



Cardiac MRI & Cardiac CT

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Cardiac Imaging Service

Department of Cardiology

Soroka University Medical Center



Advanced Cardiac Imaging Cardiac MRI & Cardiac CT





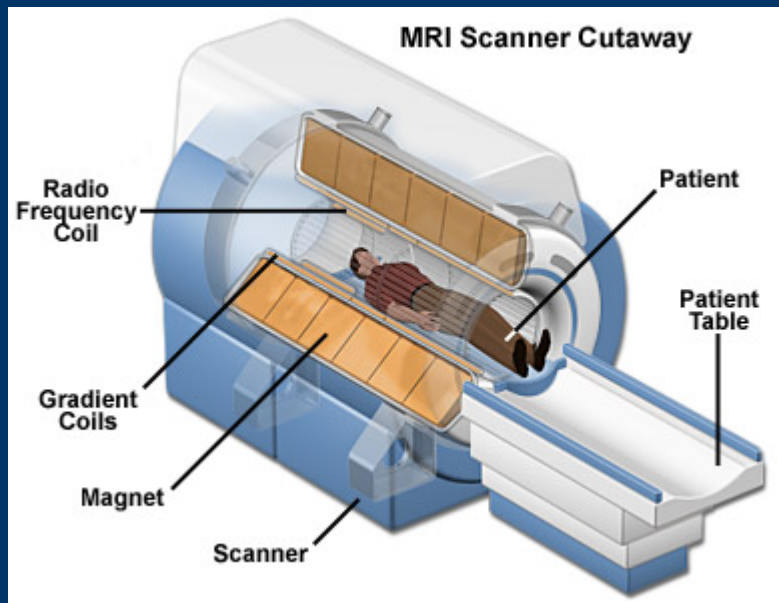
Cardiac MRI



Prerequisites

- Equipment
 - Scanner
 - Coils
 - Working station
- Staff
 - Technicians
 - Physicist
 - Cardiac imaging expert

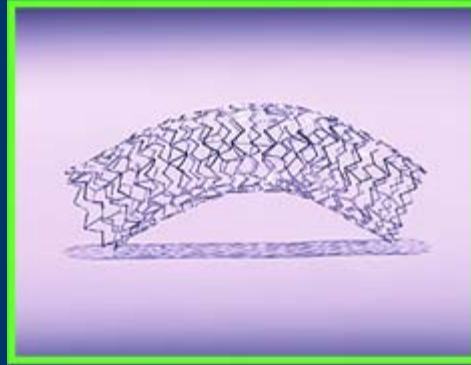
MRI principles



- Magnet static field (1.5 T)
- Radiofrequency coils
- Gradients coils → gradient in the static field



Safety





MRI protocol

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



Setup



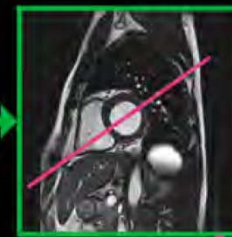
TRA Transverse



RAO Right Anterior Oblique



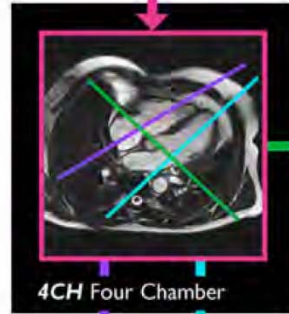
4CH Nearly Four Chamber



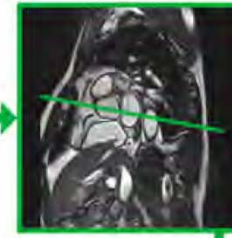
SA Short Axis



Transversal planning for RVOT



4CH Four Chamber

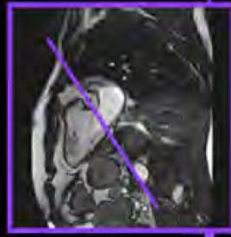


Basal Short Axis

Chambers & Outflow



RVOT Right Ventricular Outflow Tract



R2CH Right Two Chamber



L2CH Left Two Chamber



LVOT Left Ventricular Outflow Tract

Valves



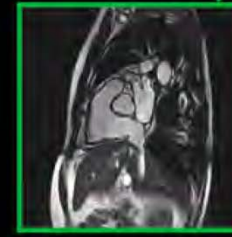
Pulmonary Valve



Tricuspid Valve



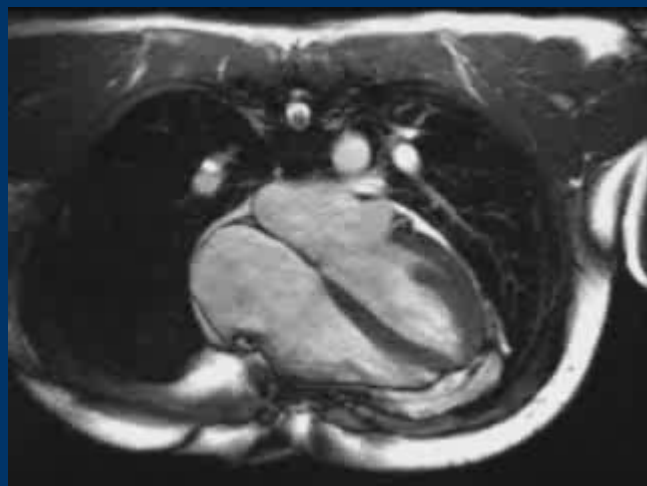
Mitral Valve



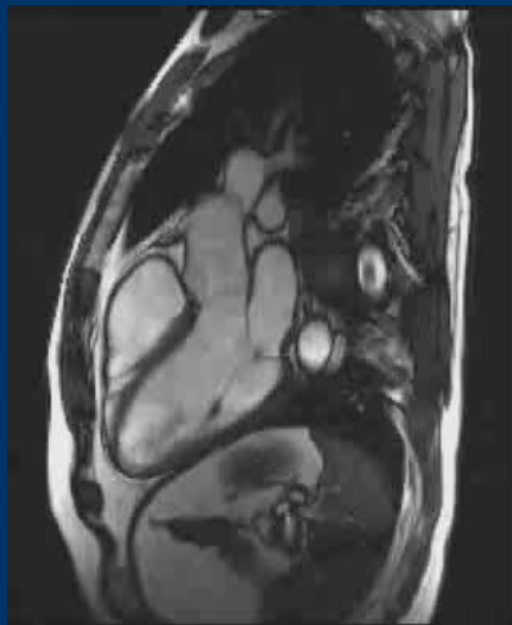
Aortic Valve



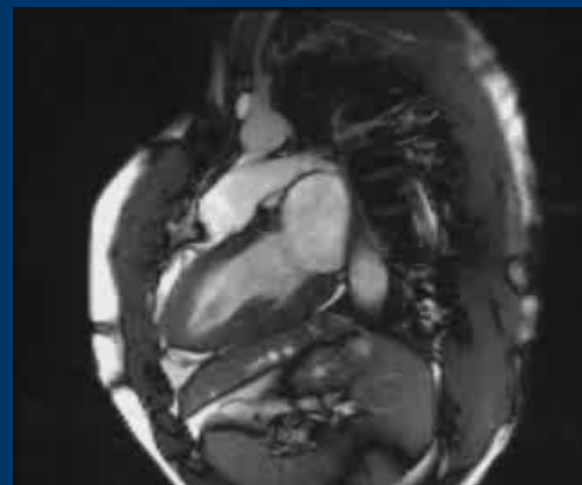
Wall Motion & Ventricular Volume



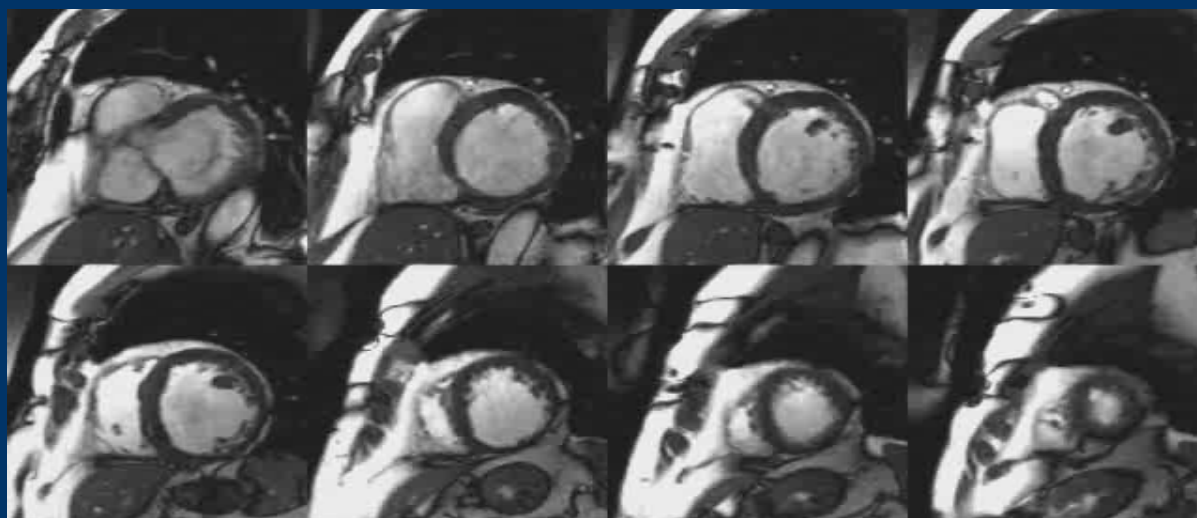
4-chamber HLA



3-chamber LVOT



2-chamber VLA



Stack of Short Axis
for Volume
Analysis



Wall Motion , Ventricular Volume & EF



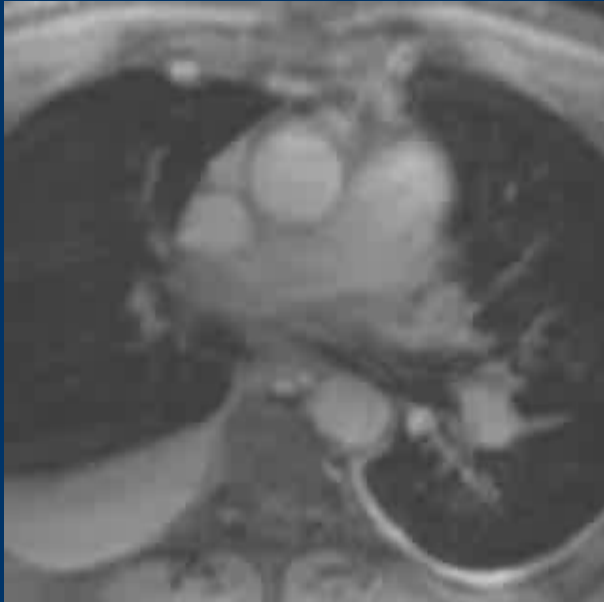


Wall Motion, Ventricular Volume & EF

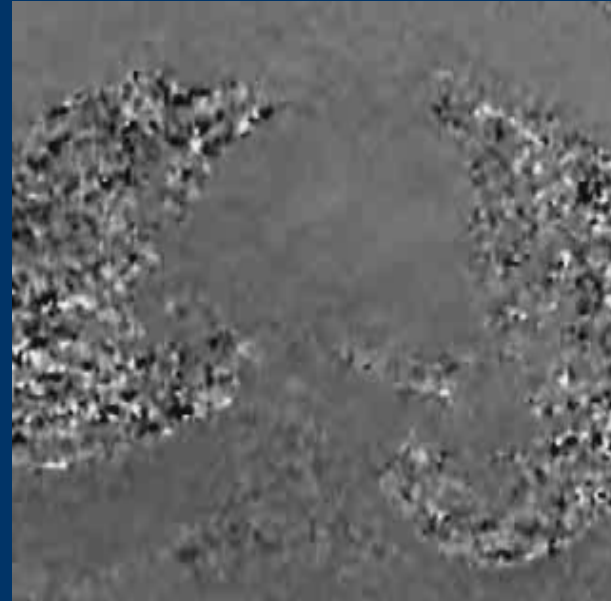




Flow

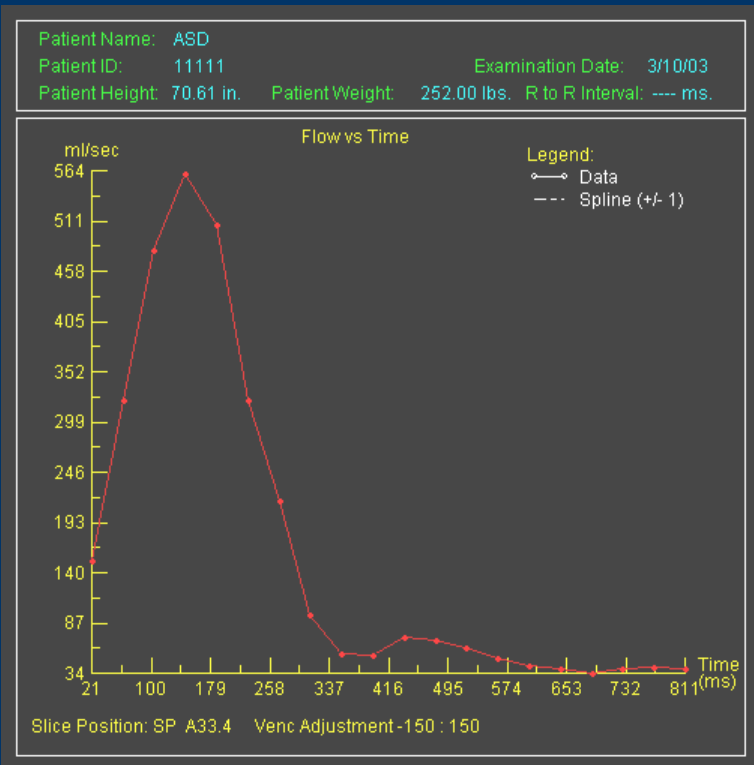


Magnitude Image



Phase Image

Flow Analysis



Flow Curves

Patient Name: ASD
 Patient ID: 11111 Examination Date: 3/10/03
 Patient Height: 70.61 in. Patient Weight: 252.00 lbs. R to R Interval: --- ms.

Slice Position: SP A33.4 Region: 1
 Range,ms: 21 to 811 Venc Adjustment -150 cm/sec 150 cm/sec
 Body Surface Area (BSA): 2.32 m²

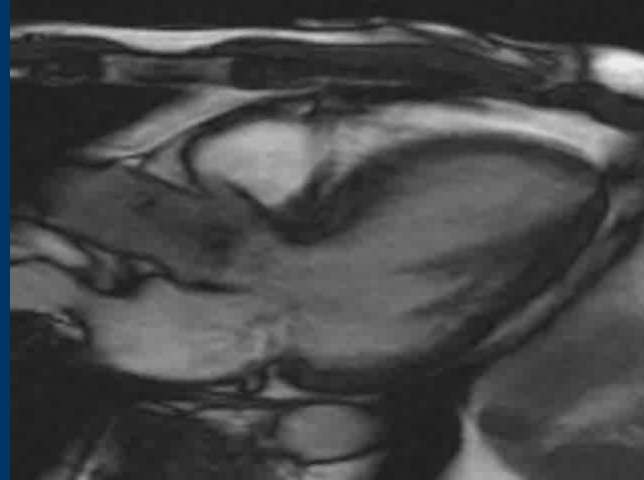
Velocity		
Peak Velocity:	78.59	cm/sec
Average Velocity:	19.86	cm/sec

Flow		
Average Flow Over Range:	165.99	ml/sec
Average Flow Per Minute:	---	L/min
Forward Volume:	131.13	ml
Reverse Volume:	0.00	ml
Net Forward Volume:	131.13	ml
Net Forward Volume / BSA:	56.57	ml/m ²

Area		
Average Area:	8.36	cm ²
Minimum Area:	7.09	cm ²
Maximum Area:	9.35	cm ²

Table of Results

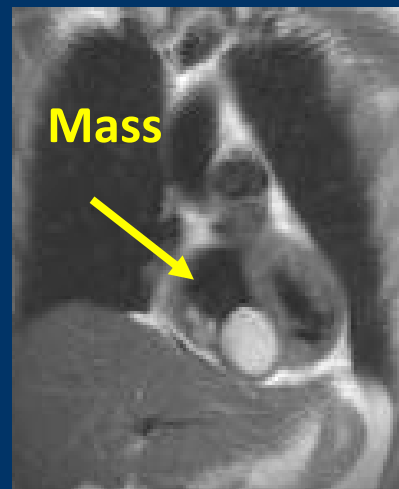
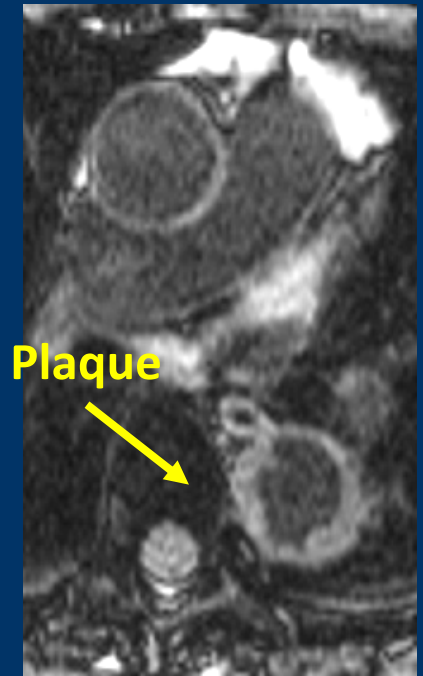
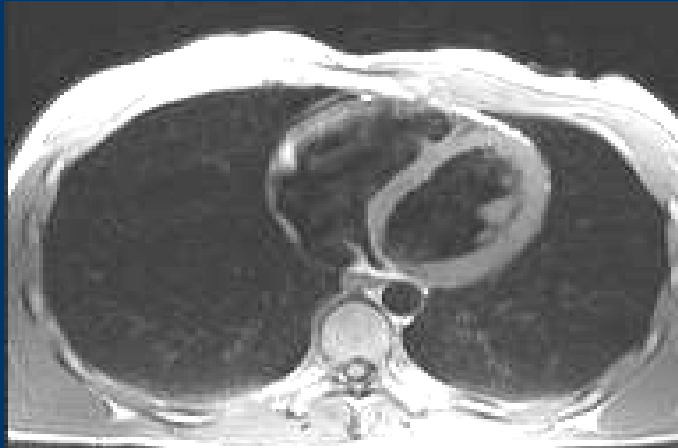
Aortic Stenosis



Patient Name:	
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
Minimum Area:	7.69 cm ²
Maximum Area:	9.79 cm ²



Morphology and Tissue Characteristics

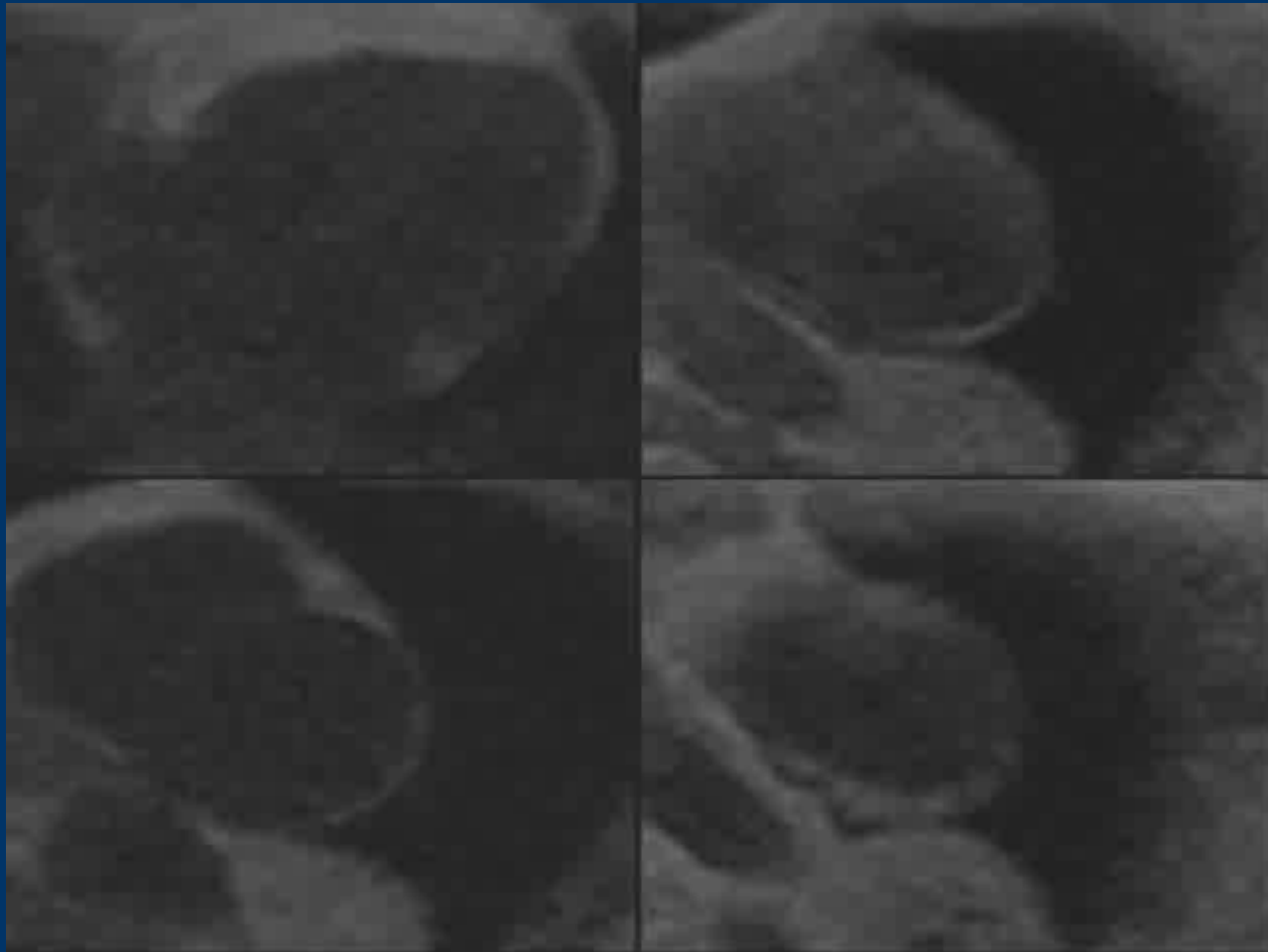




Contrast Enhancement

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

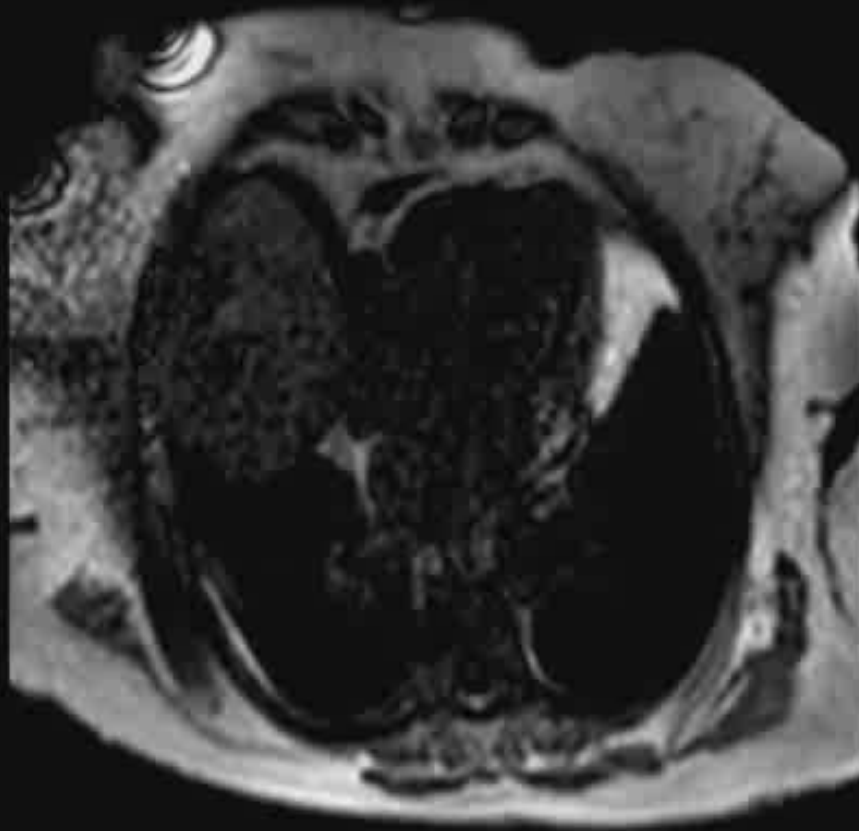
First pass /Early – perfusion Images



LAD 100% stenosis, RCA 60% stenosis

First pass /Early – perfusion Images

Sc: 15.12
R-TTE / TTE.M
DI: 000 ms
TA: 300 ms (75%)



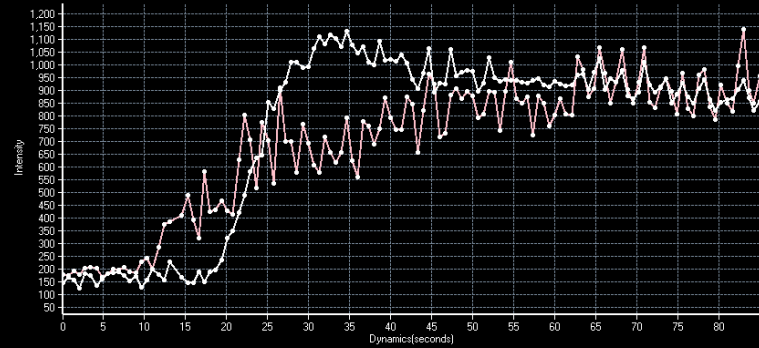
AP ->
RL ->
FH ->
A15LBR24

V: 296
I: 1177

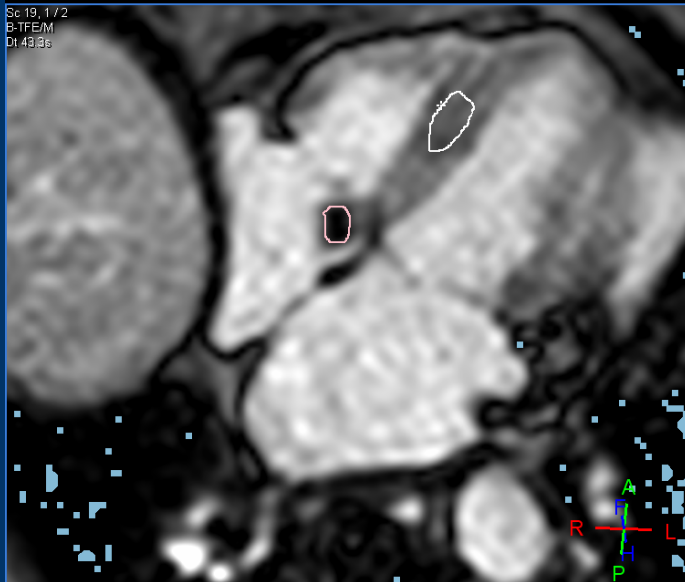
06-Oct-2018

First pass /Early – perfusion Images

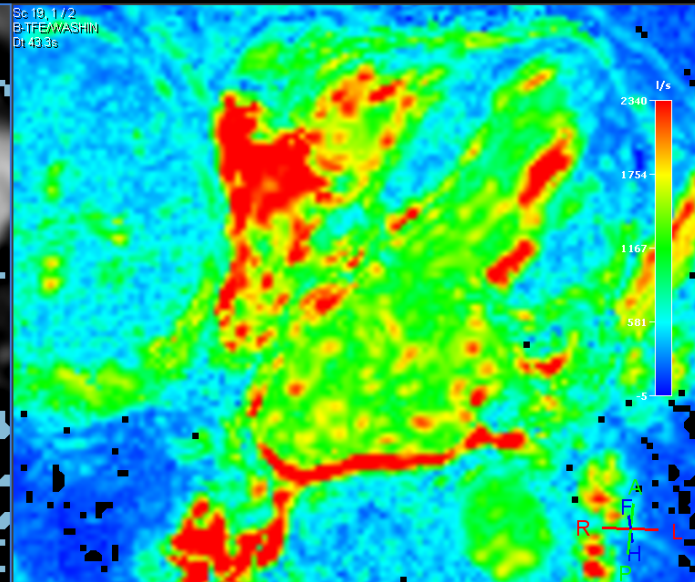
	RoI A	RoI B
Relative Enhancement (%)	268.01	523.24
Maximum Enhancement (%)	948.38	983.16
Maximum Relative Enhancement (%)	494.45	664.70
T0 (s)	9.61	2.09
Time To Peak (s)	82.93	34.61
Wash in Rate (1/s)	527.49	292.05
Wash out Rate (1/s)	359.01	259.26
Brevity of Enhancement (s)	57.18	20.30
Area under the curve	42512	50723



Sc 19, 1/2
B-TPEM
Dt 49.8s



Sc 19, 1/2
B-TPEWASHIN
Dt 49.8s

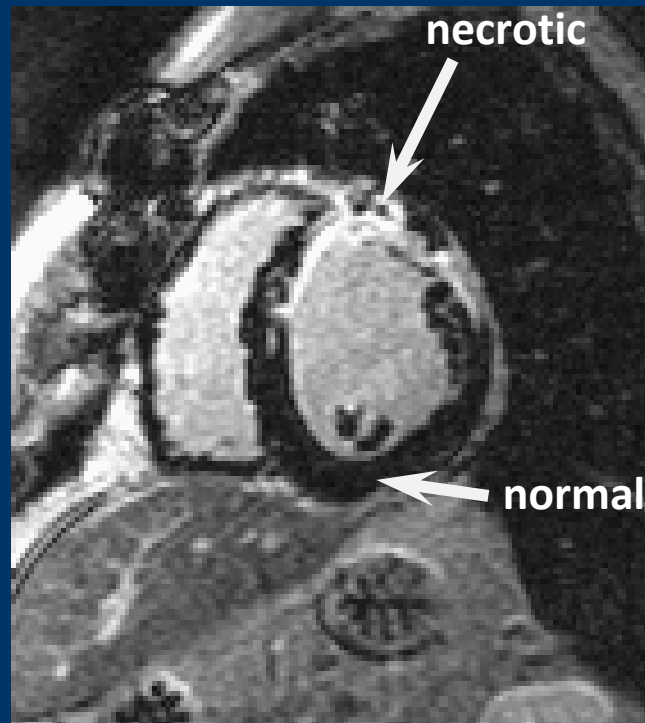




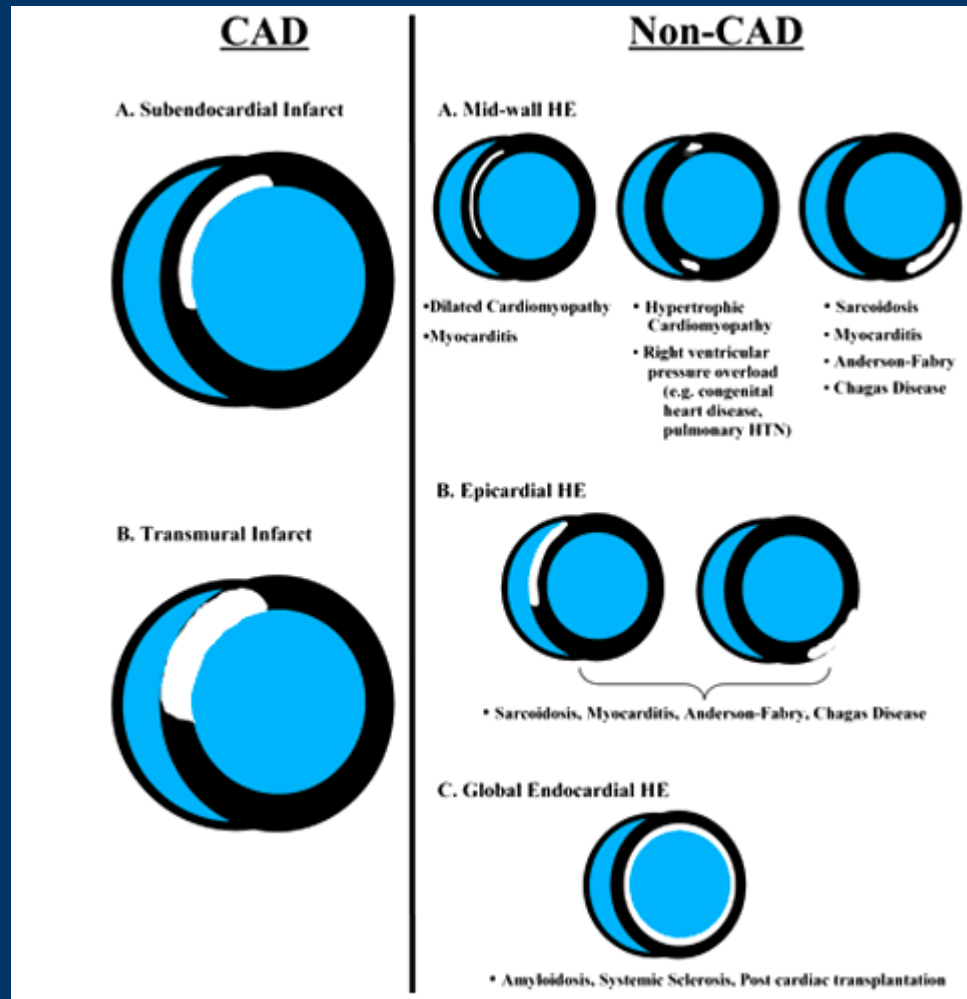
Contrast Enhancement

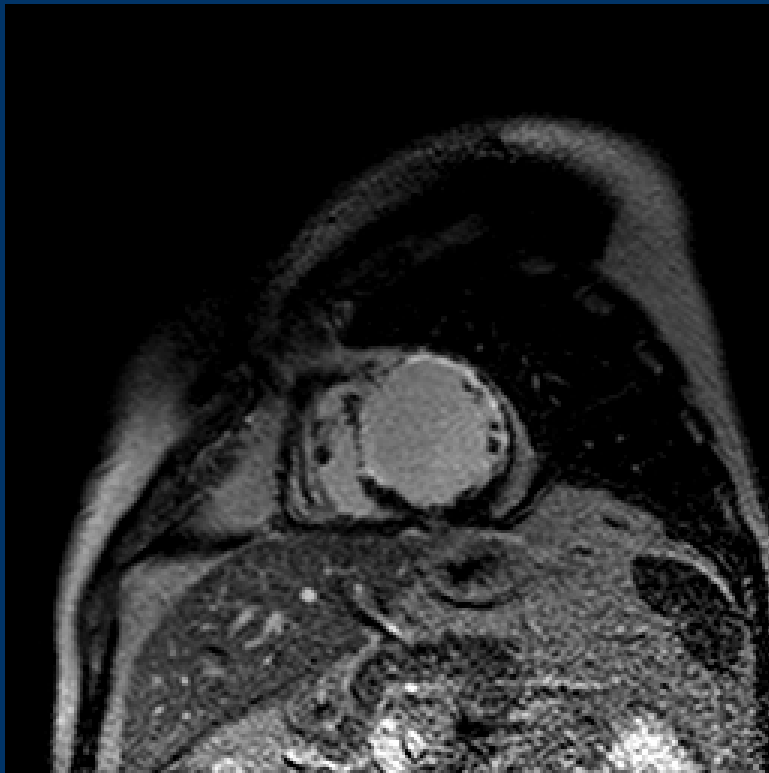
- First pass /Early Enhancement – perfusion Images, mass
- Delayed / Late Enhancement – scar, myocardial damage

Delayed / Late – scar

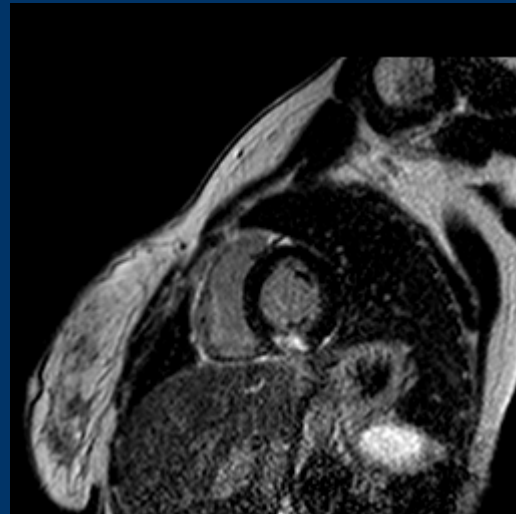
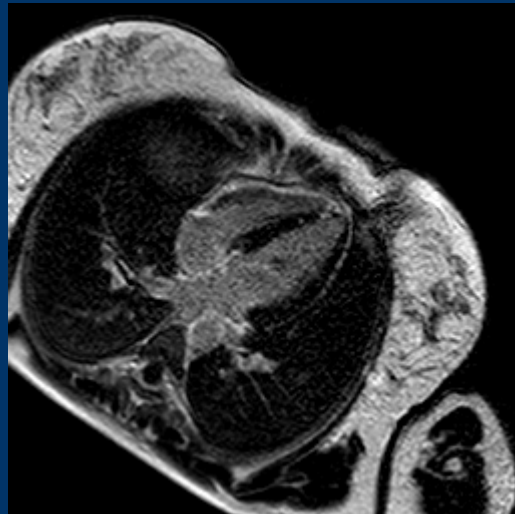
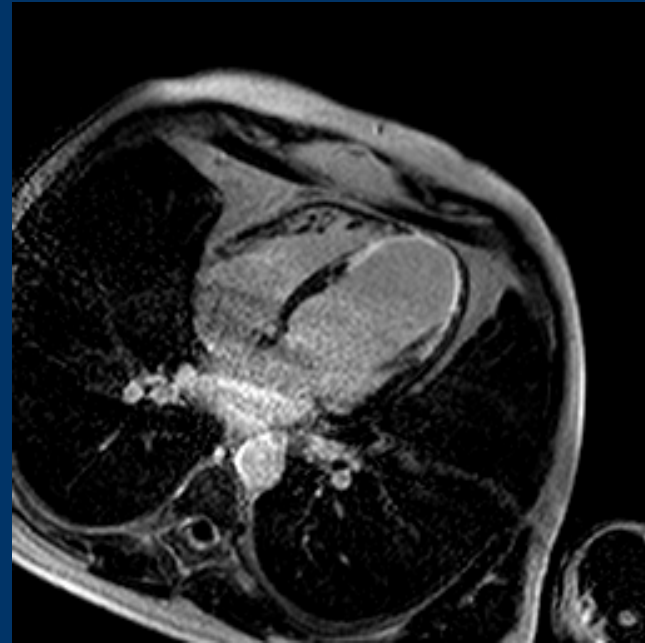


Hyperenhancement Patterns in Clinical Practice



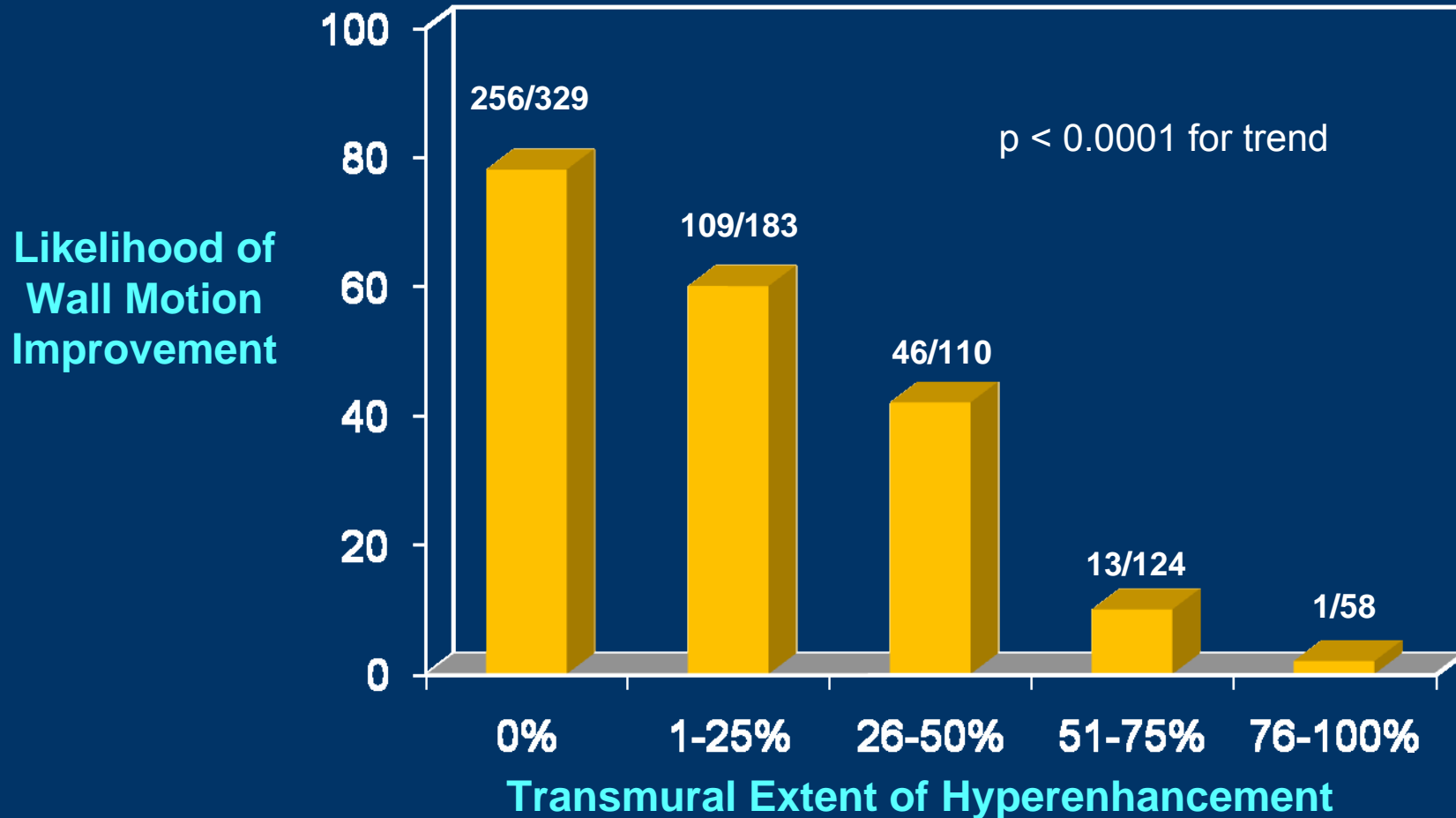


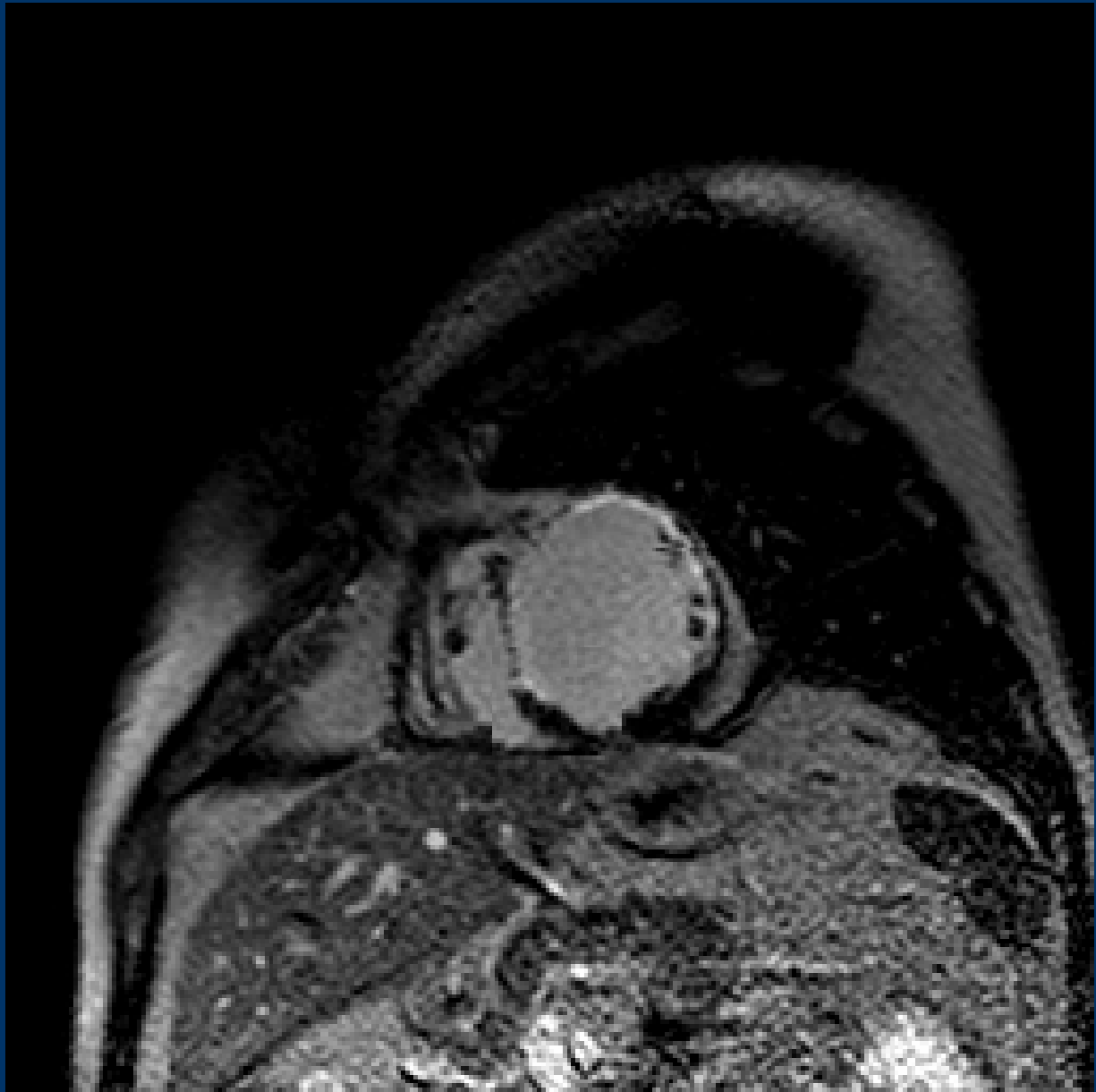
Ischemic pattern



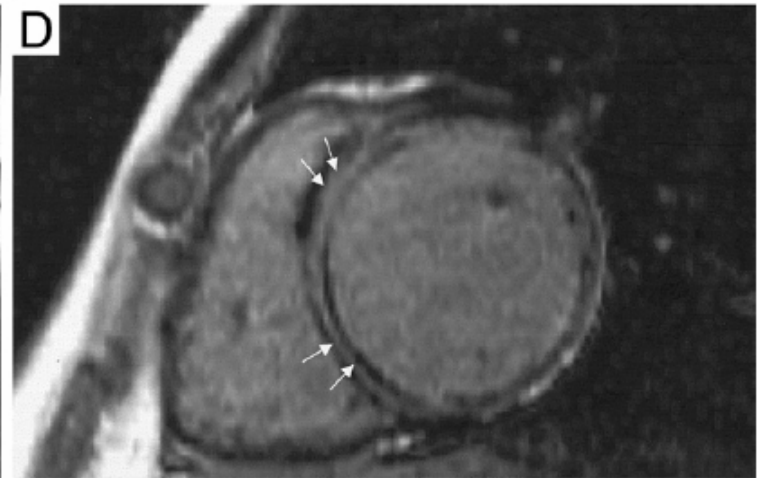
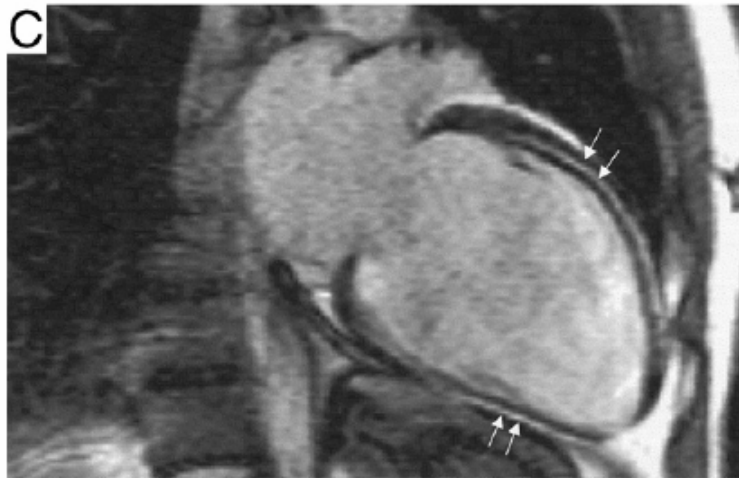
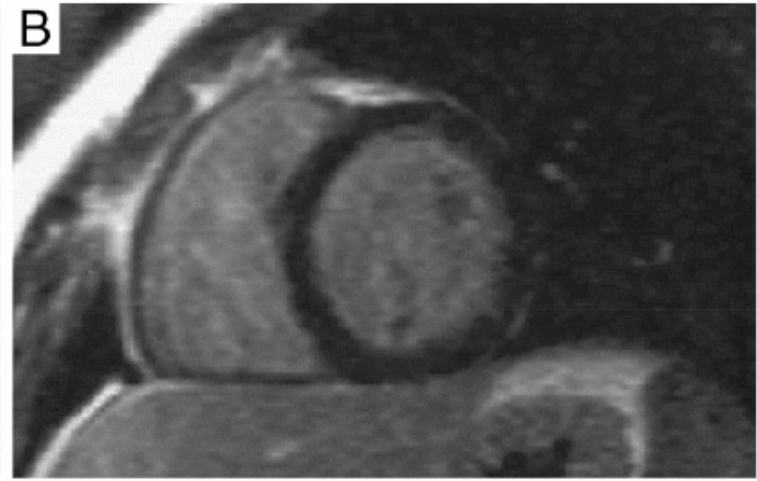
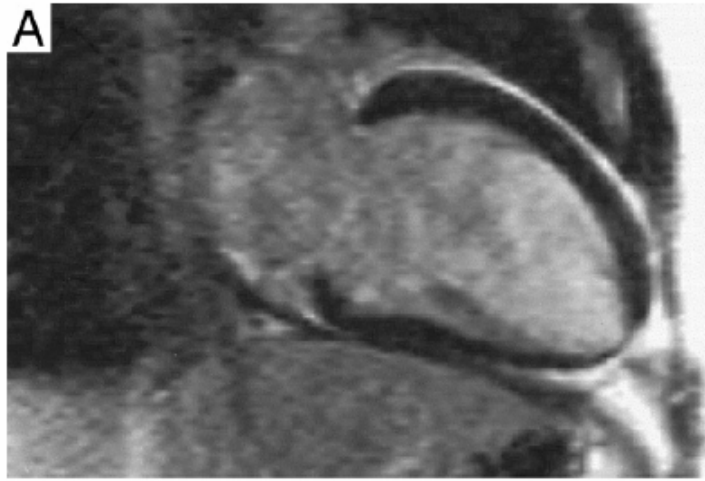
Myocarditis Pattern

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



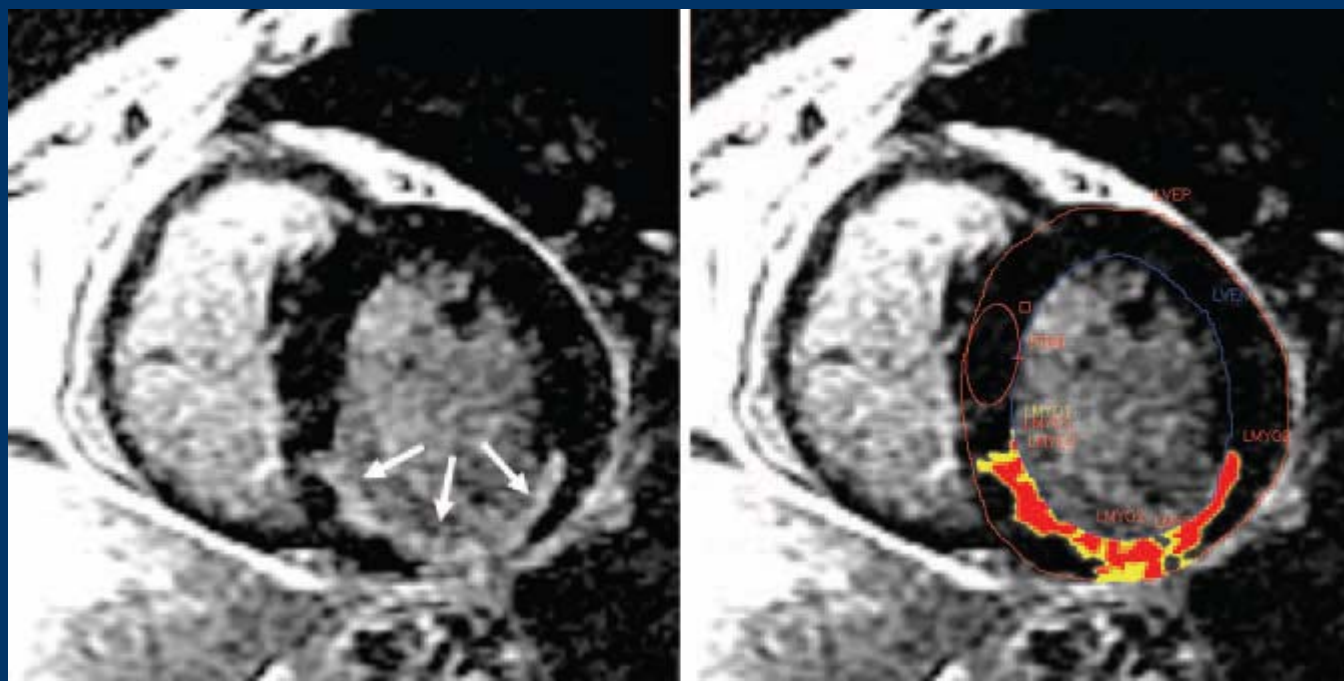


Cardiovascular Magnetic Resonance, Fibrosis, and Prognosis in Dilated Cardiomyopathy



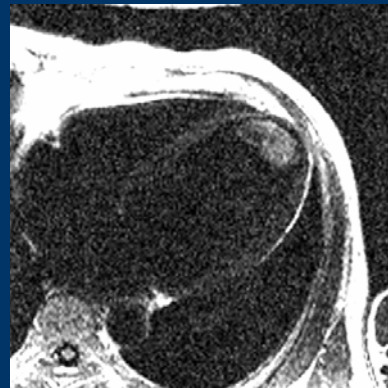
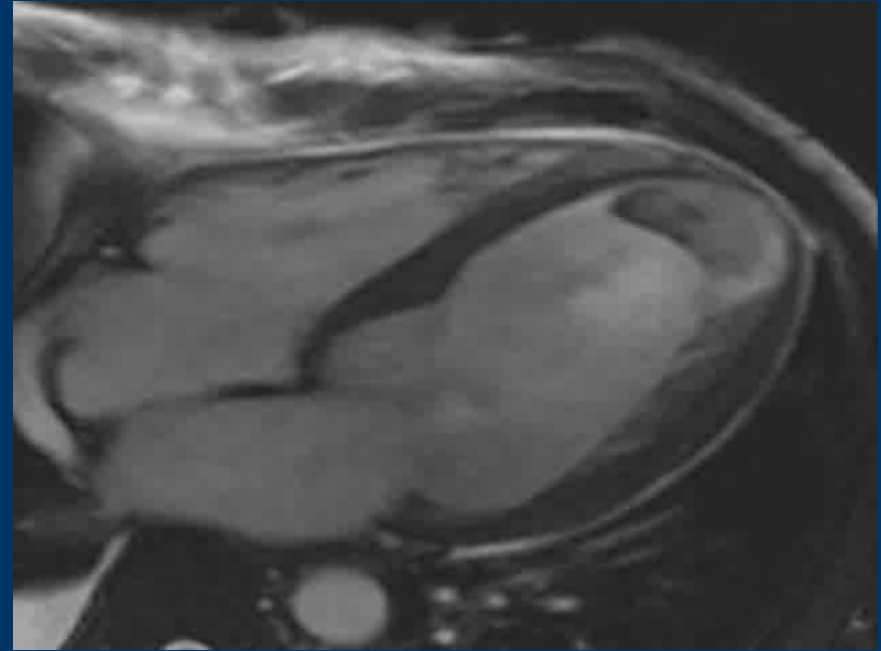
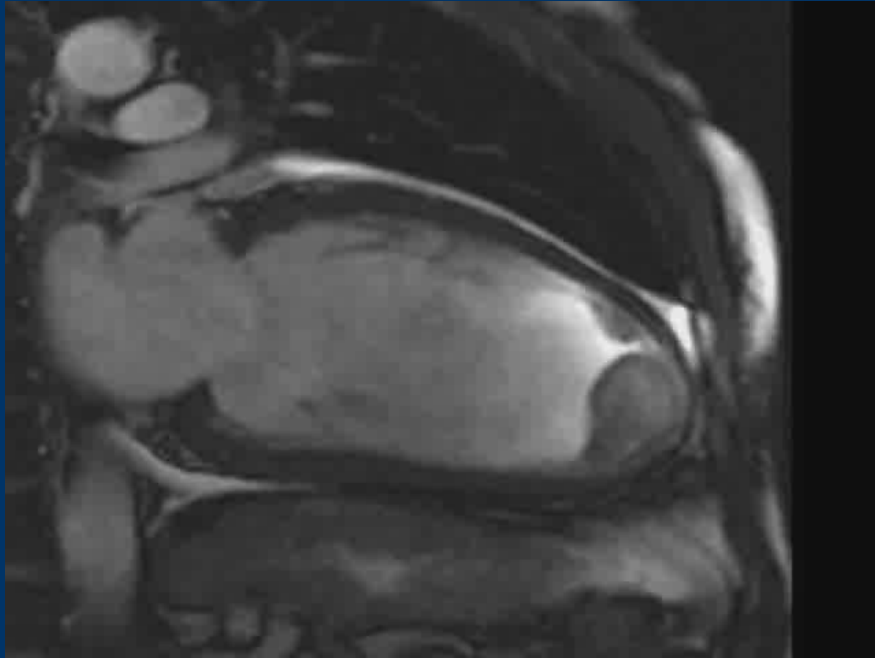


Characterization of the Peri-Infarct Zone by Contrast-Enhanced Cardiac Magnetic Resonance Imaging Is a Powerful Predictor of Post-Myocardial Infarction Mortality



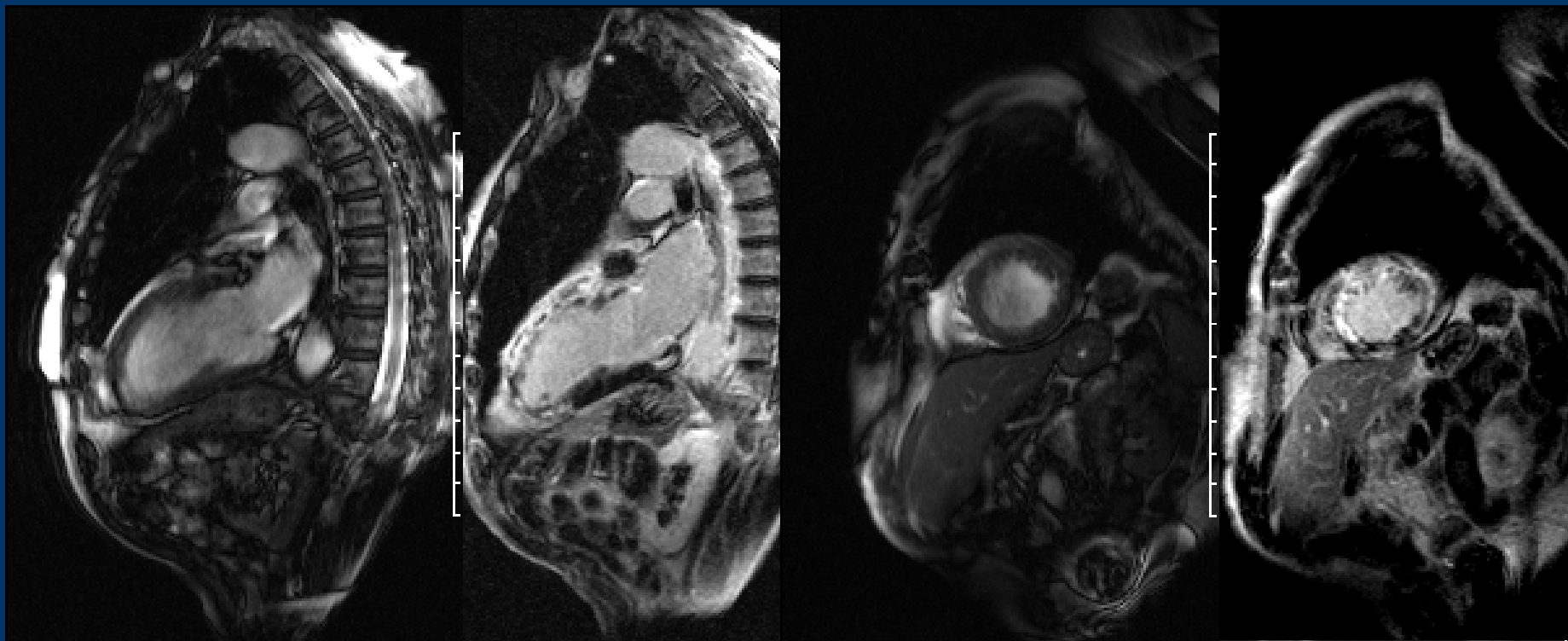
Case Samples

Thrombus





Recent STEMI

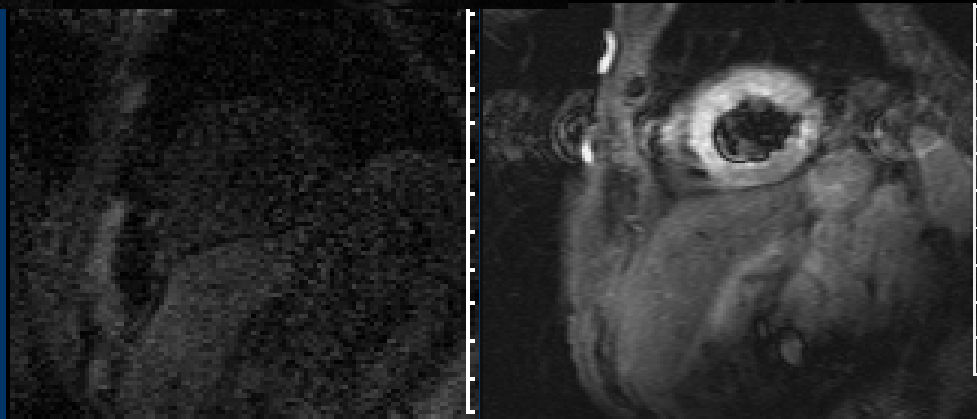


LVEF 36.0 %

EDV 131.0 ml

ESV 84.0 ml

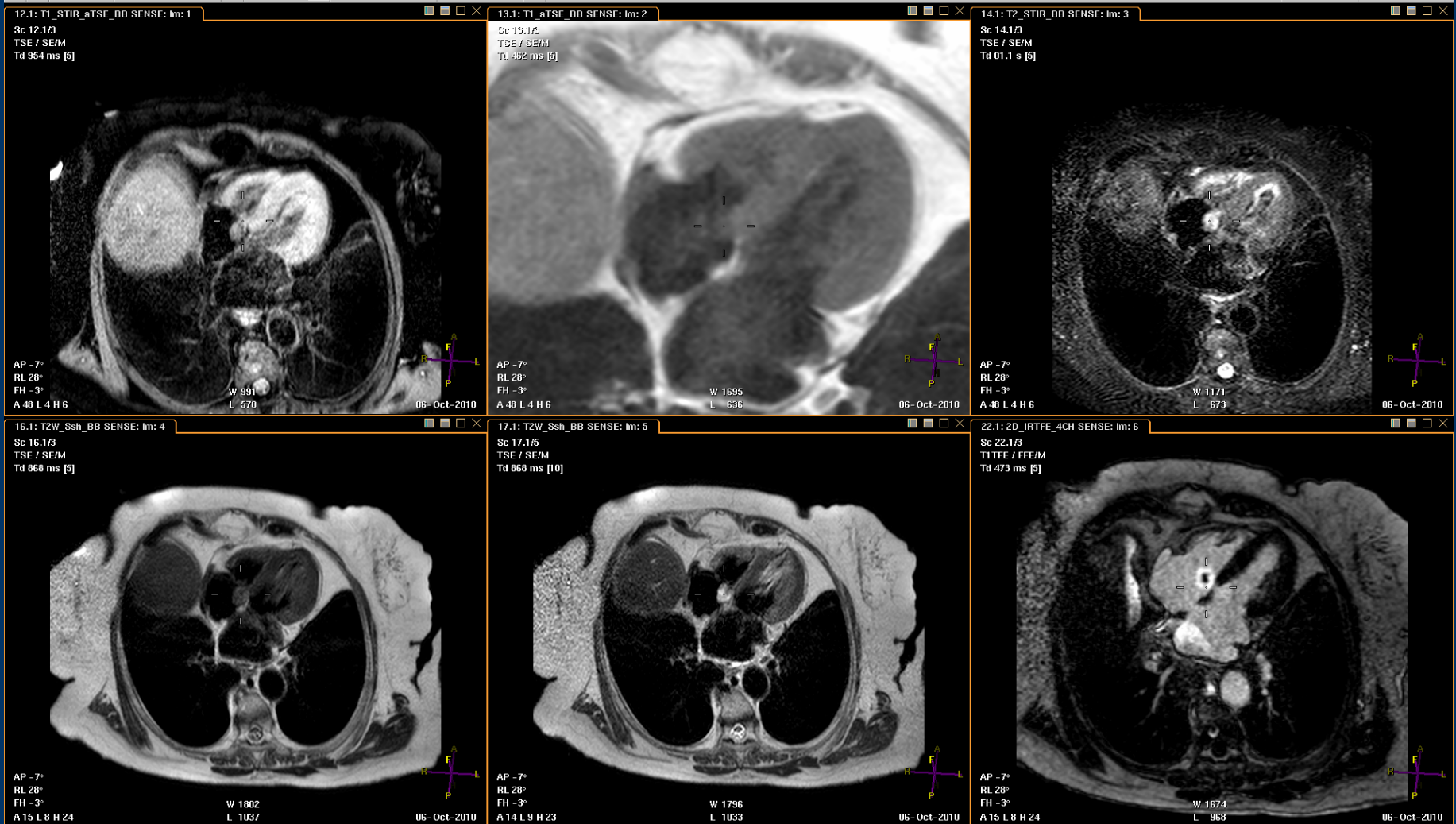
OUTPUT 2.4 L/min



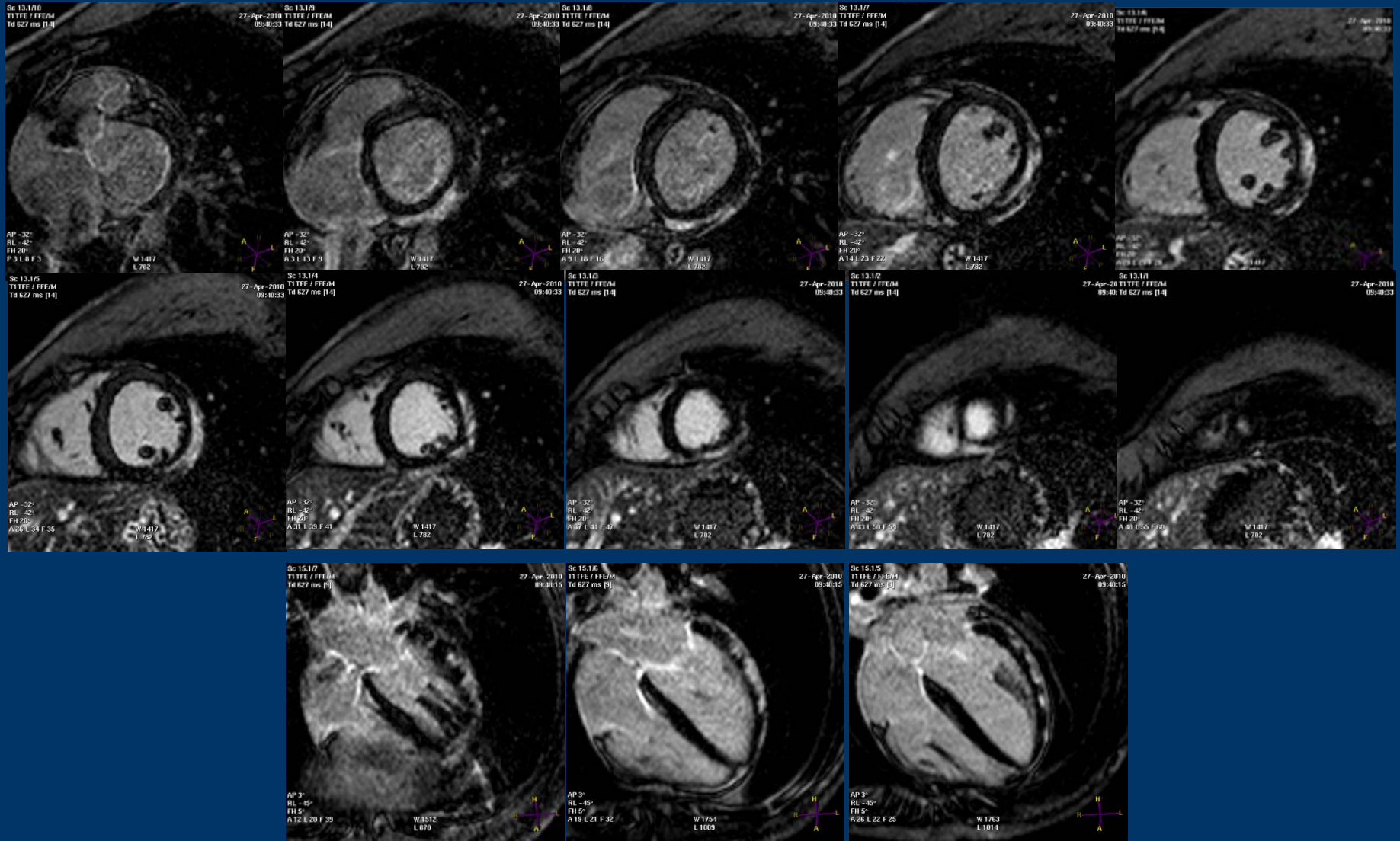
Fibroelastoma



Fibroelastoma



Myocarditis



15 y/o ♂, fever, chest pain, TnT (+), moderate LVD



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doi:10.1016/j.jacc.2006.07.003

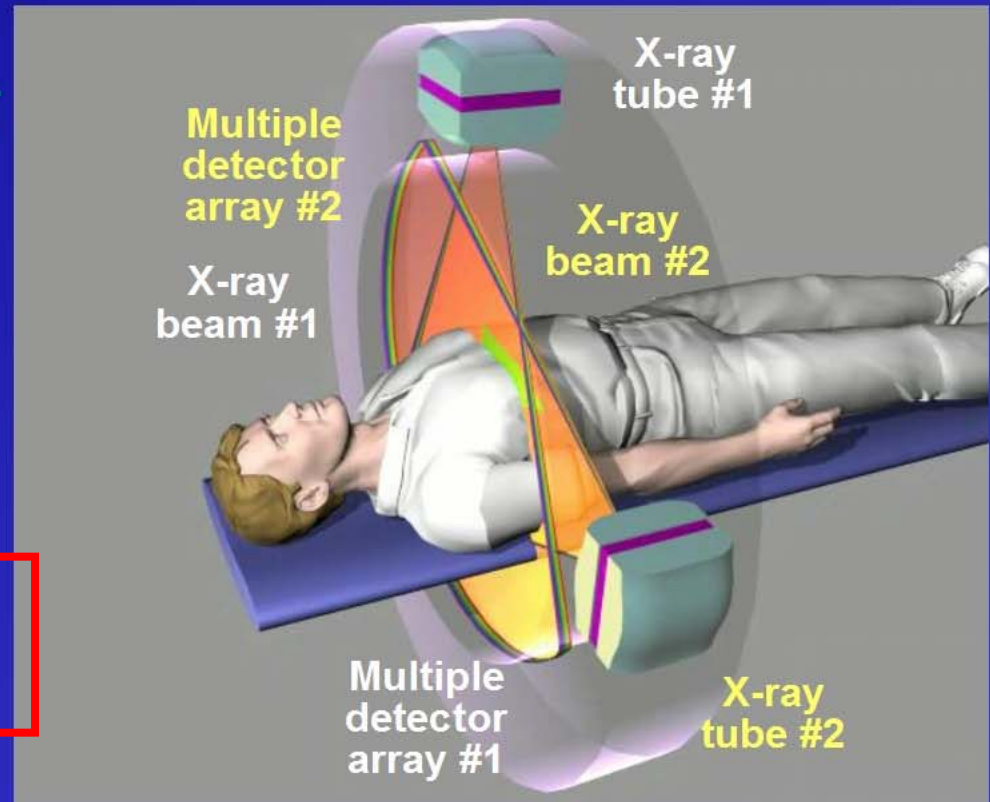
ACCF/ACR/SCCT/SCMR/ASNC/NASCI/SCAI/SIR APPROPRIATENESS CRITERIA

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

Cardiac CT

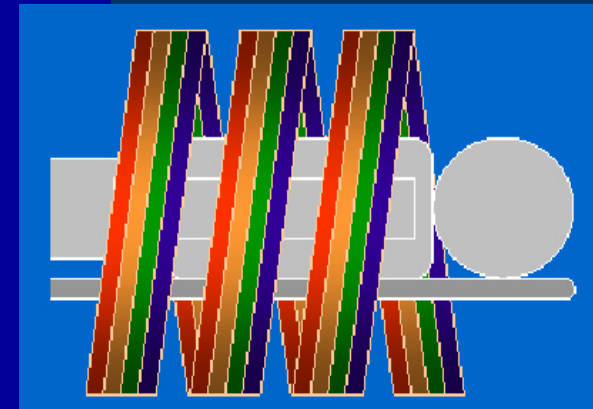
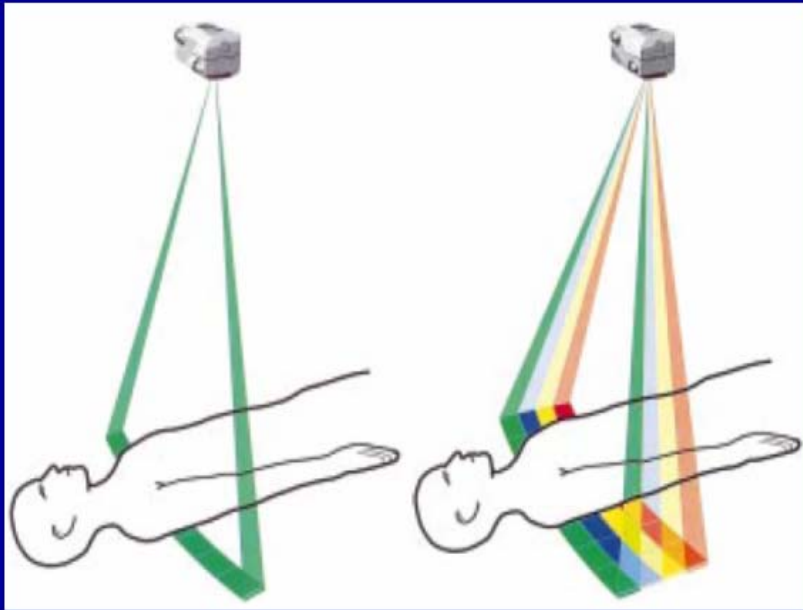
HISTORY OF CT

- **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

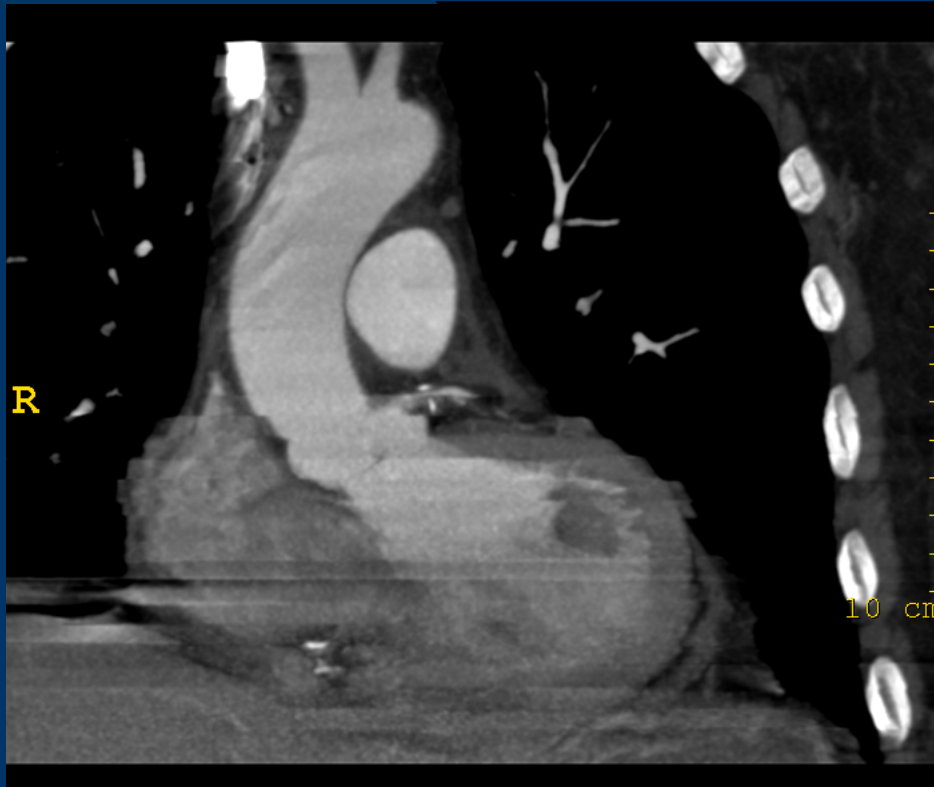


Multi-slice CT (MSCT)

Multi-detector CT (MDCT)



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

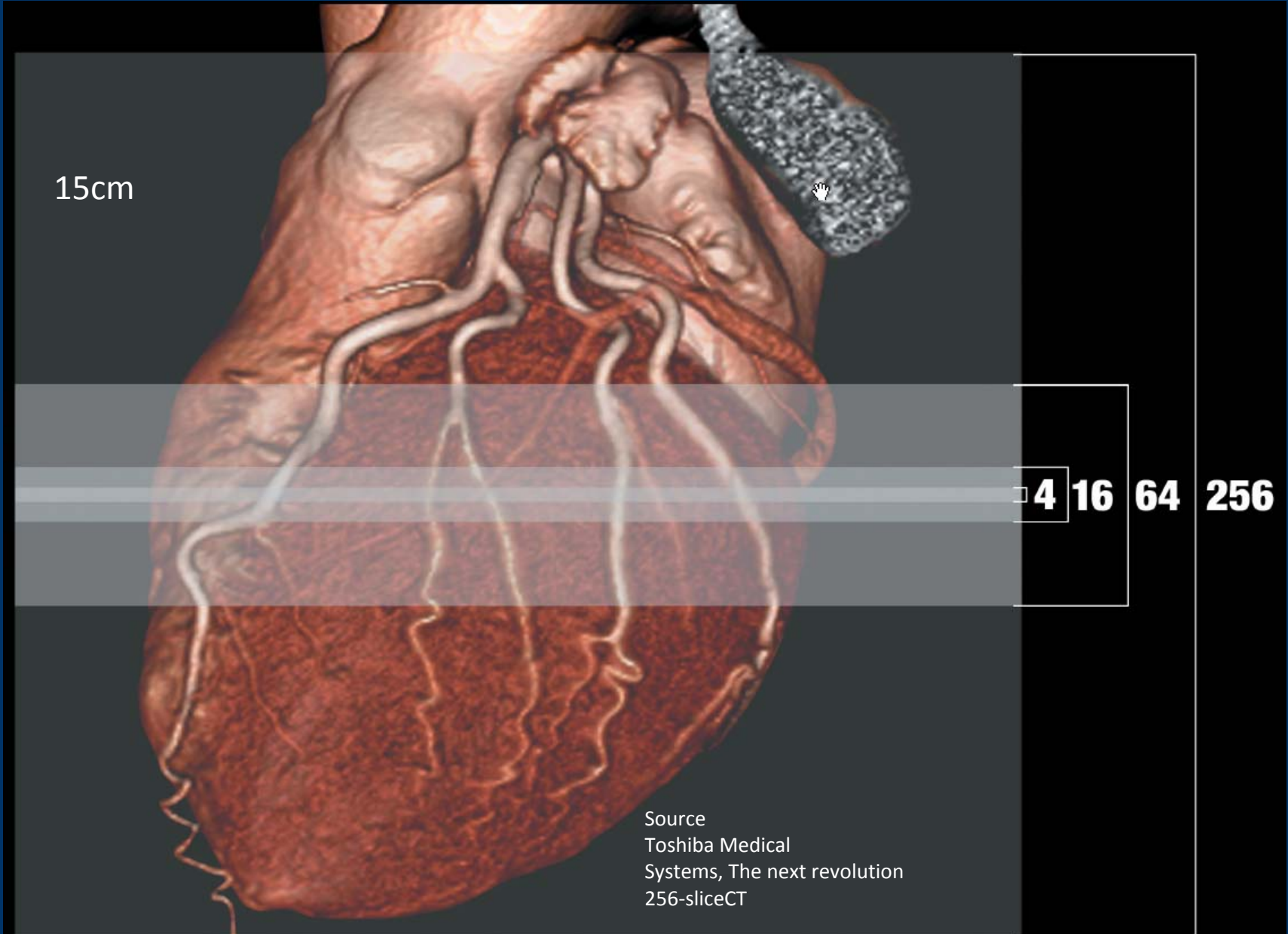


256-slice CT

15cm

4 16 64 256

Source
Toshiba Medical
Systems, The next revolution
256-sliceCT



What is a CTA (CT Angiography)?

CTA is a Contrast Enhanced ECG-gated High Resolution Spiral MDCT₆₄₋₃₂₀ of the Chest

Beta-blockers
<65



70-90 cc
4-5 cc/s



0.5-0.75mm

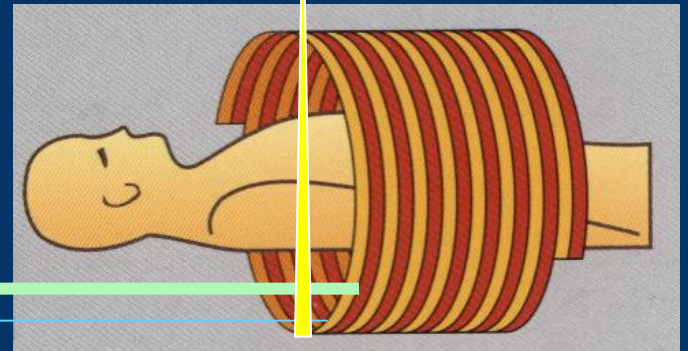
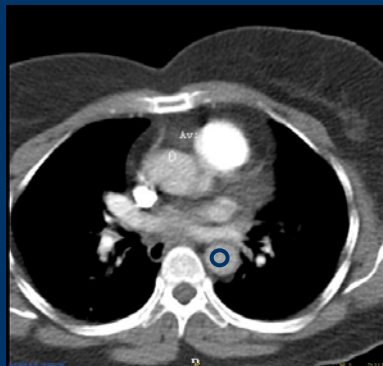
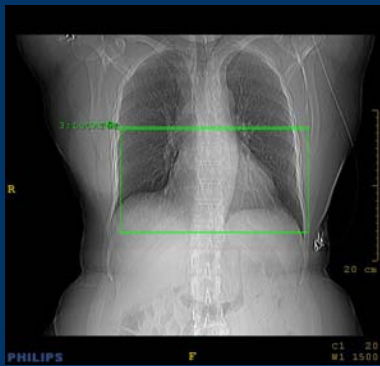


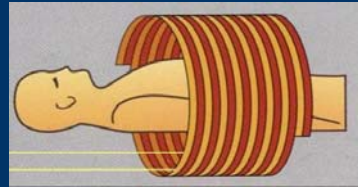
Table Moves



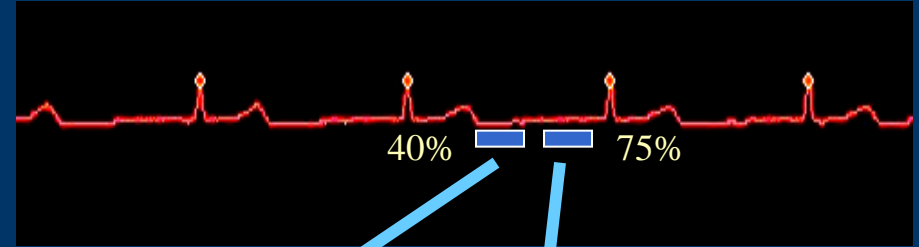
8-10 sec



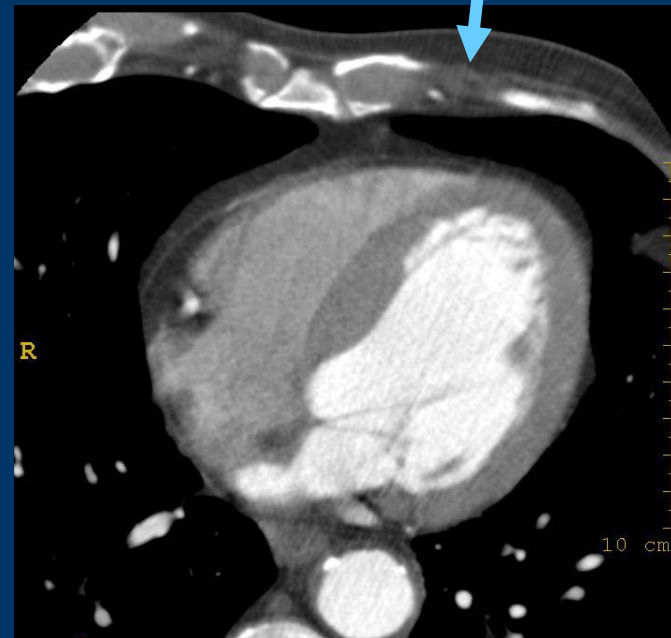
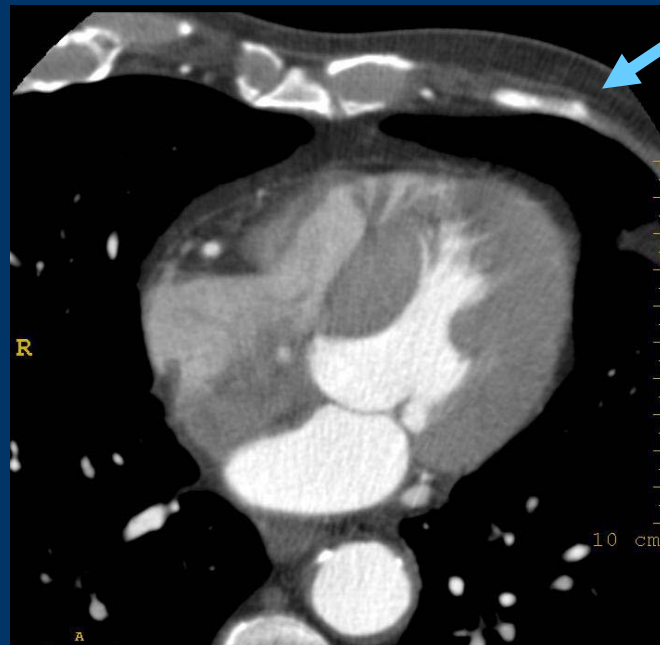
CTA Technique: Retrospective Image Reconstruction



Raw Data



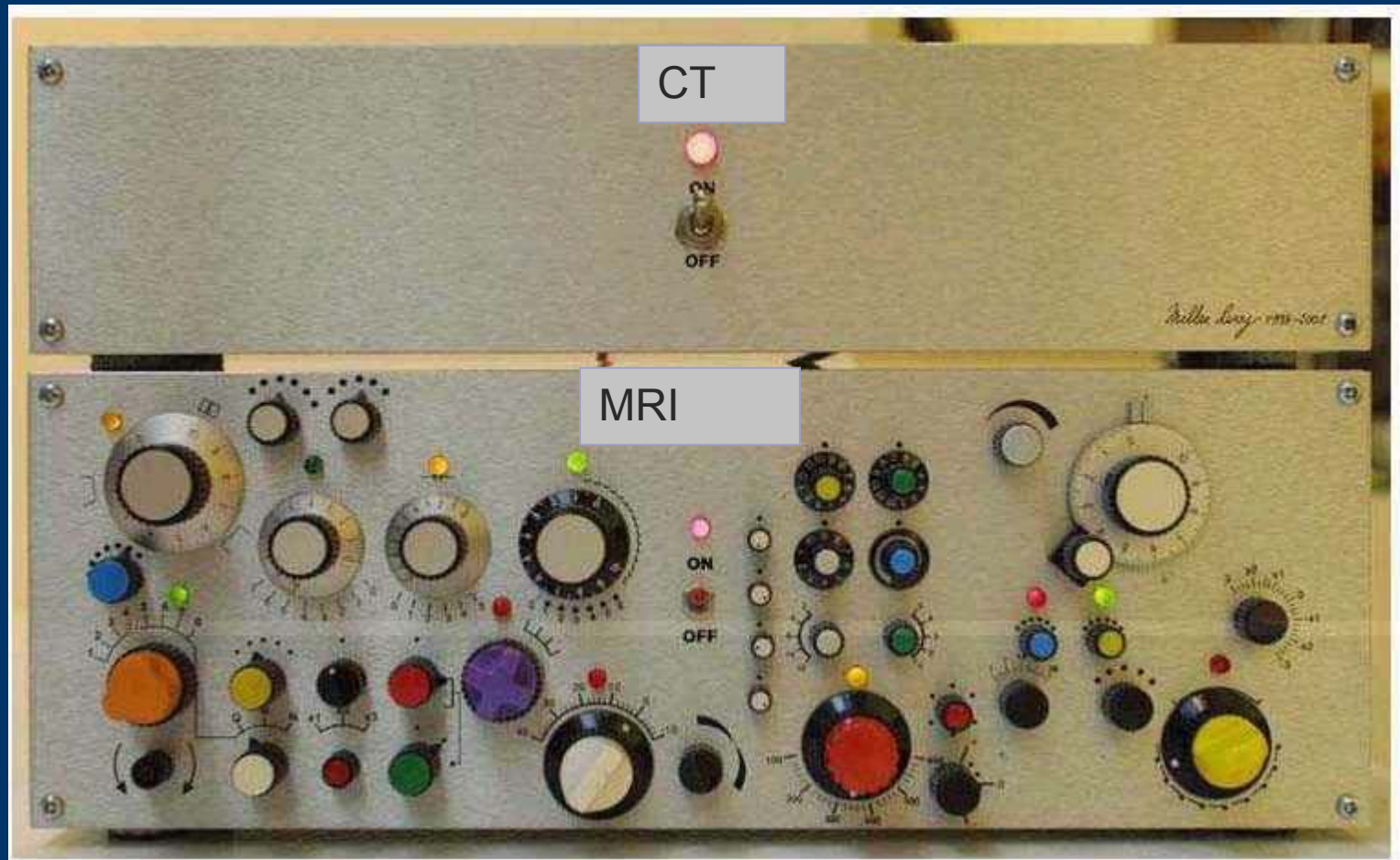
Retrospective Reconstruction



Men and Women are Not the Same!

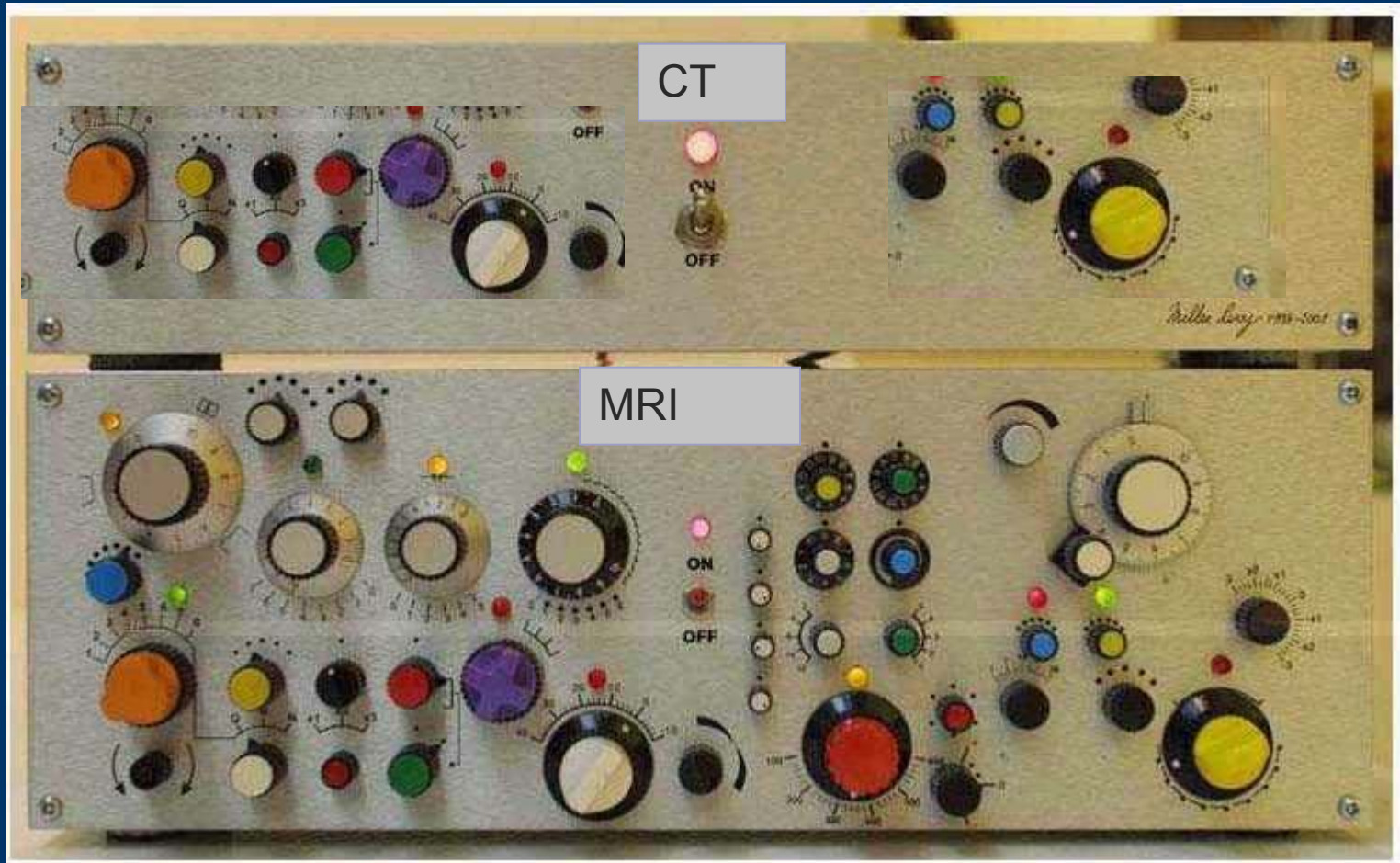


CT and MRI are Not the Same?

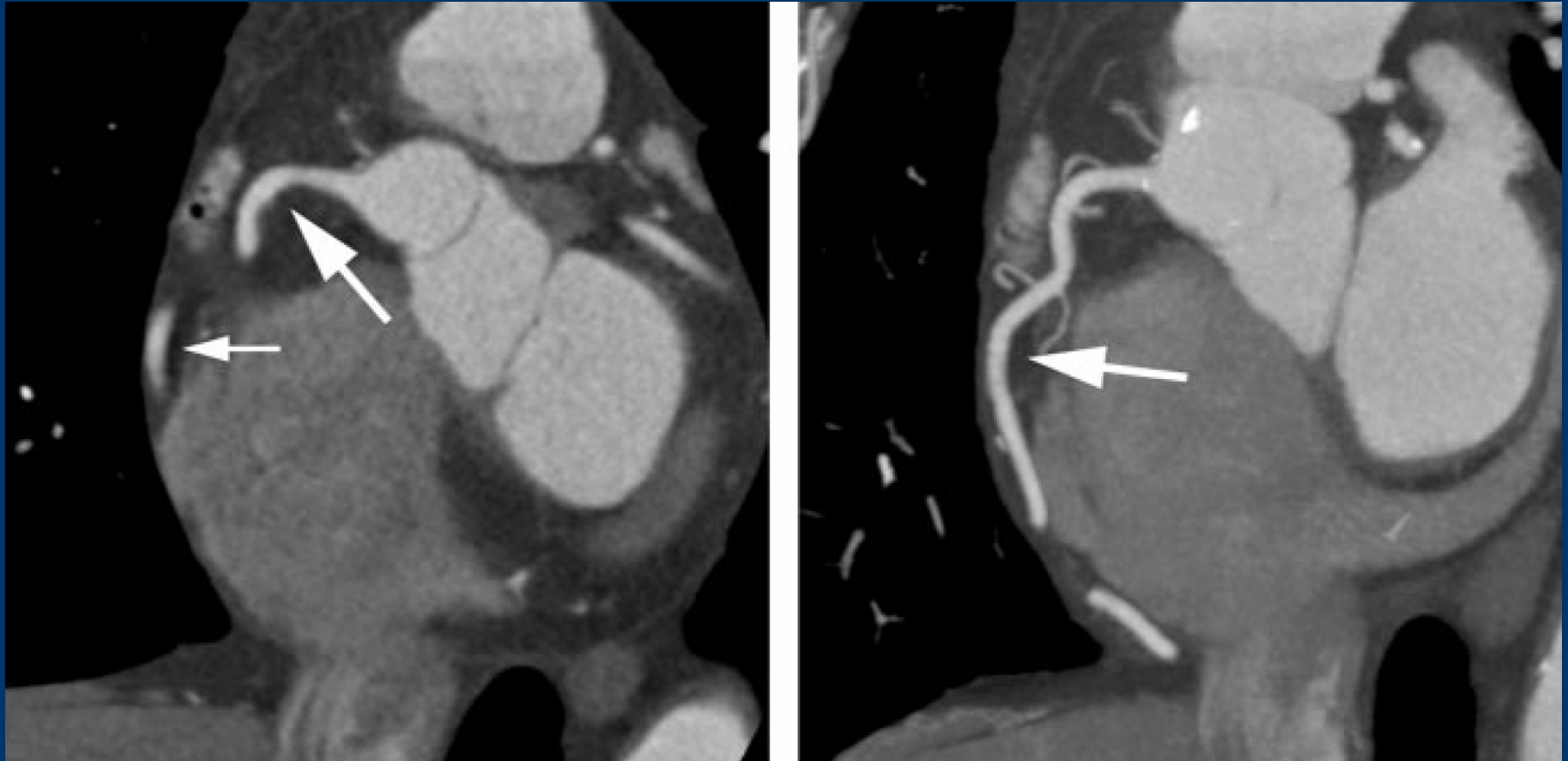


CT and MRI are Not the Same?

Probably Not –they are more or less the same

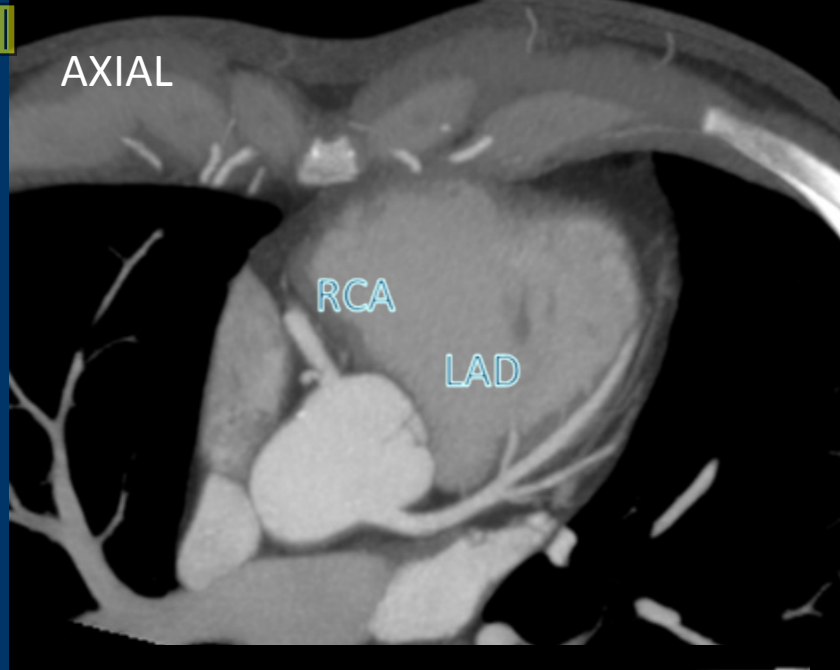


Oblique MPR / MIP

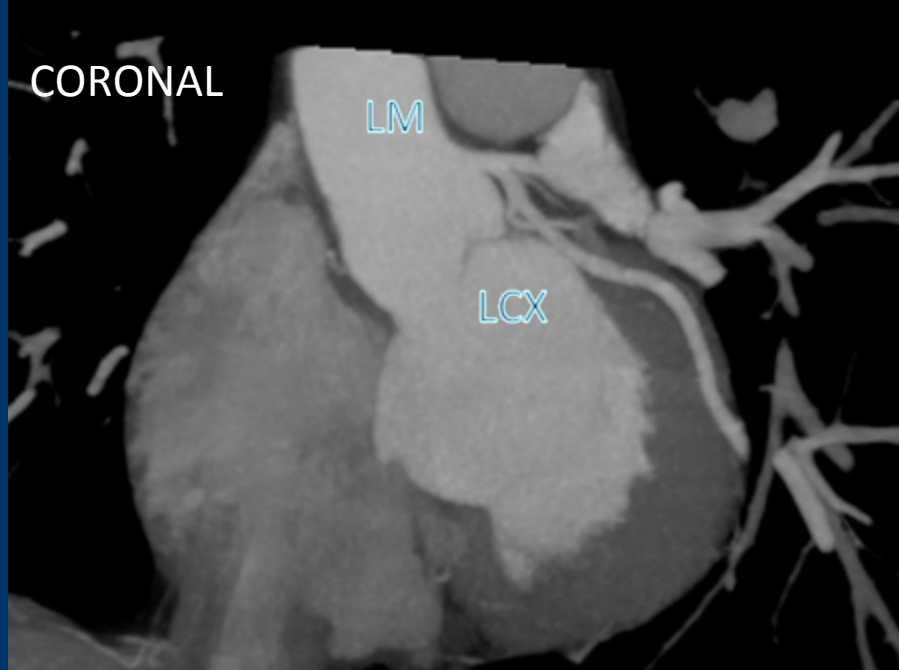




AXIAL



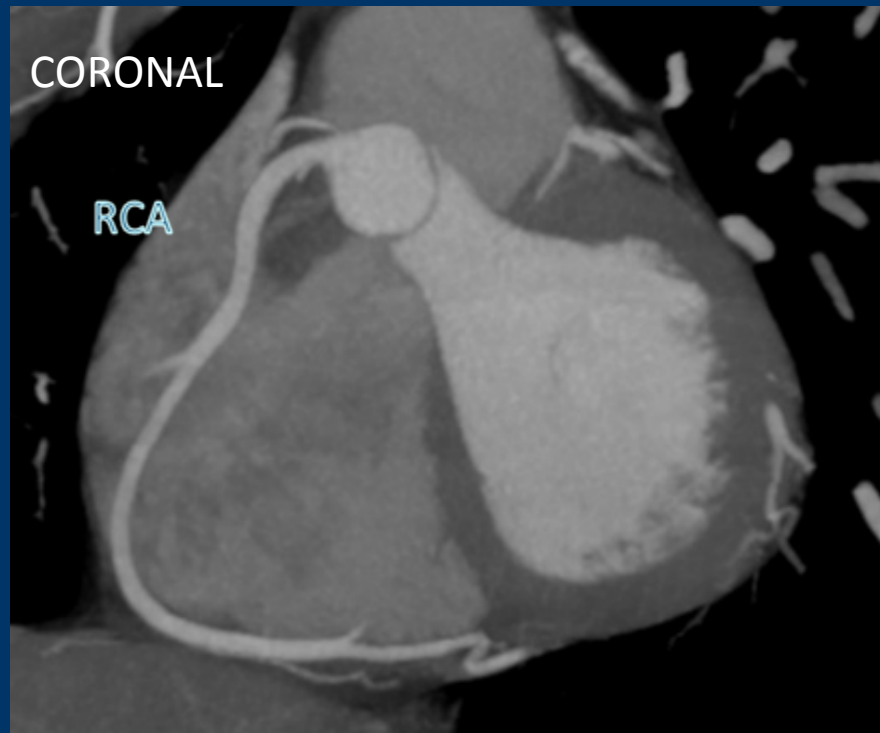
CORONAL



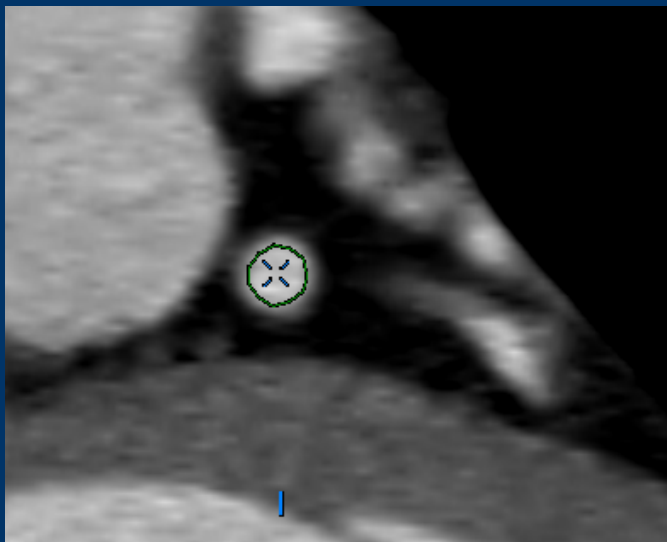
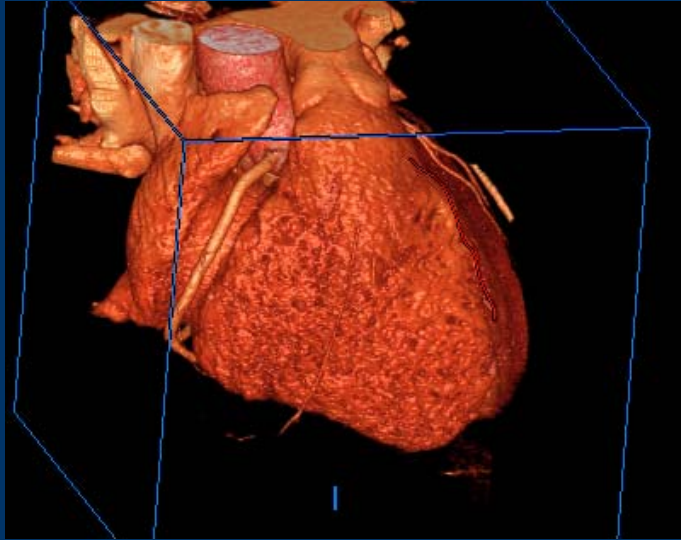
SAGITTAL



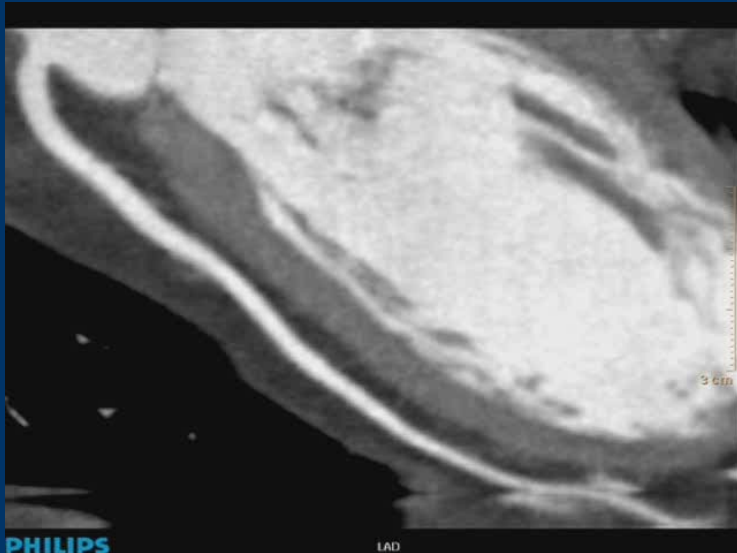
CORONAL



Curved MPR



Curved MPR



LAD

2.1
mSv

LCX



RCA

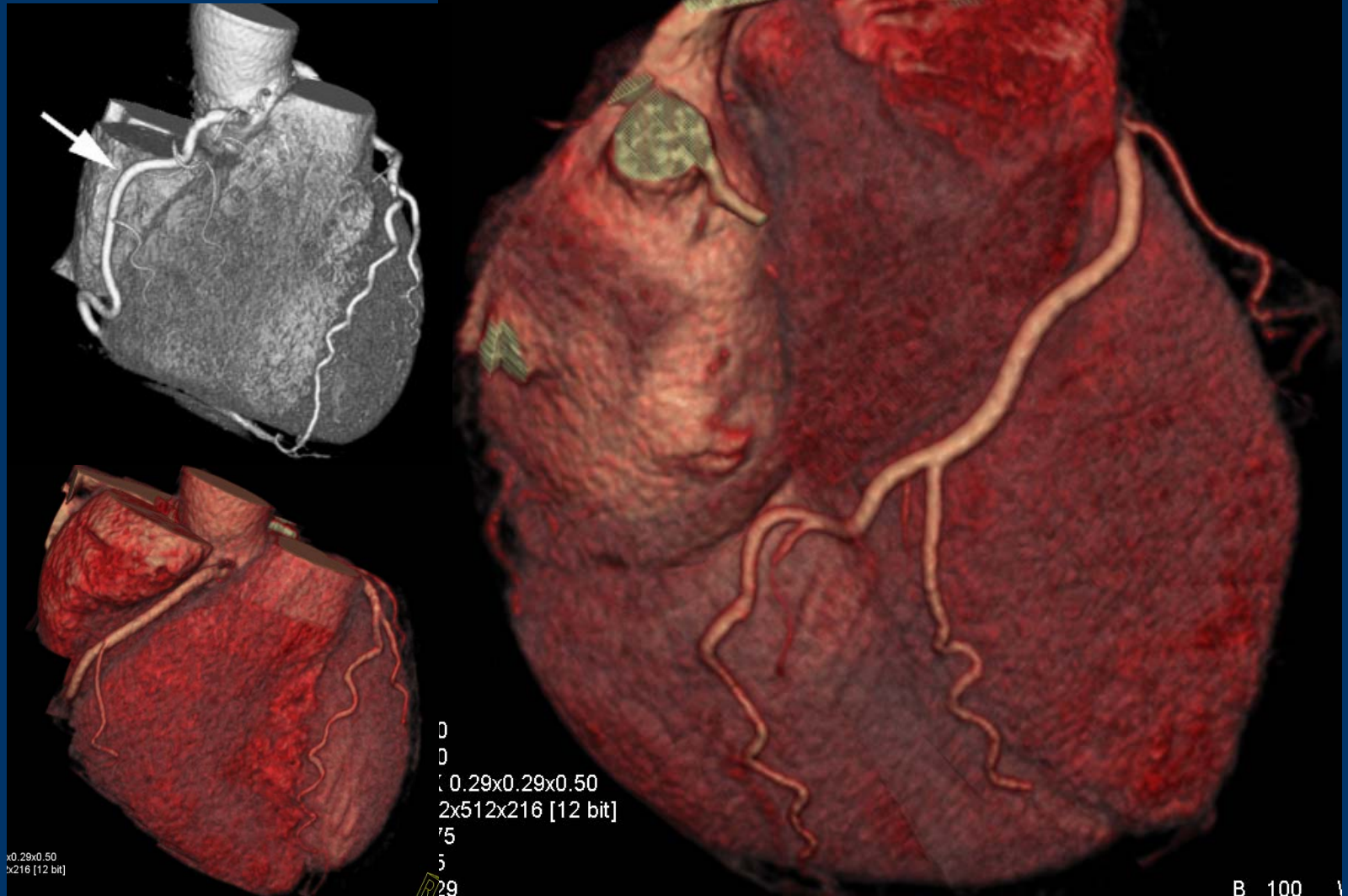


Curved MPR

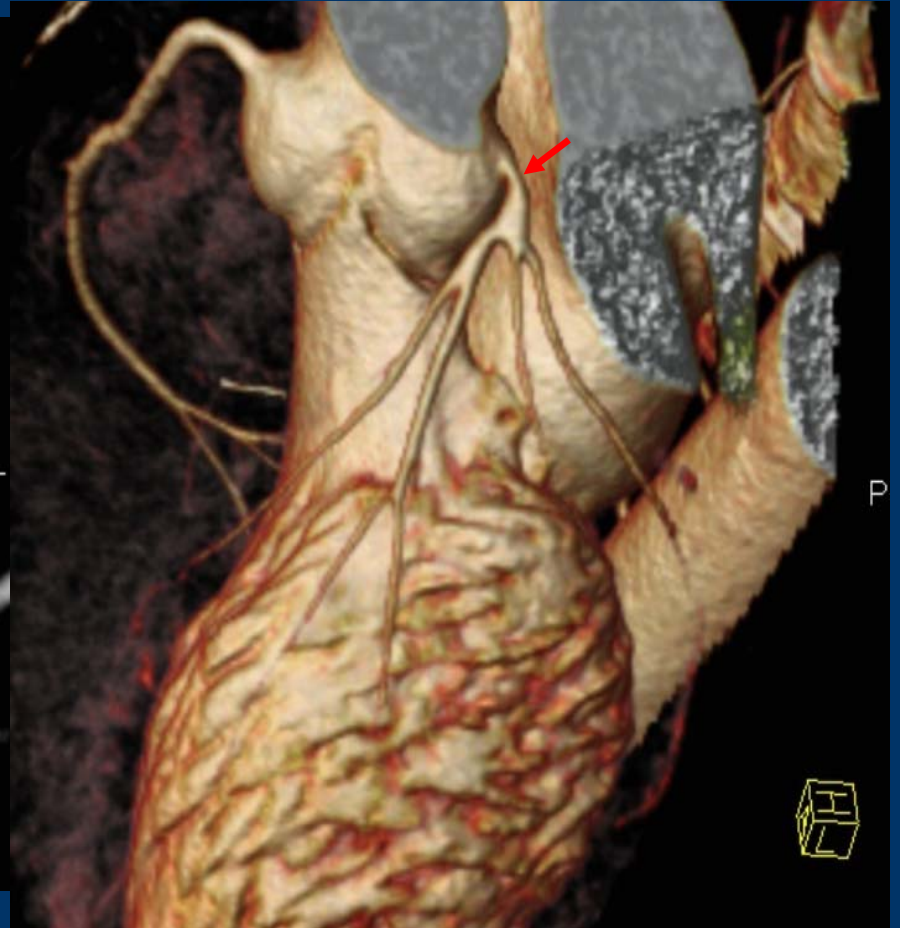
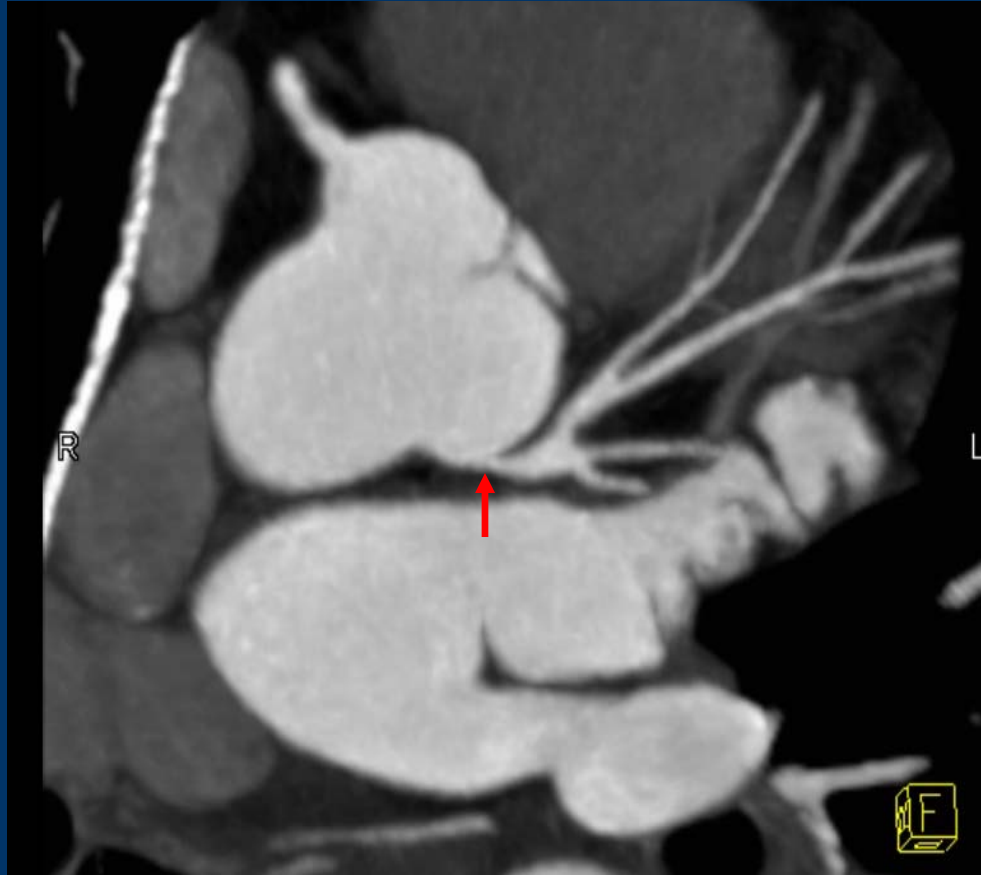


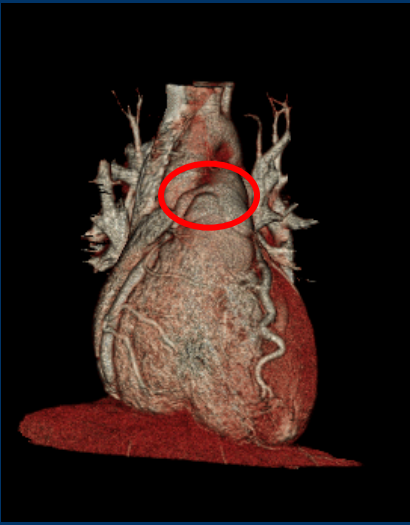


Volume Rendering



VR



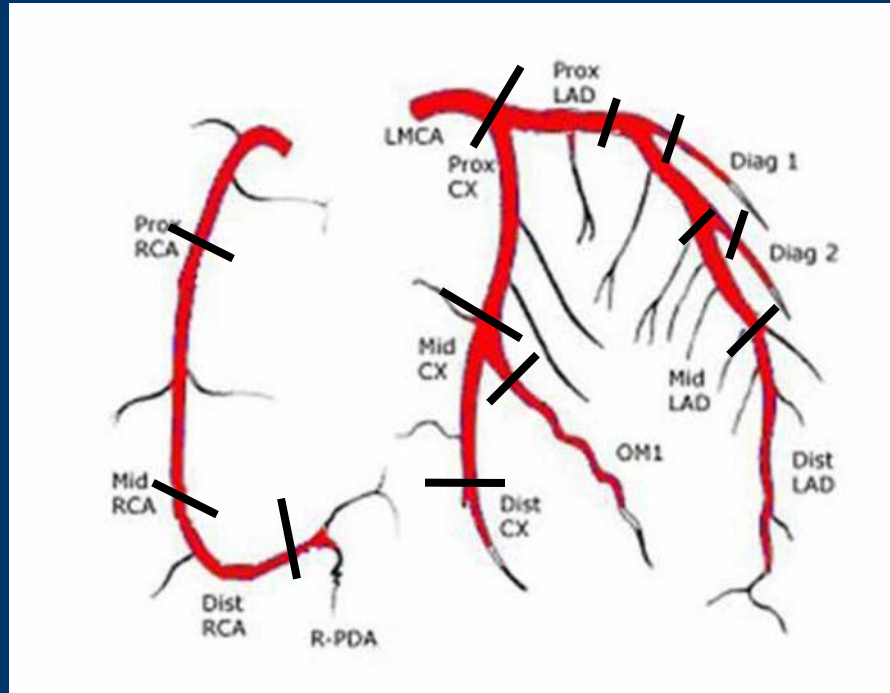


RCA from PA

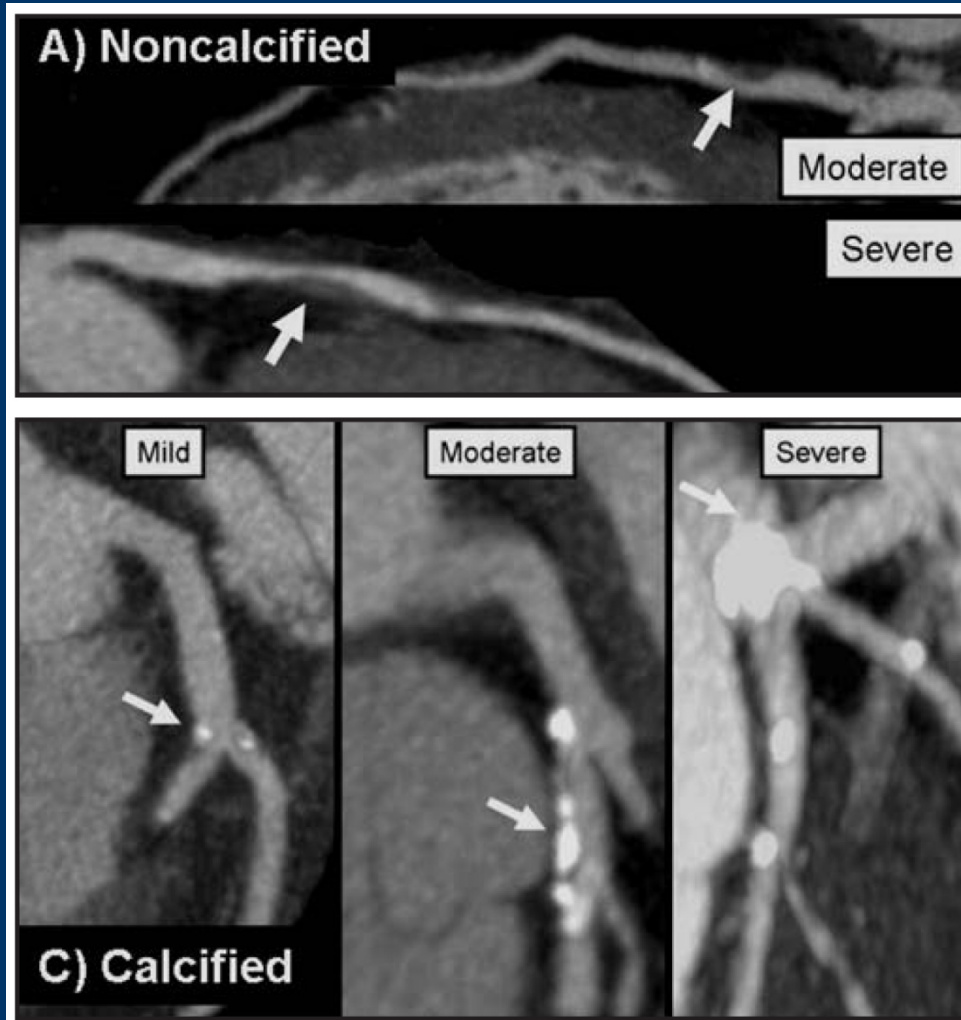


Normal Coronary Anatomy

17-segment
model



Assessment of Stenosis



Diagnostic Accuracy

Modality	Number of	Number of	Sensitivity (%)	Specificity (%)
	Studies	Patients		
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

Diagnostic Performance of Coronary Angiography by 64-Row CT

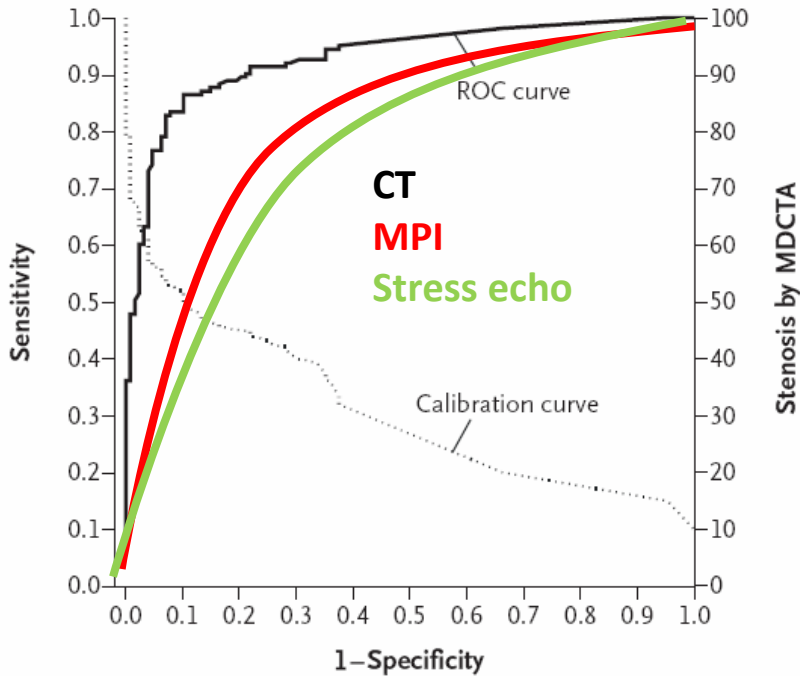
Julie M. Miller, M.D., Carlos E. Rochitte, M.D., Marc Dewey, M.D.,
Armin Arbab-Zadeh, M.D., Hiroyuki Niinuma, M.D., Ph.D., Ilan Gottlieb, M.D.,
Narinder Paul, M.D., Melvin E. Clouse, M.D., Edward P. Shapiro, M.D.,
John Hoe, M.D., Albert C. Lardo, Ph.D., David E. Bush, M.D.,
Albert de Roos, M.D., Christopher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

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

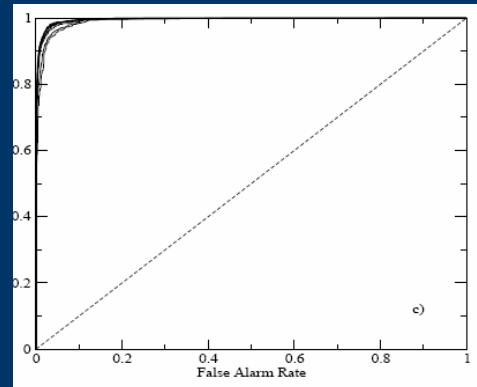
A Patient-Based Analysis for Stenosis $\geq 50\%$ by QCA



Measure of Accuracy

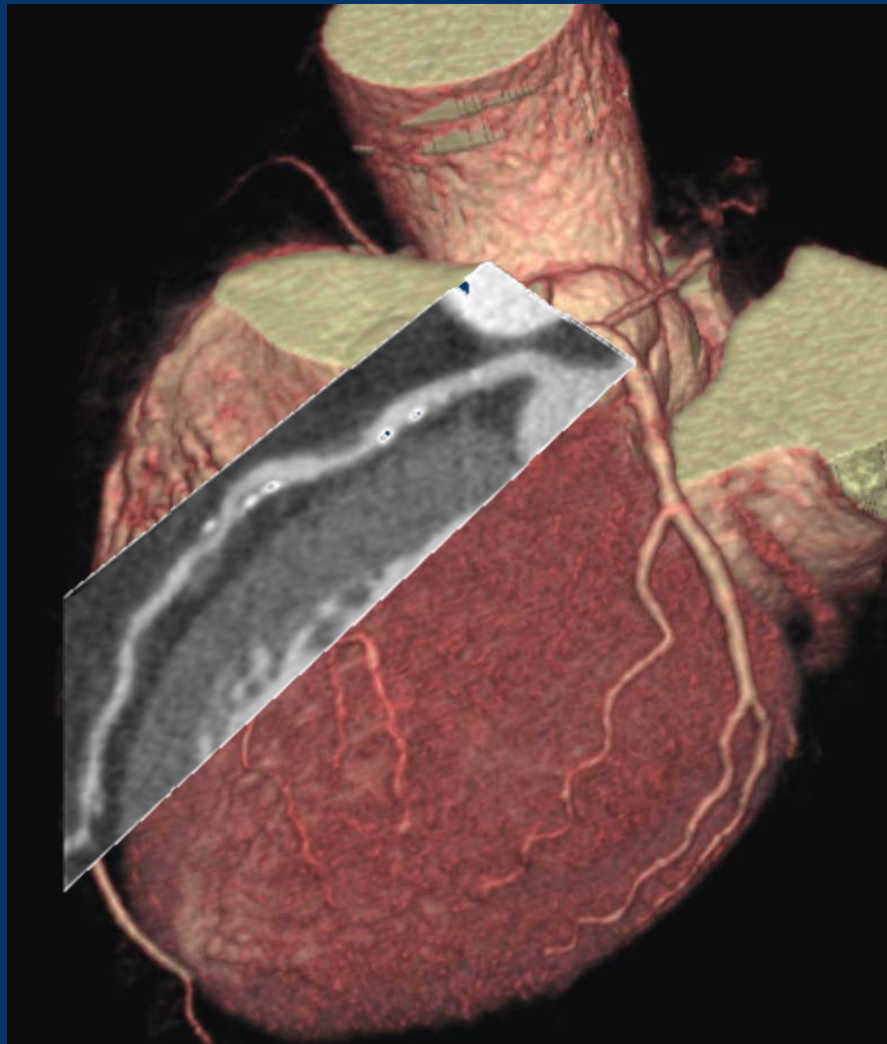
Patient-Based Detection

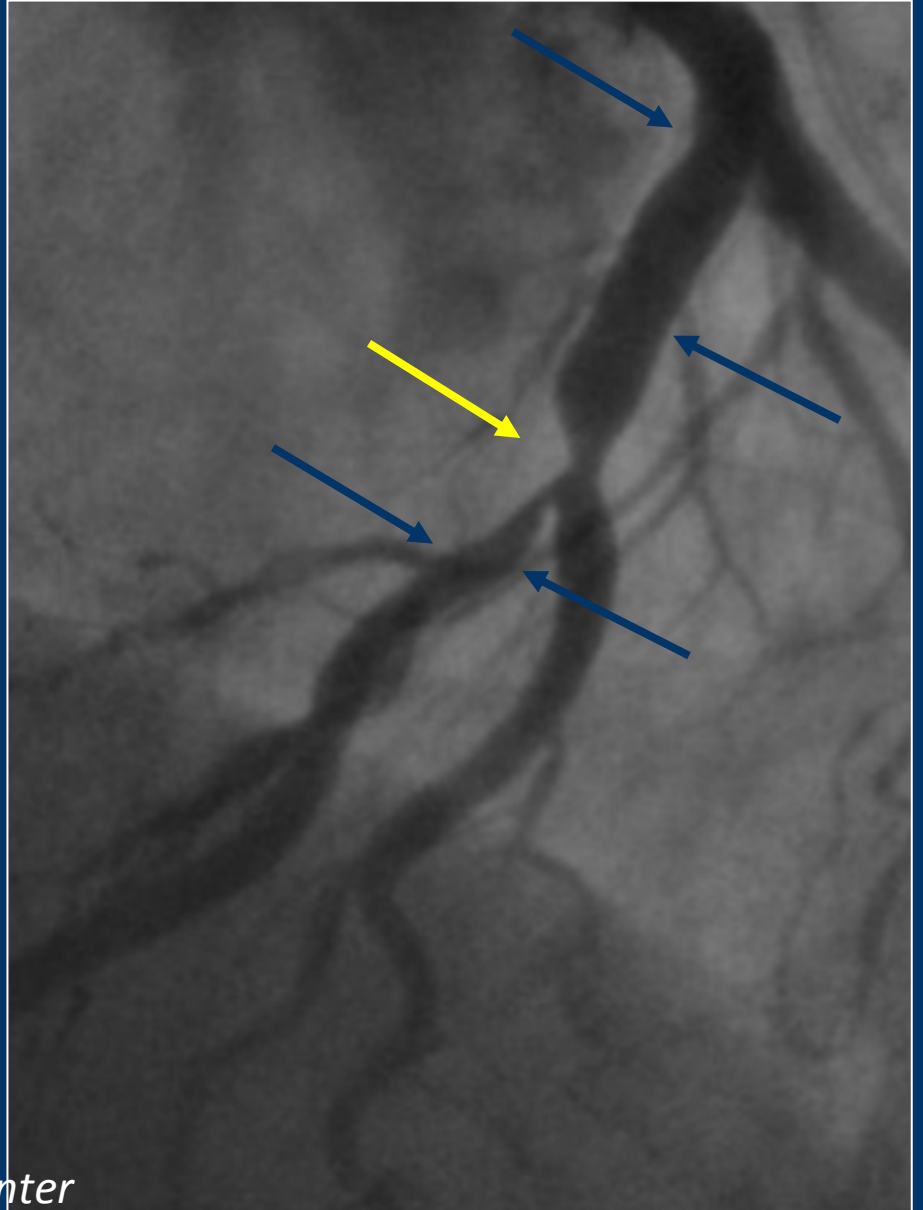
	Quantitative MDCTA (N=291)	Visual MDCTA (N=291)
AUC — median (95% CI)	0.93 (0.90–0.96)	0.93 (0.89–0.95)
Stenosis by CCA — no.	163	163
Stenosis by MDCTA — no.	152	146
False positive — no.	13	11
False negative — no.	24	28
Sensitivity — % (95% CI)	85 (79–90)	83 (76–88)
Specificity — % (95% CI)	90 (83–94)	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)





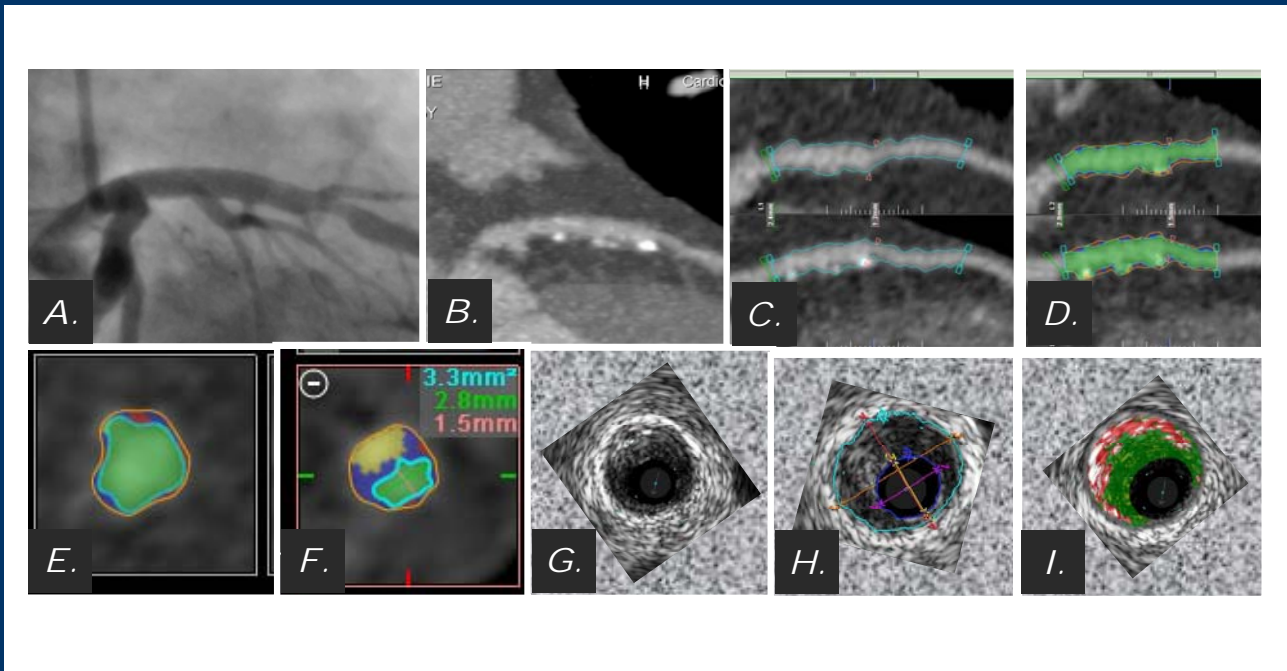
Beyond lumenography





Courtesy Dr. Weigold Washington Medical Center

Plaque quantization / burden



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,|| Yoshinori Sakai, MD, PhD,* Jagat Narula, MD, PhD‡

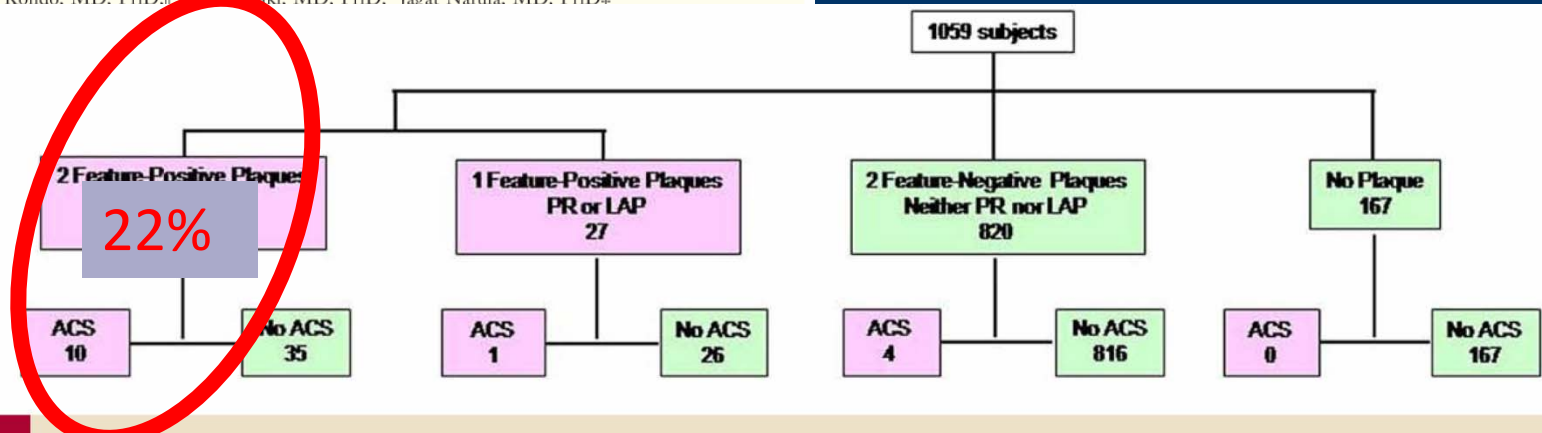


Figure 1 Acute Coronary Events in Patients on the Basis of Plaque Characteristics

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.

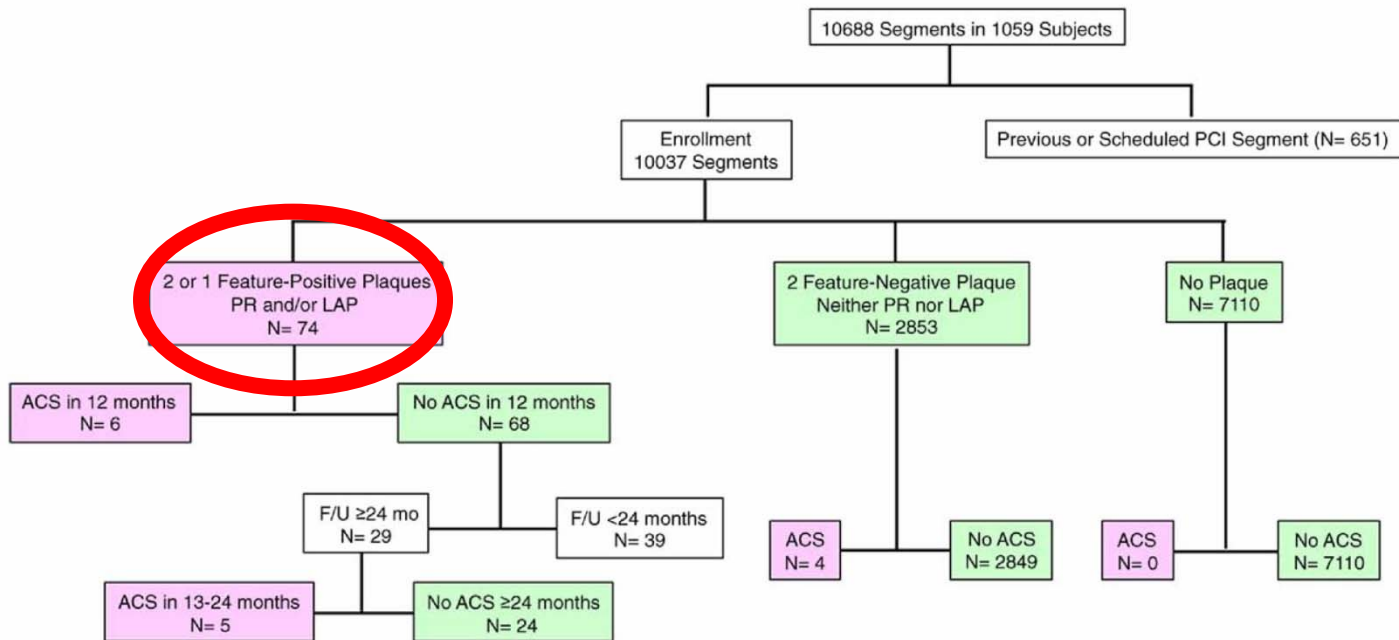


Figure 4 Plaque C **25%** CS by Segment-Based Analysis

2- and 1-feature positive plaques and 2-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.

“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 Eugene 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

2532 *Circulation* June 8, 2010

Table 4. Representative Values and Ranges of Effective Dose Estimates for Cardiac Studies

Examination	Representative Effective Dose Value (mSv)	Range of Reported Effective Dose Values (mSv)	Administered Activity (MBq)
Chest x-ray PA and lateral	0.1	0.05–0.24	N/A
Diagnostic invasive coronary angiogram	7	2–16	N/A
64-slice coronary CTA*			
Without tube current modulation	15	12–18	N/A
With tube current modulation	9	8–18	N/A
Prospectively triggered coronary CTA*	3	2–4	N/A
Percutaneous coronary intervention or radiofrequency ablation	15	7–57	N/A
Myocardial perfusion study			
Sestamibi (1-day) stress/rest	12	N/A	1480
Tetrofosmin (1-day) stress/rest	10	N/A	1480
Thallium stress/redistribution	29	N/A	130
Rubidium-82 rest/stress	10	N/A	2960
Myocardial viability study			
PET F-18 FDG	14	N/A	740
Thallium stress/reinjection	41	N/A	185



Indications

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

התוויות לביצוע טומוגרפיה ממוחשבת של הלב

מסמך עמדה משותף מטעם:
האיגוד הקרדיולוגי ואיגוד הרדיולוגים בישראל

אפריל 2010



ההסתדרות הרפואית בישראל

המועצה המדעית • האגף לאבטחה איכות

Appropriate Indications

אבחון תחלואה לבבית מבנית או בכלי הדם הגדולים

11	חשד לאנומליות של העורקים הכליליים.
12	הערכה של מומי לב מולדים כולל אנומליות של מהלך עורקים כליליים, כלי דם גדולים, חדרי לב ומסתמים, כאשר ההדמיה באקו לב וב CMR מוגבלת.
13	בירור משלים של גוש בלב (גידול או קריש דם) כשההדמיה באקו לב (TTE או TEE) ותהודה מגנטית של הלב (CMR) מוגבלת טכנית או אינה אבחנתית.
14	הערכת קרום הלב (מסה פריקרדיאלית, constrictive pericarditis, או סיבוכים לאחר ניתוחי לב) כשההדמיה באקו לב (TTE או TEE) ובדיקת תהודה מגנטית של הלב (CMR) מוגבלת טכנית או אינה אבחנתית.
15	הערכת ורידי הריאה בחולים עם פרפור פרוזודורים לפני בצוע צריבה של ורידים אלה (RF ablation), או בחשד קליני לסיבוך לאחר הפעולה.
16	מיפוי הורידים הכליליים טרם השתלת קוצב דו חדרי.
17	חשד למעורבות מוצא העורקים הכליליים במסגרת הערכה של מפרצת אאורטלית ו/או דיסקציה של האאורטה חזית.
18	הערכת מורפולוגיית ותפקוד חדר ימין כאשר ההדמיה באקו לב (TTE או TEE) מוגבלת ו CMR אינו זמין.

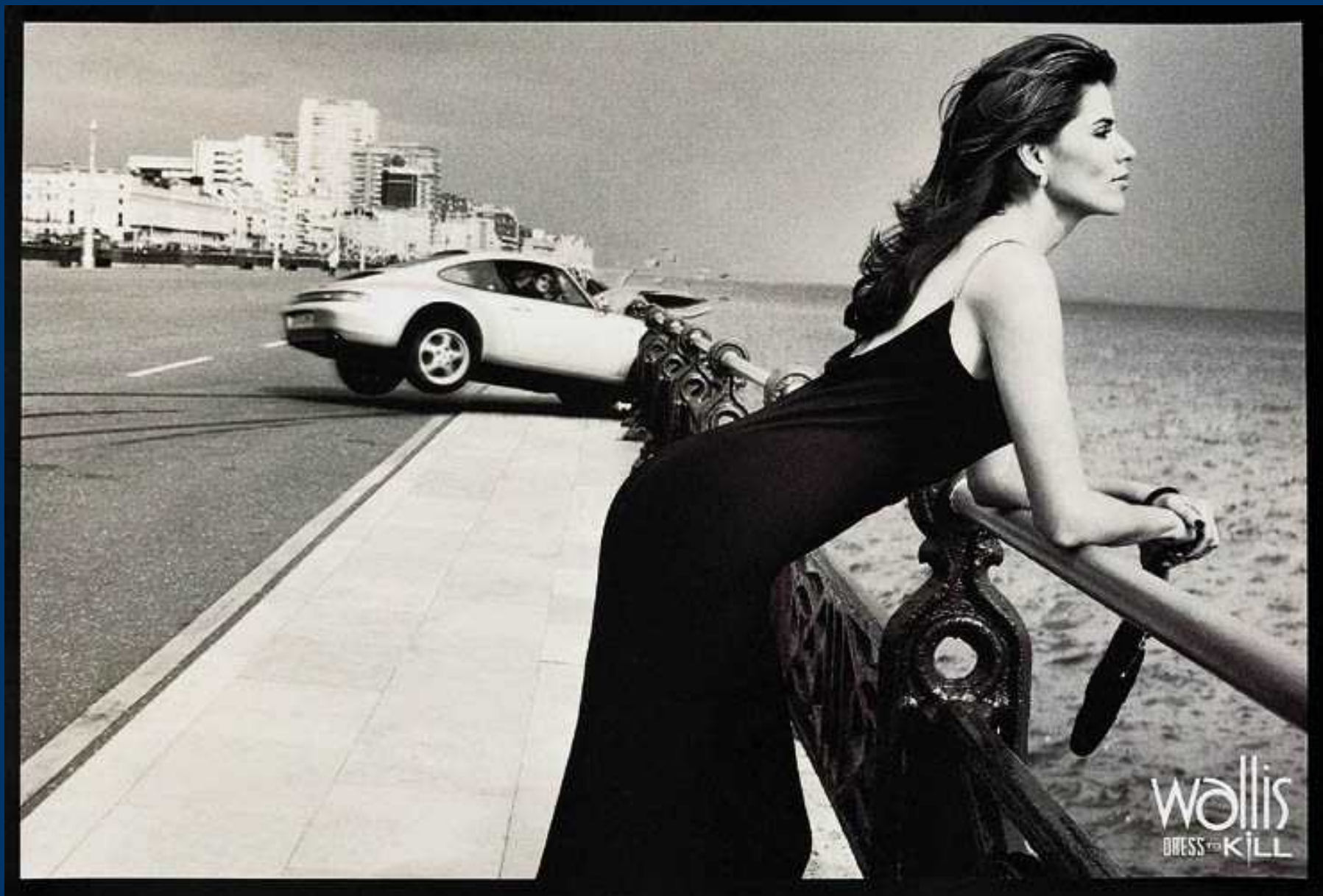
ברור אמבולטורי של כאבי חזה

1	בנבדק בסבירות נמוכה עד בינונית למחלה כלילית חסימתית ובפרט אם אינו מסוגל לבצע מאמץ אבחנתי ו/או בנוכחות תרשים א.ק.ג שמקשה על פענוח (כגון CLBBB, שינויי רפולריזציה).
2	בנבדק עם מבחן מאמץ, מיפוי או אקו לב במאמץ בלתי החלטיים או שאינם ניתנים לפענוח, אך נדרש המשך בירור.
3	אבחון חסימות של מעקפים כליליים בחולים לאחר ניתוח מעקפים (CABG) הסובלים מכאבי חזה לא טיפוסיים.
כאבי חזה חדים (Acute chest pain)	
4	כאבים בחזה בנבדק בסבירות נמוכה עד בינונית למחלה כלילית חסימתית, ללא שינויים איסכמיים בתרשים הא.ק.ג וללא עליה בסמני הלב בדם בבדיקות עוקבות.
5	לשלילת מחלה כלילית, תסחיף ריאתי ודיסקציה אאורטלית בהסתמנות חדה (Triple rule-out) כשקיימת אבחנה מובדלת עם חשד קליני סביר לבעיות הנייל.
צורך בהערכה קרדיאלית במצבים קליניים שונים	
6	הדגמה של עורקים כליליים בחולים עם חשד קליני לקרדיומיופטיה לא איסכמית חדשה New-onset non-ischemic cardiomyopathy
7	לצורך אבחון משלים של המהלך האנטומי של עורק השד הפנימי (IMA) ומעקפים כליליים לפני ניתוח חוזר REDO, או ניתוח מסתמים בחולה לאחר CABG, על מנת להעריך את מרחק המעקפים מן הסטרנום וכן מידת קרבת חדר ימין לסטרנום.
8	לשלילת מחלה כלילית חסימתית בחולים עם סיכון נמוך עד בינוני לקיום מחלה כלילית חסימתית, לפני ניתוח במסתמי הלב או לתיקון בעיות מבניות קרדיאליות.
9	כאשר לא ניתן לבצע בדיקת דימות מיטבית של העורקים הכליליים באמצעות בדיקת צנתור לב מסיבות טכניות או בטיחותיות או בשל היעדר מידע אבחנתי מלא בצנתור כלי דם כליליים (סעיף א' בהמלצת משרד הבריאות משנת 2005).
10	כאלטרנטיבה לא פולשנית לביצוע מעקב לאחר הכנסת תומכן בעורק שמאלי ראשי (Left main coronary artery).

Intermediate risk 20-80%

Summary

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



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Thank you

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