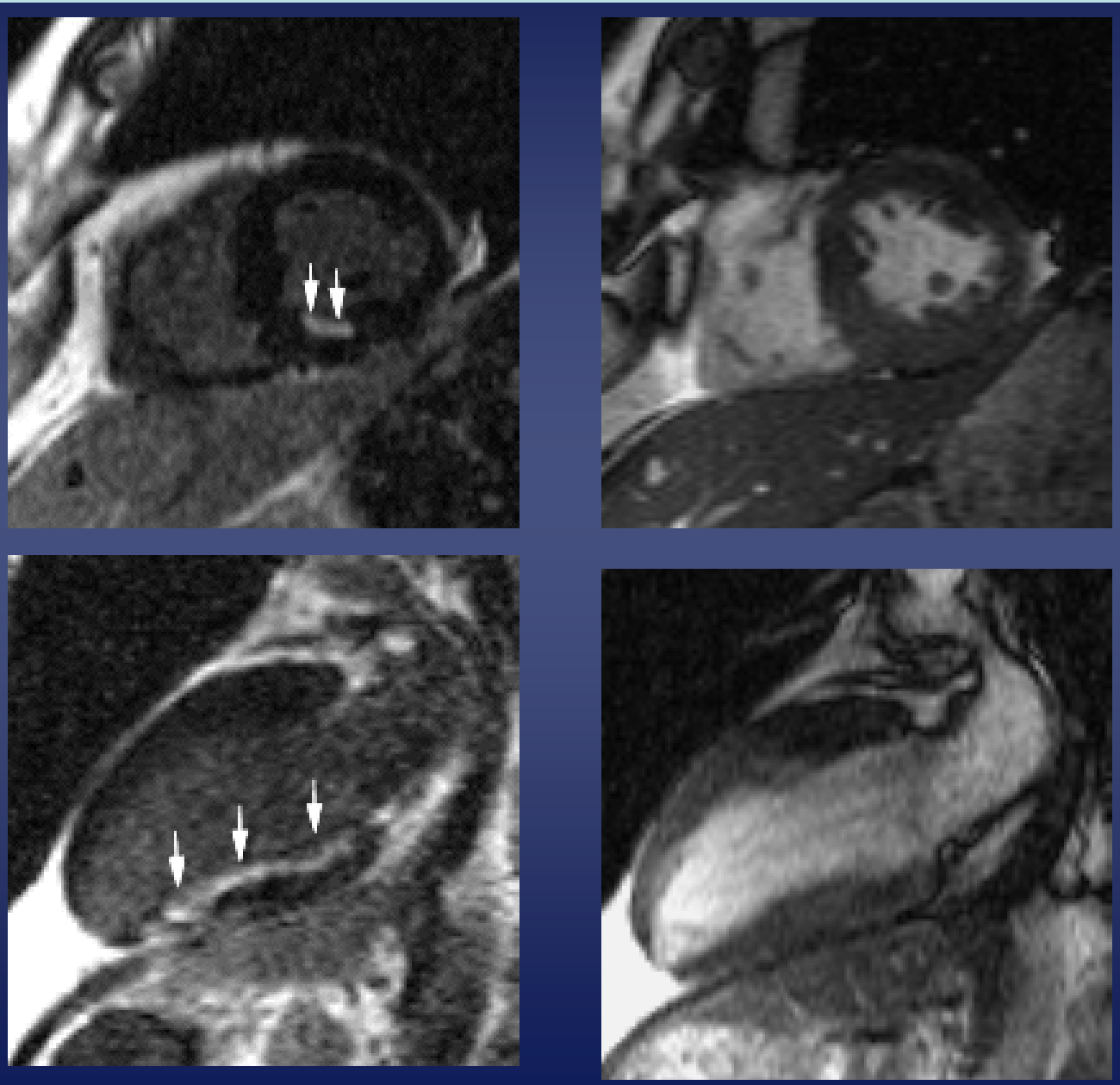


Non transmural

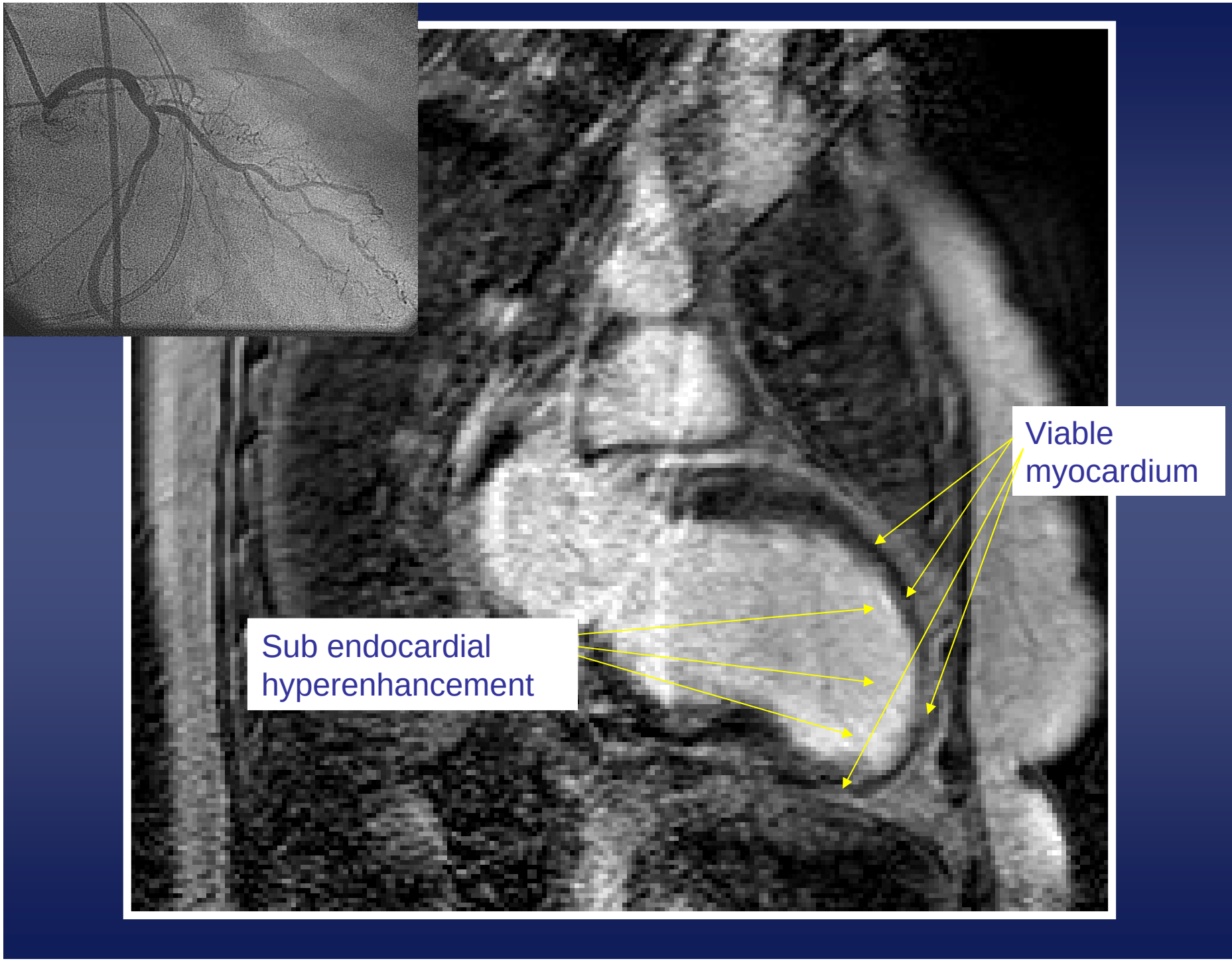
Transmural

Garot et al. JACC 2000;36:2339-2346

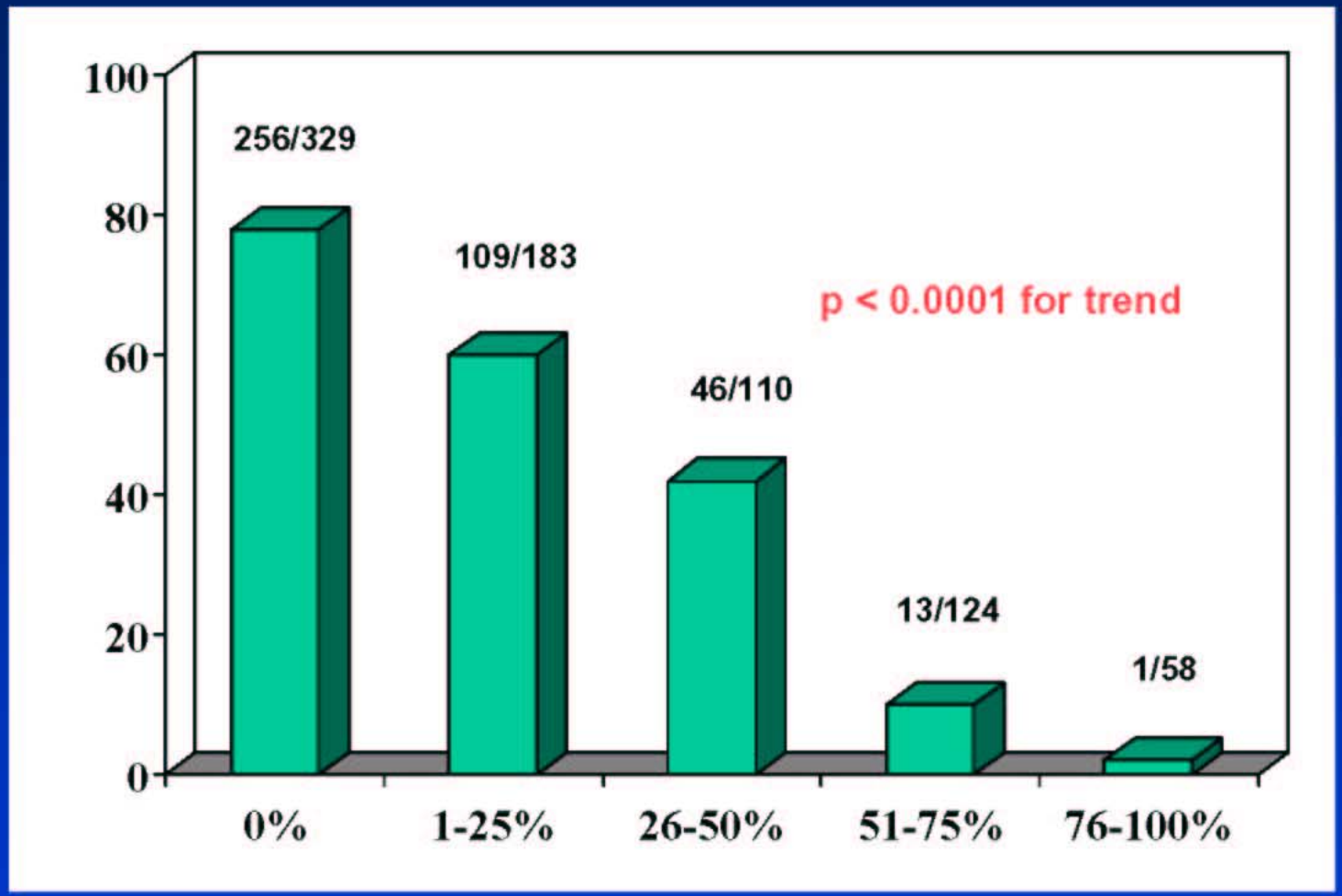
# Non-transmural Myocardial Infarct



http://dcmrc.mc.duke.edu/mahrholdt/fig1/.

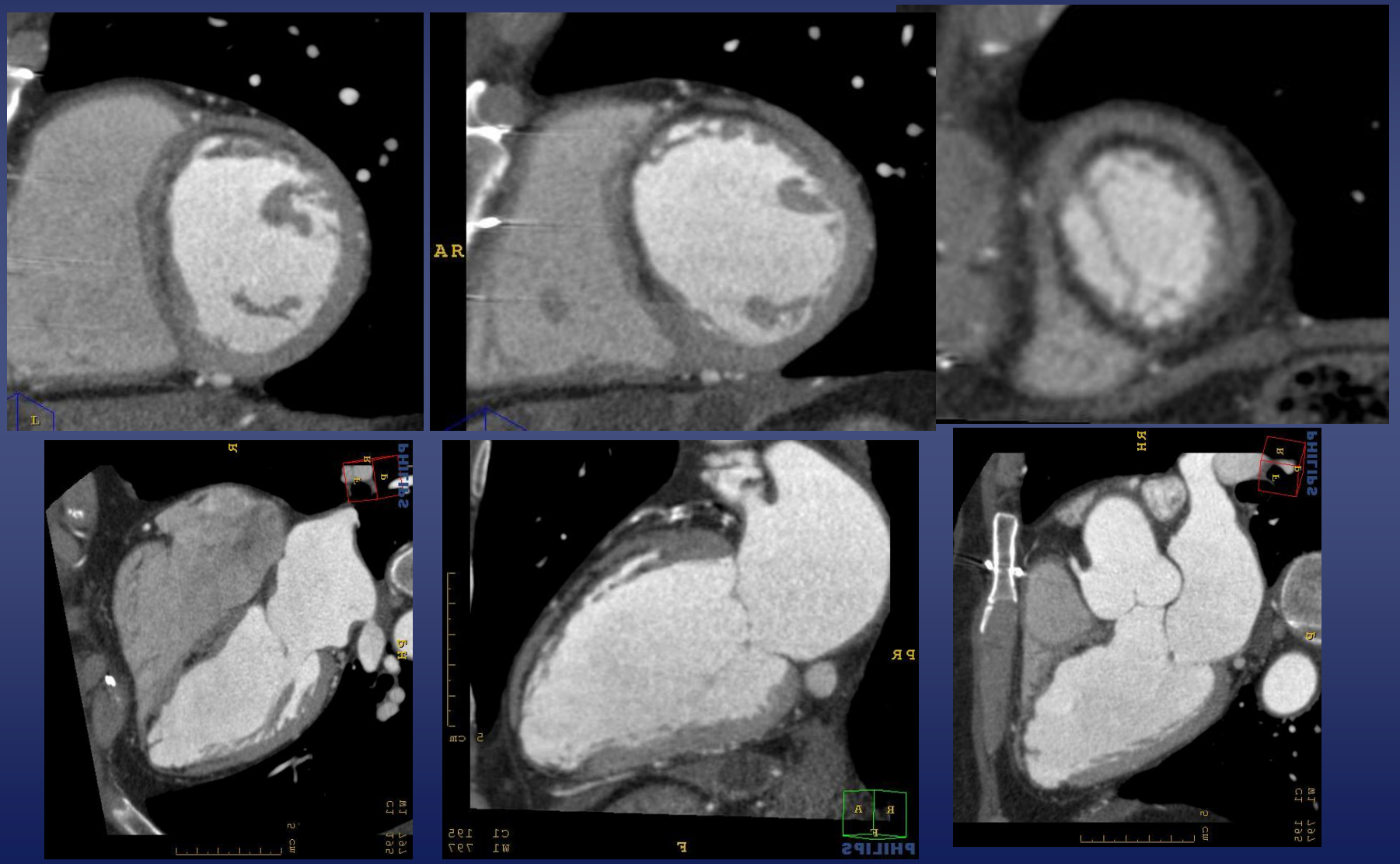

Viable
myocardium
Sub endocardial
hyperenhancement

# Prediction of Wall Motion Improvement




*Kim et al . NEJM 2000;343:1445-53*

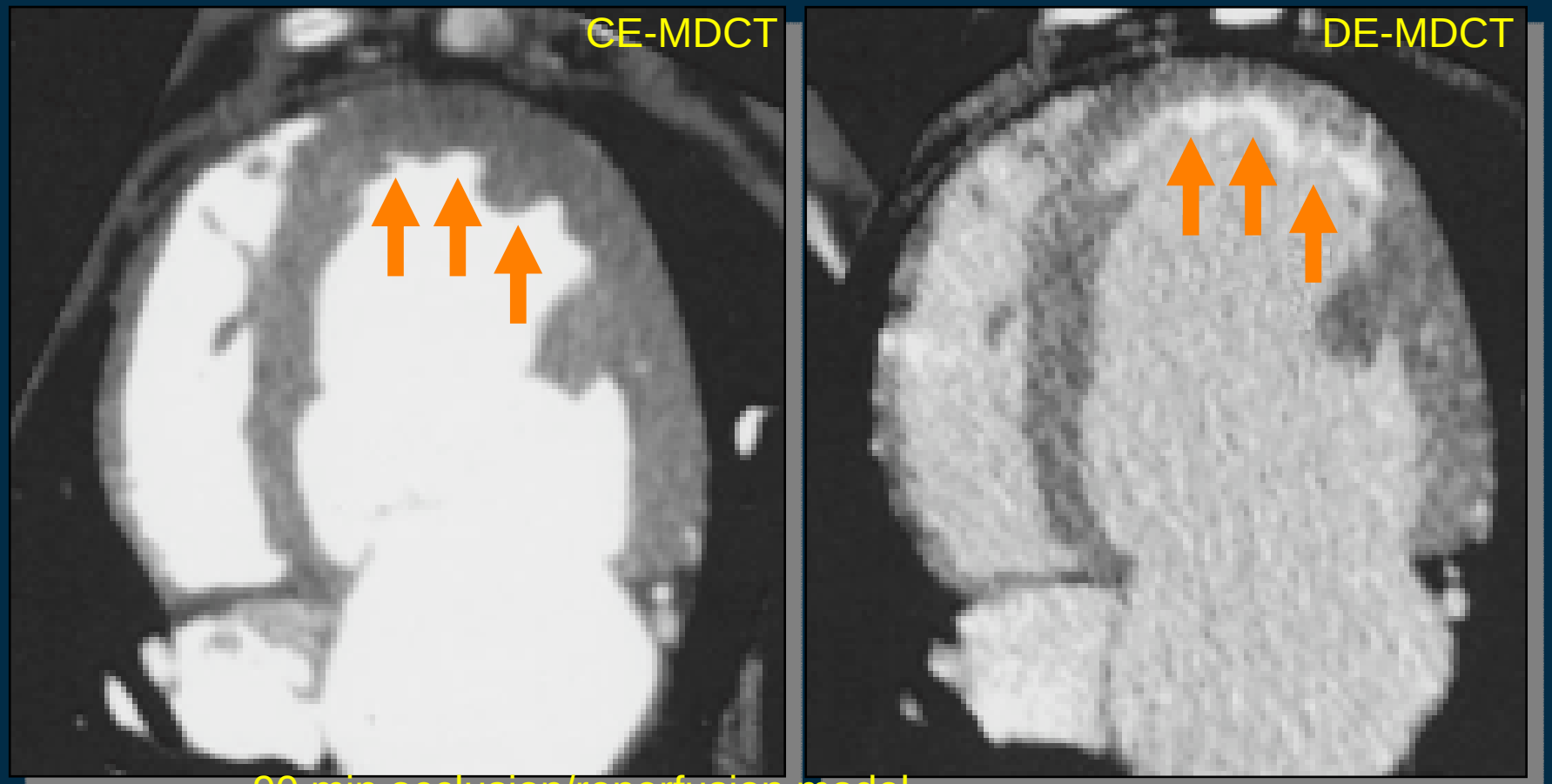
# Myocardial Infarct by first pass CT



# Contrast-Enhanced Multidetector Computed Tomography Viability Imaging After Myocardial Infarction

## Characterization of Myocyte Death, Microvascular Obstruction, and Chronic Scar

Albert C. Lardo, PhD; Marco A.S. Cordeiro, MD, PhD; Caterina Silva, MD; Luciano C. Amado, MD; Richard T. George, MD; Anastasios P. Saliaris, MD; Karl H. Schuleri, MD; Veronica R. Fernandes, MD; Menekhem Zviman, PhD; Saman Nazarian, MD; Henry R. Halperin, MD, MA; Katherine C. Wu, MD; Joshua M. Hare, MD; Joao A.C. Lima, MD




90 min occlusion/reperfusion model

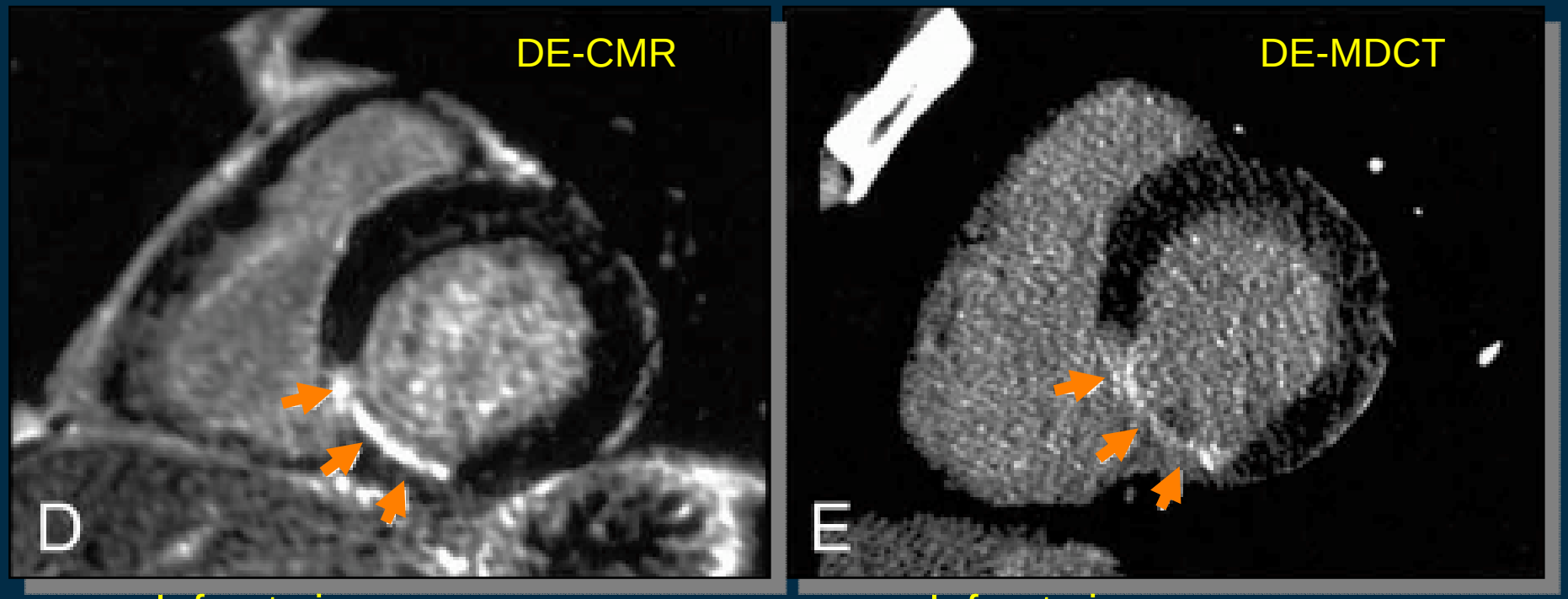
*Circulation* 2006;113;394-404

# Delayed MDCT for MI Detection

| Author | Patients /segments | Reference | Sensitivity (%) | Specificity (%) |
|---|---|---|---|---|
| Paul | 34/578 | SPECT | 78 | 91 |
| Mahnken | 28/448 | CMR | 97 | 98 |
| Gerber | 16/256 | CMR | 85 | 90 |
| Habis | 36/576 | DSE | 92 | 100 |

# DE-MDCT

## *Patient study - reperfused AMI*




Infarct size =
31.2%/slice

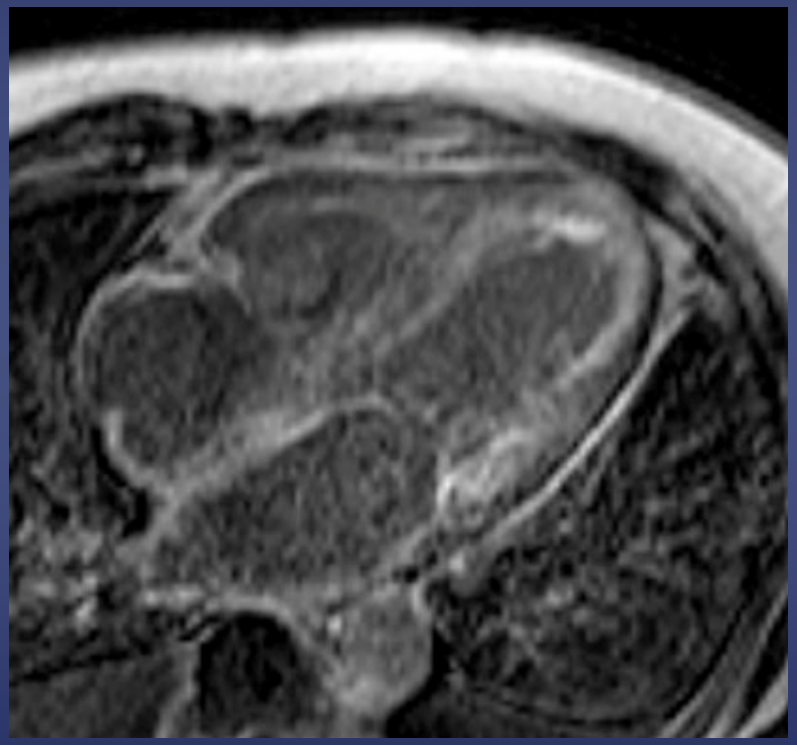
Infarct size =
33.3%/slice

Mahnken, *JACC* 2005.

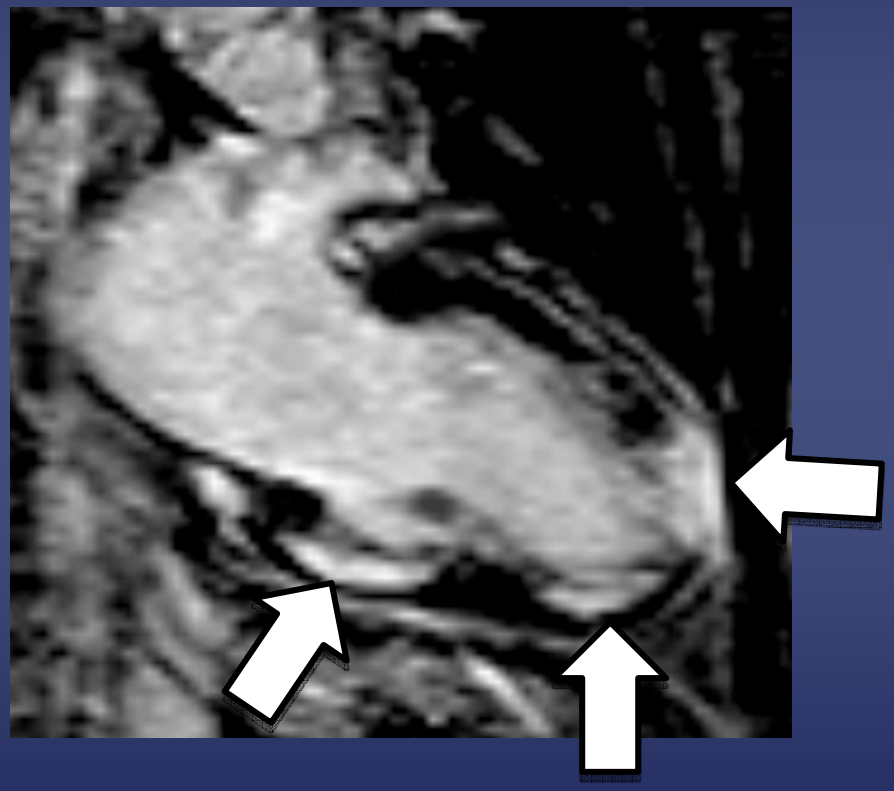
Washington Hospital Center

# Infiltrative Cardiomyopathies:

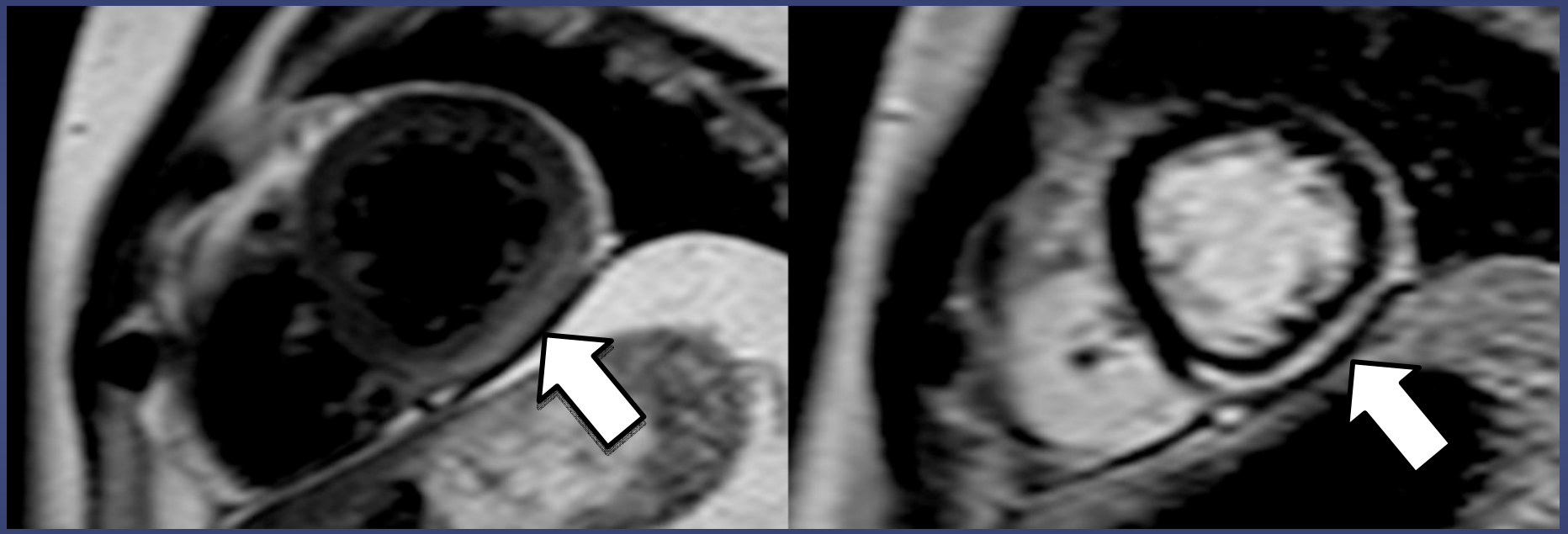
## Amyloidosis



## Sarcoidosis



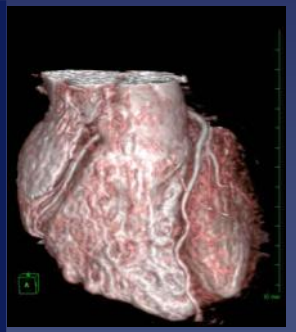
# Bright T2 and Epicardial Gadolinium Enhancement in Myocarditis



# Evaluation of Chest Pain

## Exclusion of CAD in Suspected False Abnormal Stress Test

- A robust application of CT
- Detailed anatomy of the entire coronary tree from a single 5-10 second acquisition
- Either as first-line test or follow-up to equivocal stress test
- Detects non-obstructive CAD

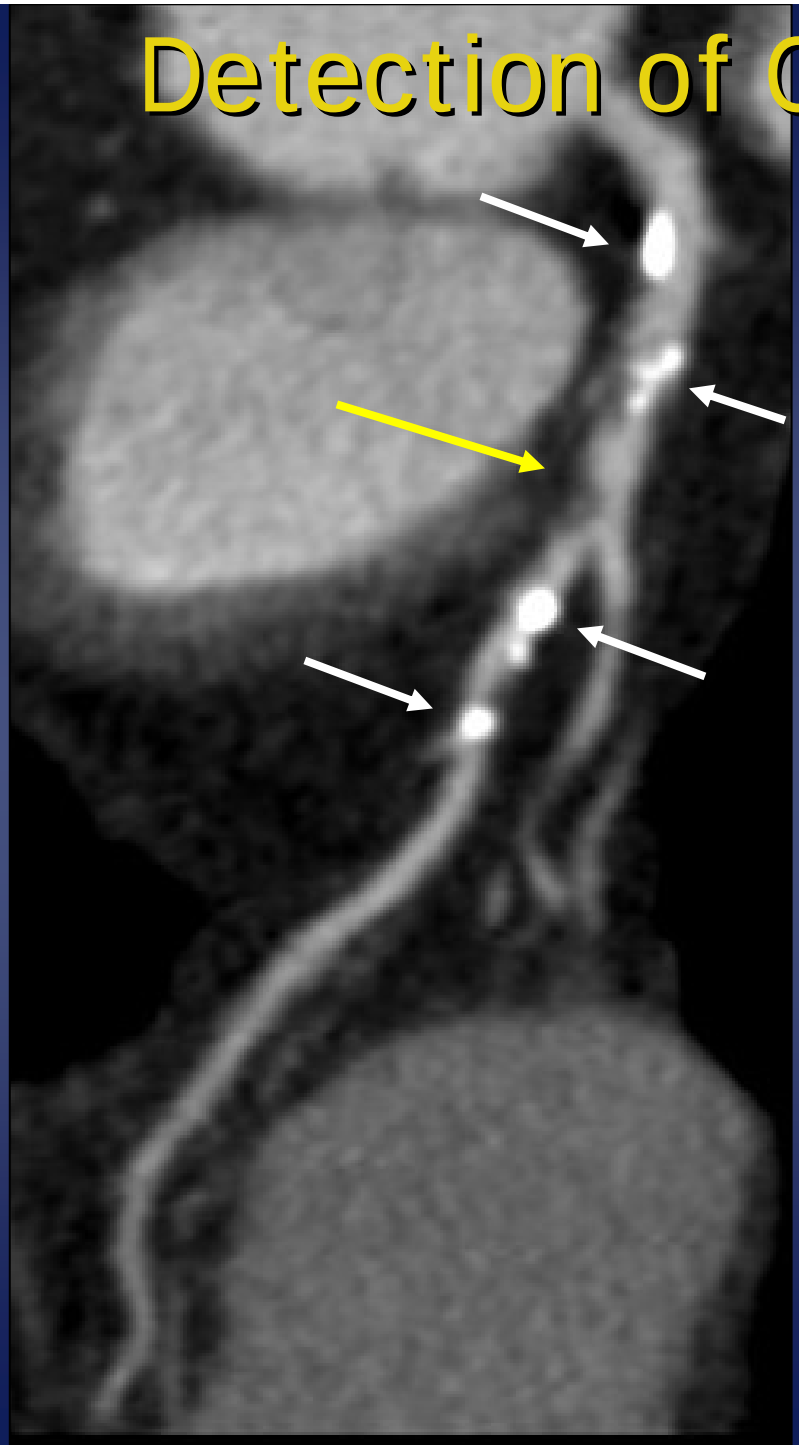


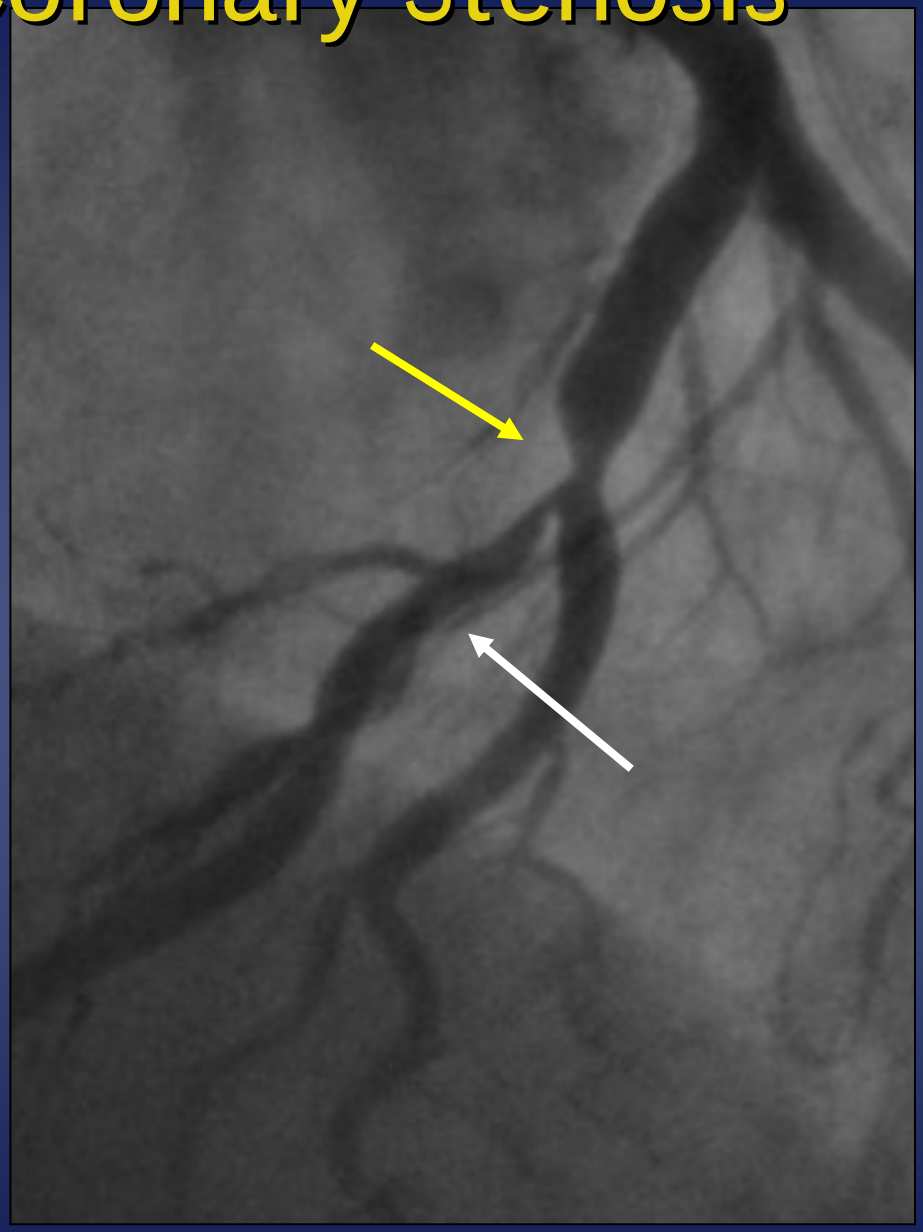
# Chest Pain: Pre-test Probability of Significant CAD

| | Age | Symptoms | | |
|---|---|---|---|---|
| | | Non-anginal | Atypical | Typical |
| Men | 30-39 | 5 | 22 | 70 |
| | 40-49 | 14 | 46 | 87 |
| | 50-59 | 22 | 59 | 92 |
| | 60-69 | 28 | 67 | 94 |
| Women | 30-39 | 1 | 4 | 26 |
| | 40-49 | 3 | 13 | 55 |
| | 50-59 | 8 | 32 | 79 |
| | 60-69 | 19 | 54 | 91 |

Diamond et al. NEJM. 1979

# Detection of Coronary Stenosis





# Accuracy

| | | n | Sens. | Spec. | Not evaluable |
|---|---|---|---|---|---|
| **64 SLICE CT** | | | | | |
| Herzog | Radiology 2007 | 50 | 89% | 92% | -- |
| Mühlenbruch | Eur Radiol 2007 | 51 | 87% | 95% | -- |
| Shabestari | Am J Cardiol 2007 | 143 | 94% | 97% | 2% |
| Cademartiri | Radiol Med 2007 | 72 | 100% | 99% | -- |
| Hausleiter | Eur Heart J 207 | 114 | 100% | 92% | 8% |
| Sheth | Am Heart J 2008 | 80 | 90% | 96% | 3% |
| Bayrak | Acta Cardiol 2008 | 100 | 91% | 97% | -- |
| Brodoefel | Eur J Radiol 2008 | 102 | 91% | 99% | 11% |
| Meijboom | JACC 2008 | 245 | 88% | 94% | -- |
| **DUAL SOURCE CT** | | | | | |
| Weustink | JACC 2007 | 100 | 95% | 95% | -- |
| Johnson | Invest Radiol 2007 | 35 | 88% | 98% | 2% |
| Leber | Eur Heart J 2007 | 90 | 90% | 98% | -- |
| Scheffel | Eur Radiol 2006 | 30 | 96% | 98% | -- |
| Ropers | JACC 2007 | 100 | 90% | 98% | 4% |
| Achenbach | iJACC 2008 | 50 | 97% | 97% | 2% |
| Brodoefel | Radiology 2008 | 100 | 91% | 92% | 10% |
| Alkadhi | Eur Heart J 2008 | 150 | 97% | 95% | 2% |
| **320 ROW CT** | | | | | |
| Dewey | Circulation 2009 | 30 | 89% | 96% | -- |

CT-STAT trial: recently discussed at American Heart Assoc. annual meeting (Nov 18th)

- Compared to serial ECG's/enzymes followed by SPECT…
- CT cut time to diagnosis by 54%
- CT cut cost by 38%
- With no difference in 6-month MACE

*82% of patients had minimal or no CAD*

- N

USA TODAY Home News Travel Money Sports Life Tech

News » Health & Behavior

## CT heart scan finds blockage faster than standard method

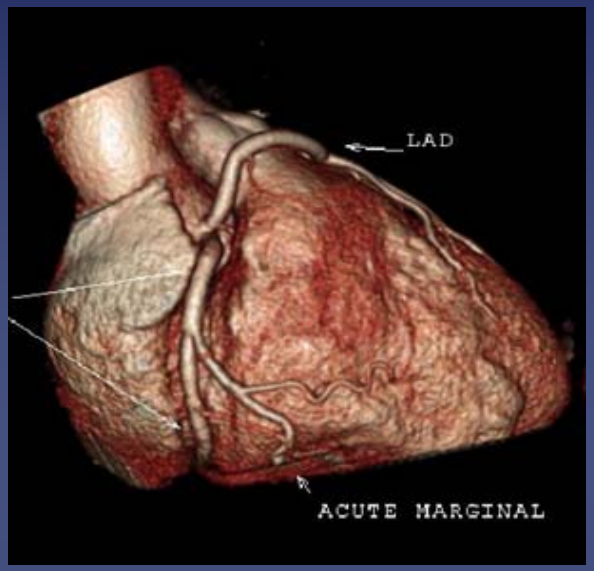
Posted 21h 53m ago | Comments 22 | Recommend 9

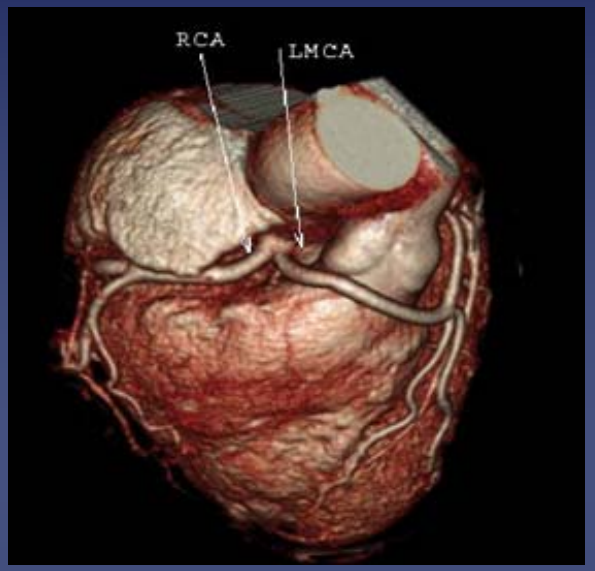
By Steve Sternberg, USA TODAY

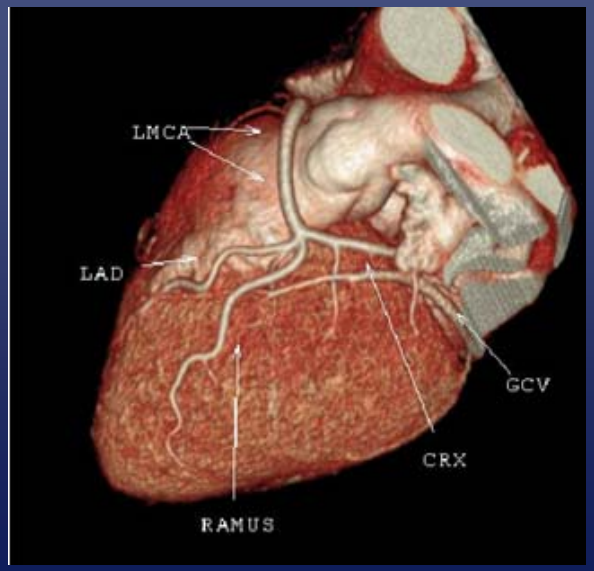
ORLANDO — A rapid CT scan of the heart may provide doctors with a more efficient way to diagnose blocked arteries in people complaining of chest pain, doctors here reported Wednesday.

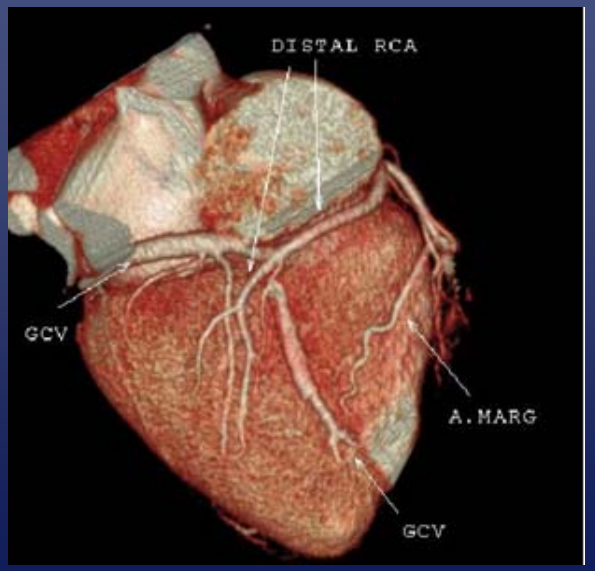
A study of 701 patients found that the scans, called CT angiography, cuts in half the time it usually takes for a doctor to detect a blockage in an artery supplying the heart. It also shaves nearly 40% off the cost of making the diagnosis.

# Anomalous LMCA

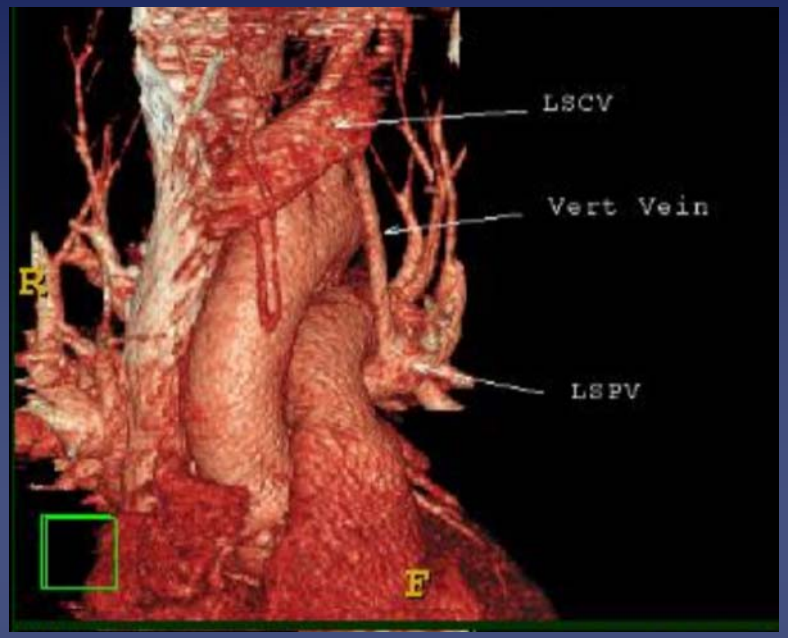


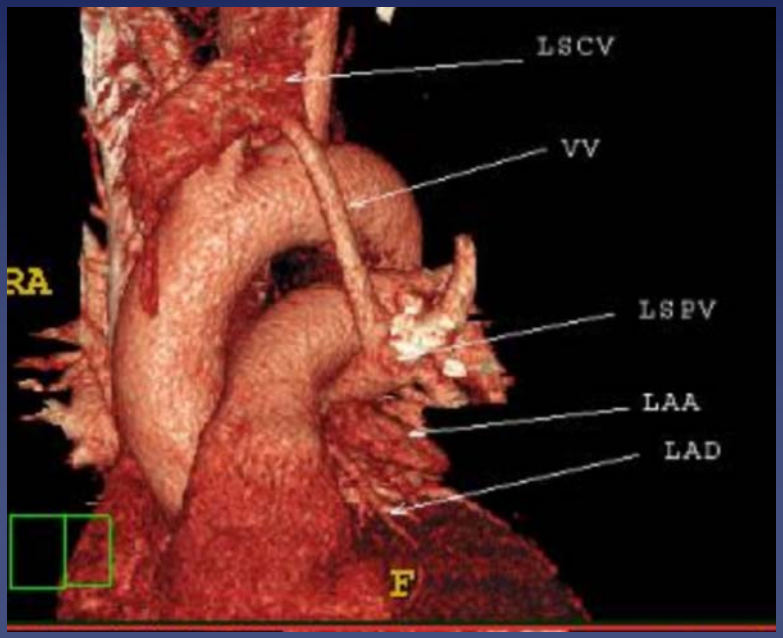



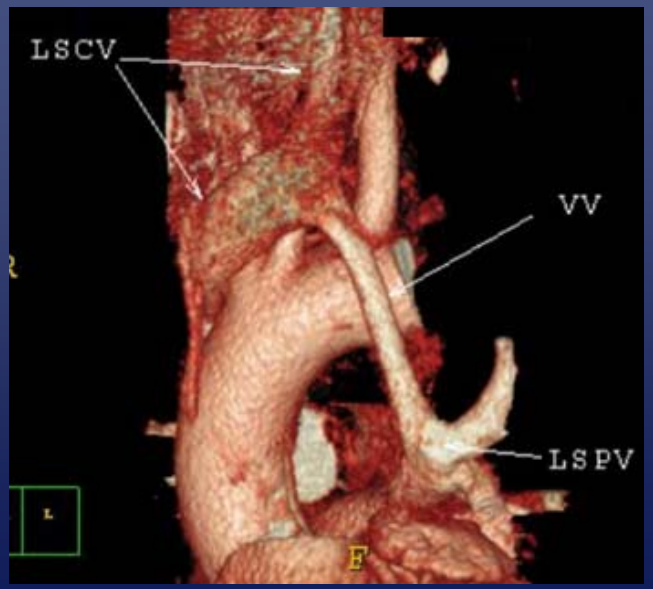



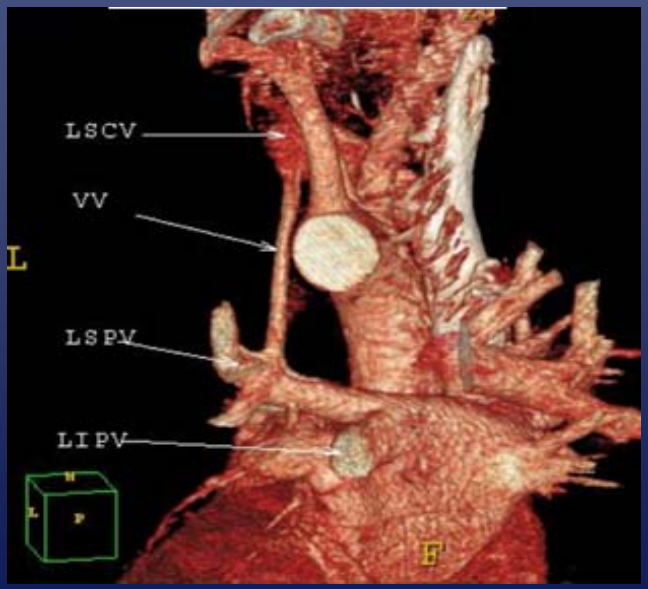



# Persistent Vertical Vein

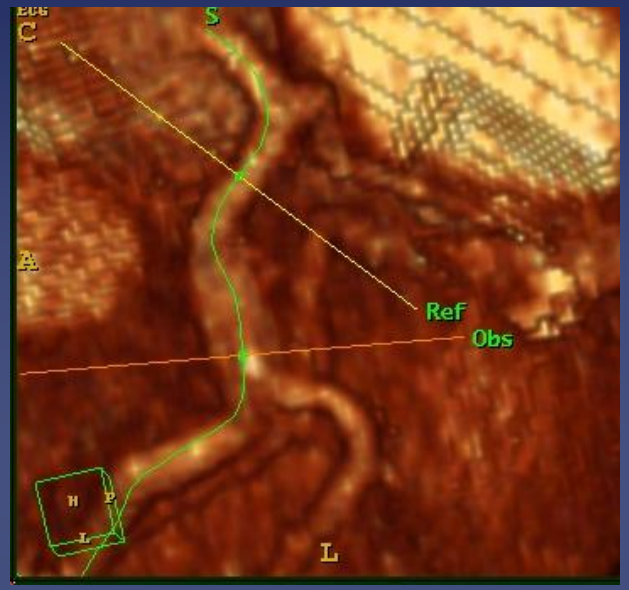


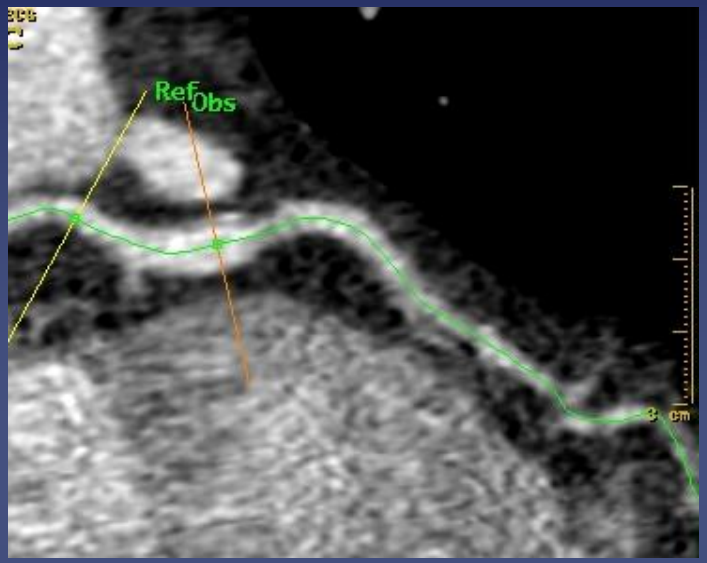



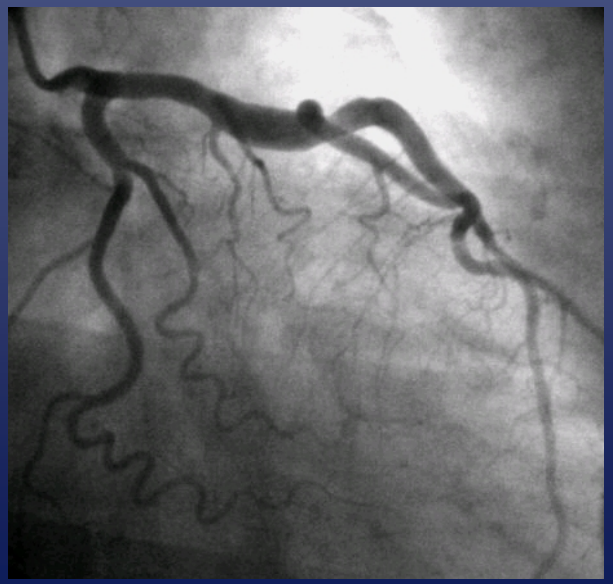



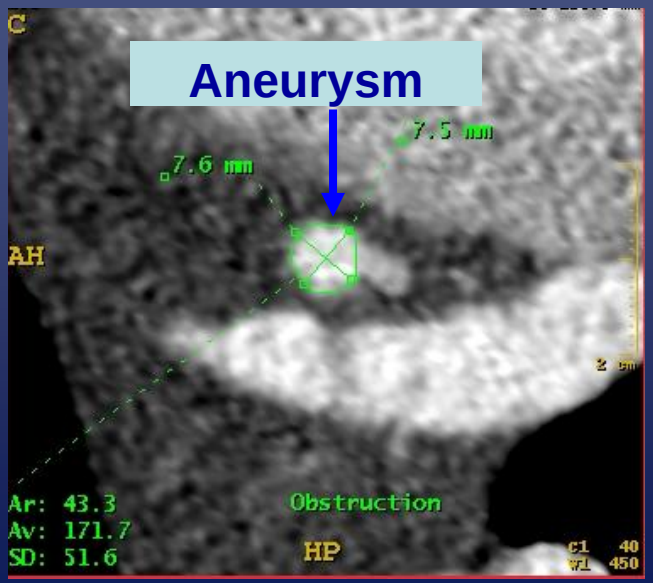



# Coronary Artery Aneurysm

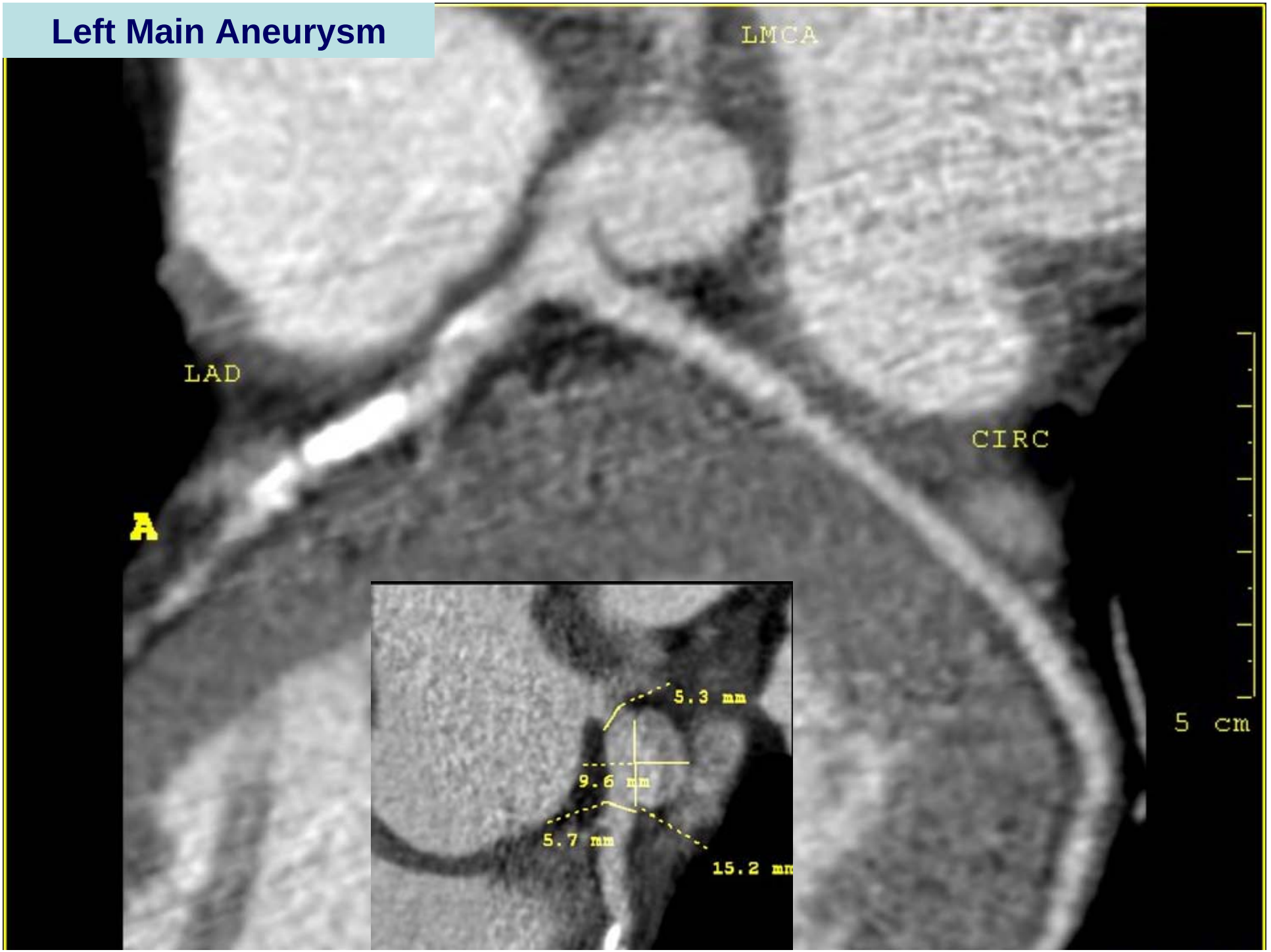


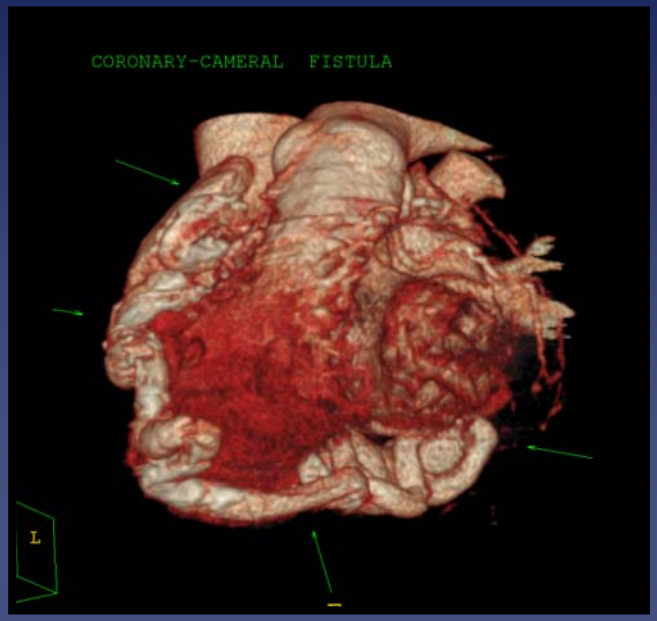



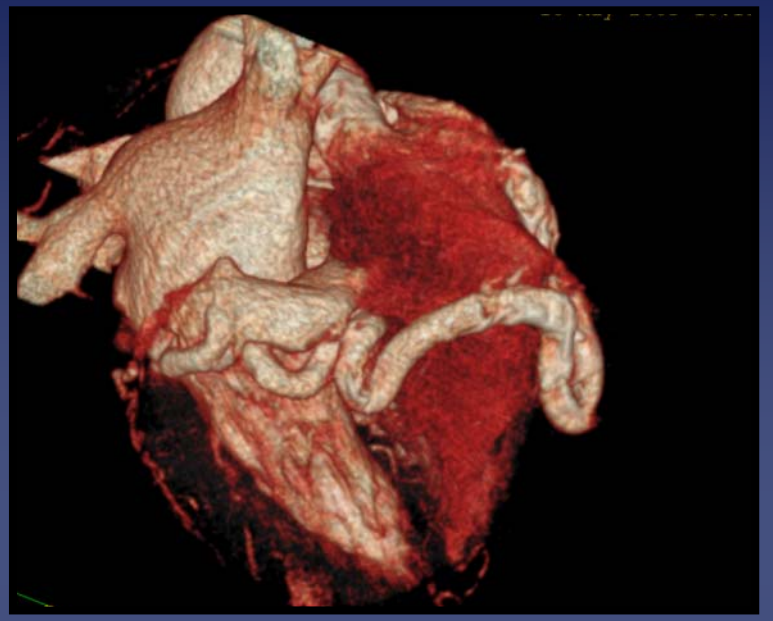


# Left Main Aneurysm



# Coronary Fistula



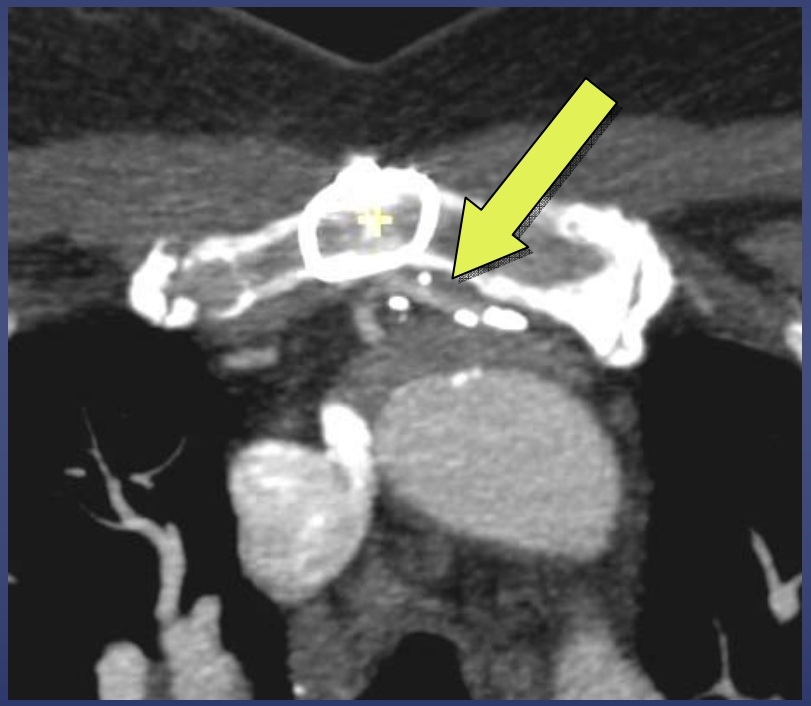



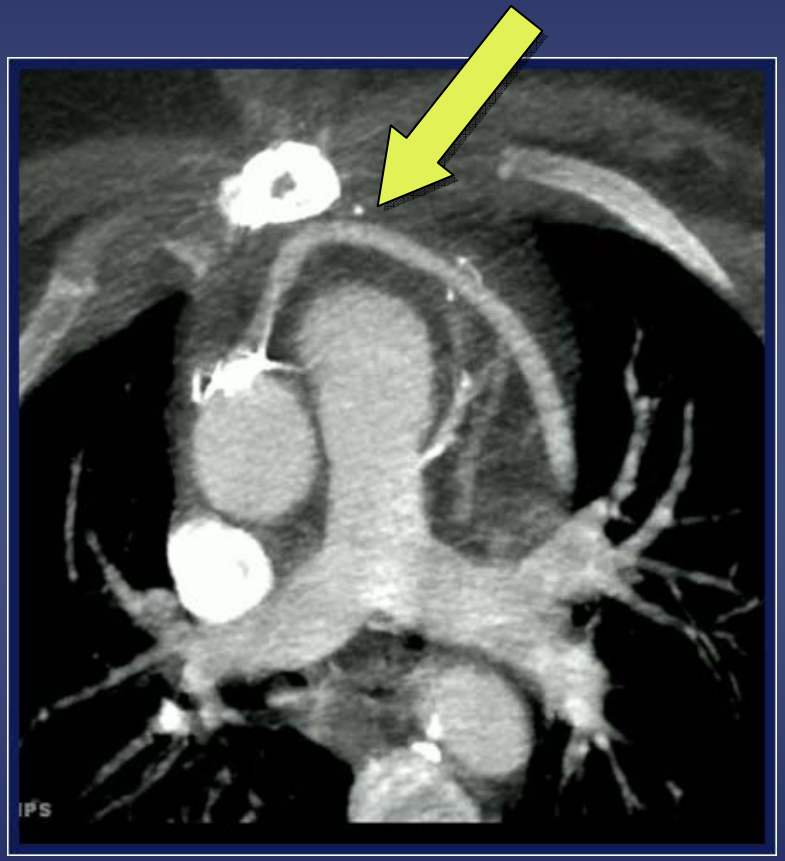
# Stents?

## Accuracy: In-stent Stenosis

| Author | not evaluable | | Sens. | Spec. | PPV |
|---|---|---|---|---|---|
| Rixe | 42% | 86% | 98% | 86% | |
| Oncel | 0% | 89% | 95% | 90% | |
| Rist | 2% | 75% | 92% | 67% | |
| Ehara | 12% | 91% | 93% | 54% | 90% >= 3.0 mm |
| Cademartiri | 7% | 95% | 93% | 63% | |
| Manghat | 10% | 85% | 86% | 61% | Mean: 3.3 mm |
| Hecht | 0% | 94% | 87% | 39% | |
| Schuijf | 14% | 100% | 100% | 71% | Mean: 3.4 mm |
| Pugliese | 0% | 94% | 92% | 77% | |
| Pflederer | 8% | 87% | 95% | 73% | Only > 3.0 mm |

# Pre-op: Repeat Cardiac Surgery





# Appropriateness Criteria for CCT and CMR

J Am Coll Cardiol. Oct 2006;48(7):1475-97

ACCF/ SCCT/SCMR/ACR/AHA/ASNC/NASCI/SCAI/SIR APPROPRIATENESS CRITERIA

## ACCF/SCCT/SCMR/ACR/AHA/ASNC/ NASCI/SCAI/SIR Appropriateness Criteria for Cardiac Computed Tomography and Cardiac Magnetic Resonance Imaging[1]

A Report of the American College of Cardiology Foundation Quality Strategic Directions Committee Appropriateness Criteria Working Group, Society of Cardiac Computed Tomography, Society for Cardiovascular Magnetic Resonance, American College of Radiology, American Heart Association, American Society of Nuclear Cardiology, North American Society for Cardiac Imaging, Society for Cardiovascular Angiography and Interventions, and Society of Interventional Radiology

*Endorsed by*

# Indications for Cardiac CT

1. Chest pain syndrome, intermediate likelihood of significant CAD (7)
2. Chest pain syndrome, uninterpretable or equivocal stress test (7)
3. Acute chest pain [without abnormal ECG or markers] (7)
4. New onset heart failure (rule out ischemic cardiomyopathy) (7)
5. Suspected coronary anomaly (9)
6. Coronary vein mapping prior to Bi-V PM implantation (8)
7. Prior to repeat cardiac surgery (8)
8. Pulmonary vein mapping prior to RFA for AF (8)
9. Congenital heart disease (7)
10. Intra-cardiac mass, echo and/or MR limited (8)
11. Pericardial disease, echo and/or MR limited (8)
12. Suspected aortic dissection or aneurysm (9)
13. Suspected pulmonary embolism (9)

# Indications for Cardiac MR

1. Chest pain syndrome and intermediate pre-test likelihood of significant CAD (vasodilator perfusion CMR or dobutamine stress function CMR) (7)
2. Suspected coronary anomaly (coronary MRA) (8)
3. Congenital heart disease (9)
4. LV function when echo limited or discordant results (8)
5. Evaluation of specific non-ischemic cardiomyopathies (amyloid, sarcoid, HCM, cardiotoxin, myocarditis) (8)
6. Native and prosthetic valves when echo limited (8)
7. Arrhythmogenic right ventricular dysplasia (ARVD) (9)
8. Intracardiac mass (9)
9. Pericardial disease (8)
10. Aortic dissection (8)
11. Pulmonary vein mapping prior to RFA for AF (8)
12. Infarct detection and viability (9)

# Comparison of Indications

## 2006 Appropriateness Criteria

| CT More Appropriate | Either Appropriate | MR More Appropriate |
|---|---|---|
| | Chest pain workup (coronary CTA or adenosine or dobutamine MR) | |
| | Coronary anomaly | |
| | Congenital heart disease | |
| | Cardiac mass | |
| | Pericardial disease | |
| | Aortic dissection | |
| Acute chest pain eval | | Infarct / Viability Imaging |
| Prior to repeat cardiac surgery | | ARVD / specific cardiomyopathies |
| Rule out pulmonary embolism | | Native or prosthetic valves |

# CT and MR: Conclusions

Test Factors → **Best Test** ← Patient Factors


- Choosin ent for the righ
  - Know t capabilities and limitations of the tests
  - Know the Appropriate Use Criteria
    - *Updates coming in 2010*
  - Know your institutions “local expertise”