Cardiac MRI & Cardiac CT

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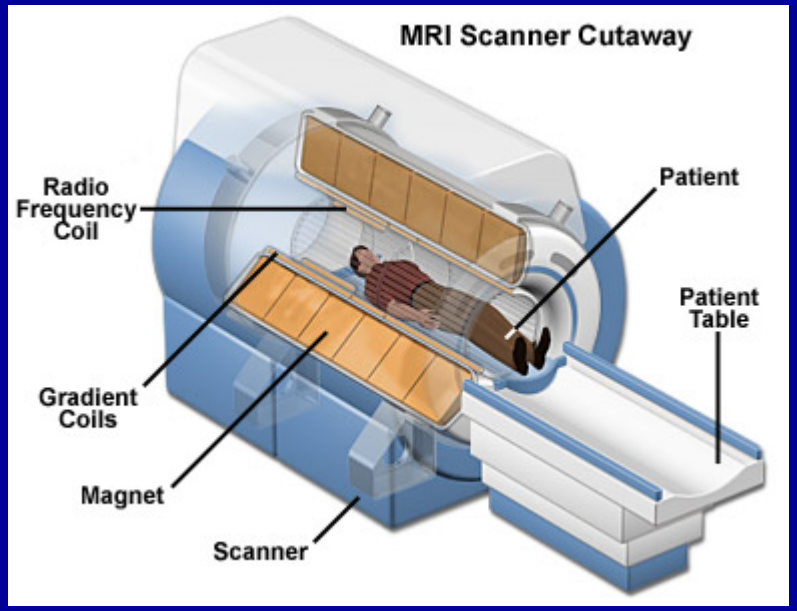
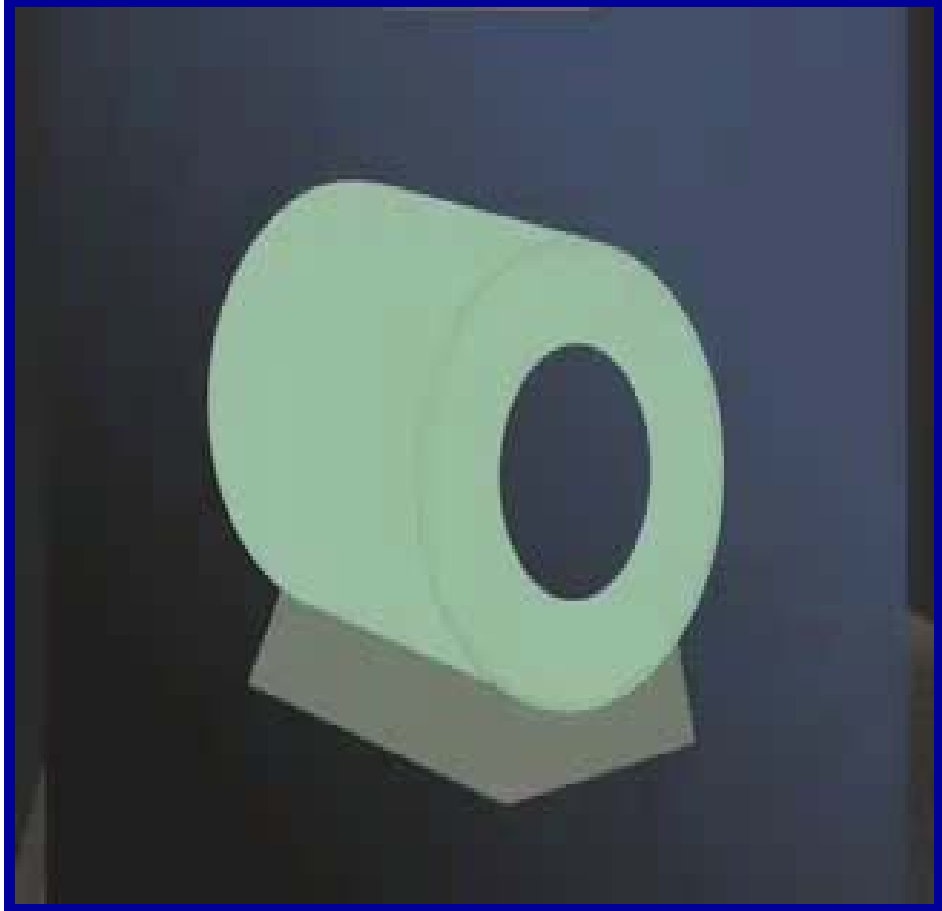
Cardiac MRI

MRI principles



- Static field (1.5 T)
- Radiofrequency energy
- Gradients
- Views flexibility
- Contrast

MRI principles

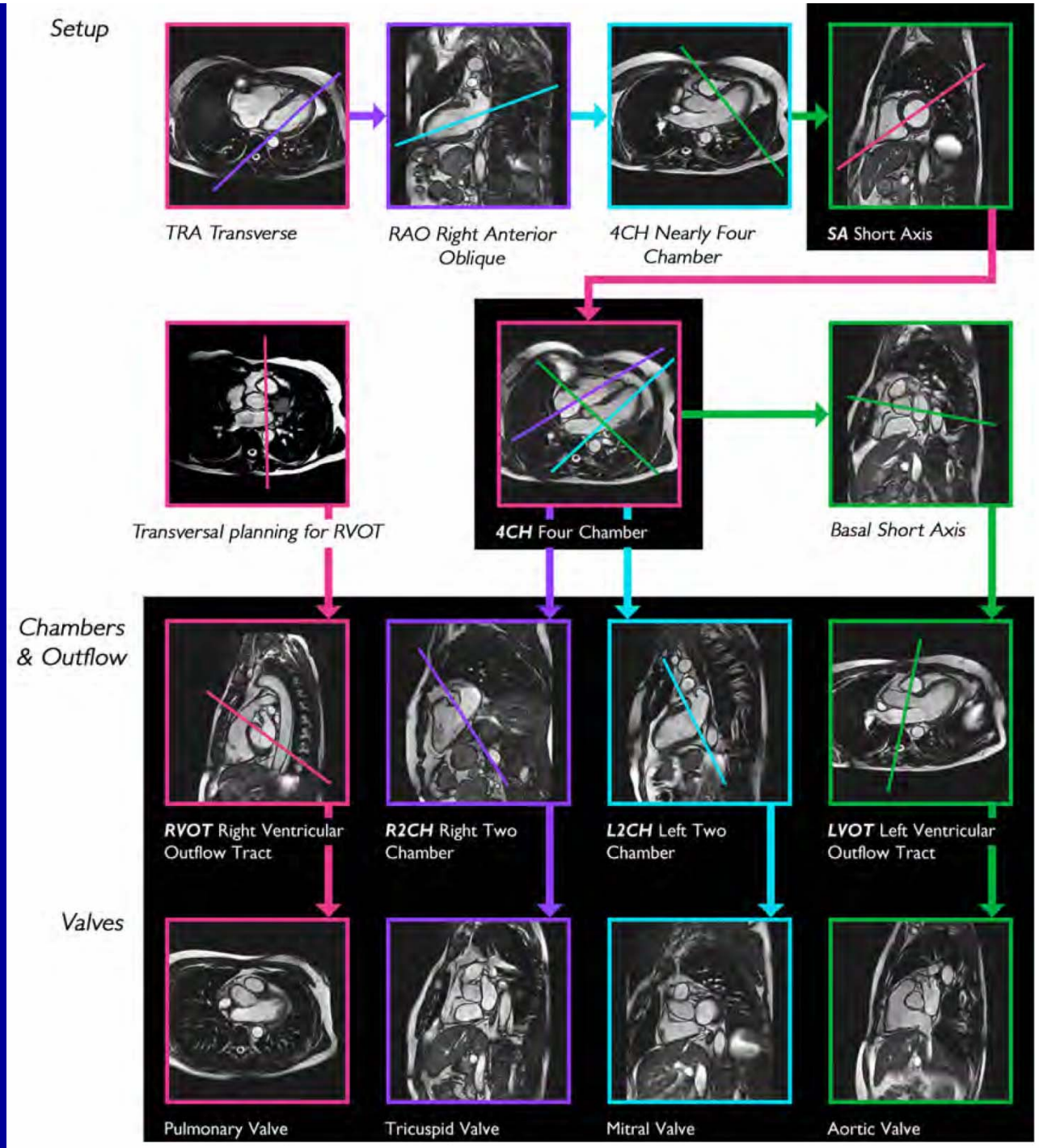


- Static field (1.5 T)
- Radiofrequency energy
- Gradients
- Views flexibility
- Contrast

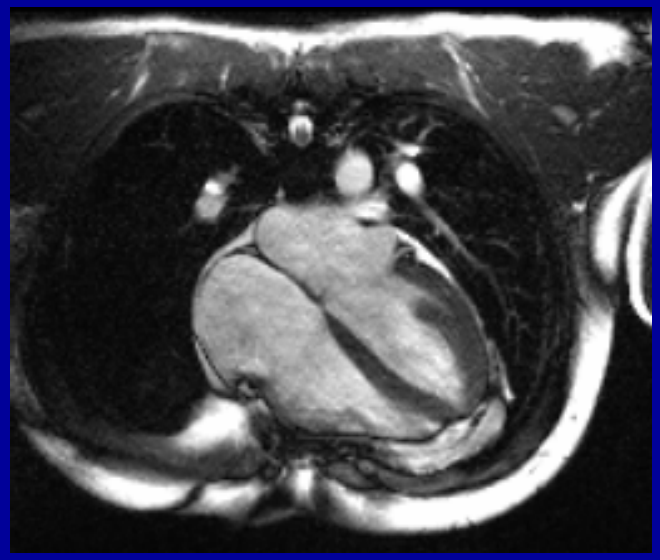
Safety

MRI protocol

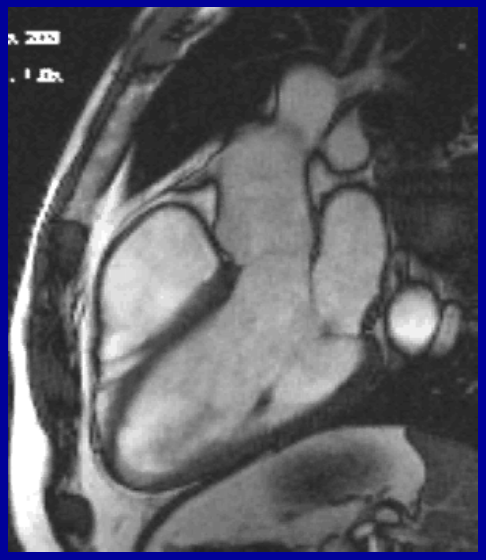
- Clinically dependent:
  - Motion, function, volume
  - Flow
  - Morphology
  - Tissue characteristics
  - Perfusion
  - Viability
- Plan → Reassess


Setup
TRA Transverse
RAO Right Anterior Oblique
4CH Nearly Four Chamber
SA Short Axis
Transversal planning for RVOT
4CH Four Chamber
Basal Short Axis
Chambers & Outflow
RVOT Right Ventricular Outflow Tract
R2CH Right Two Chamber
L2CH Left Two Chamber
LVOT Left Ventricular Outflow Tract
Valves
Pulmonary Valve
Tricuspid Valve
Mitral Valve
Aortic Valve

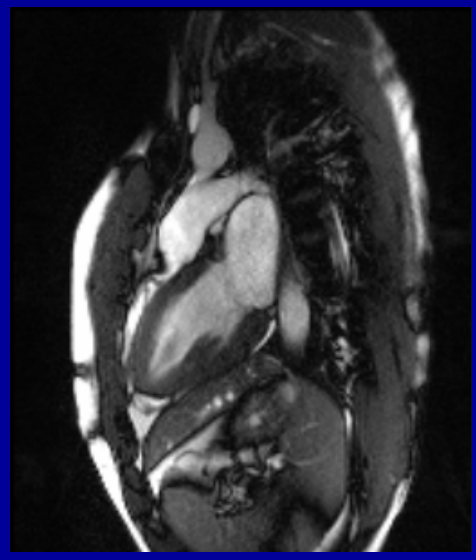
Wall Motion & Ventricular Volume



4-chamber HLA

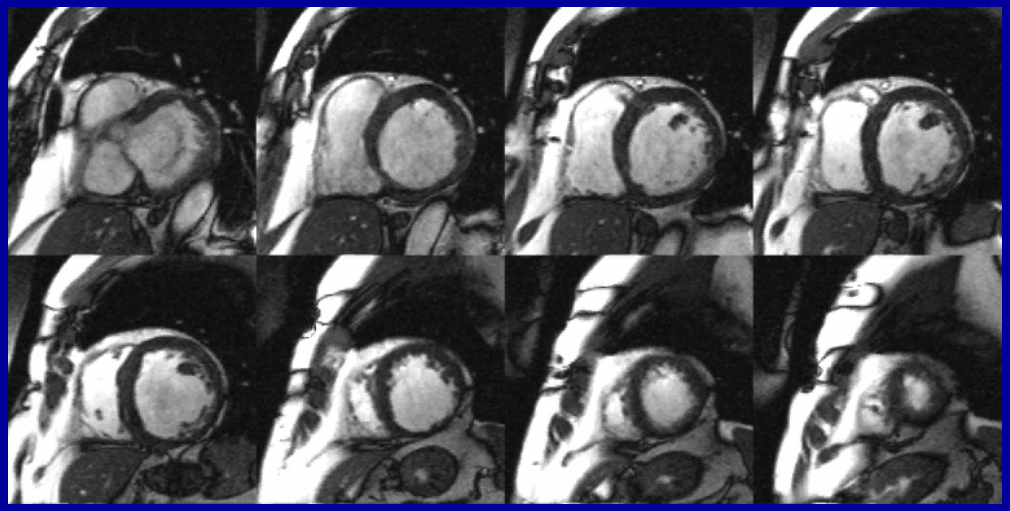


3-chamber LVOT

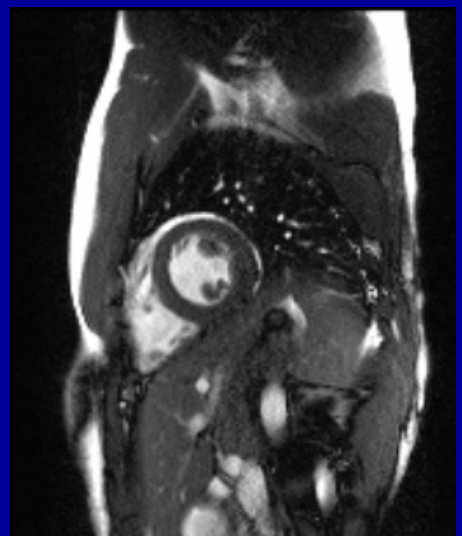


2-chamber VLA

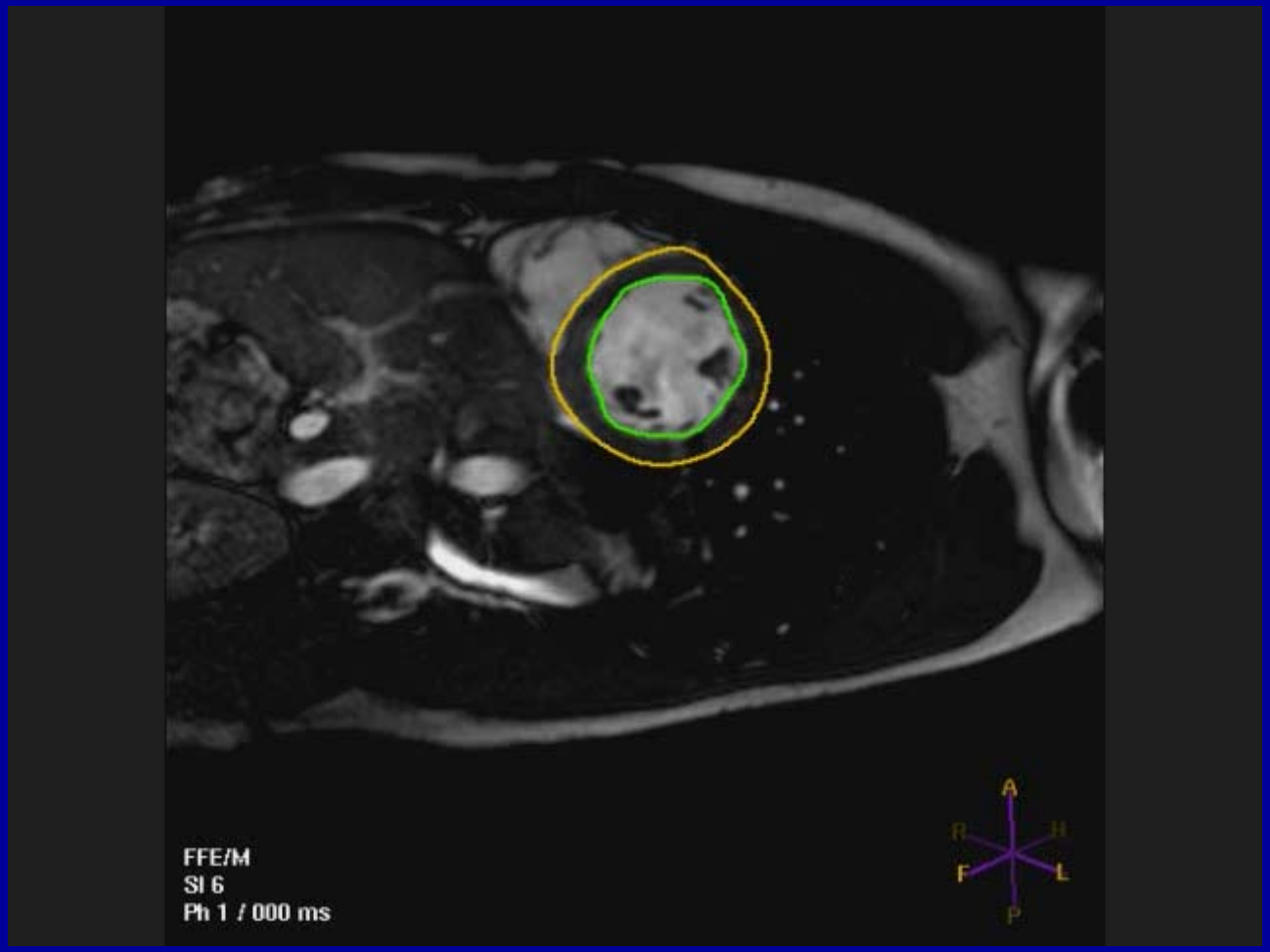
Stack of Short Axis for Volume Analysis



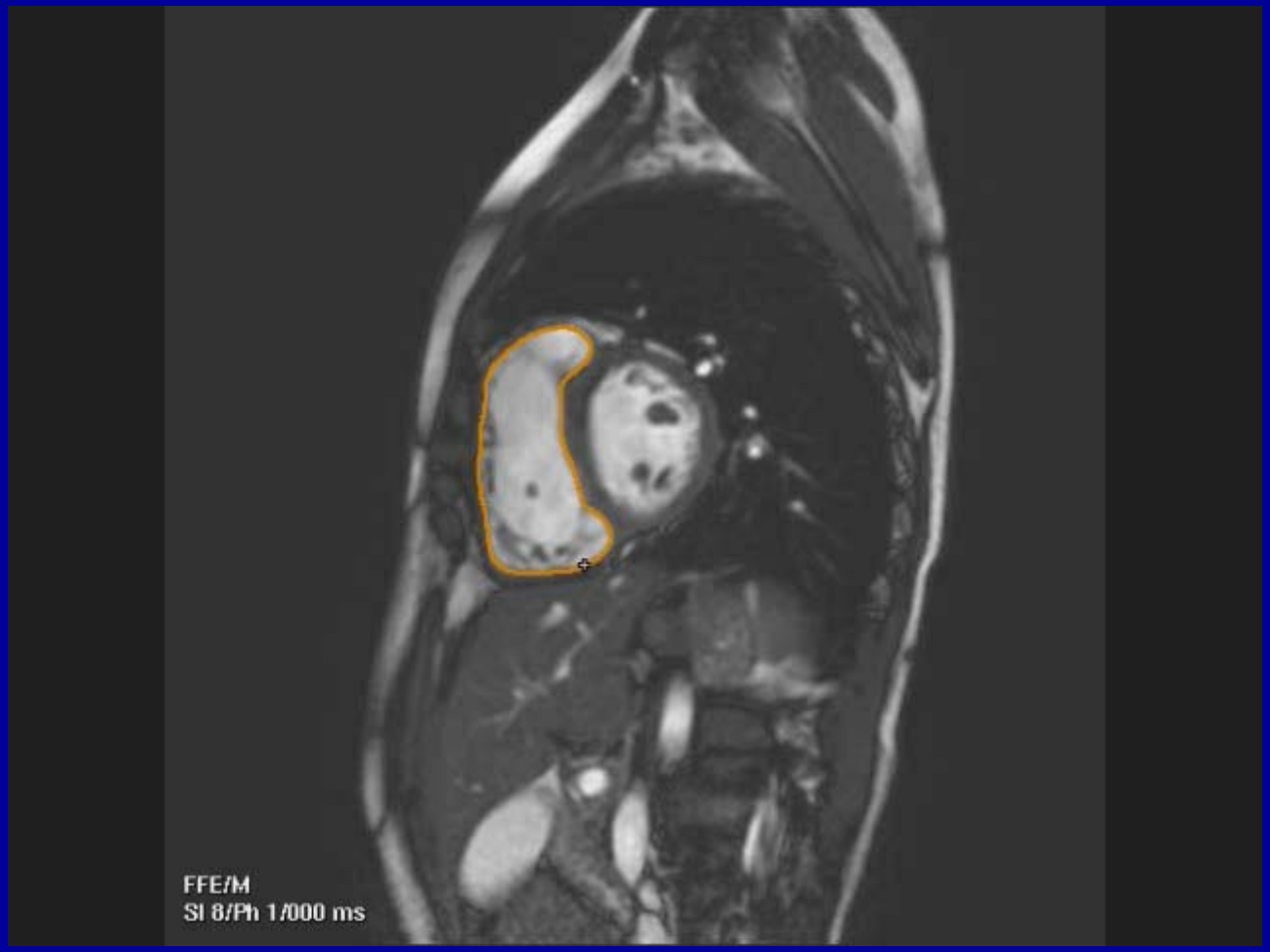
Mid-ventricular SA



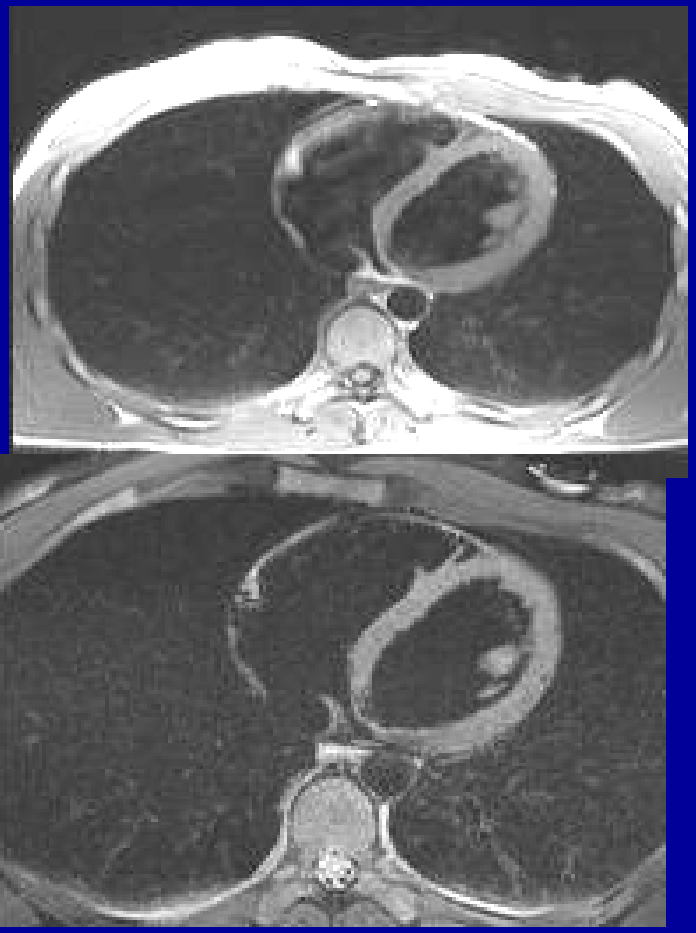
Wall Motion , Ventricular Volume & EF

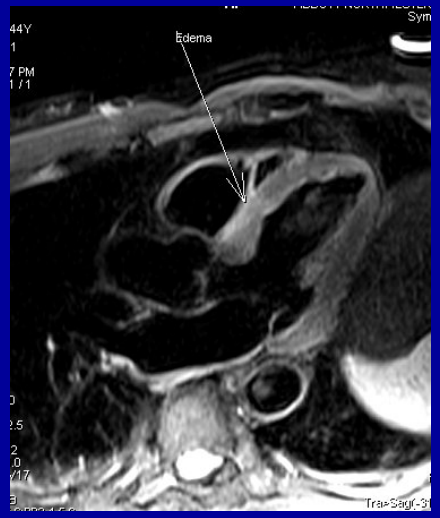


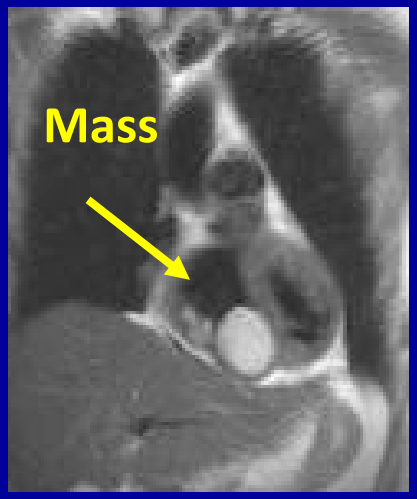
Wall Motion , Ventricular Volume & EF

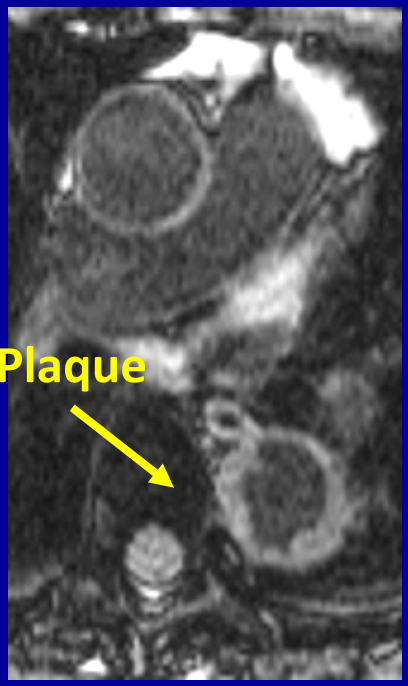


Morphology and Tissue Characteristics

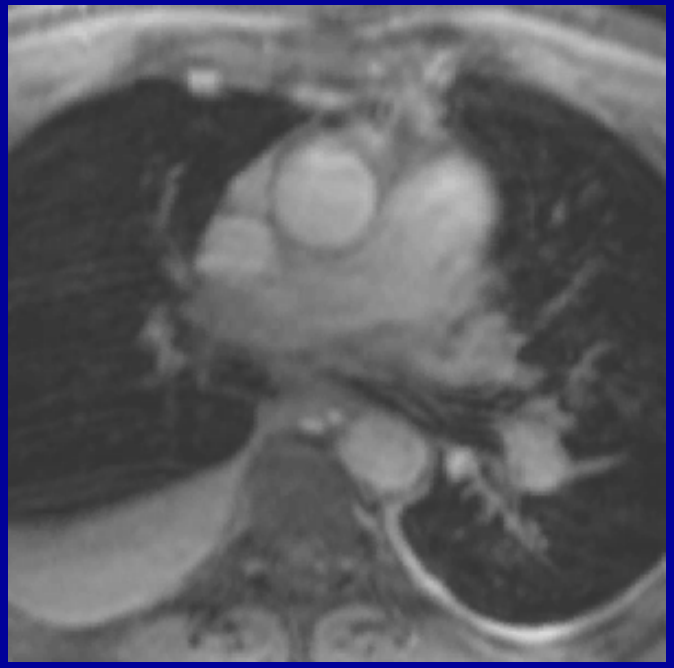




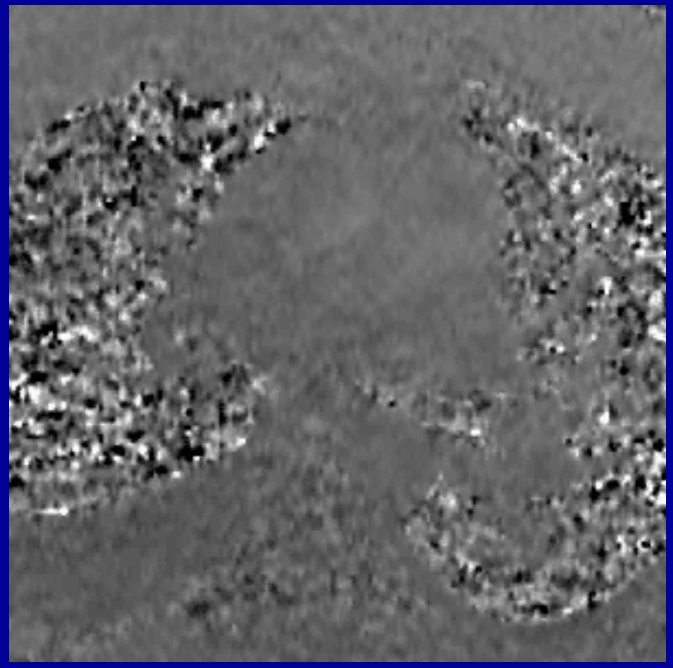




Flow

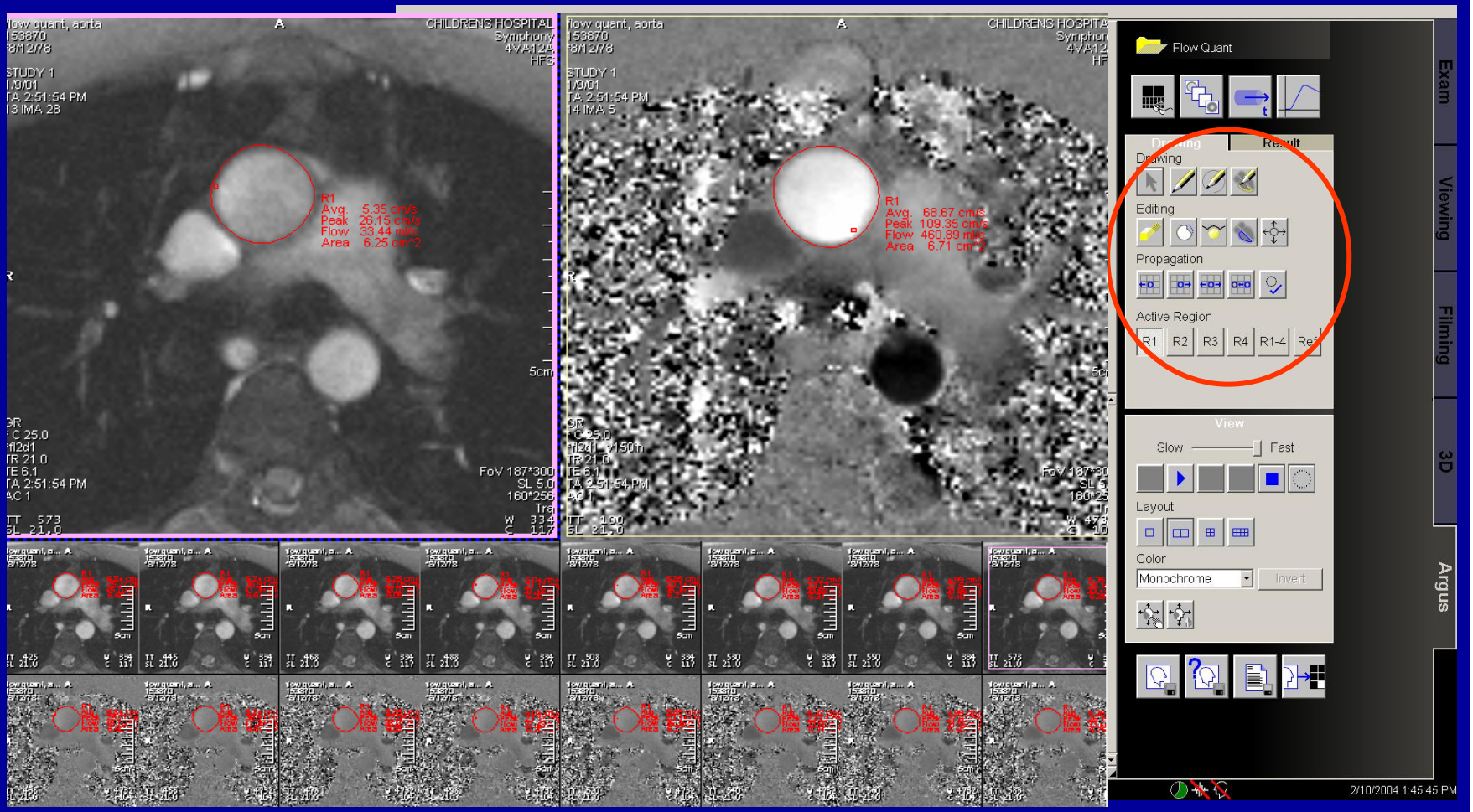


Magnitude Image



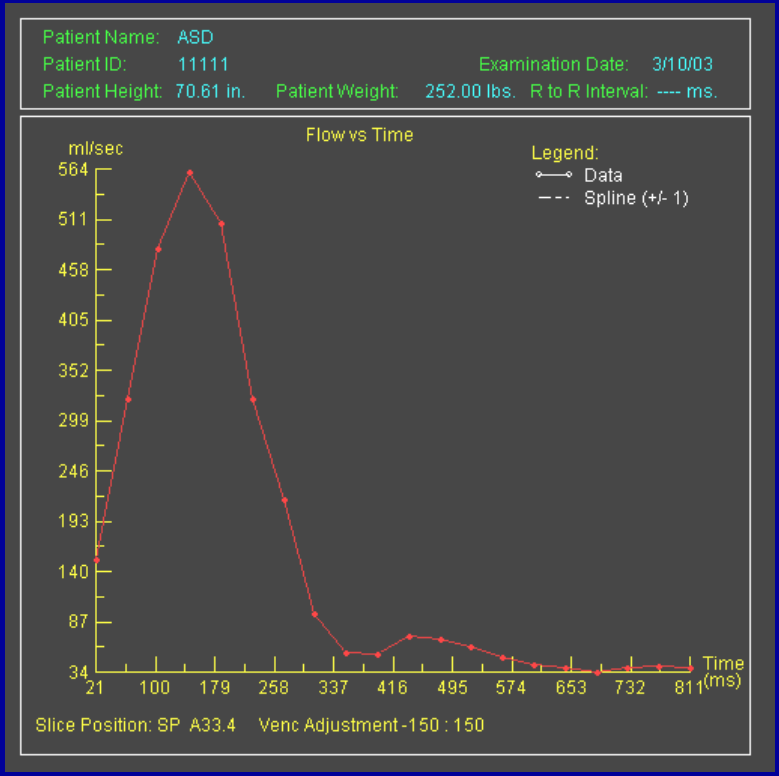
Phase Image

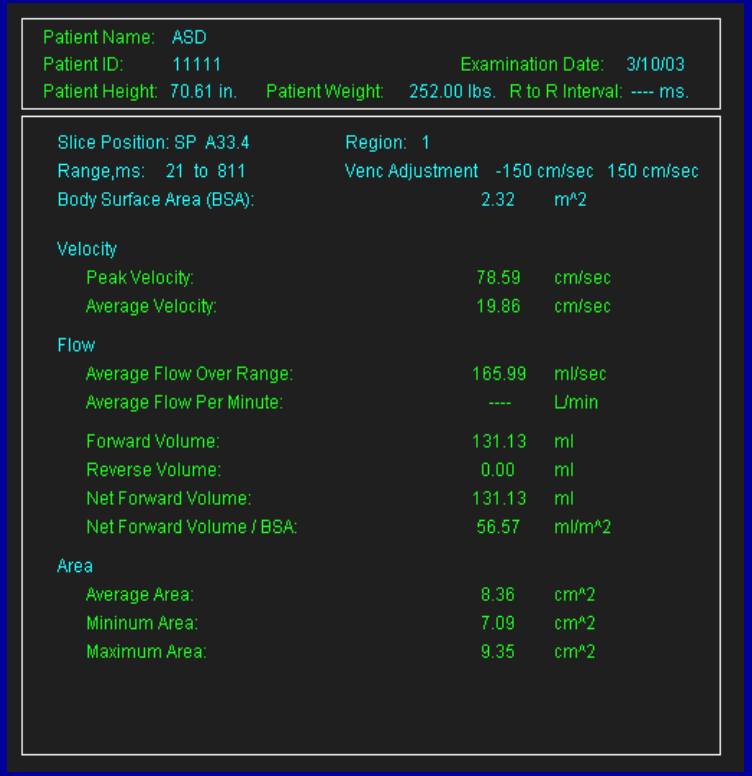
Flow Analysis



Magnify, Draw, Propagate, Preview contours in Movie, then Edit contours for accuracy.

Flow Analysis

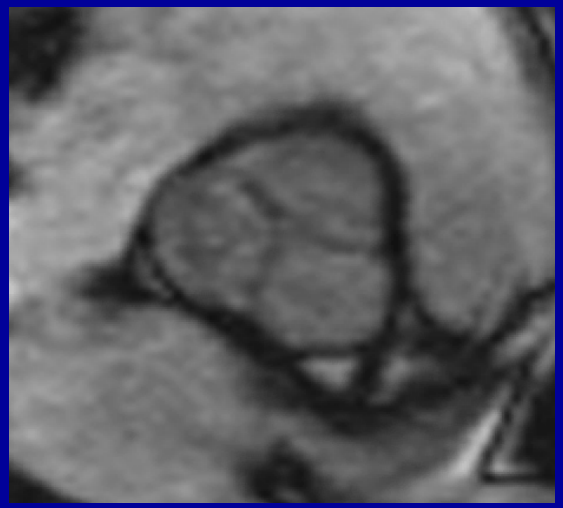


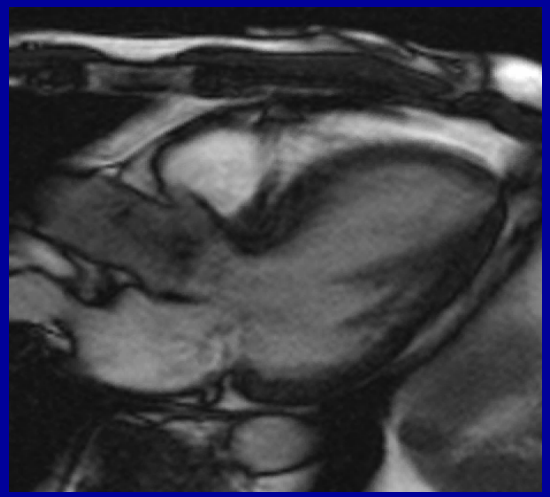


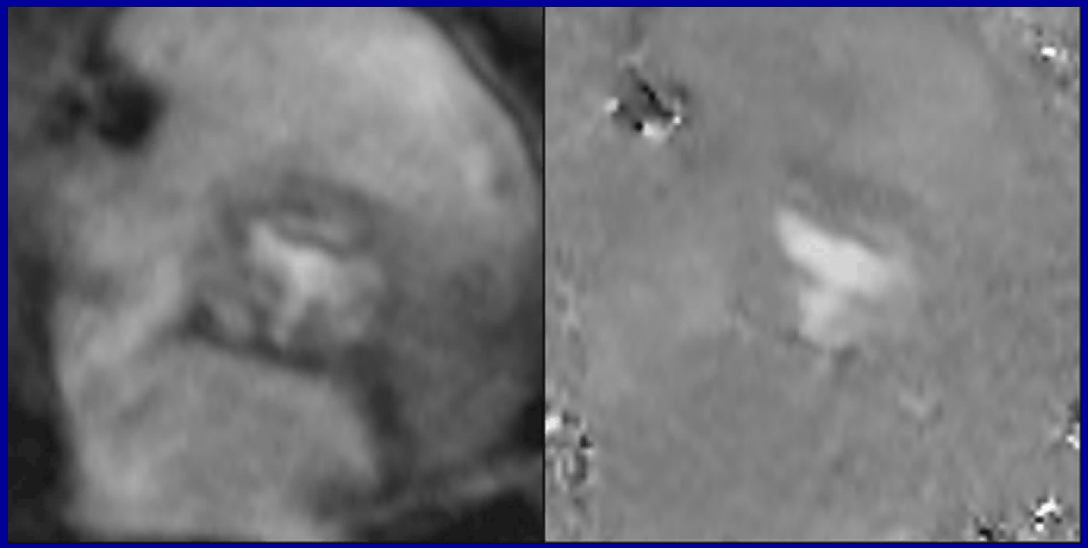
Flow Curves

Table of Results

Aortic Stenosis



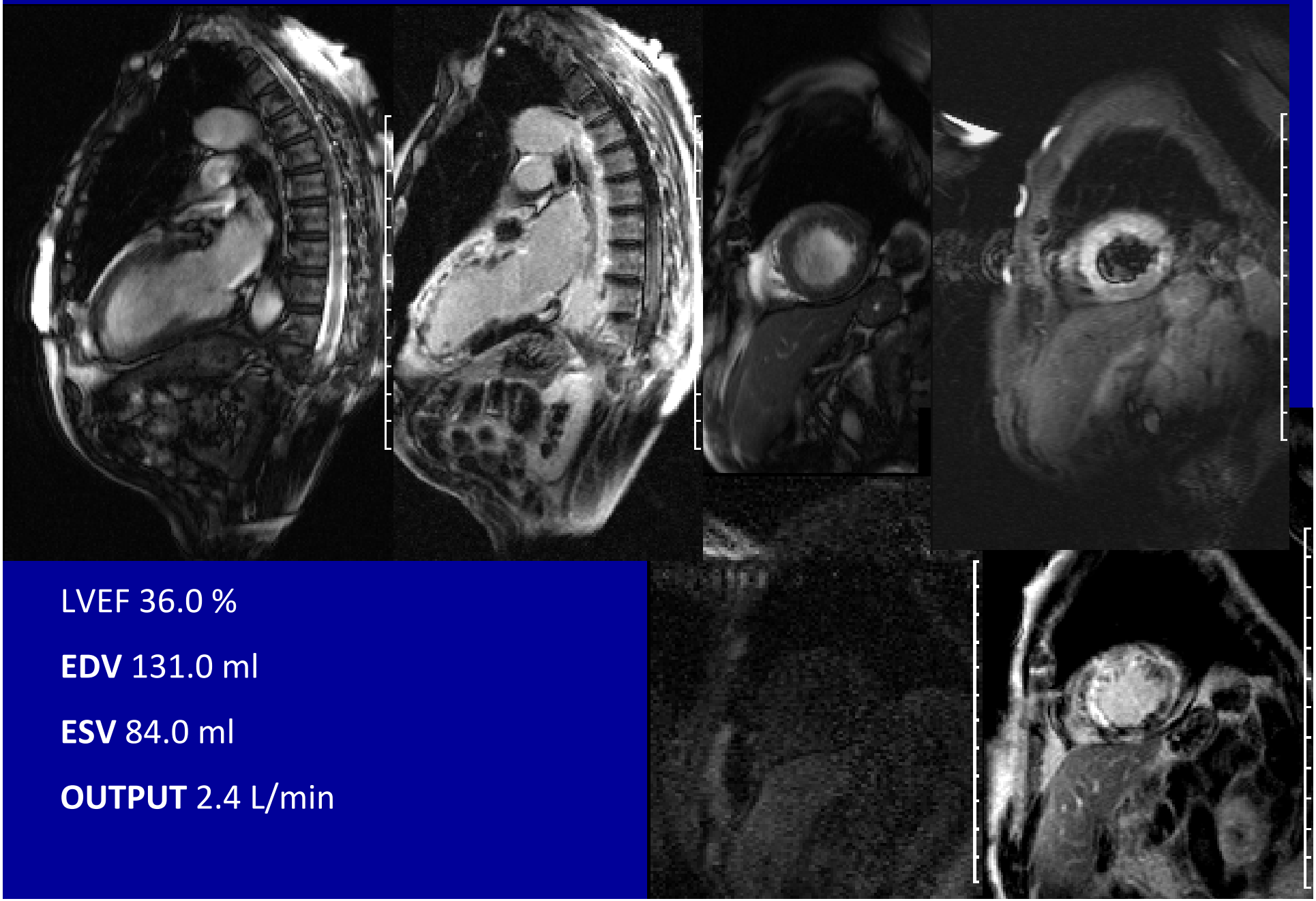




Patient Name:	SHALLMAN, WILLIAM		
Patient ID:	00115...	Examination Date:	2/20/2008
Patient Height:	---- in.	Patient Weight:	0.00 lbs.
Heart Rate:	74 Beats/min		
Slice Position: SP H34.2		Region: 1	
Range,ms: 0 to 695		Venc Adjustment	-450 cm/sec 450 cm/sec
Body Surface Area (BSA):		----	m^2
Velocity			
Peak Velocity:	304.98	cm/sec	
Average Velocity:	20.81	cm/sec	
Flow			
Average Flow Over Range:	180.78	ml/sec	
Average Flow Per Minute:	9.30	l/min	
Forward Volume:	129.77	ml	
Reverse Volume:	4.12	ml	
Net Forward Volume:	125.64	ml	
Net Forward Volume / BSA:	----	ml/m^2	
Area			
Average Area:	8.69	cm^2	
Mininum Area:	7.69	cm^2	
Maximum Area:	9.79	cm^2	

Contrast Enhancement

- First pass /Early – perfusion Images, mass
- Delayed / Late – scar, infiltration



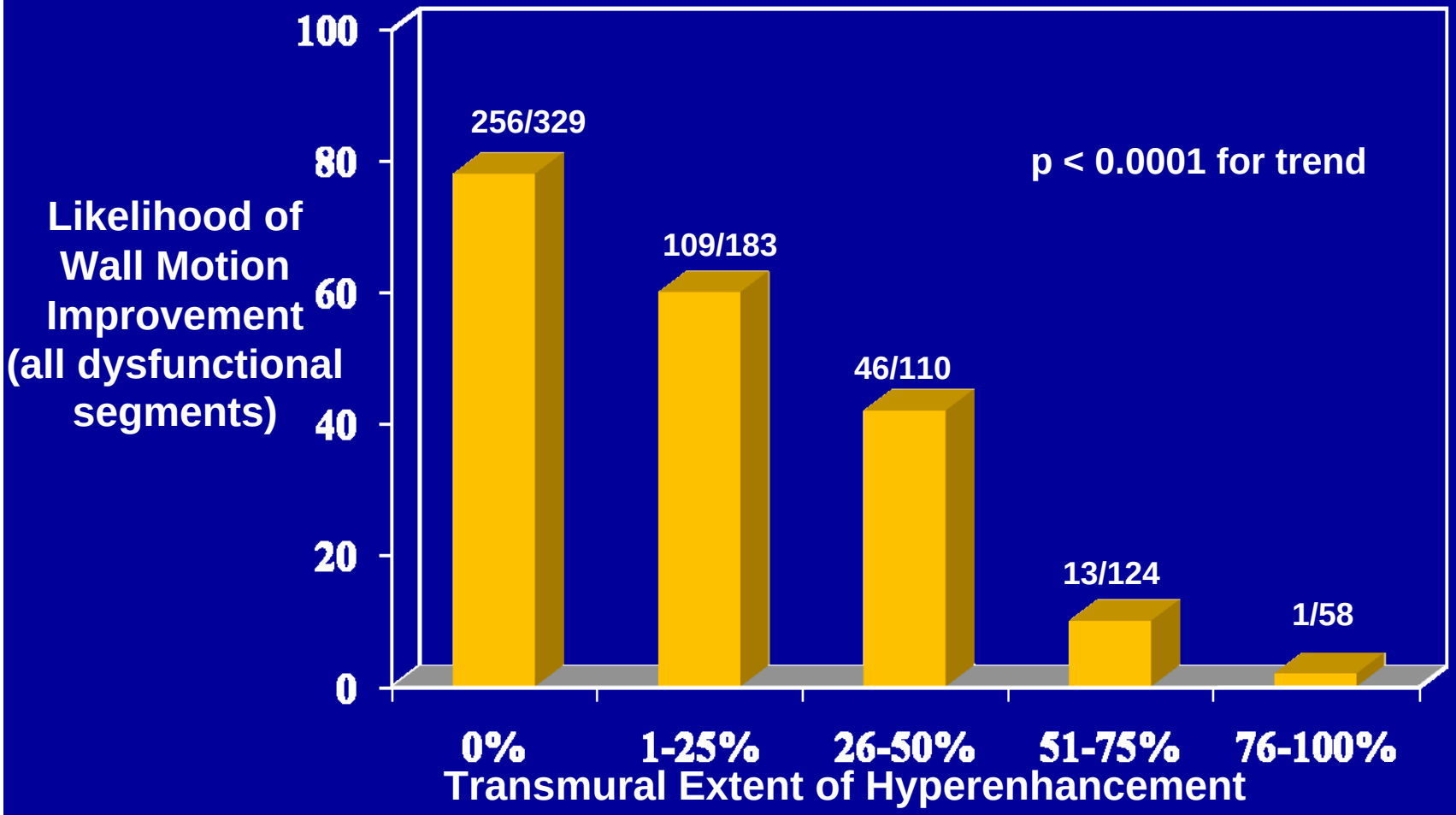
LVEF 36.0 %

EDV 131.0 ml

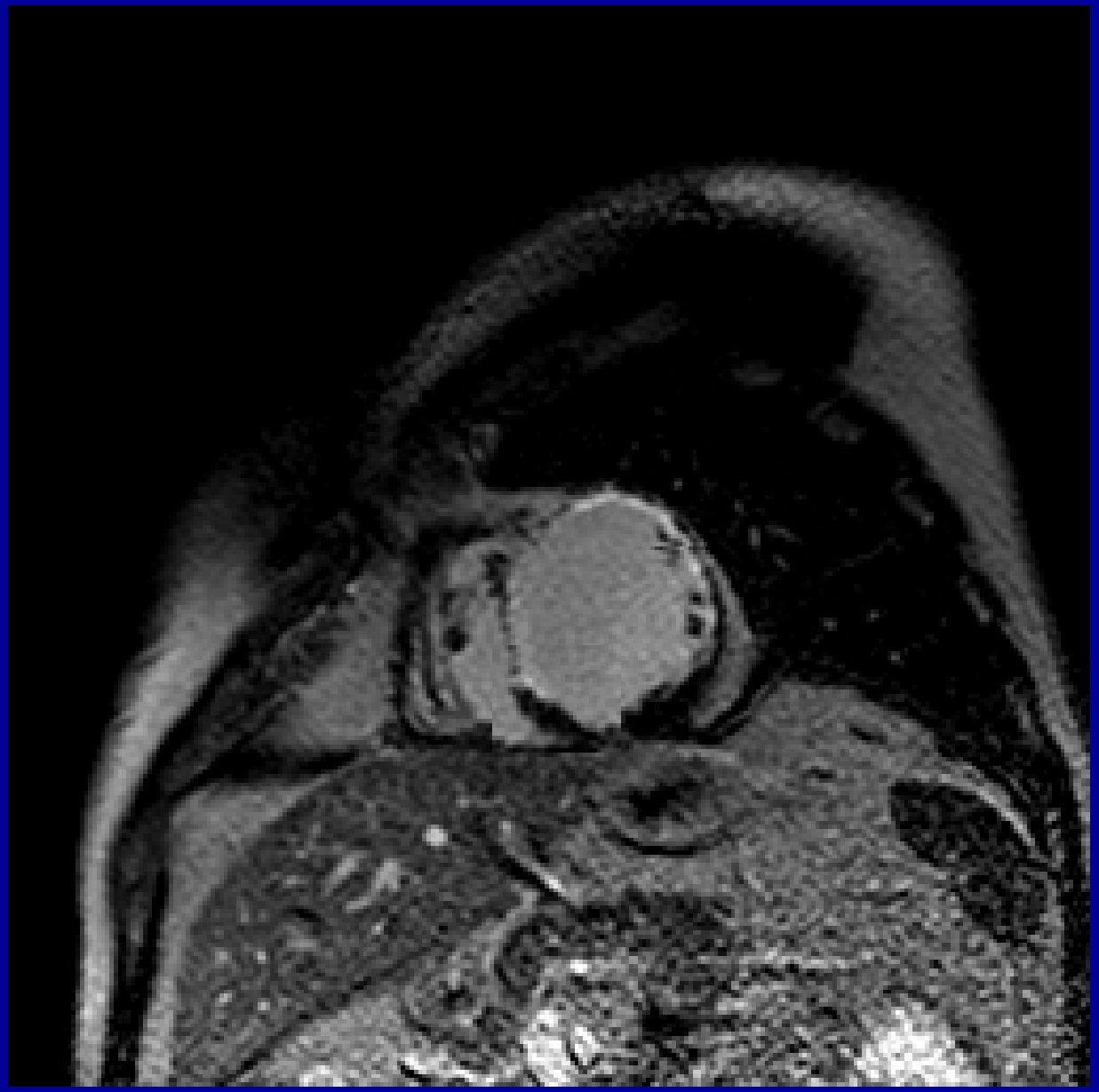
ESV 84.0 ml

OUTPUT 2.4 L/min

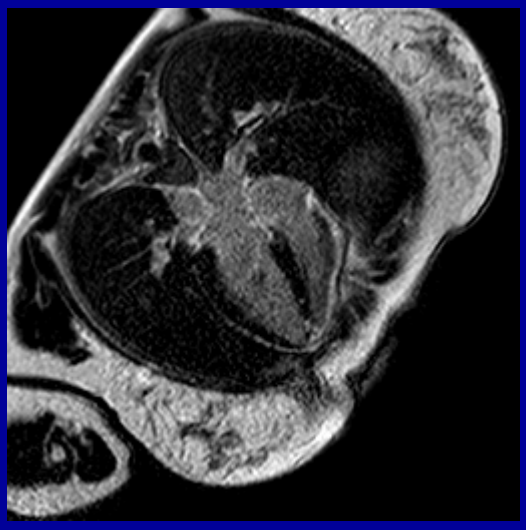
Extent of transmural hyperenhancement by ceCMR in chronic LV dysfunction predicts improvement in wall motion after revascularization

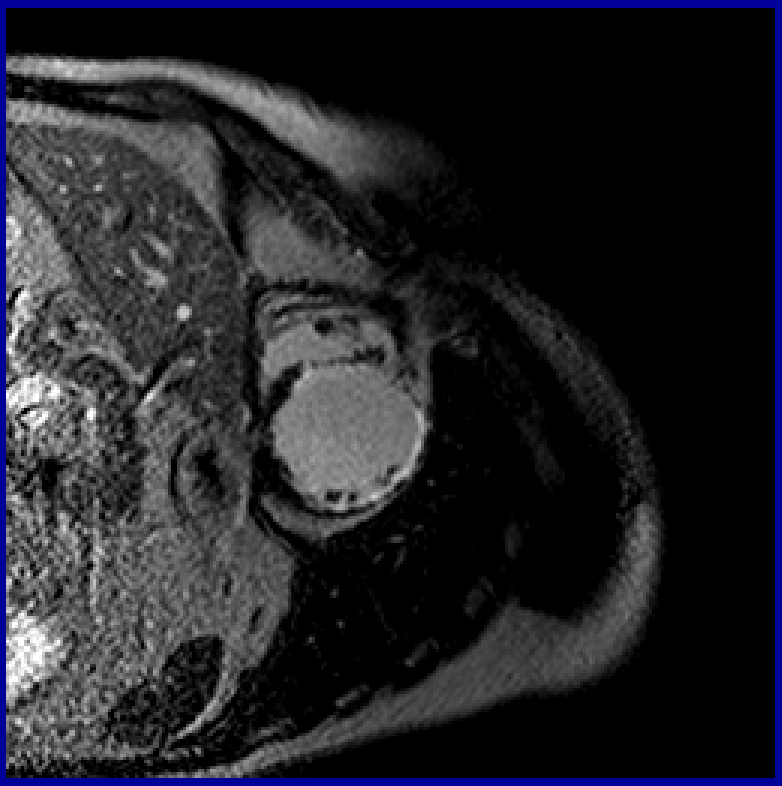


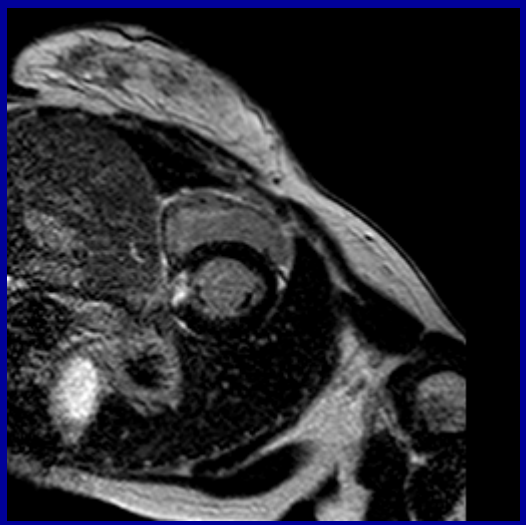
Kim RJ et al. The use of contrast enhanced magnetic resonance imaging to identify reversible myocardial dysfunction. NEJM 2000;343:1445-1453

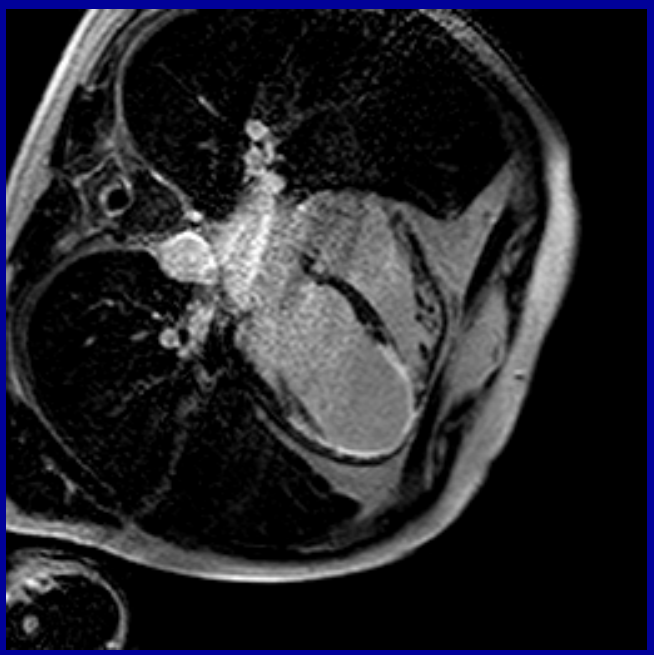


IA

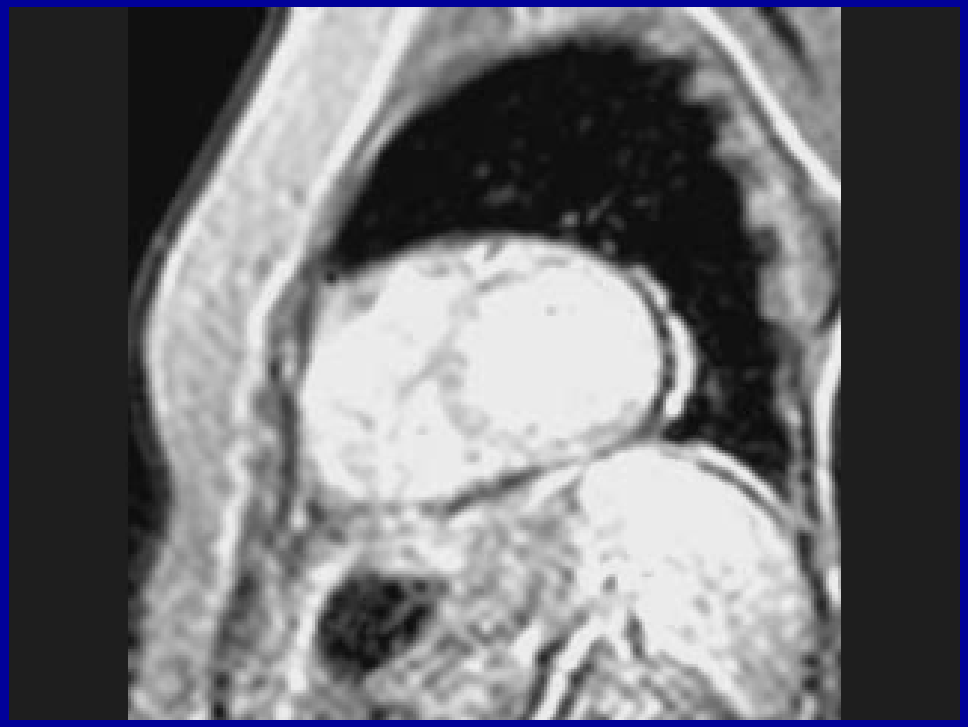




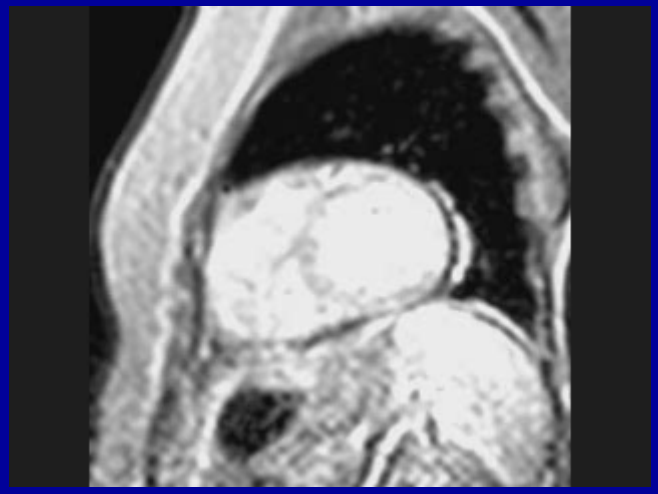




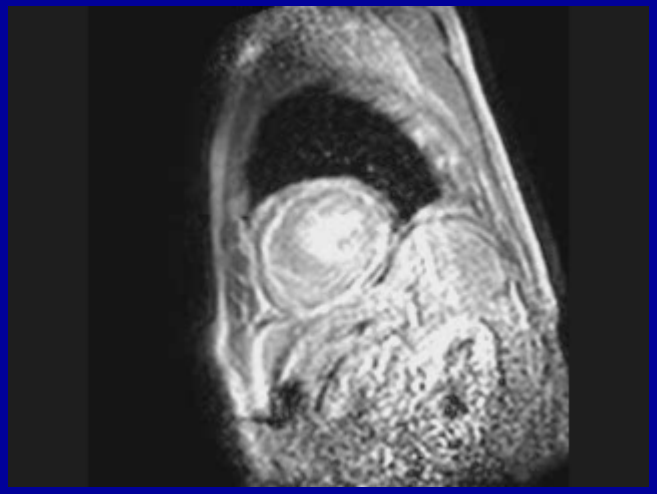
TI scout /Look Locker Sequence



TI scout /Look-Locker Sequence



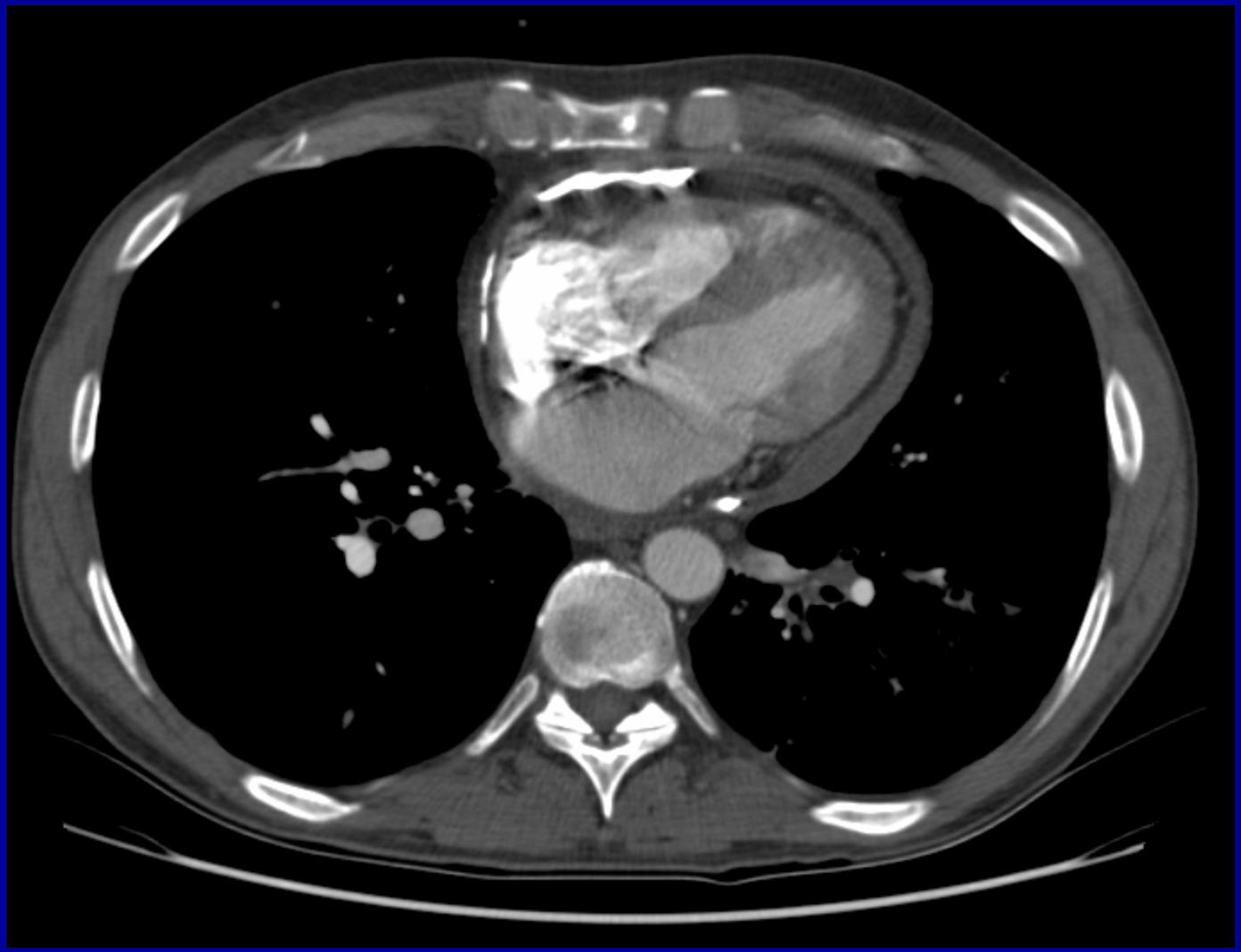
Normal

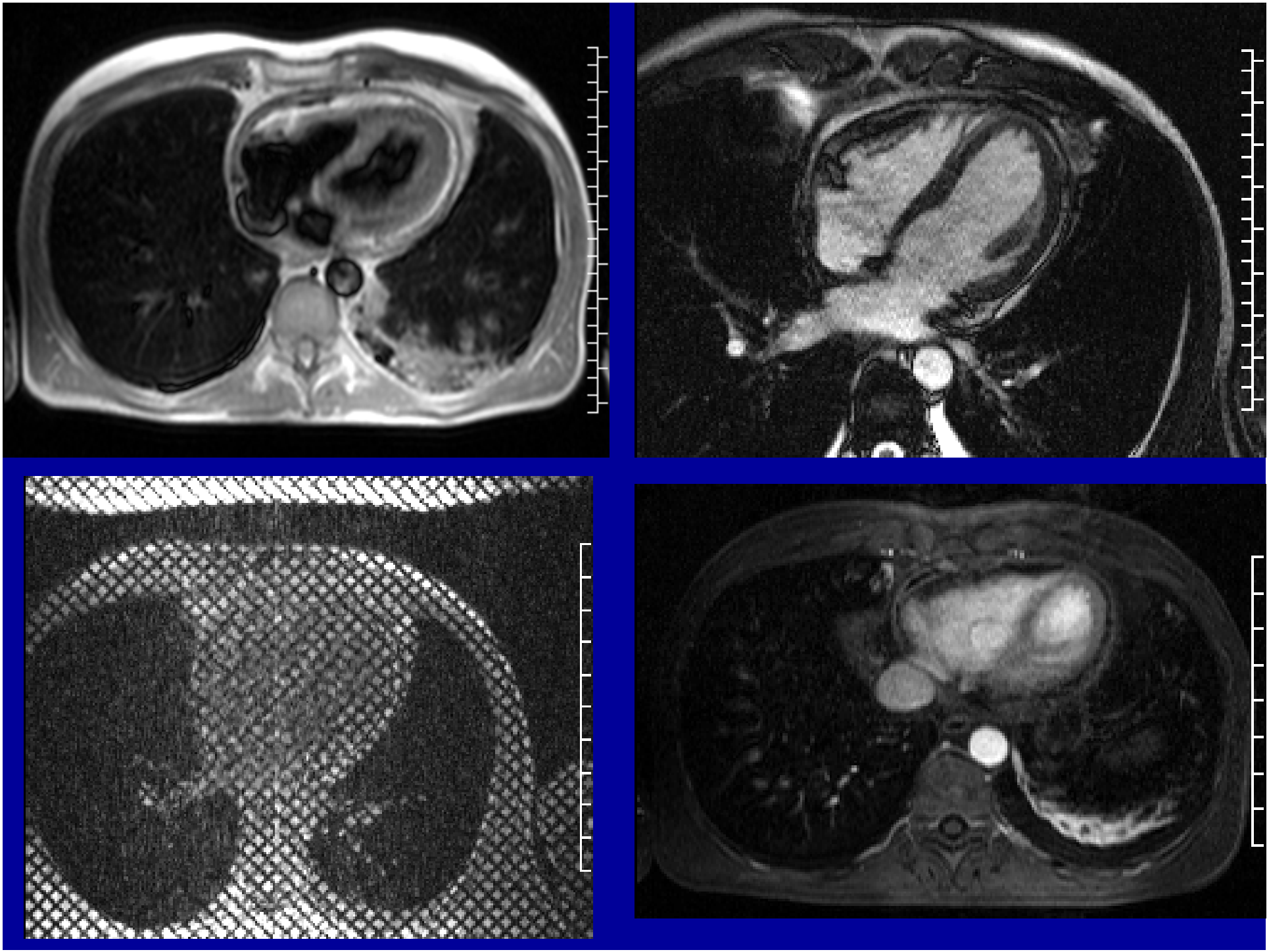


Amyloidosis

Tissue Tagging

- Diastolic dysfunction assessment
- Pericardial diseases





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

ACCF/ACR/SCCT/SCMR/ ASNC/NASCI/SCAI/SIR 2006 Appropriateness Criteria for Cardiac Computed Tomography and Cardiac Magnetic Resonance Imaging*

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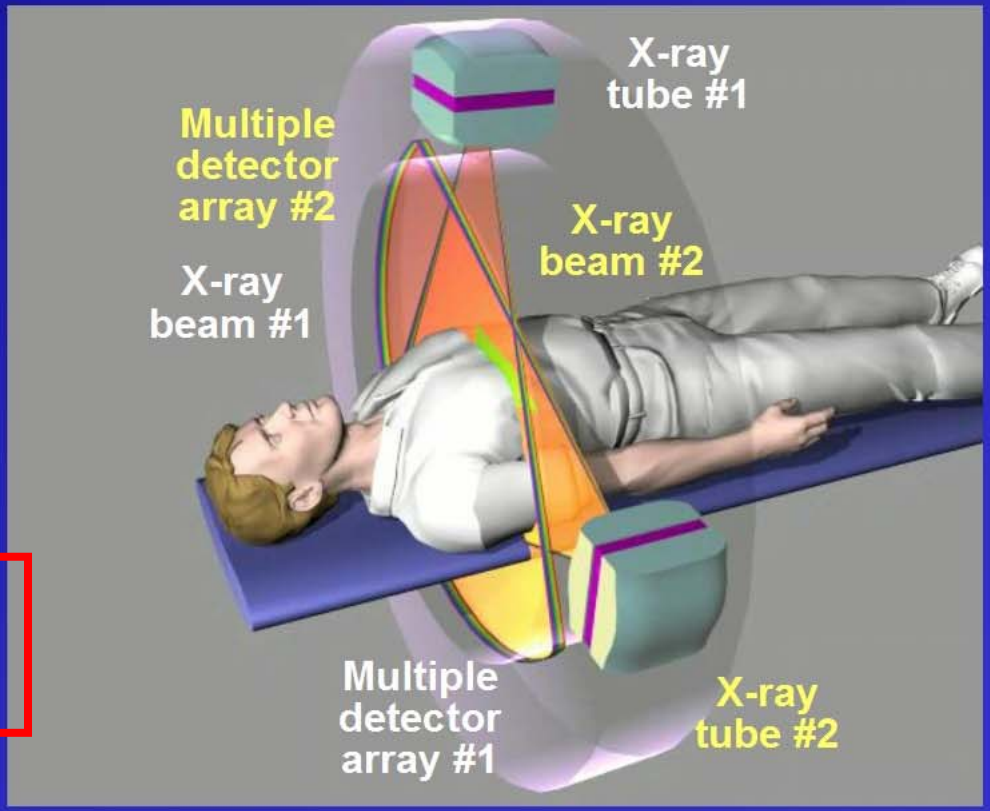
ACCF/ACR/SCCT/SCMR/ASNC/NASCI/SCAI/SIR 2006 Appropriateness Criteria for Cardiac Computed Tomography and Cardiac Magnetic Resonance Imaging*

Structure and Function—Evaluation of Ventricular and Valvular Function Procedures may include LV/RV mass and volumes, MR angiography, quantification of valvular disease, and delayed contrast enhancement		
18.	• Assessment of complex congenital heart disease including anomalies of coronary circulation, great vessels, and cardiac chambers and valves • Procedures may include LV/RV mass and volumes, MR angiography, quantification of valvular disease, and contrast enhancement	**A (9)**
20.	• Evaluation of LV function following myocardial infarction OR in heart failure patients • Patients with technically limited images from echocardiogram	**A (8)**
21.	• Quantification of LV function • Discordant information that is clinically significant from prior tests	**A (8)**
22.	• Evaluation of specific cardiomyopathies (infiltrative [amyloid, sarcoid], HCM, or due to cardiotoxic therapies) • Use of delayed enhancement	**A (8)**
23.	• Characterization of native and prosthetic cardiac valves—including planimetry of stenotic disease and quantification of regurgitant disease • Patients with technically limited images from echocardiogram or TEE	**A (8)**
24.	• Evaluation for arrythmogenic right ventricular cardiomyopathy (ARVC) • Patients presenting with syncope or ventricular arrhythmia	**A (9)**
25.	• Evaluation of myocarditis or myocardial infarction with normal coronary arteries • Positive cardiac enzymes without obstructive atherosclerosis on angiography	**A (8)**

Cardiac CT

HISTORY OF CT

- **1970s**: mechanical CT used clinically
- **1983**: electron beam CT introduced for cardiac
- **1998**: 4-slice CT introduced
- **2001**: 16-slice CT introduced
- **2003-2004**: 64-slice CT introduced
- **2005**: dual source CT introduced

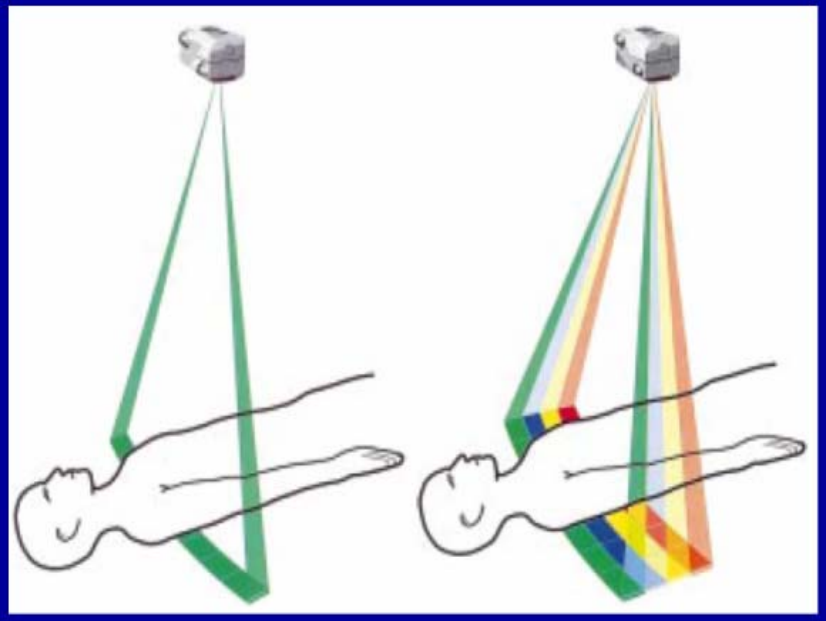


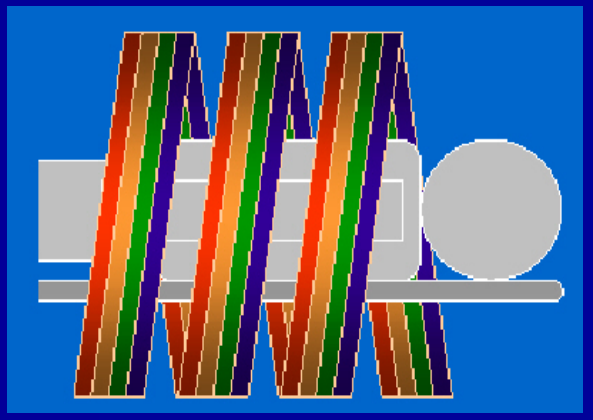
Courtesy of Dr. Sandra Halliburton, Cleveland Clinic

CLEVELAND CLINIC

Multi-slice CT (MSCT)

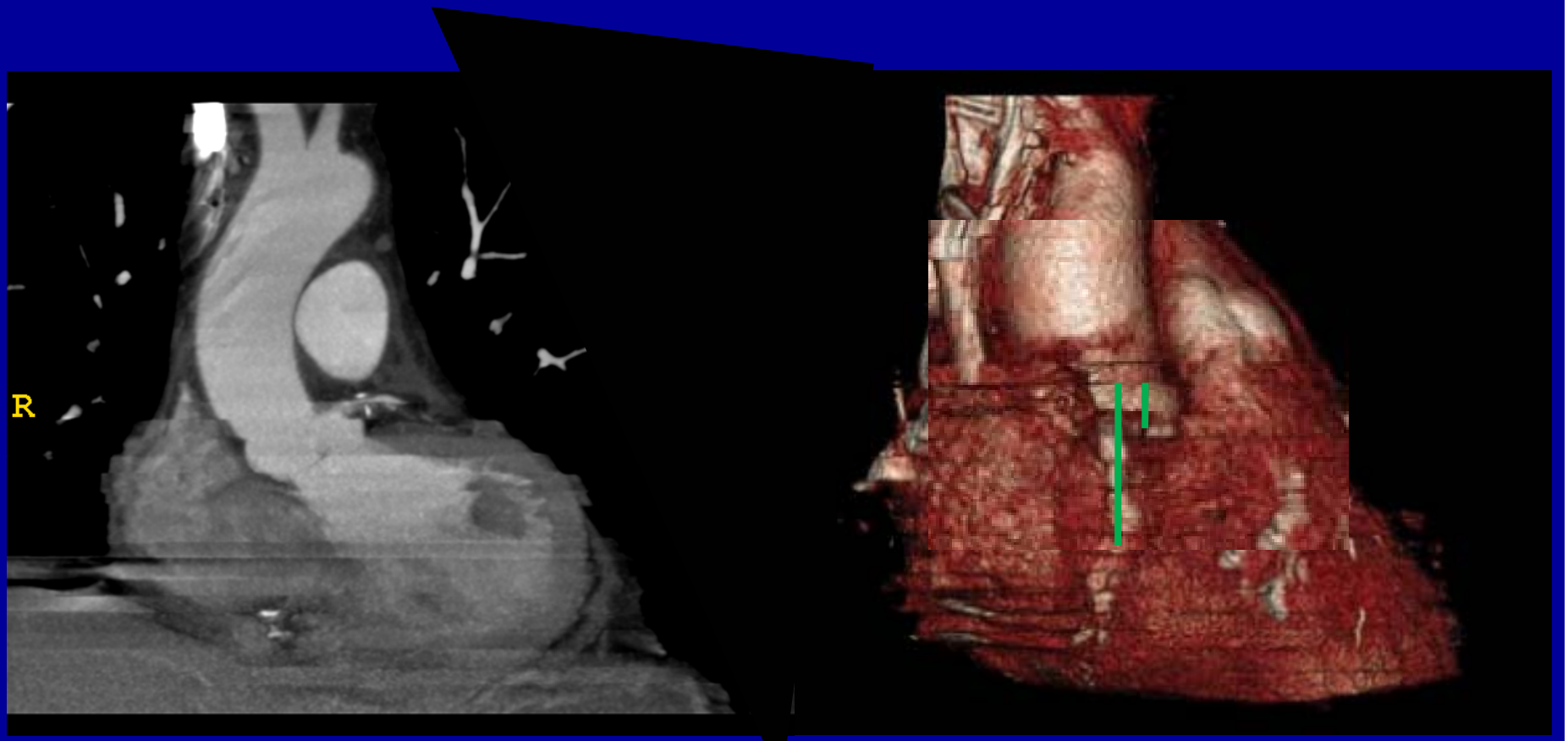
Multi-detector CT (MDCT)





*Rydberg et. al., Radiographics 2000, 20:1787

Multiple heat beats are not the same : slab/stairstep artifacts



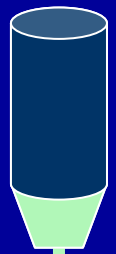
Phillips Gemini 16-slice CT, CSMC

What is a CTA (CT Angiography)?

CTA is a Contrast Enhanced ECG-gated High Resolution Spiral MDCT$_{64\text{-}320}$ of the Chest

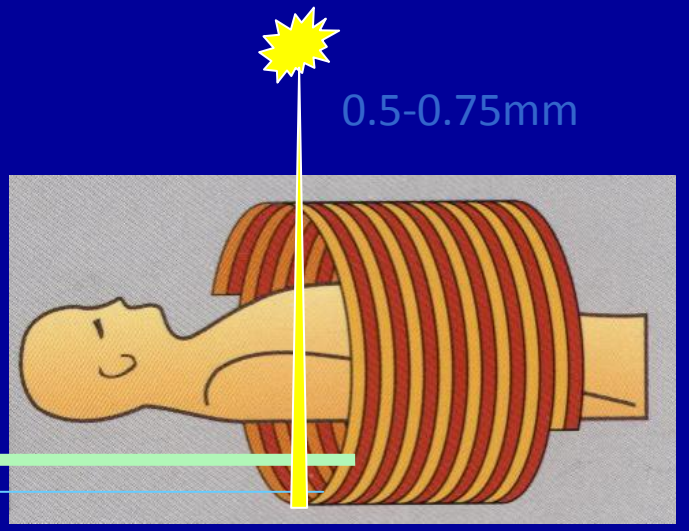
Beta-blockers

<65

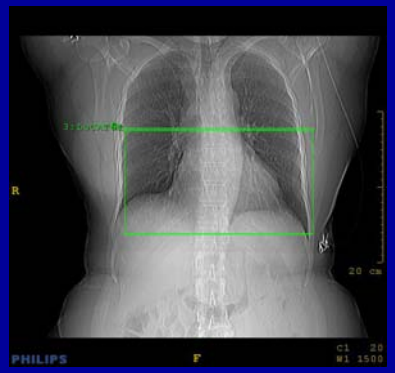


70-90 cc

4-5 cc/s



0.5-0.75mm



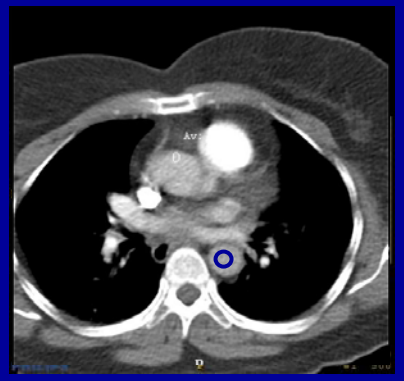
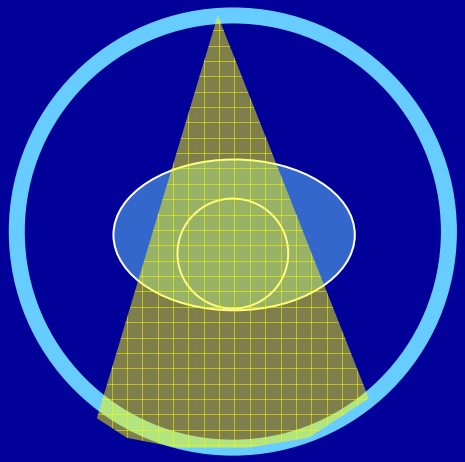
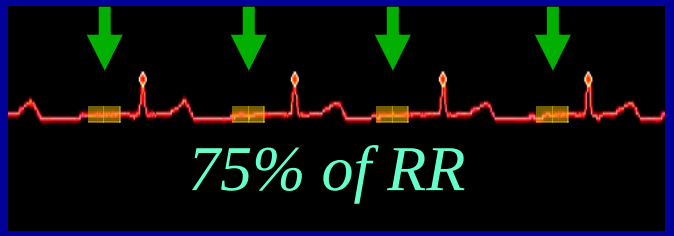


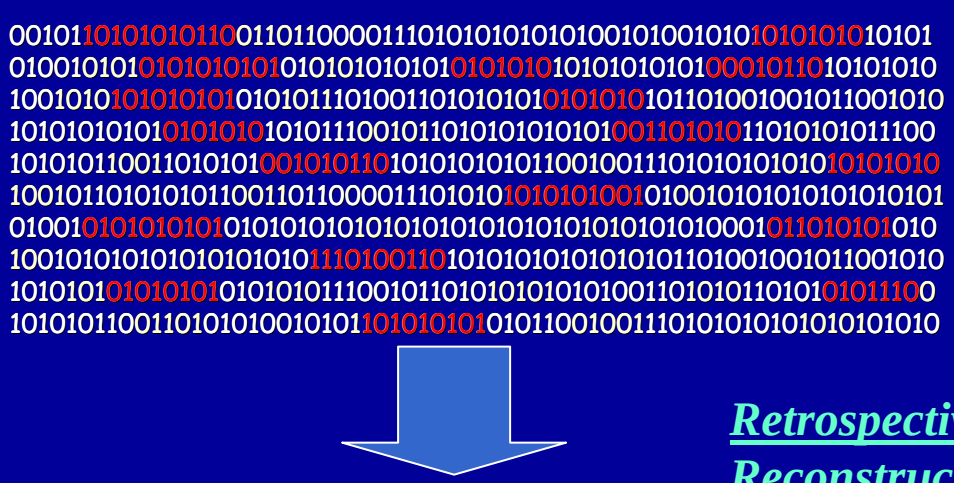
Table Moves

8-10 sec

CTA: ECG-Gating

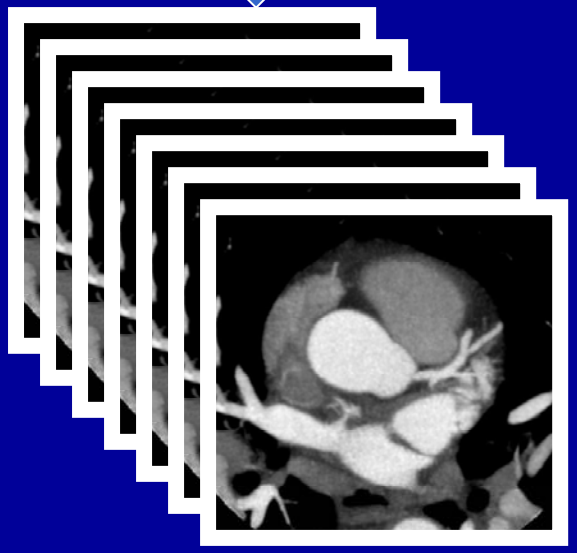




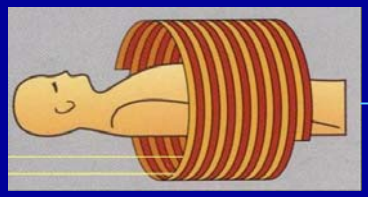


Retrospective Reconstruction

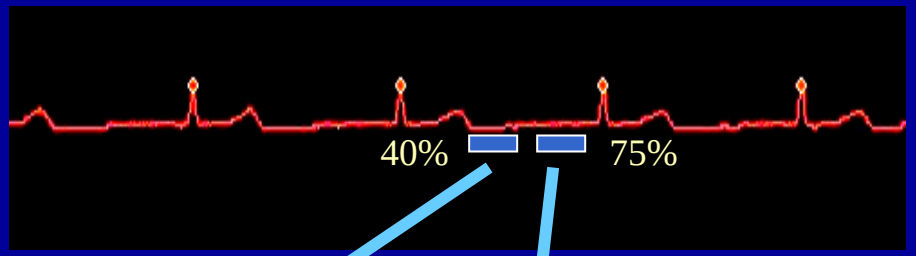
75% of RR



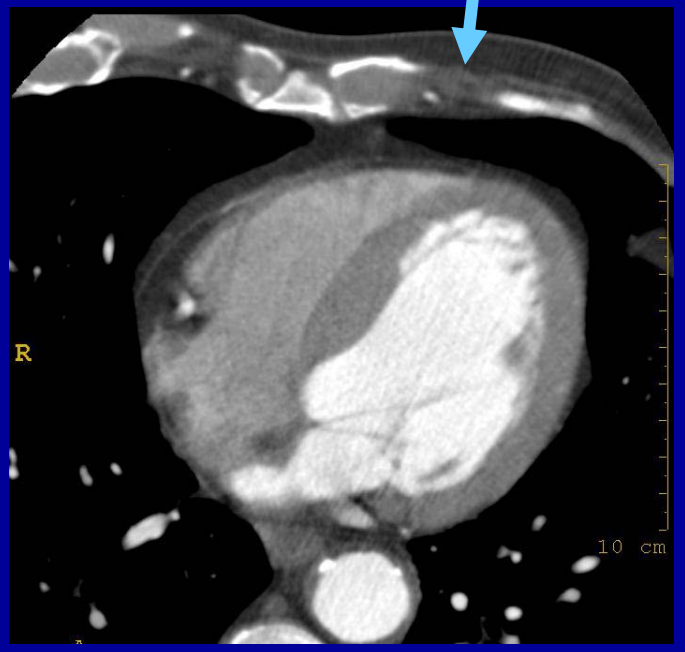
CTA Technique:
Retrospective Image Reconstruction



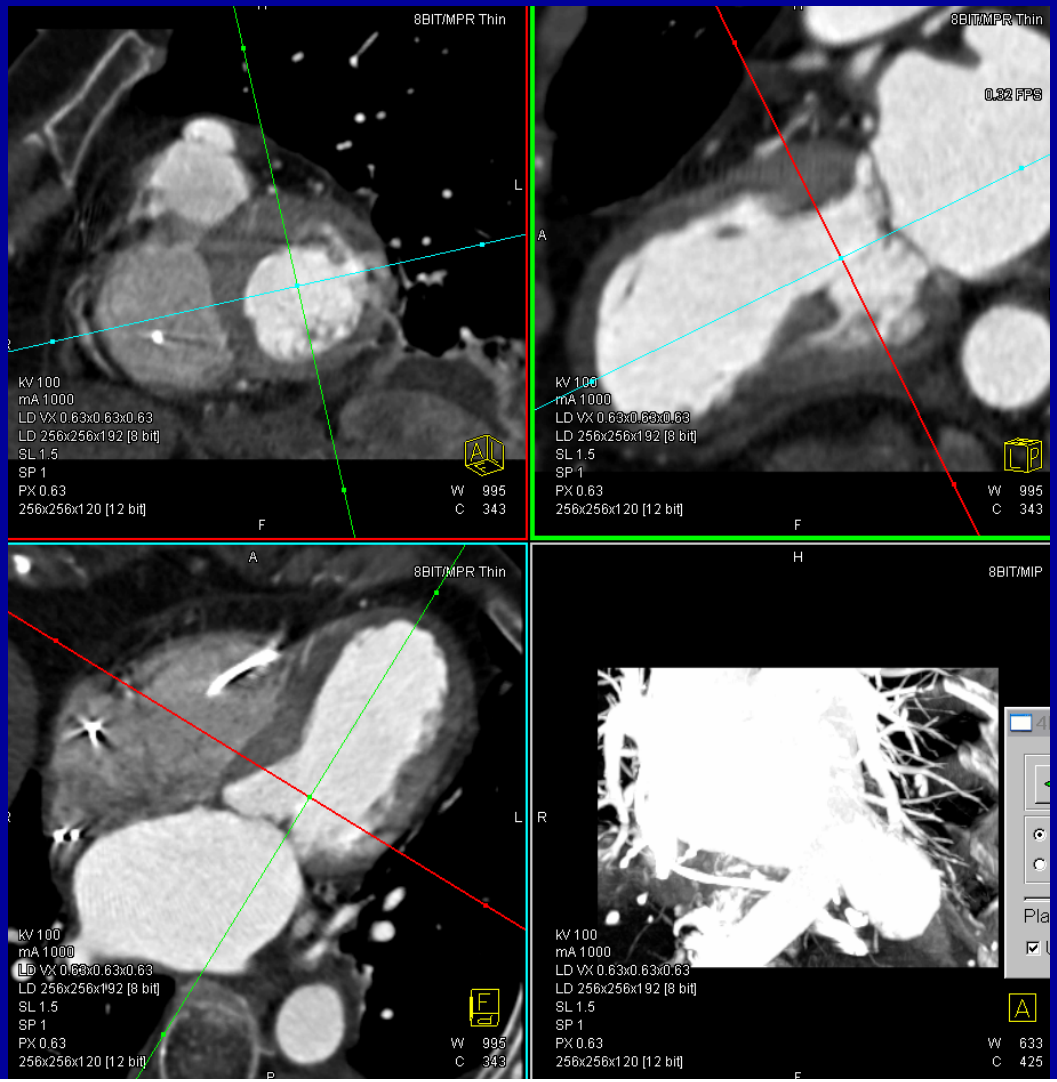
Raw Data



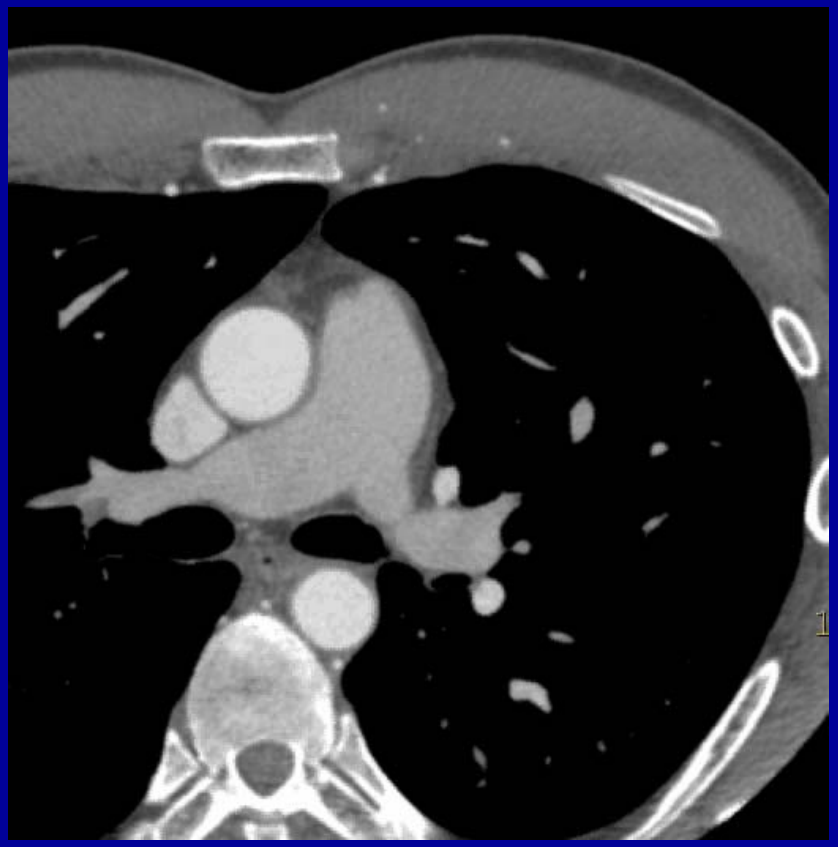
Retrospective Reconstruction

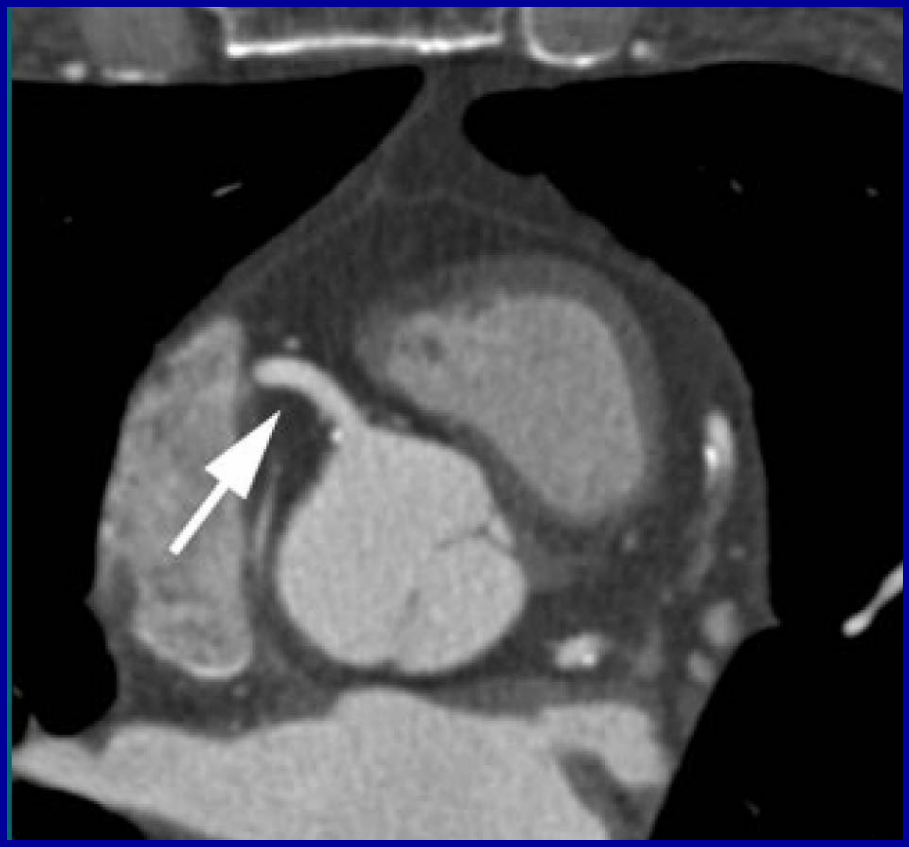


EF and WM calculation

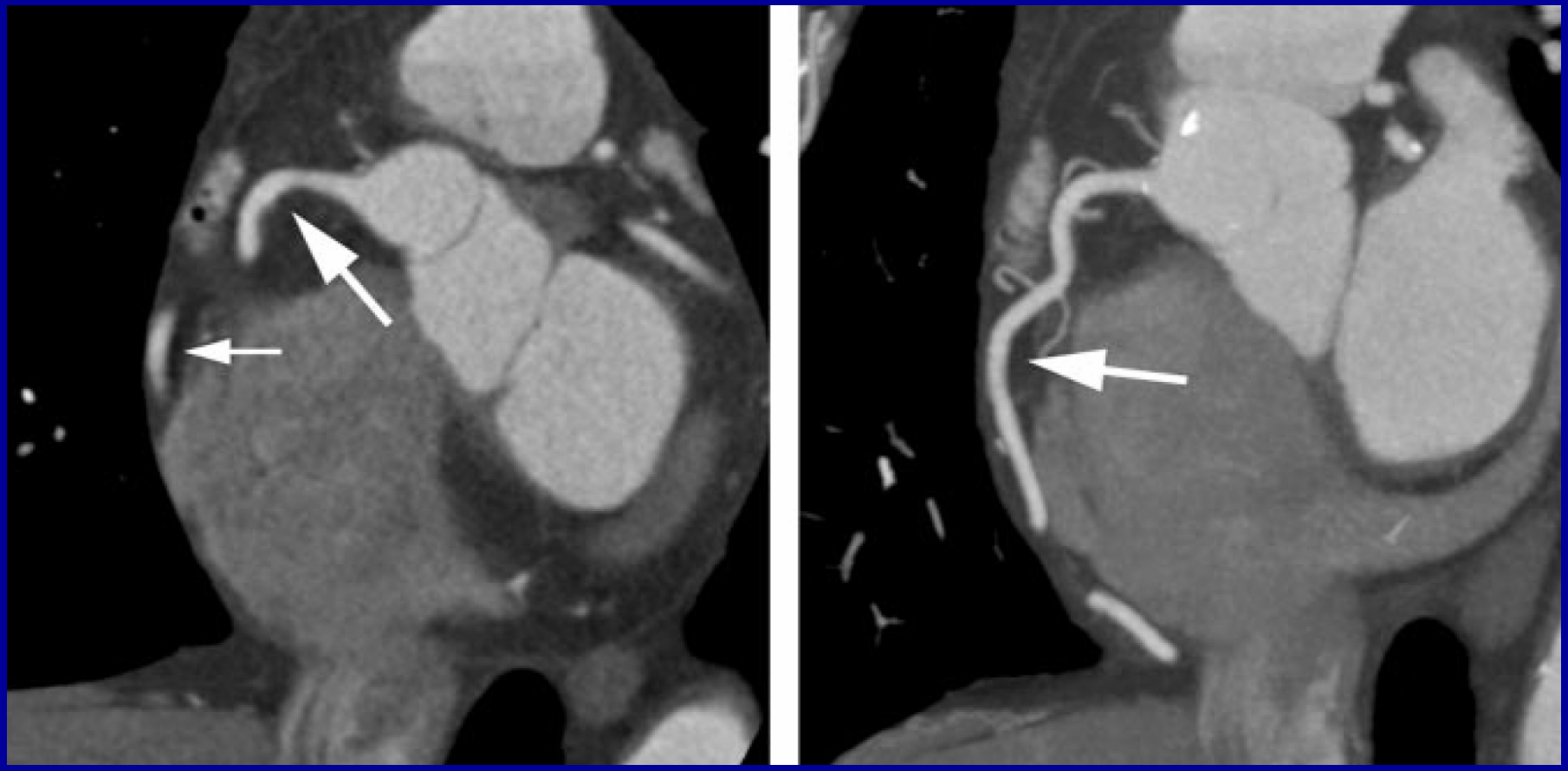


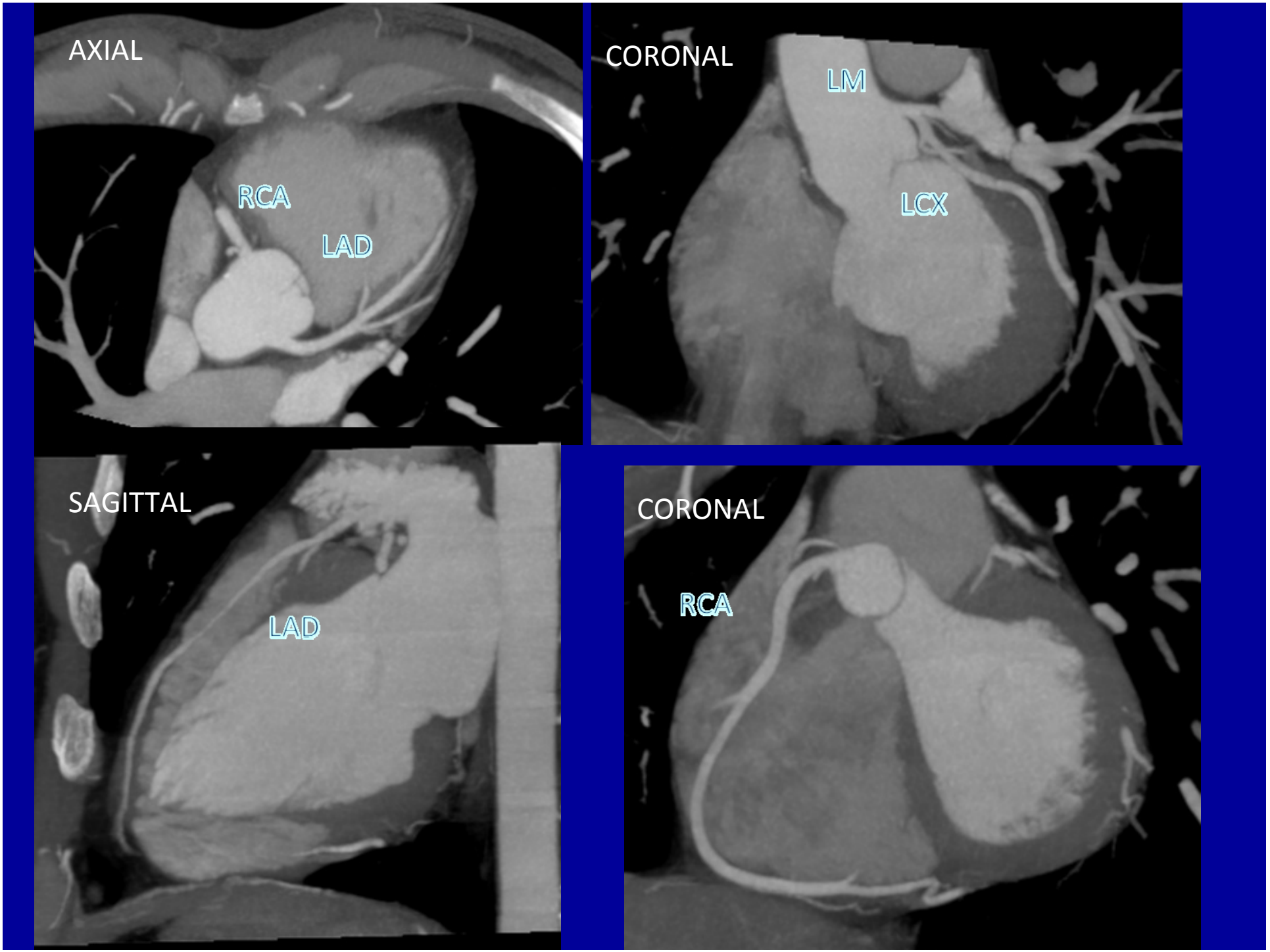
Transverse Images



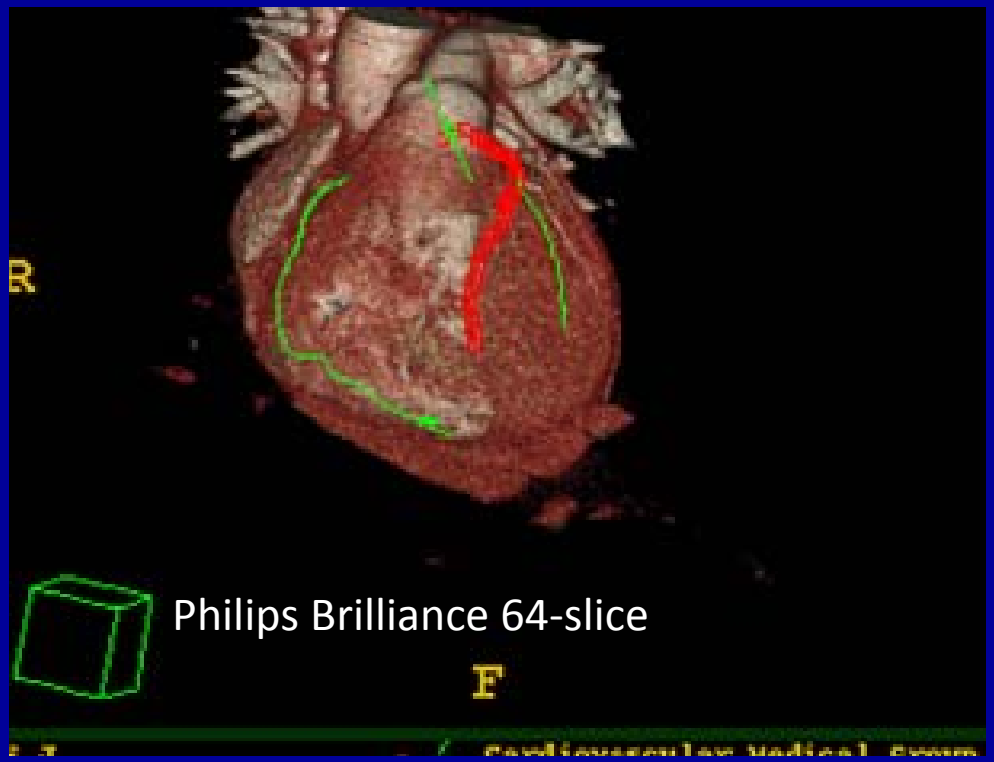


Oblique MPR / MIP

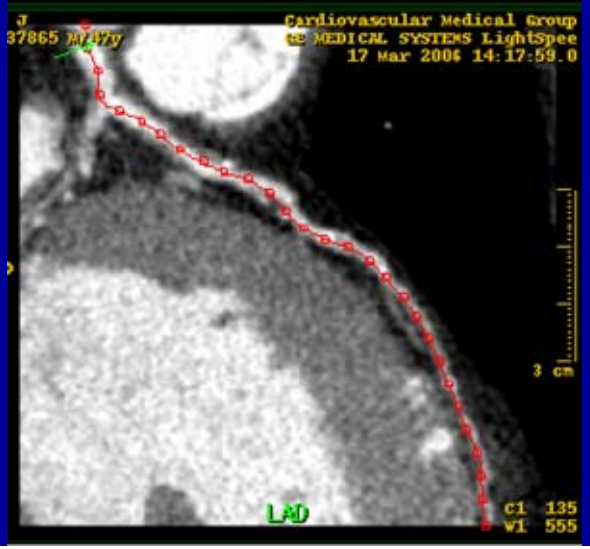


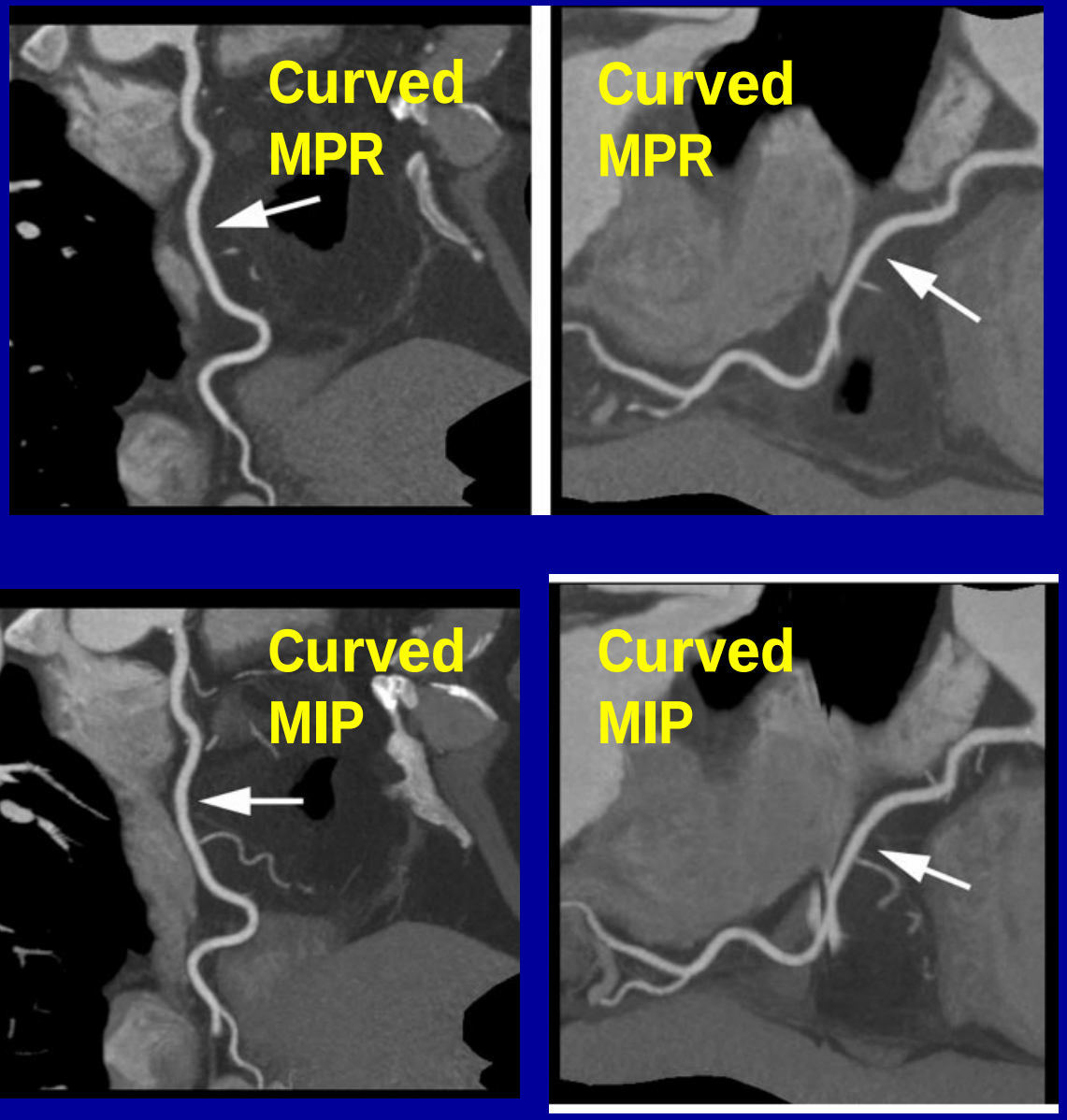

AXIAL
RCA
LAD
CORONAL
LM
LCX
SAGITTAL
LAD
CORONAL
RCA

Curved MPR

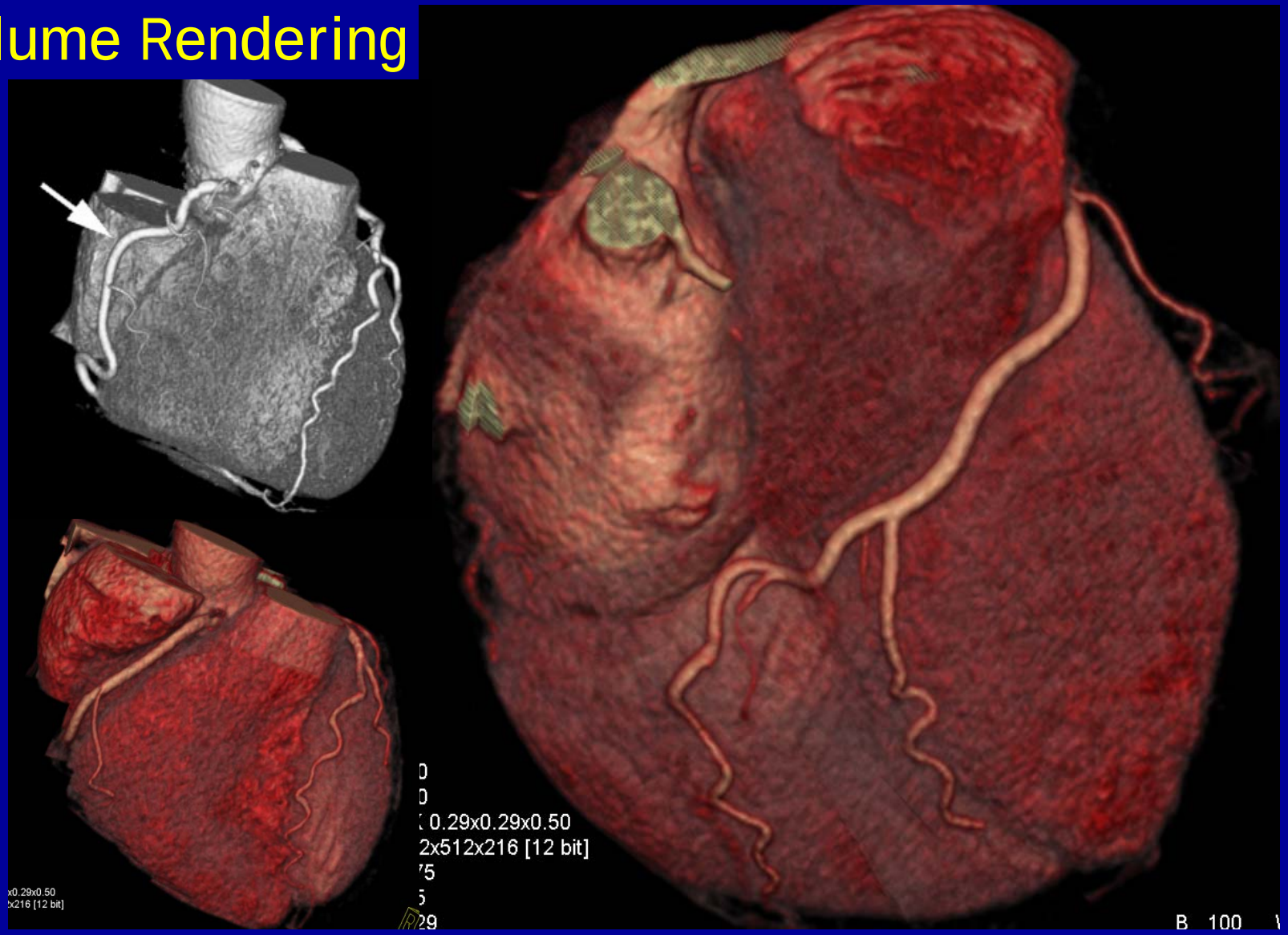


Philips Brilliance 64-slice



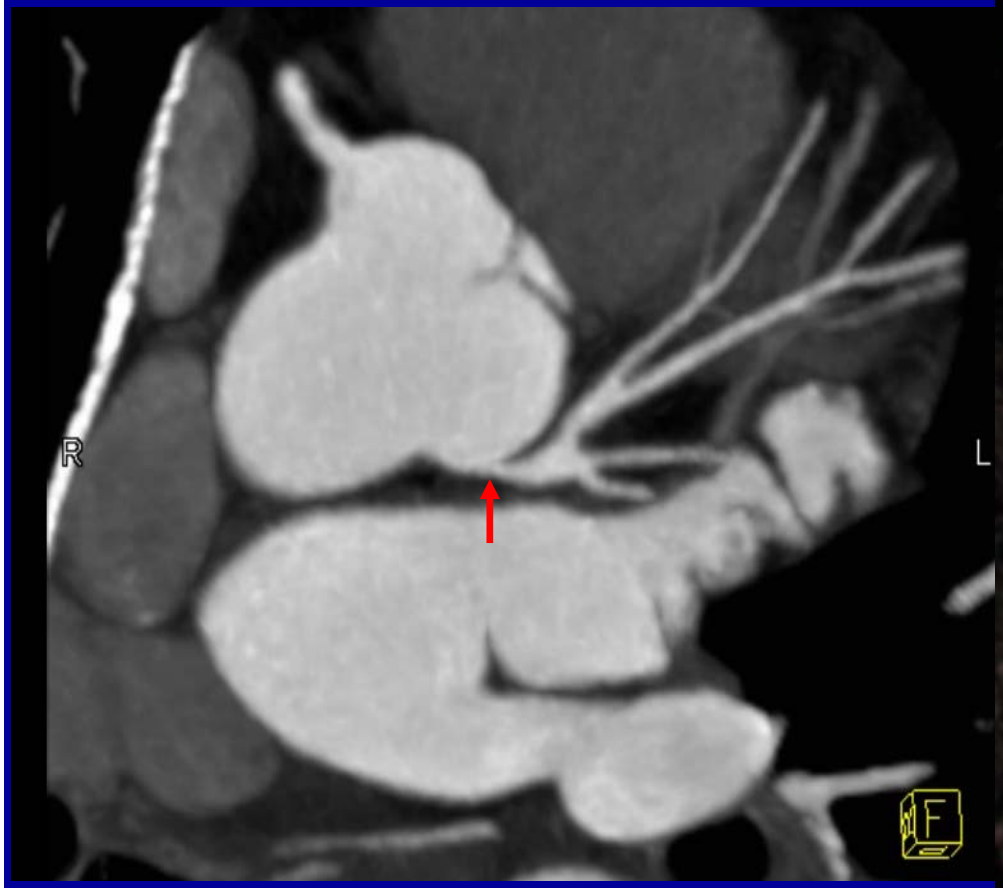

Curved
MPR
Curved
MPR
Curved
MIP
Curved
MIP

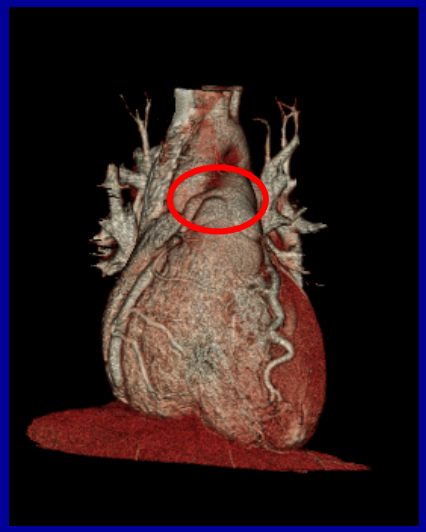
Volume Rendering

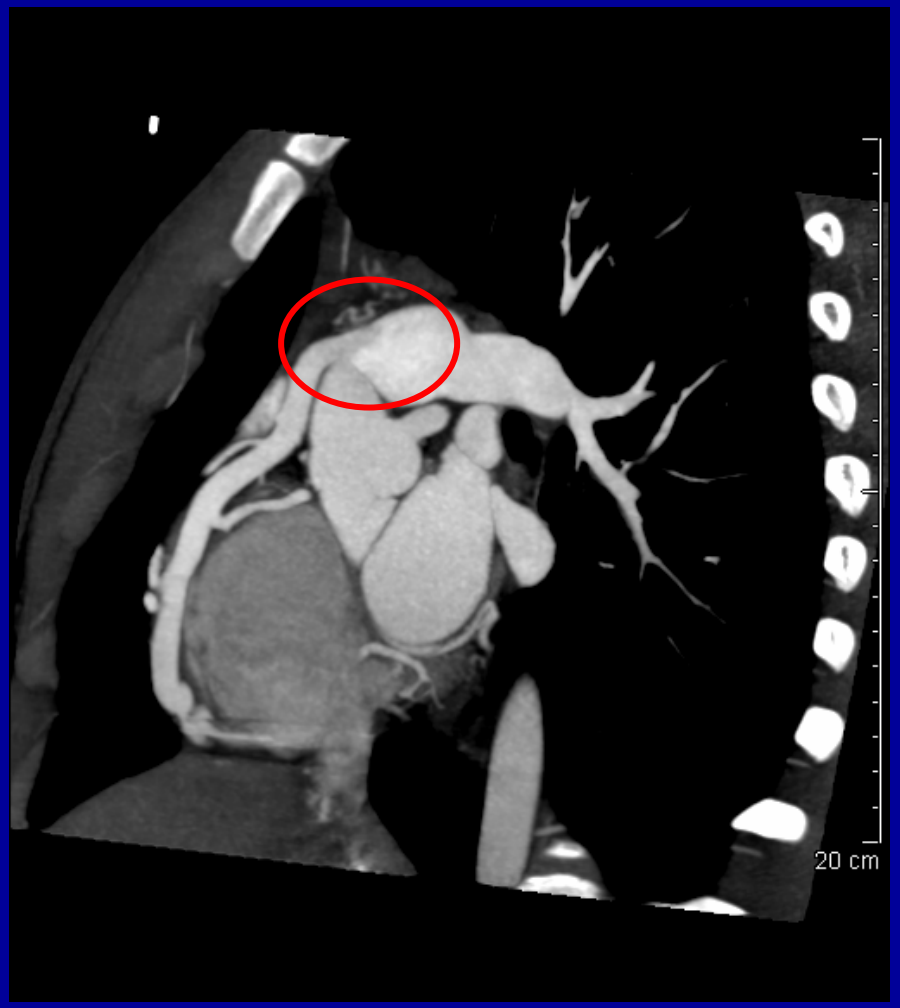


Siemens DSCT

VR



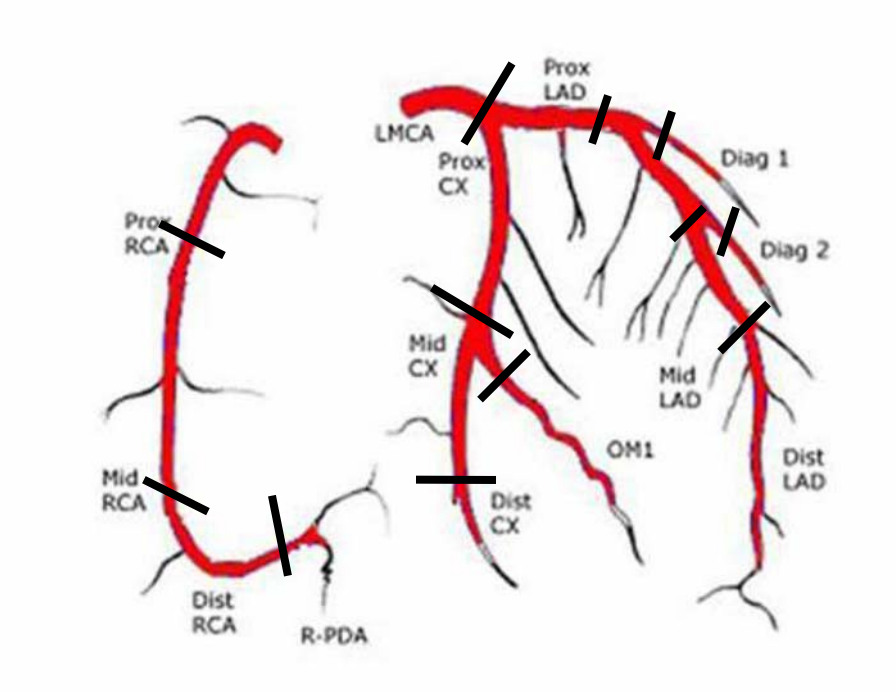




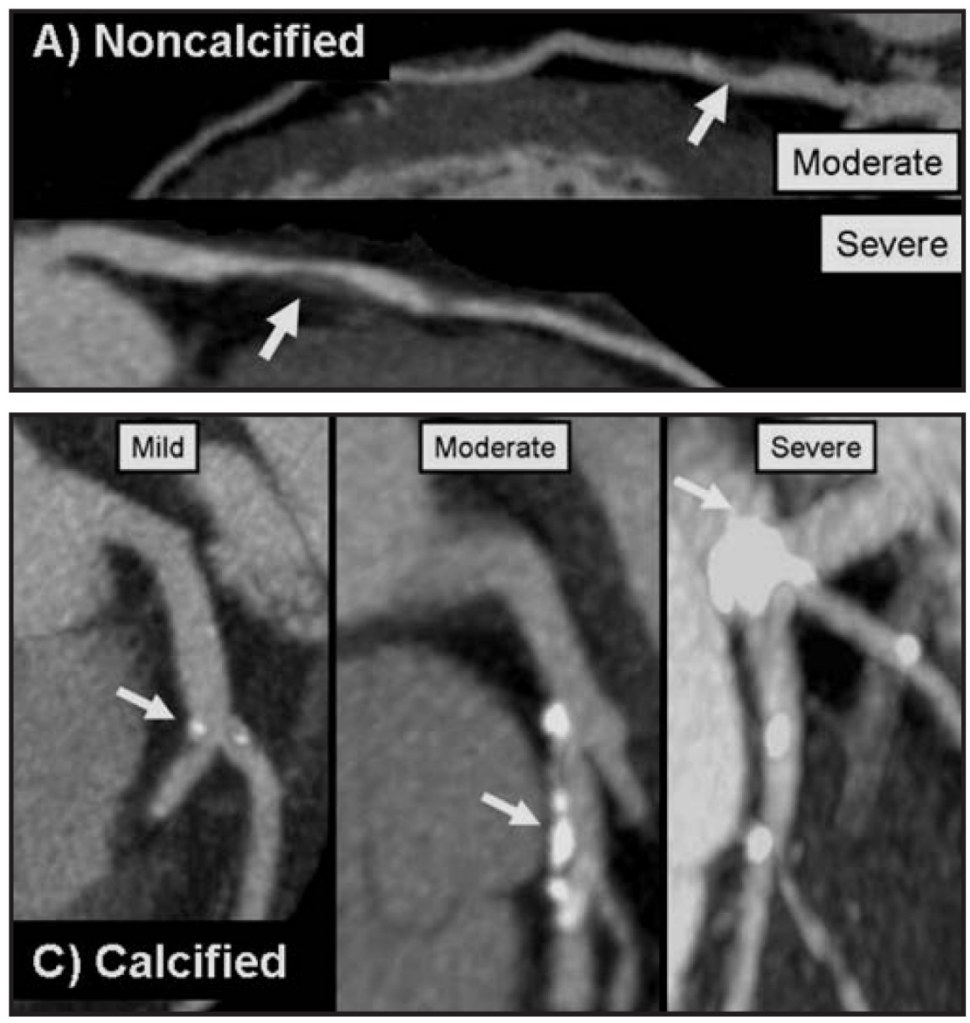
RCA from PA

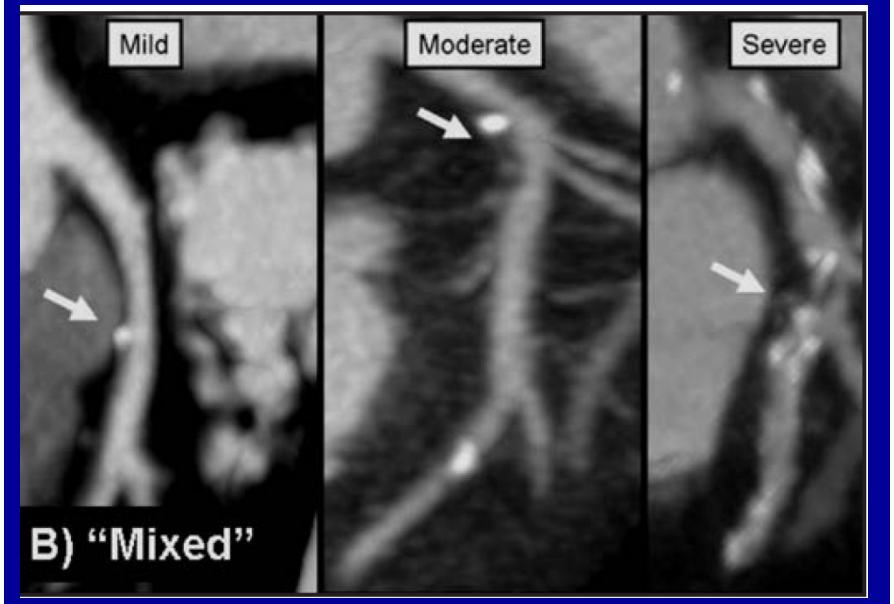
Normal Coronary Anatomy

17-segment model



Assessment of Stenosis





Diagnostic Accuracy

Modality	Number of Studies	Number of Patients	Sensitivity (%)	Specificity (%)
CTA	21	1650	94	77
Exercise ECG	58	11,691	67	72
Exercise SPECT	22	2,360	87	73
Tc-99m agents only			88	72
Adenosine SPECT	11	3,539	89	77
Tc-99m agents only			87	86
Dobutamine SPECT	20	1,419	85	79
Tc-99m agents only			83	76
Exercise Echocardiography	13	741	83	84
Dobutamine Stress Echocardiography	13	436	75	83

The NEW ENGLAND JOURNAL of MEDICINE

Diagnostic Performance of Coronary Angiography by 64-Row CT

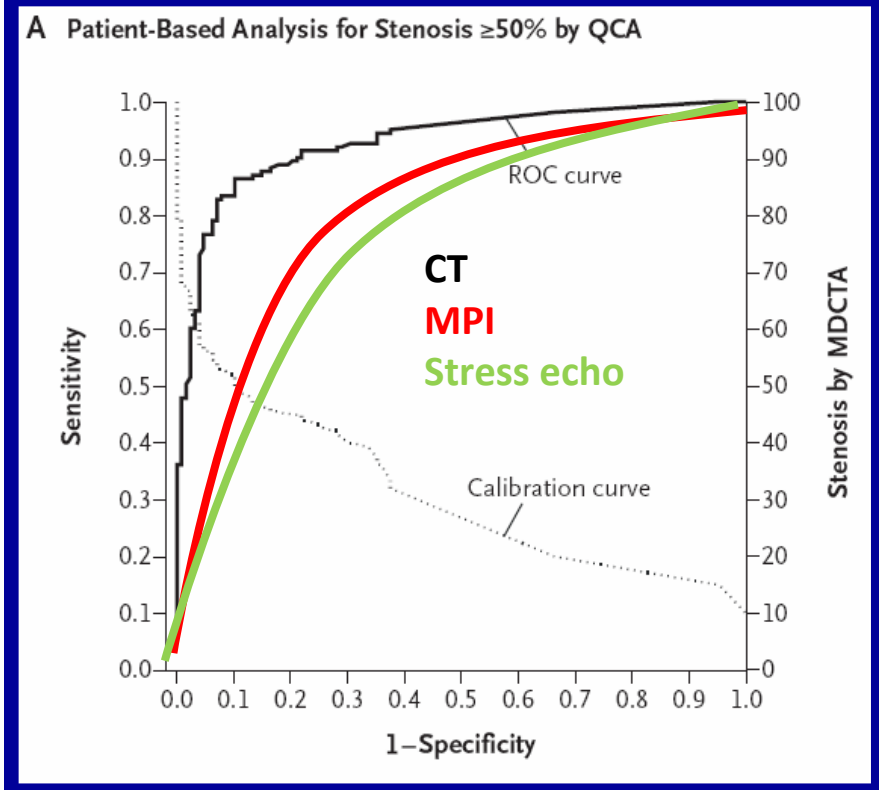
Julie M. Miller, M.D., Carlos E. Rochitte, M.D., Marc Dewey, M.D., Armin Arbab-Zadeh, M.D., Hiroyuki Niinuma, M.D., Ph.D., Ilan Gottlieb, M.D., Narinder Paul, M.D., Melvin E. Clouse, M.D., Edward P. Shapiro, M.D., John Hoe, M.D., Albert C. Lardo, Ph.D., David E. Bush, M.D., Albert de Roos, M.D., Christopher Cox, Ph.D., Jeffery Brinker, M.D., and João A.C. Lima, M.D.

NEJM 359;22 November 27, 2008

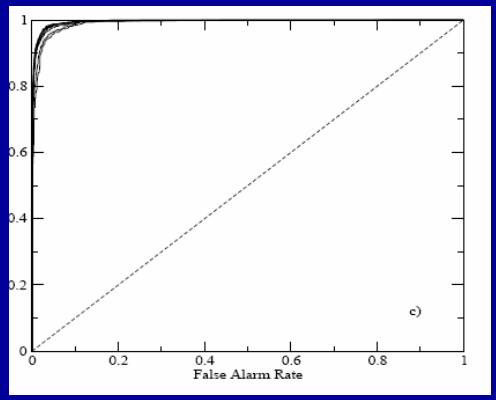
Core 64

- Modified Duke Coronary Artery Disease Index MDCT vs. ICA:
  - The ratio of the standard deviations from MDCT angiography and quantitative coronary angiography was 1.05 (P = 0.16)
  - The bias between the two methods was −0.71 Duke Index unit (P = 0.90)
  - The correlation was good (r = 0.81; 95% CI, 0.76 to 0.84)
- The extent of obstructive coronary artery disease can be accurately assessed by means of 64-row MDCT

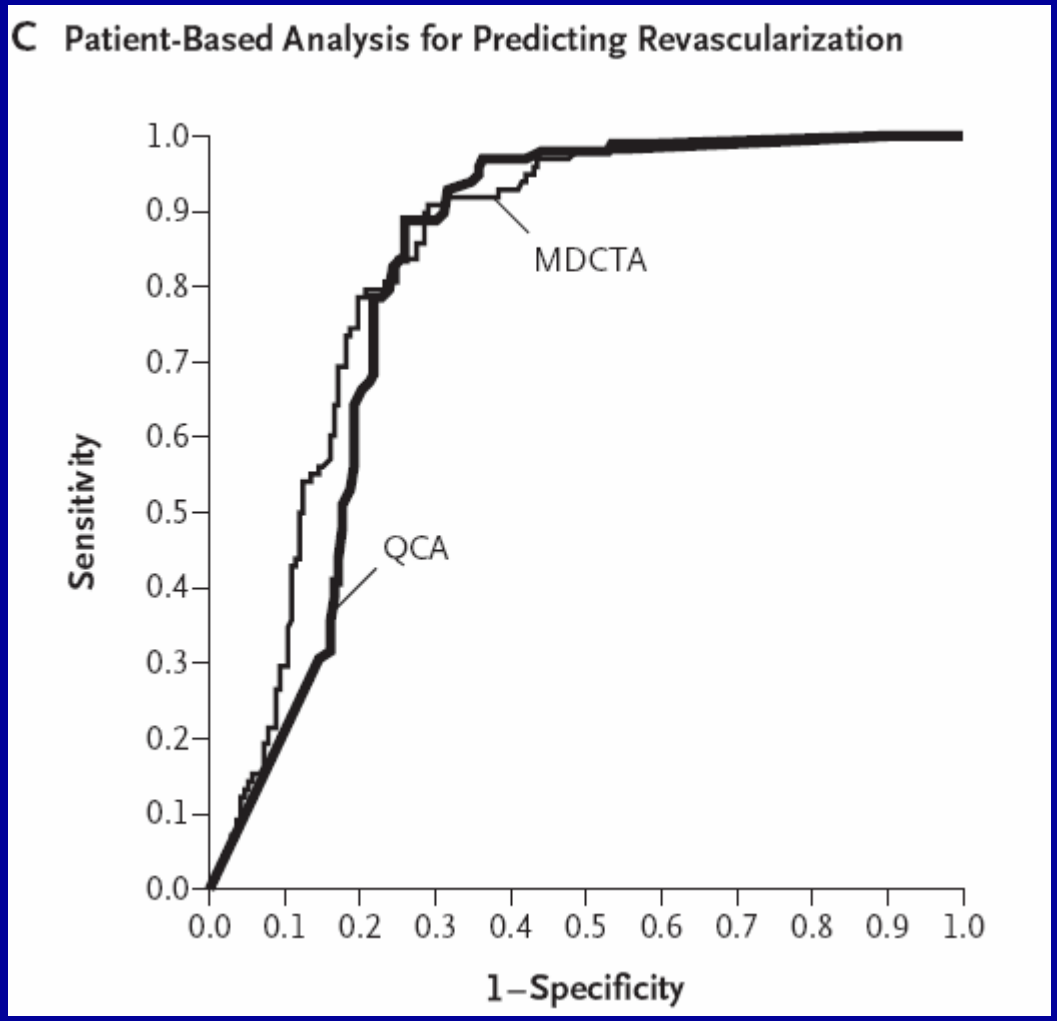
Core 64



Measure of Accuracy	Patient-Based Detection	
	Quantitative MDCTA (N=291)	Visual MDCTA (N=291)
AUC — median (95% CI)	0.93 (0.90–0.96)	0.93 (0.89–0.95)
Stenosis by CCA — no.	163	163
Stenosis by MDCTA — no.	152	146
False positive — no.	13	11
False negative — no.	24	28
Sensitivity — % (95% CI)	85 (79–90)	83 (76–88)
Specificity — % (95% CI)	90 (83–94)	91 (85–96)
Positive predictive value — % (95% CI)	91 (86–95)	92 (87–96)
Negative predictive value — % (95% CI)	83 (75–89)	81 (73–87)



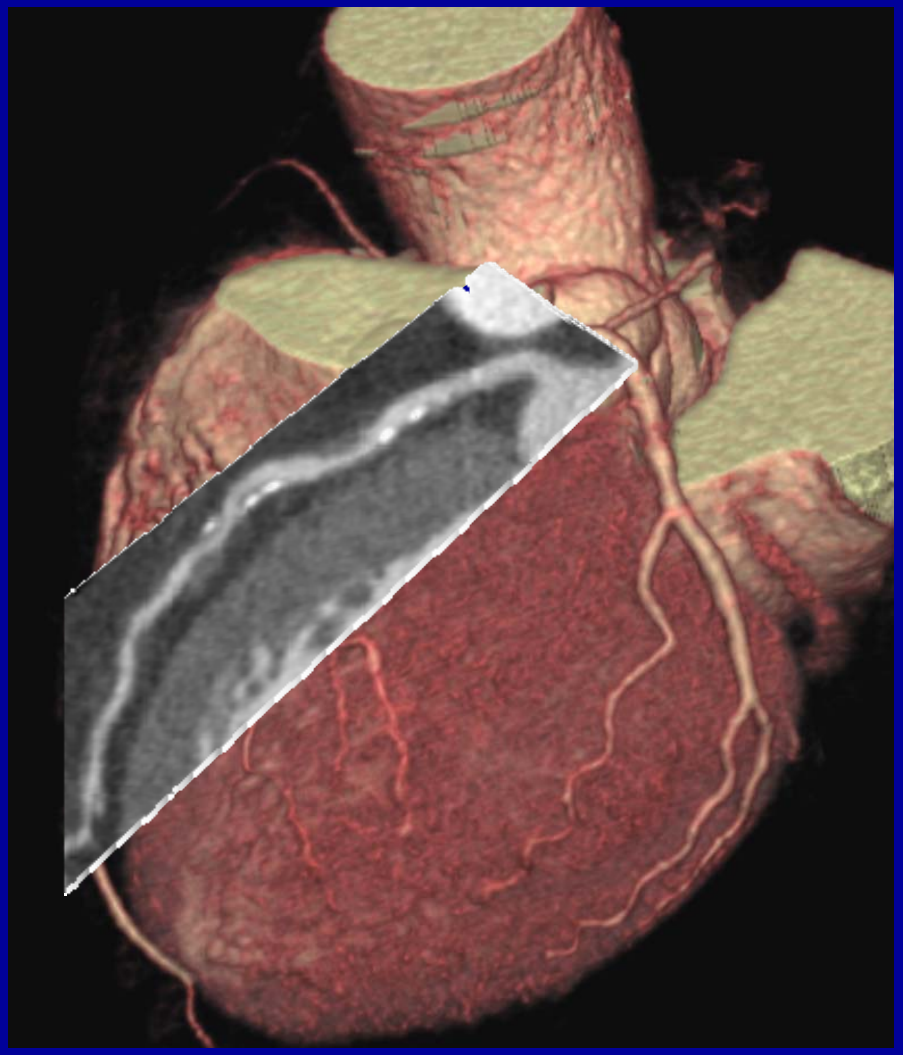
Core 64

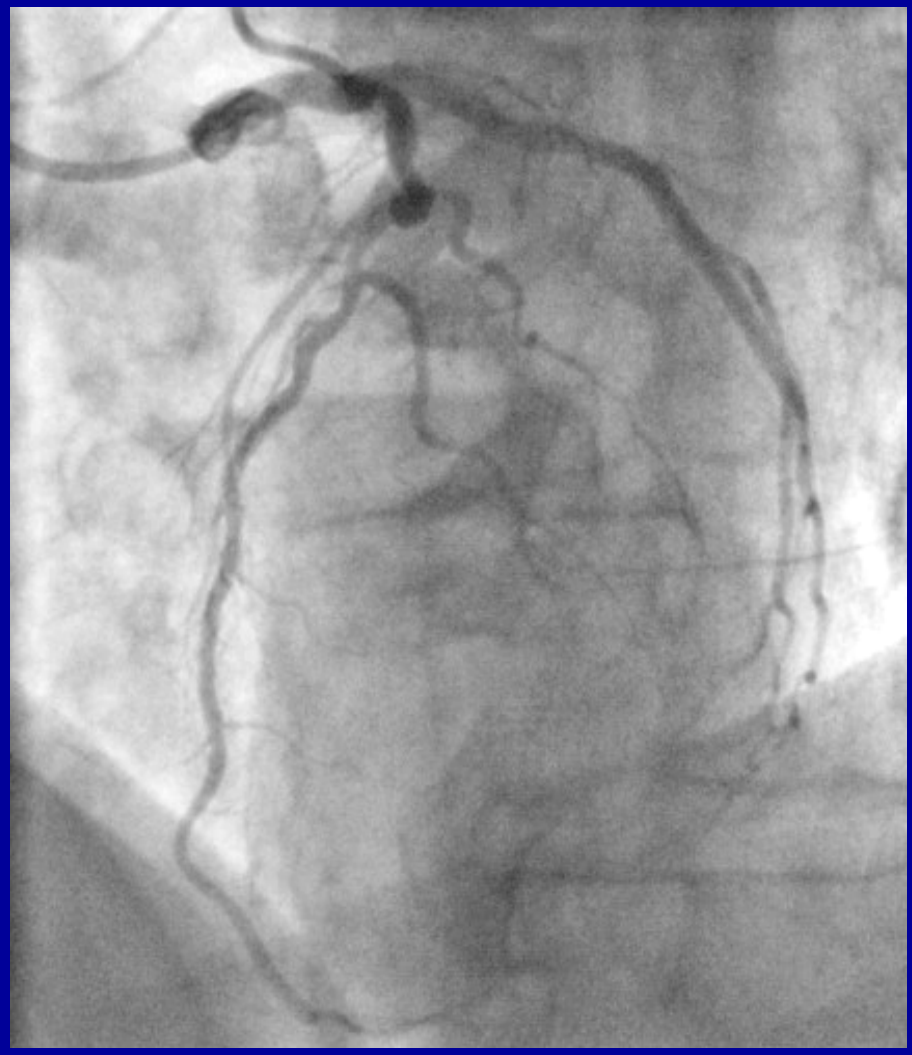


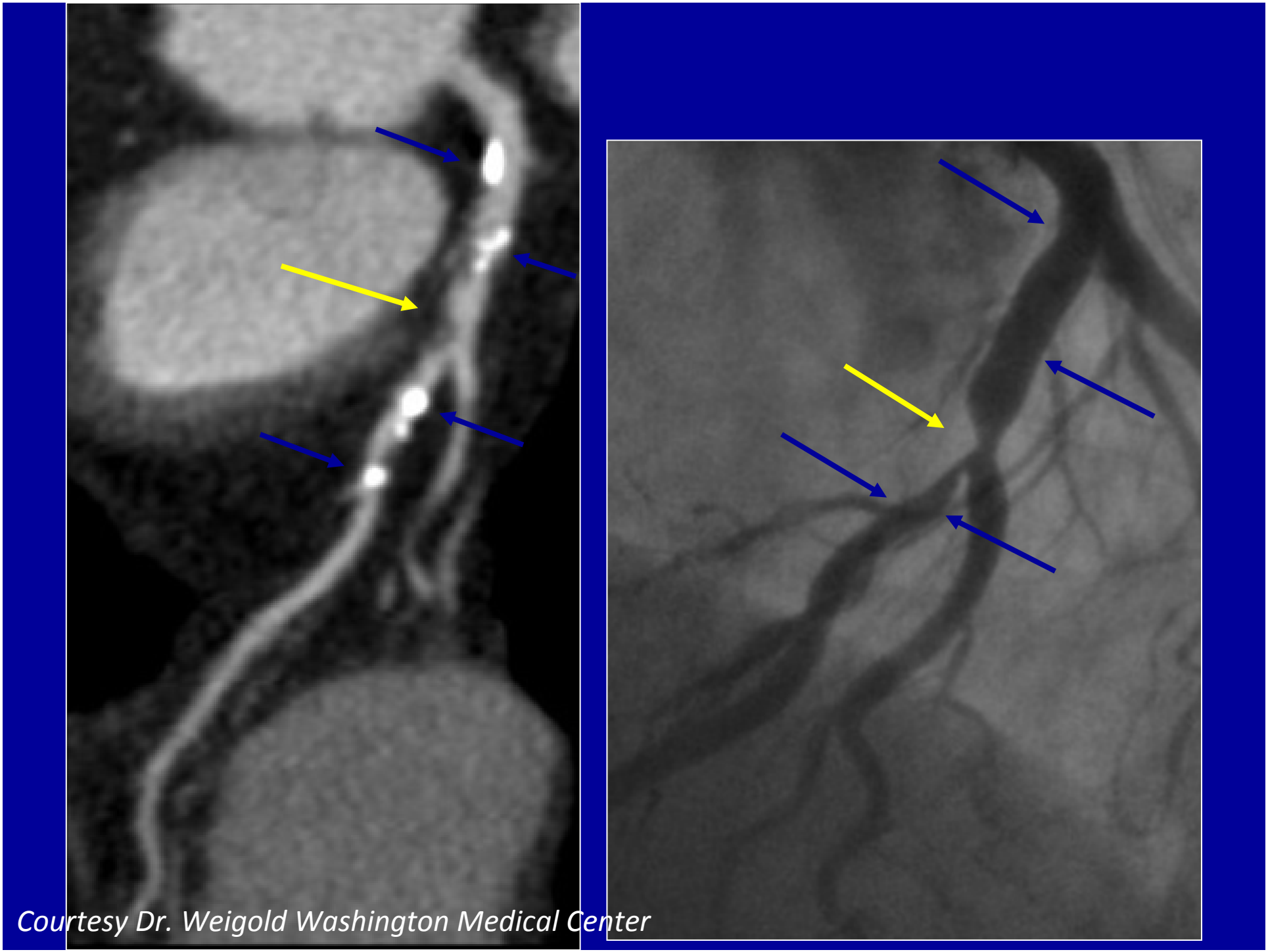
- MDCT (AUC, 0.84; 95% CI, 0.79 to 0.88)
- QCA (AUC, 0.82; 95% CI, 0.77 to 0.86)

similar abilities of the two methods to identify, on the basis of obstructive coronary stenoses, patients who underwent revascularization

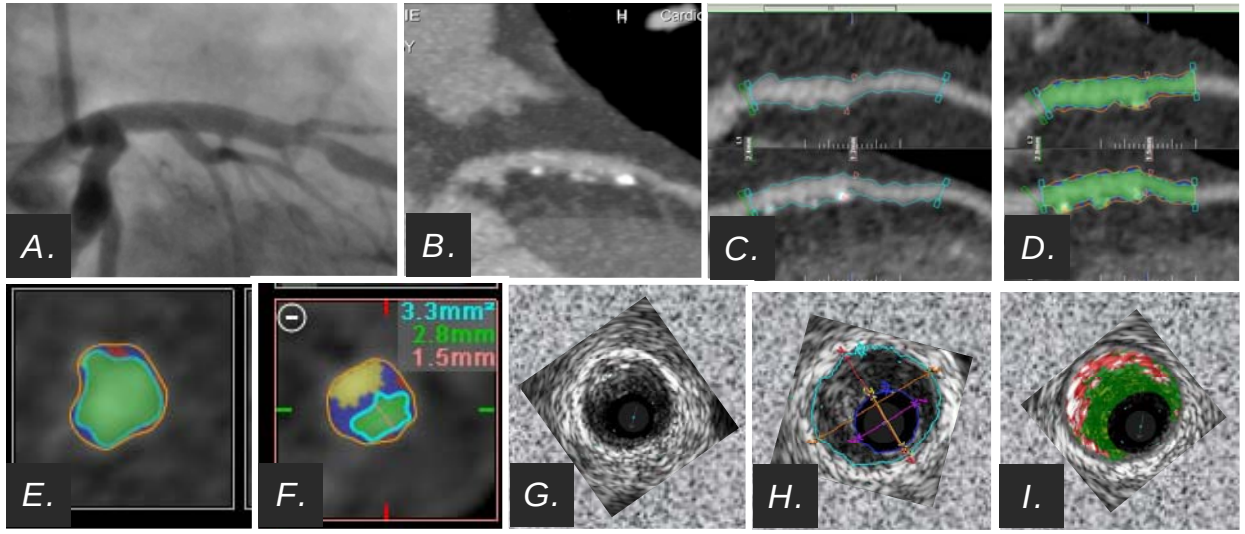
Beyond lumenography






Courtesy Dr. Weigold Washington Medical Center

Plaque quantization / burden



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Cardiac Imaging

Computed Tomographic Angiography Characteristics of Atherosclerotic Plaques Subsequently Resulting in Acute Coronary Syndrome

Sadako Motoyama, MD, PHD,*‡ Masayoshi Sarai, MD, PHD,* Hiroto Harigaya, MD,* Hirofumi Anno, MD, PHD,† Kaori Inoue, MD,* Tomonori Hara, MD,* Hiroyuki Naruse, MD, PHD,* Junichi Ishii, MD, PHD,* Hitoshi Hishida, MD, PHD,* Nathan D. Wong, PHD,‡ Renu Virmani, MD,§ Takeshi Kondo, MD, PHD,‖ Y[illegible]ki, MD, PHD,* Jagat Narula, MD, PHD‡

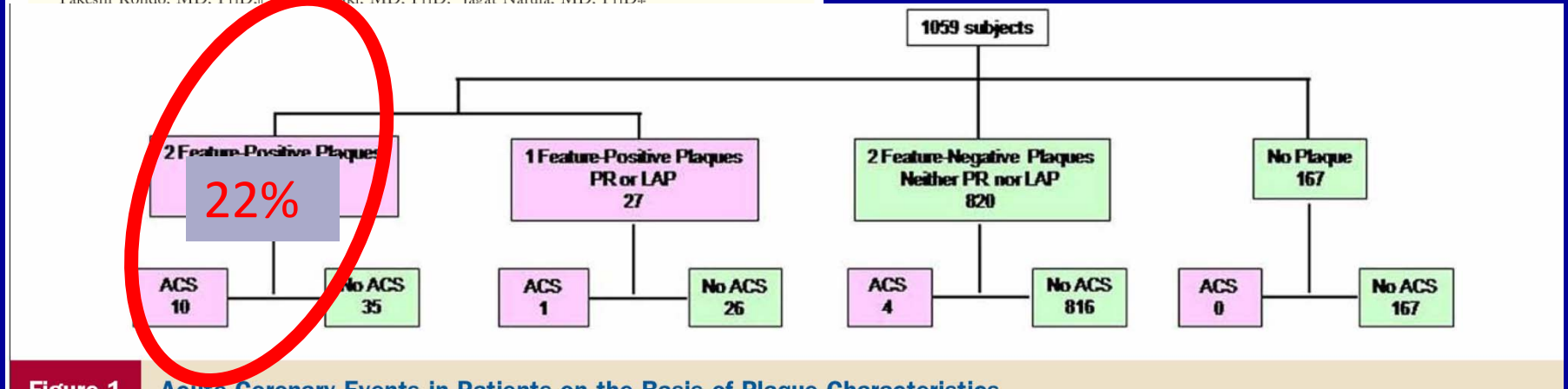

Figure 1 Acute Coronary Events in Patients on the Basis of Plaque Characteristics

Of the 45 patients showing 2-feature positive plaques, 10 (22.2%) developed acute coronary syndrome (ACS), whereas 1 of the 27 patients with 1-feature positive plaques had ACS (3.7%). Only 4 (0.5%) of the 820 patients with 2-feature negative lesions had an acute event, and none of the 167 patients with normal arteries developed ACS. LAP = low-attenuation plaque; PR = positive vessel remodeling.

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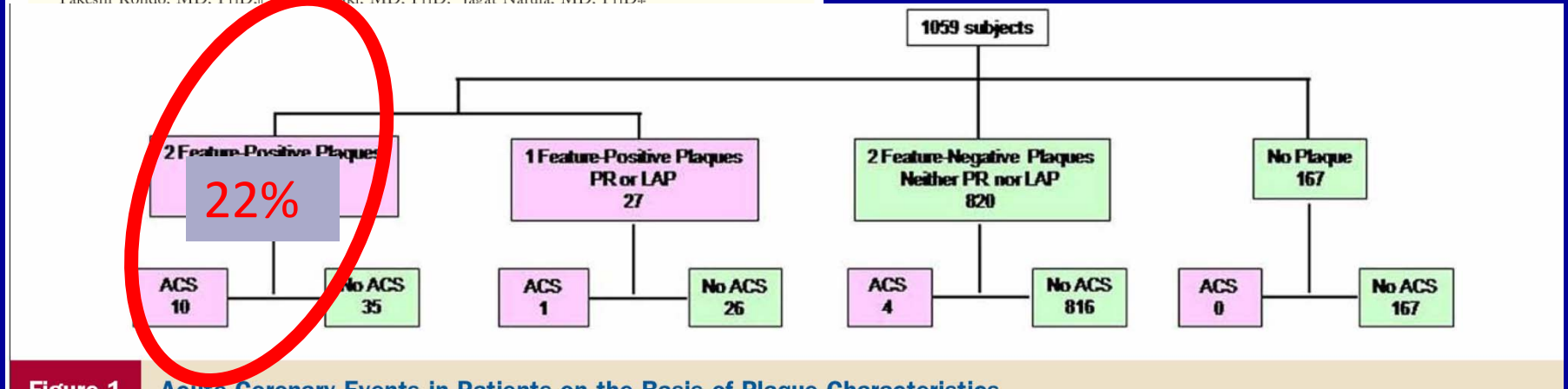

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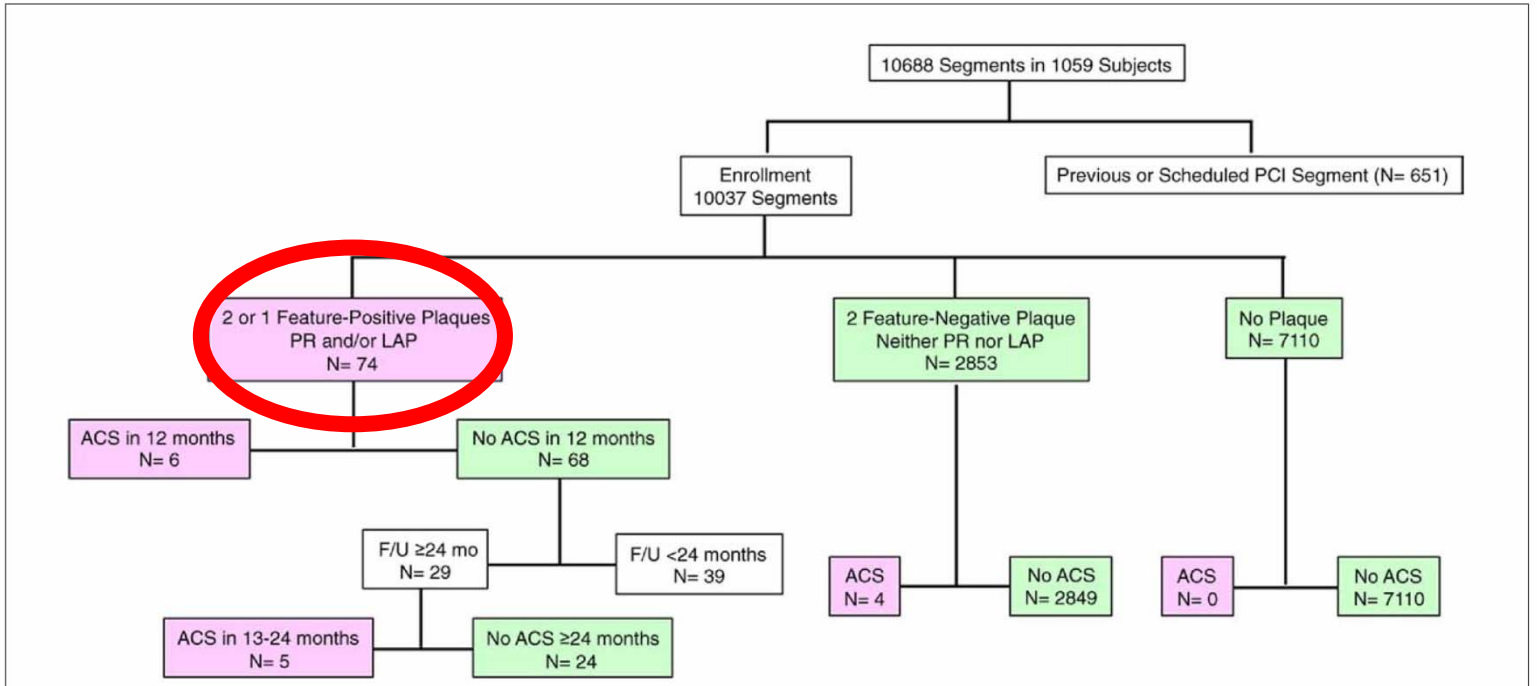

Figure 4 Plaque C… CS by Segment-Based Analysis

25%

2- and 1-feature positive … -feature negative plaques were observed in 2,853 of 10,037 segments, and no plaques were seen in 7,110 segments. Of 74 segments with 2- and 1-feature positive plaques, 6 (8.1%) resulted in acute coronary syndrome (ACS) in the first 12 months after computed tomography examination, and an additional 5 (17.2%) of 29 plaques resulted in ACS in 13 to 24 months. F/U = follow-up; LAP = low-attenuation plaque; PCI = percutaneous coronary intervention; PR = positive vessel remodeling.

Of 74 segments with 2- and 1-feature positive plaques, 6 (**8.1%**) resulted in acute coronary syndrome (ACS) in the first 12 months after computed tomography examination, and an additional 5 (**17.2%**) of 29 plaques resulted in ACS in 13 to 24 months.

“The widespread clinical application of the approach of Motoyama et al. for the detection of vulnerable plaques at risk of future rupture (namely, locking the barn door before the horse is stolen) would require the development of measures for the prevention of plaque rupture that are more potent than those currently employed, in what we currently refer to as intensive prevention.

One measure could be the use of dual antiplatelet therapy (aspirin and a thienopyridine), although the risk of bleeding from the prolonged use must be considered. Perhaps stenting or surgically bypassing these plaques could be considered in some patients.

Newer and more potent anti-inflammatory drugs are in the developmental stage, and if proved to be safe for long-term administration, they could be employed. Indeed, the ability to detect these vulnerable plaques noninvasively is likely to serve as a powerful stimulus for increased effort in the developmentof such therapies . **When more effective therapies for these plaques do become available, the paper by Motoyama et al. will be surely become a landmark in the effort to prevent acute coronary events.**

Editorial by Eugine Braunwald

MDCT

- Pros:
  - Noninvasive
  - Provides visualization of luminal obstruction as well as atherosclerotic plaque.
  - Provides ancillary information about cardiac morphology and function
  - 4D dataset
  - Provides extraxardiac information
- Cons:
  - Contrast exposure involved
  - Radiation exposure
  - Limited by HR > 60 to 70 BPM
  - Limited by severe coronary calcification
  - Pts cooperation is required

Radiation Exposure

1-6 mSv

Mean ≈ 3 mSV

Indications

ACCF/ACR/SCCT/SCMR/
ASNC/NASCI/SCAI/SIR 2006 Appropriateness
Criteria for Cardiac Computed Tomography
and Cardiac Magnetic Resonance Imaging*

Indications

	Indication	Appropriateness Criteria (Median Score)
	Detection of CAD: Symptomatic—Evaluation of Chest Pain Syndrome (Use of CT Angiogram)	
2.	• Intermediate pre-test probability of CAD • ECG uninterpretable OR unable to exercise	**A (7)**
	Detection of CAD: Symptomatic—Evaluation of Intra-Cardiac Structures (Use of CT Angiogram)	
4.	• Evaluation of suspected coronary anomalies	**A (9)**
	Detection of CAD: Symptomatic—Acute Chest Pain (Use of CT Angiogram)	
6.	• Intermediate pre-test probability of CAD • No ECG changes and serial enzymes negative	**A (7)**
	Detection of CAD With Prior Test Results—Evaluation of Chest Pain Syndrome (Use of CT Angiogram)	
16.	• Uninterpretable or equivocal stress test (exercise, perfusion, or stress echo)	**A (8)**
	Structure and Function—Morphology (Use of CT Angiogram)	
28.	• Assessment of complex congenital heart disease including anomalies of coronary circulation, great vessels, and cardiac chambers and valves	**A (7)**
29.	• Evaluation of coronary arteries in patients with new onset heart failure to assess etiology	**A (7)**
	Structure and Function—Evaluation of Intra- and Extra-Cardiac Structures (Use of Cardiac CT)	
33.	• Evaluation of cardiac mass (suspected tumor or thrombus) • Patients with technically limited images from echocardiogram, MRI, or TEE	**A (8)**
34.	• Evaluation of pericardial conditions (pericardial mass, constrictive pericarditis, or complications of cardiac surgery) • Patients with technically limited images from echocardiogram, MRI, or TEE	**A (8)**
35.	• Evaluation of pulmonary vein anatomy prior to invasive radiofrequency ablation for atrial fibrillation	**A (8)**
36.	• Noninvasive coronary vein mapping prior to placement of biventricular pacemaker	**A (8)**
37.	• Noninvasive coronary arterial mapping, including internal mammary artery prior to repeat cardiac surgical revascularization	**A (8)**
	Structure and Function—Evaluation of Aortic and Pulmonary Disease (Use of CT Angiogram*)	
38.	• Evaluation of suspected aortic dissection or thoracic aortic aneurysm	**A (9)**
39.	• Evaluation of suspected pulmonary embolism	**A (9)**

Indications

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
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• Evaluation of suspected pulmonary embolism

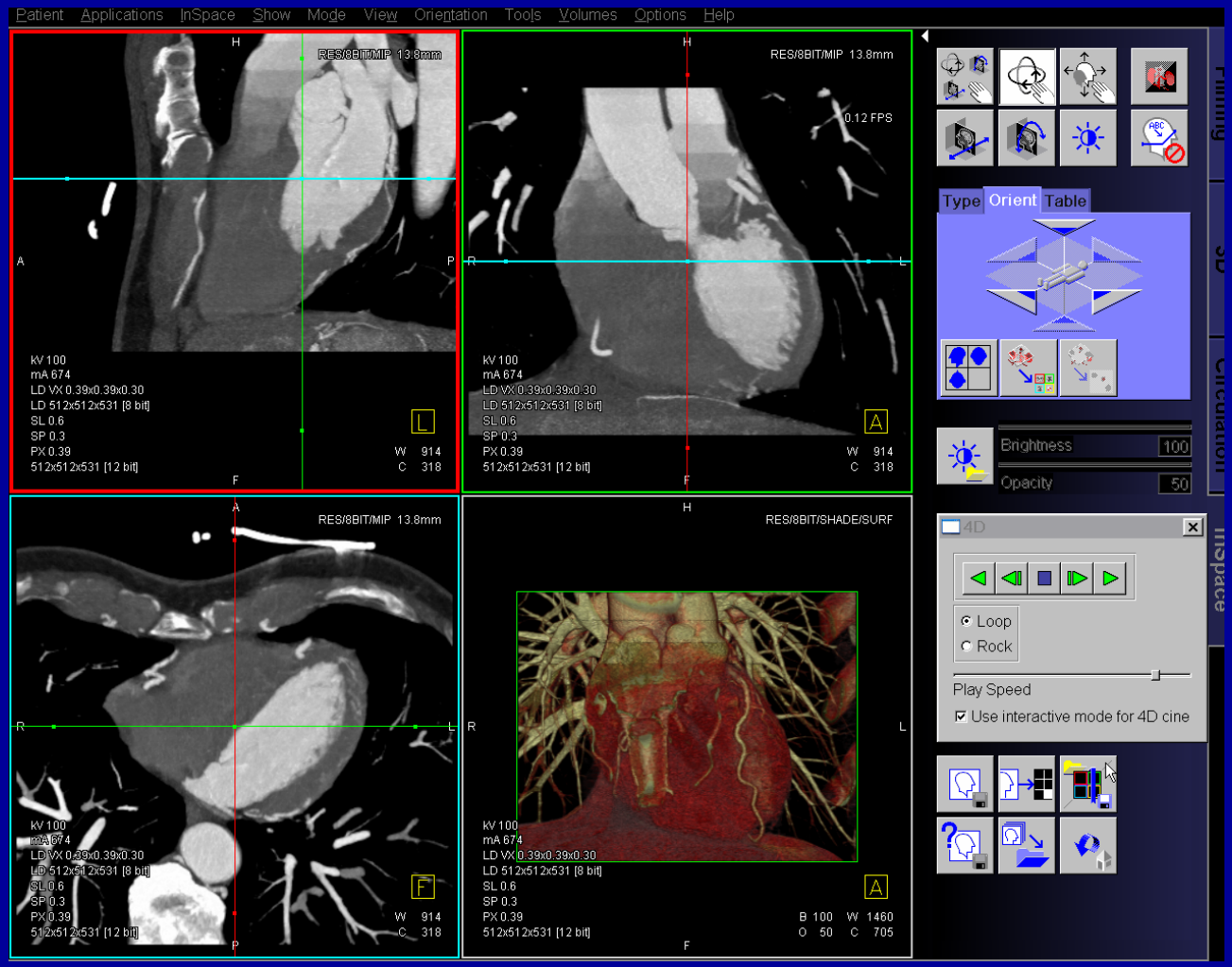
Indications

Detection of CAD: Symptomatic—Evaluation of Chest Pain Syndrome (Use of CT Angiogram)	
• Intermediate pre-test probability of CAD • ECG uninterpretable OR unable to exercise	
Detection of CAD: Symptomatic—Evaluation of Intra-Cardiac Structures (Use of CT Angiogram)	
• Evaluation of suspected coronary anomalies	
Detection of CAD: Symptomatic—Acute Chest Pain (Use of CT Angiogram)	
• Intermediate pre-test probability of CAD • No ECG changes and serial enzymes negative	
Detection of CAD With Prior Test Results—Evaluation of Chest Pain Syndrome (Use of CT Angiogram)	
• Uninterpretable or equivocal stress test (exercise, perfusion, or stress echo)	

Summary

- Cardiac CT is an excellent relevant alternative in the evaluation of patients with suspected CAD

Thank You


Patient Applications InSpace Show Mode View Orientation Tools Volumes Options Help
RES/8BIT/MIP 13.8mm
0.12 FPS
RES/8BIT/SHADE/SURF
Type Orient Table
Brightness 100
Opacity 50
4D
Loop
Rock
Play Speed
Use interactive mode for 4D cine
Filming
3D
Circulation
InSpace