Advanced Imaging
MRI and CTA

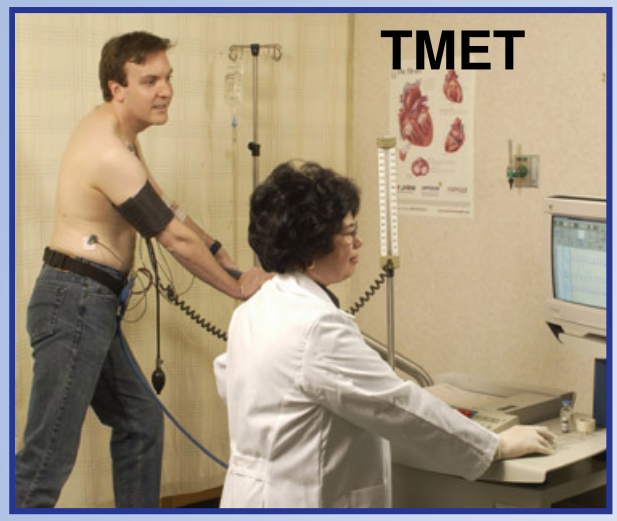
Who and why may benefit.

Matthew W. Martinez, M.D. FACC
Lehigh Valley Health Network
Director, Cardiovascular Imaging

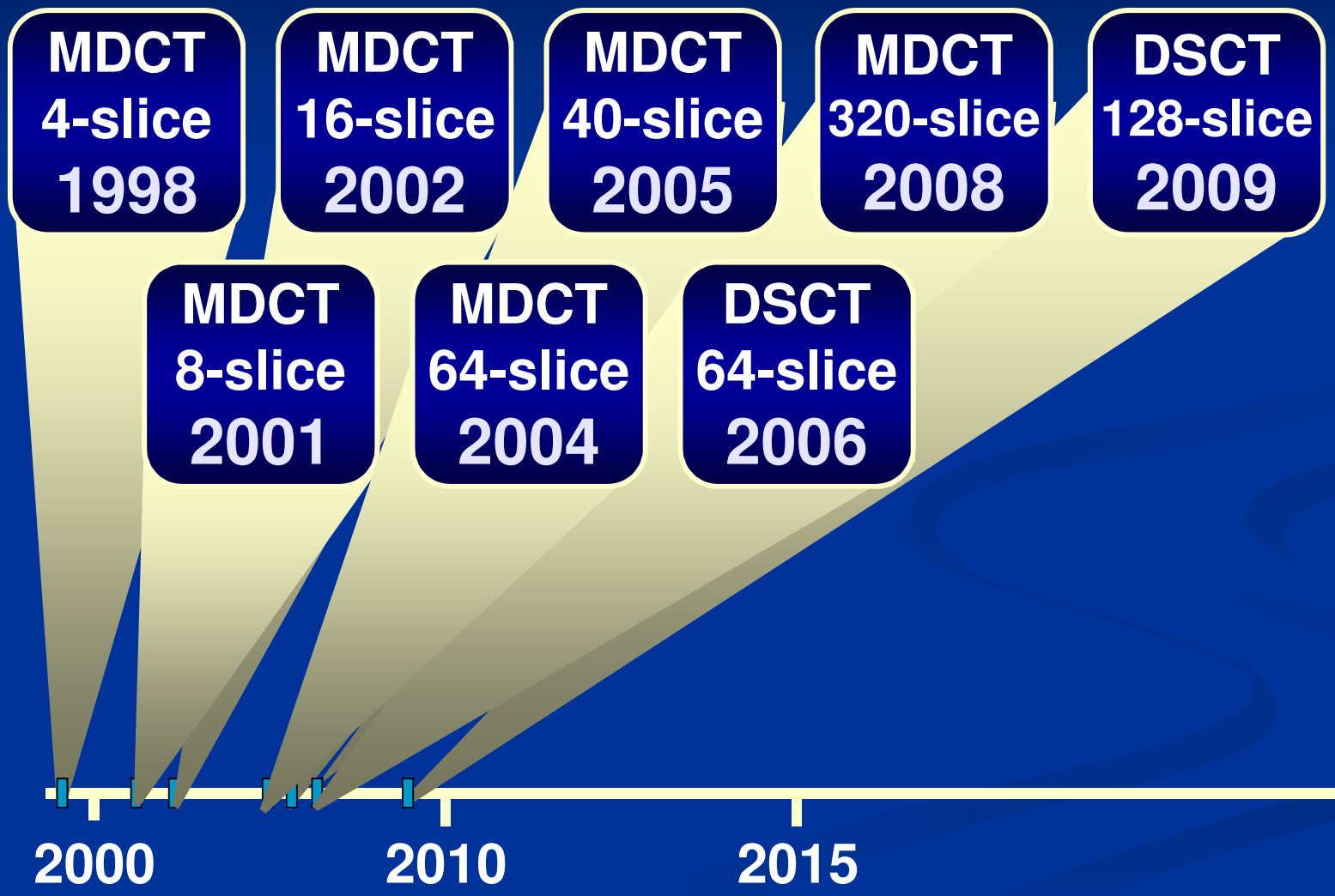
Learning Objectives

- Review basics of CMR and CTA
- Review utility of CMR and cardiac CT in clinical practice
- Clinical cases

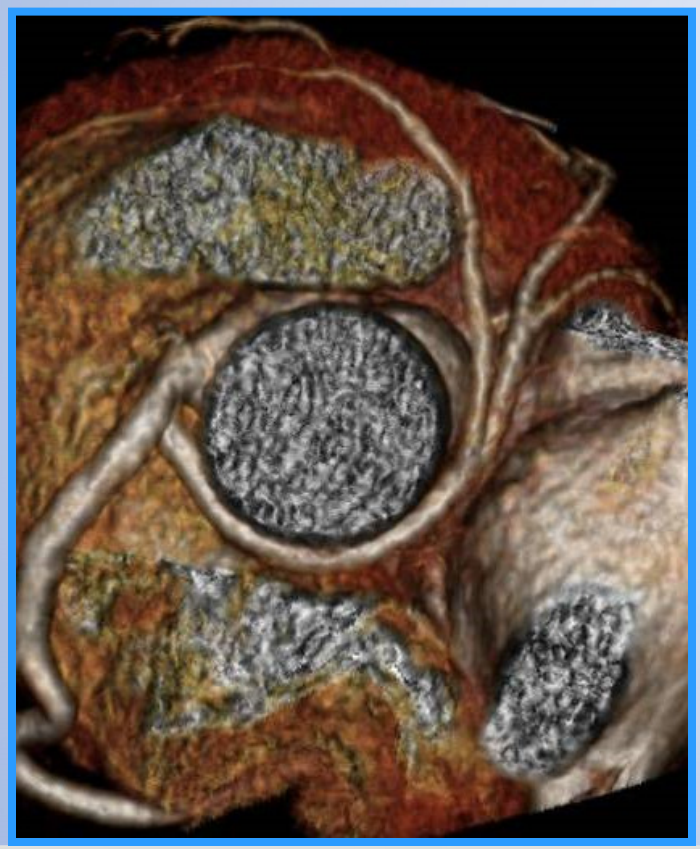
Noninvasive Testing

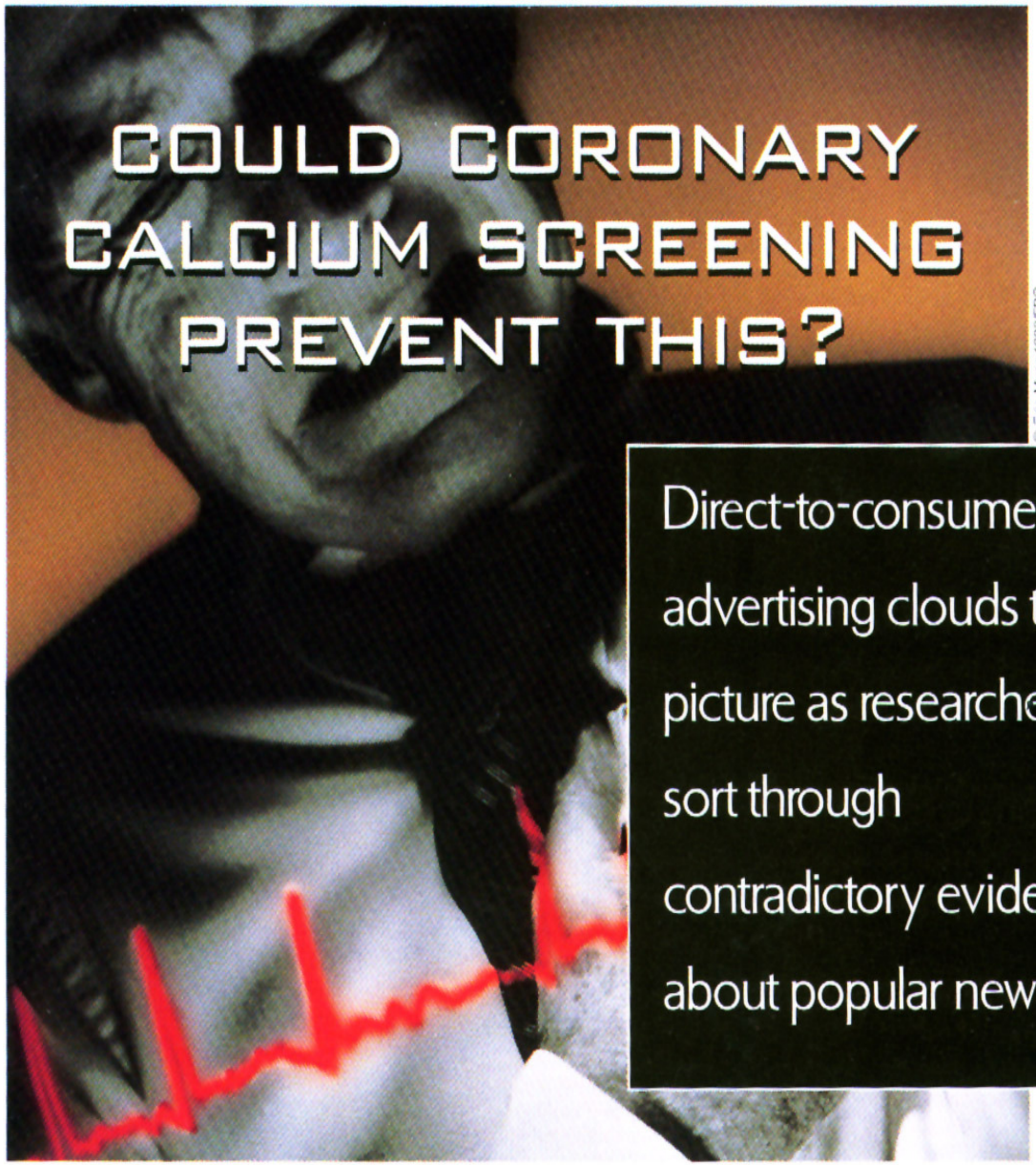


Development of CT



Minimally Invasive Coronary Artery Assessment




COULD CORONARY
CALCIUM SCREENING
PREVENT THIS?
Direct-to-consumer
advertising clouds the
picture as researchers
sort through
contradictory evidence
about popular new test

A physician's referral is not required for a coronary calcium scan. A final written report will be mailed or faxed to the patient and the designated cardiologist or other physician within 48 hours of the test. The report includes the findings from the medical history, the cholesterol level and the results of the coronary calcium scan.

Give a Heart Screening for Someone You Love

Printer Friendly
Email to a Friend
Have Questions?

Most people who suffer heart attacks have only average or slightly

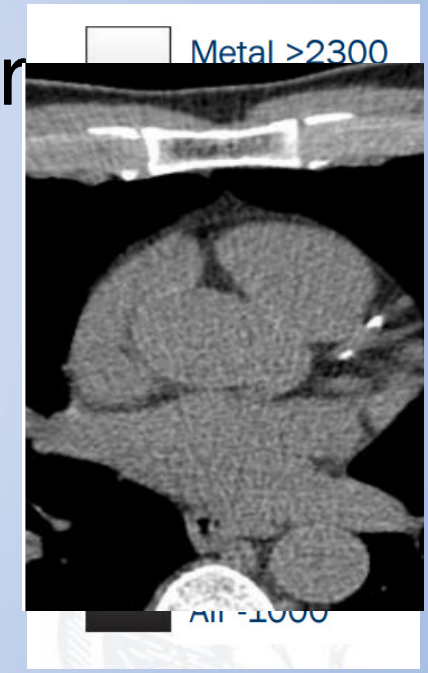
For More Information

The cost of a coronary calcium scan is $395 and is not covered by most insurance plans. To purchase a gift certificate, schedule an appointment or learn more, please contact:

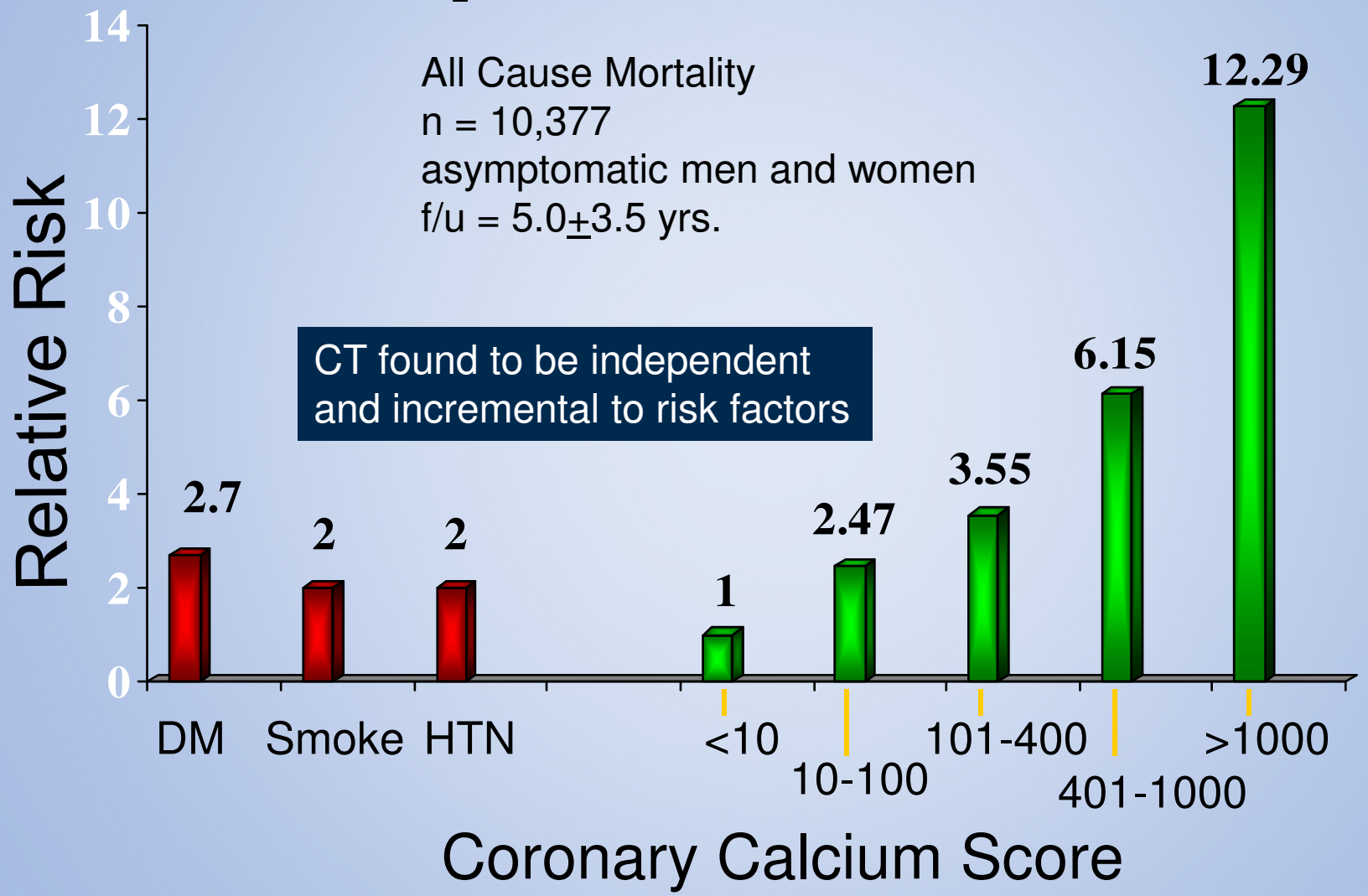
A coronary calcium scan is the first step towards ensuring a healthy heart. What better gift could you give for someone you love?

Calcium scan: – noncontrast, ECG-triggered CT

- HU: unit of CT signal intensity
- Calcium has high HU; threshold for calcium scoring = 130
- Agatston score: weighted sum
- CAC indicates plaque burden
  - Calcification is one aspect of atherosclerosis
- CAC does not indicate % stenosis



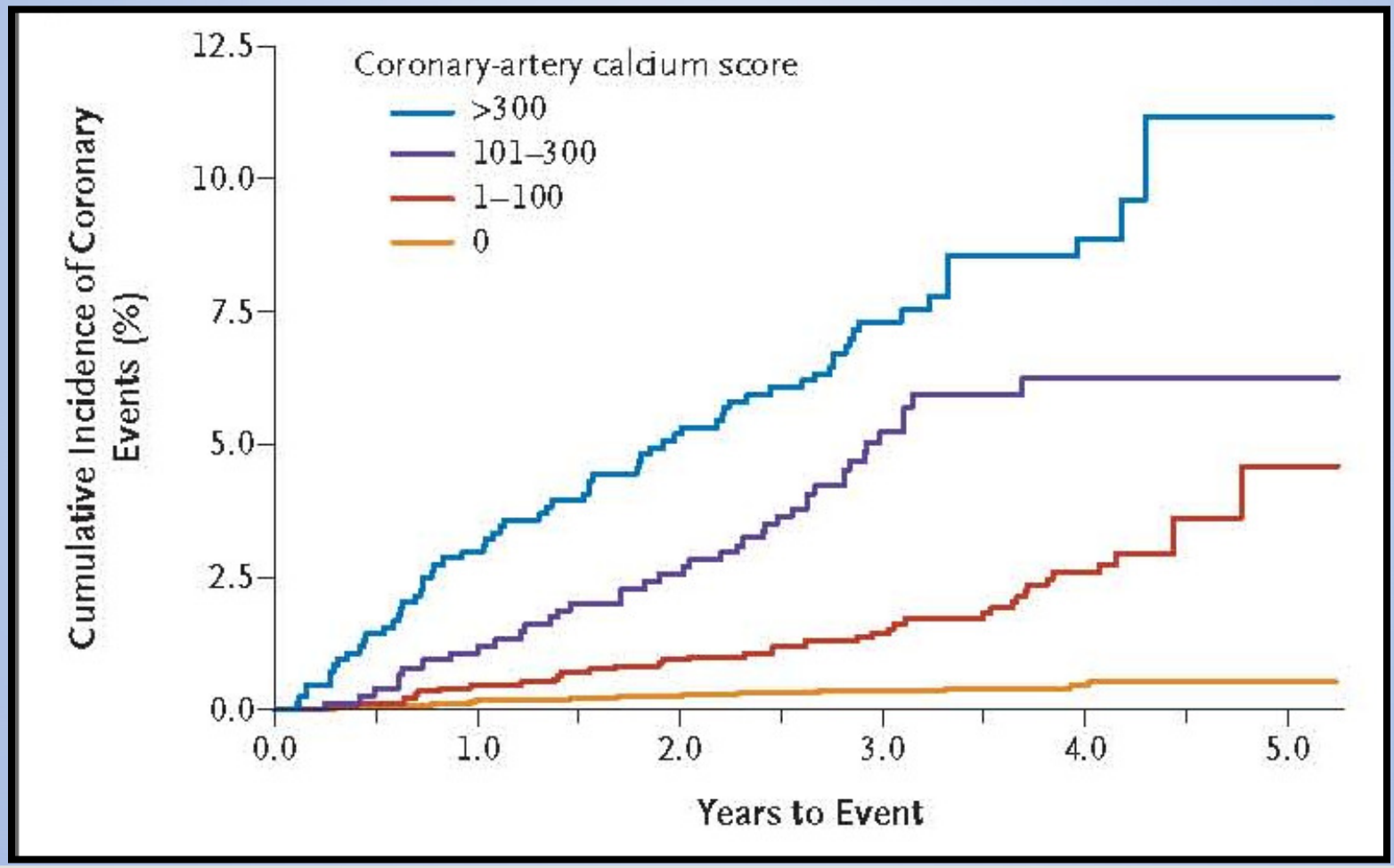
Coronary Artery Calcification



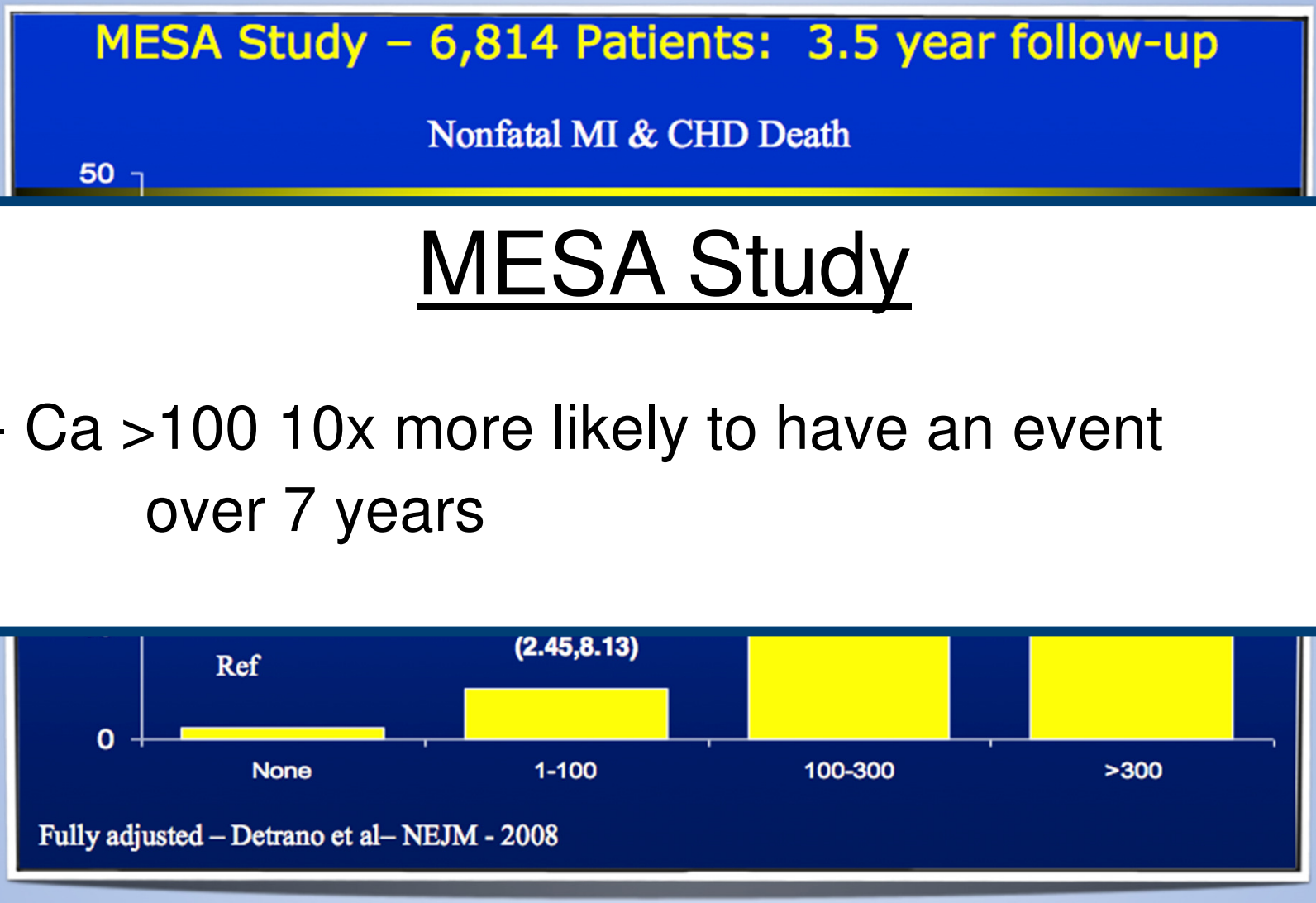
Shaw, Raggi et al Radiology 2003

MESA
Unadjusted Kaplan–Meier Cumulative-Event Curves for Any Incident CHD by CAC Score

Rates for any coronary event



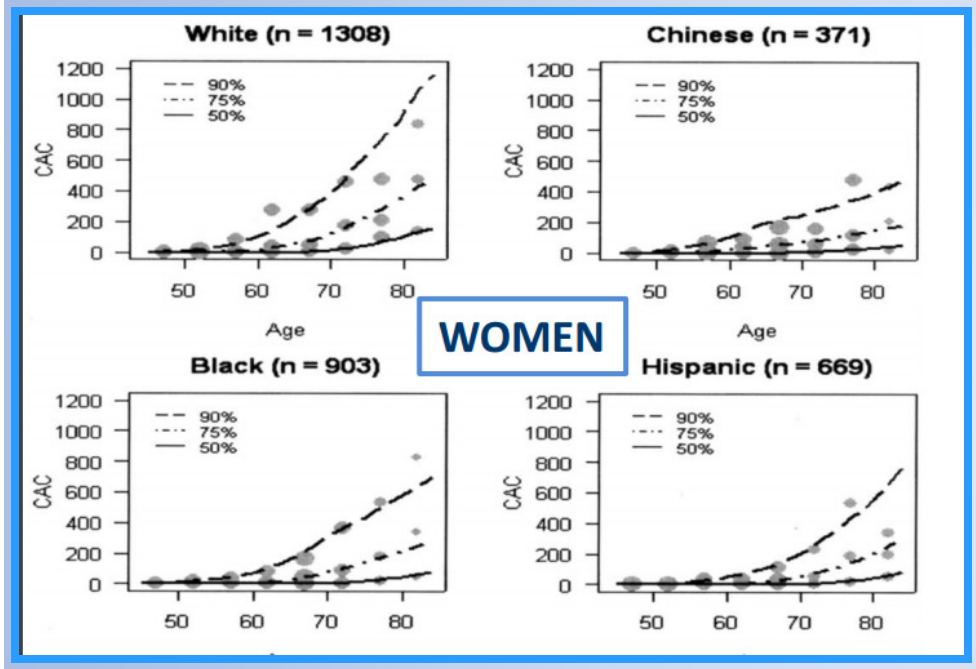
Detrano, et al. *N Engl J Med*. 2008;358:13.

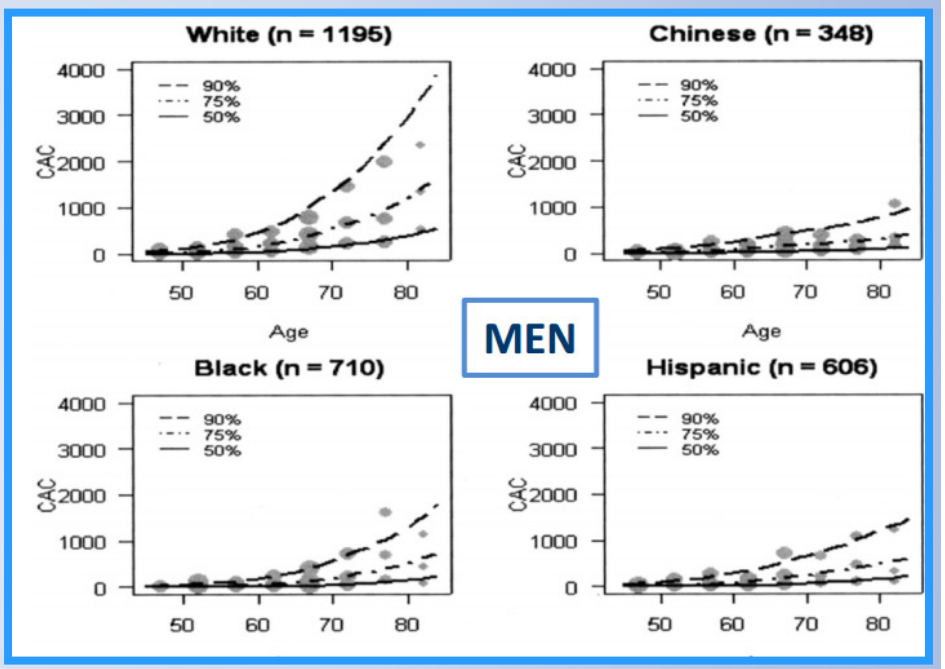


MESA Study

- Ca >100 10x more likely to have an event over 7 years

Individualized CAC score

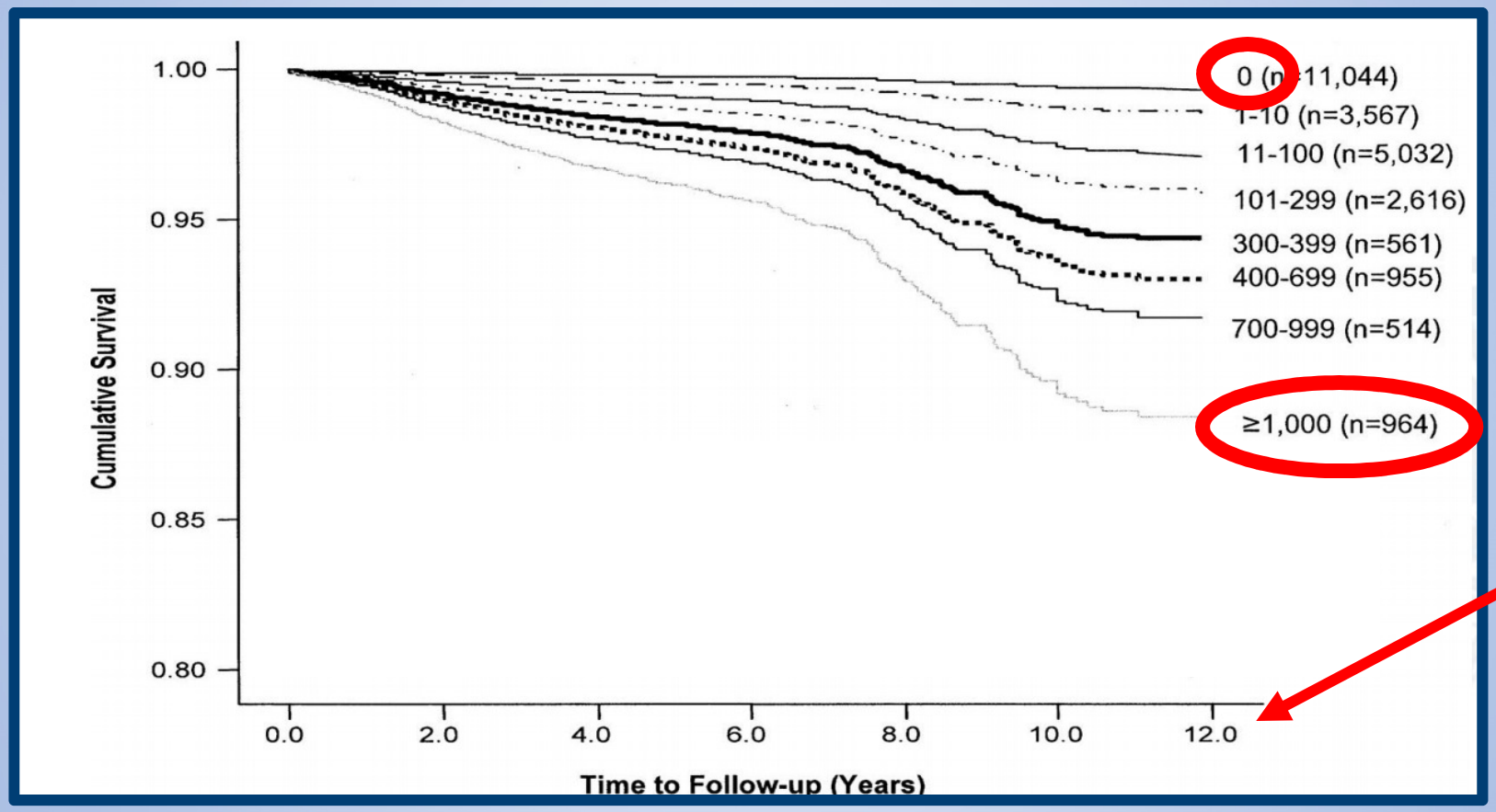




www.mesa-nhlbi.org

McClelland RL et al. Circ 2006.

CAC and prognosis



Budoff MJ et al JACC 2007

New Guidelines

2010 ACCF/AHA Guideline for Assessment of Cardiovascular Risk in Asymptomatic Adults

A Report of the American College of Cardiology Foundation/American Heart Association Task Force on Practice Guidelines

Developed in Collaboration With the American Society of Echocardiography, American Society of Nuclear Cardiology, Society of Atherosclerosis Imaging and Prevention, Society for Cardiovascular Angiography and Interventions, Society of Cardiovascular Computed Tomography, and Society for Cardiovascular Magnetic Resonance

Writing Committee Members

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Michael S. Lauer, MD, FACC, FAHA

Leslee J. Shaw, PhD, FACC, FAHA§§

ACC Guidelines

Recommendations for Calcium Scoring Methods

Measurement of CAC is reasonable for cardiovascular risk assessment in asymptomatic adults at intermediate risk (10% to 20% 10-year risk.

Measurement of CAC may be reasonable for cardiovascular risk assessment persons at low to intermediate risk (6% to 10% 10-year risk).

Persons at low risk (<6% 10-year risk) should not undergo CAC measurement for cardiovascular risk assessment.

Coronary calcium

- Worried well

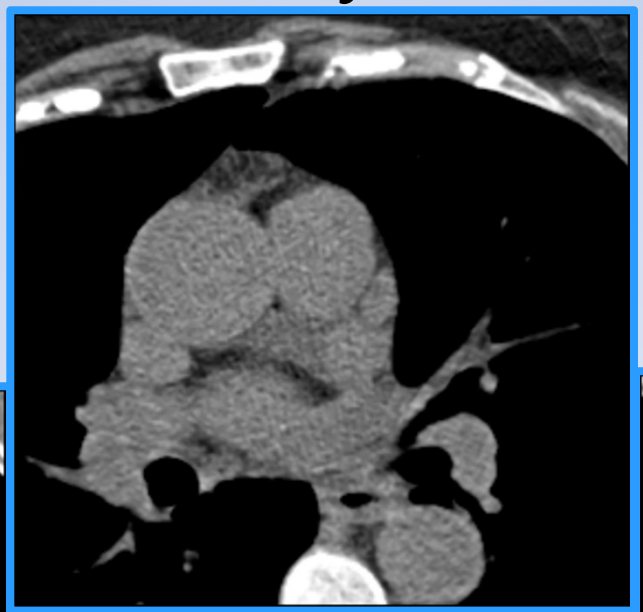
- Asymptomatic with a strong family history

- Atypical chest pain

Modifier of Risk

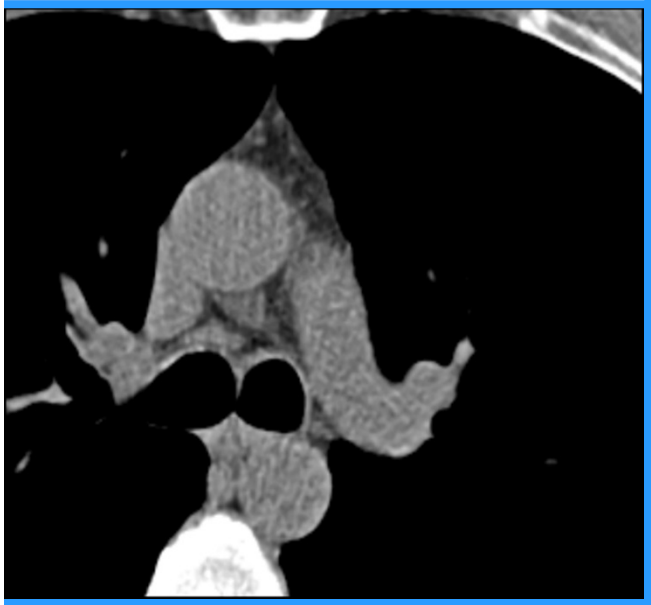
Measure	Support Revising Risk Assessment Upward	Do Not Support Revising Risk Assessment
FH of premature CVD	1st-degree M <55 or 1st-degree F <65	Occurrences at older ages only
hsCRP	≥2 mg/L	<2 mg/L
CAC score	**≥300 Agatston units *or* ≥75th percentile**	**<300 *and* <75th %ile**
ABI	<0.9	≥0.9

55 yo



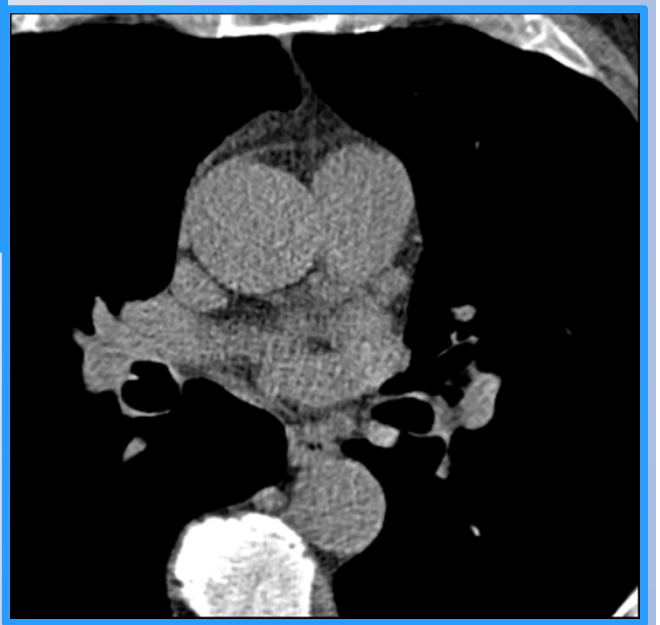
Calcium score ZERO

49 yo



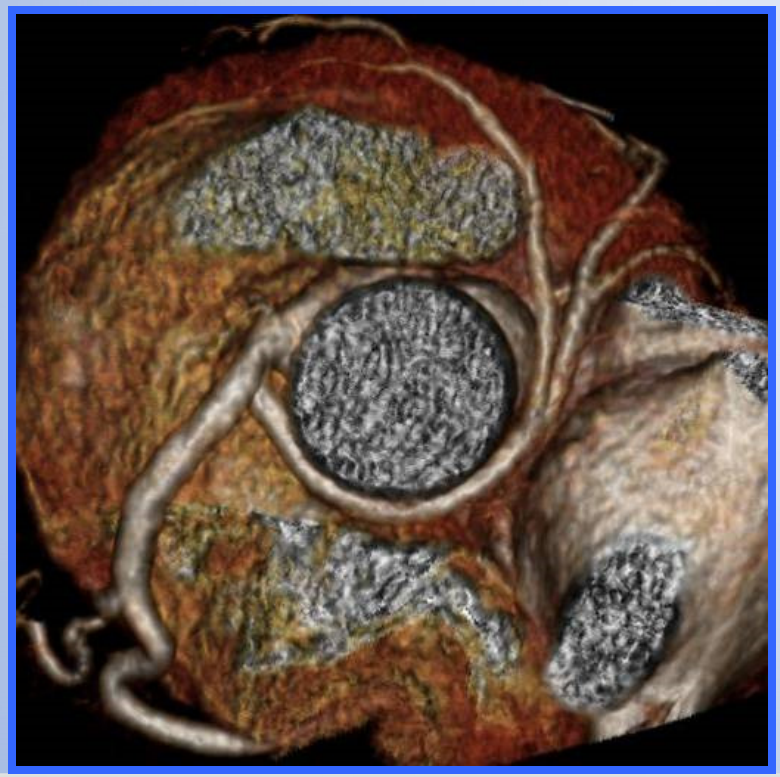
Calcium score >100

48 yo



Calcium score >400

Minimally Invasive Angiography



Radiation in the news

Science News Share Blog Cite

Radiation Exposure Poses Similar Risk of First and Second Cancers in Atomic Bomb Survivors

ScienceDaily (Sep. 15, 2010) — It is well known that exposure to radiation has multiple harmful effects -- including causing cancer -- but until now, it has been unclear to what extent such exposure increases a person's risk of developing more than one cancer.

See Also:

Health & Medicine
- Breast Cancer
- Cancer

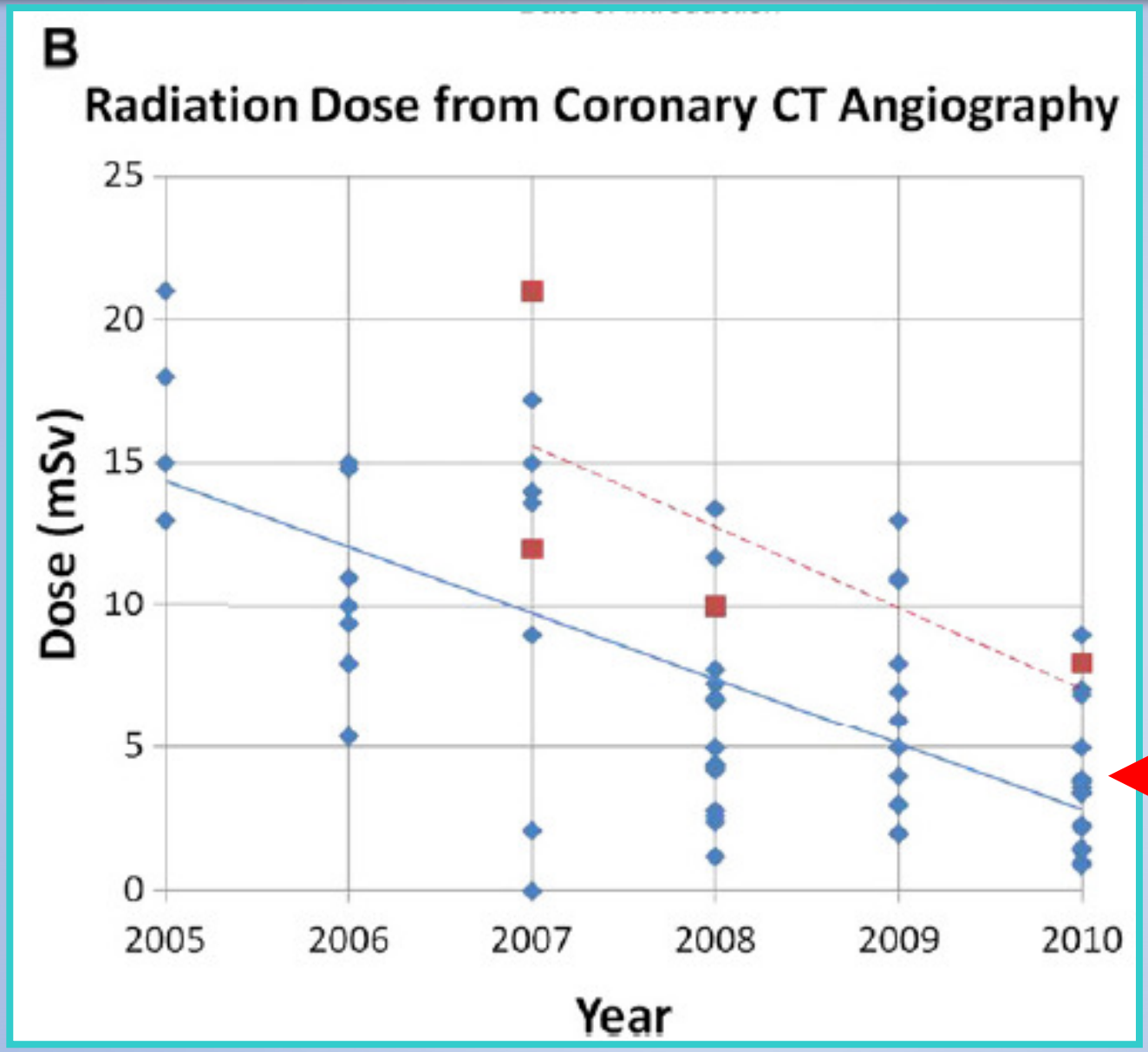
Earth & Climate
- Atmosphere
- Geomagnetic Storms

Science & Society
- Public Health
- Disaster Plan

Reference
- Metastasis

The first large-scale study of the relationship between radiation dose and risk of multiple cancers among atomic bomb survivors in Hiroshima and Nagasaki, Japan reveals a similar risk in the development of first and second subsequent cancers.

Christopher I. Li, M.D., Ph.D., and colleagues at Fred Hutchinson Cancer Research Center led the study in collaboration with investigators at the Radiation Effects Research Foundation in Hiroshima and Nagasaki and the National Cancer Institute. The results appear in the Sept. 15 issue of Cancer

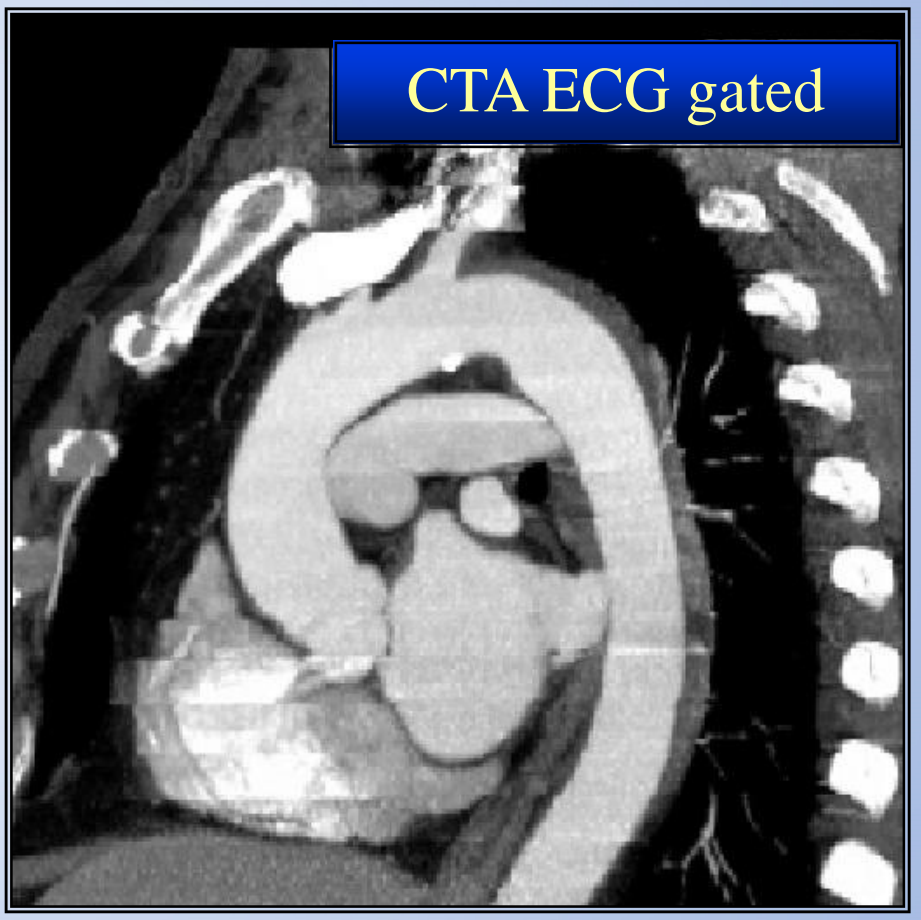


Lehigh Valley Health Network
A PASSION FOR BETTER MEDICINE.

LVHN avg CT coronary radiation = 3.8 mSv

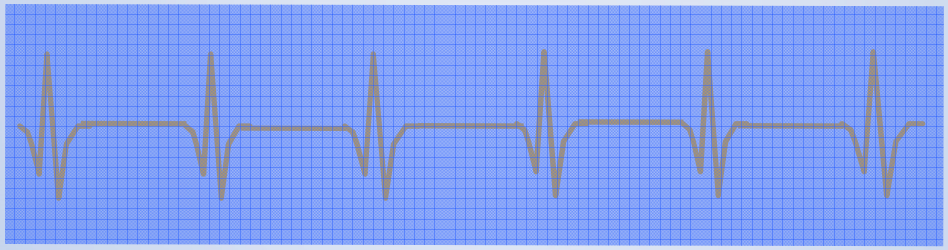
CT Angiography

CTA ungated



Synchronization with cardiac motion

- **Retrospective Gating**
- **Prospective Gating**

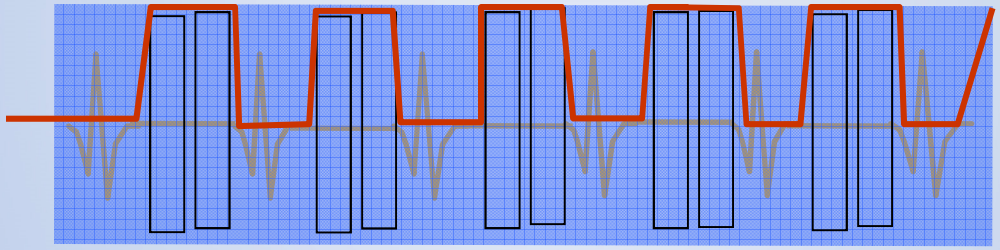


Which is better?

Depends on the patient

Synchronization with cardiac motion

- **Retrospective Gating**

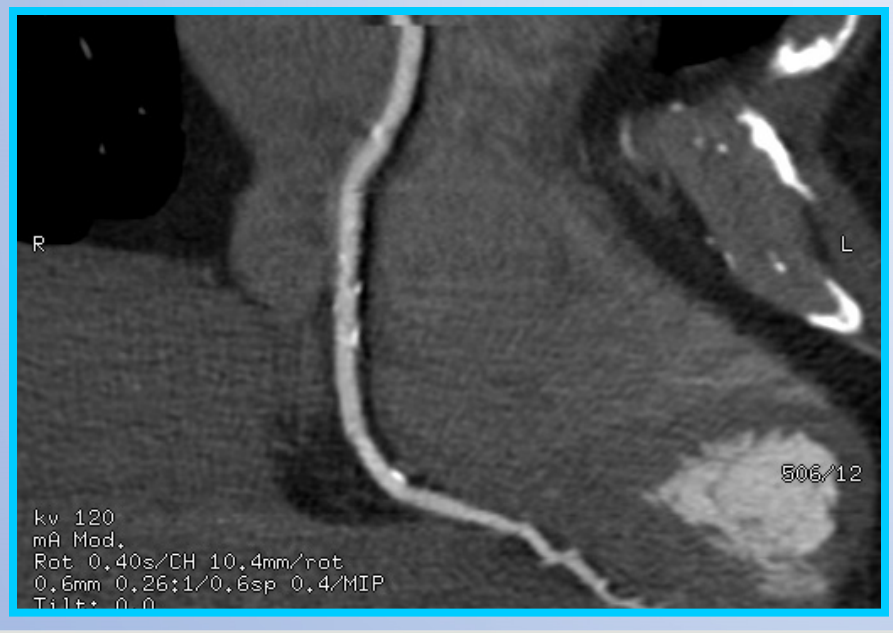


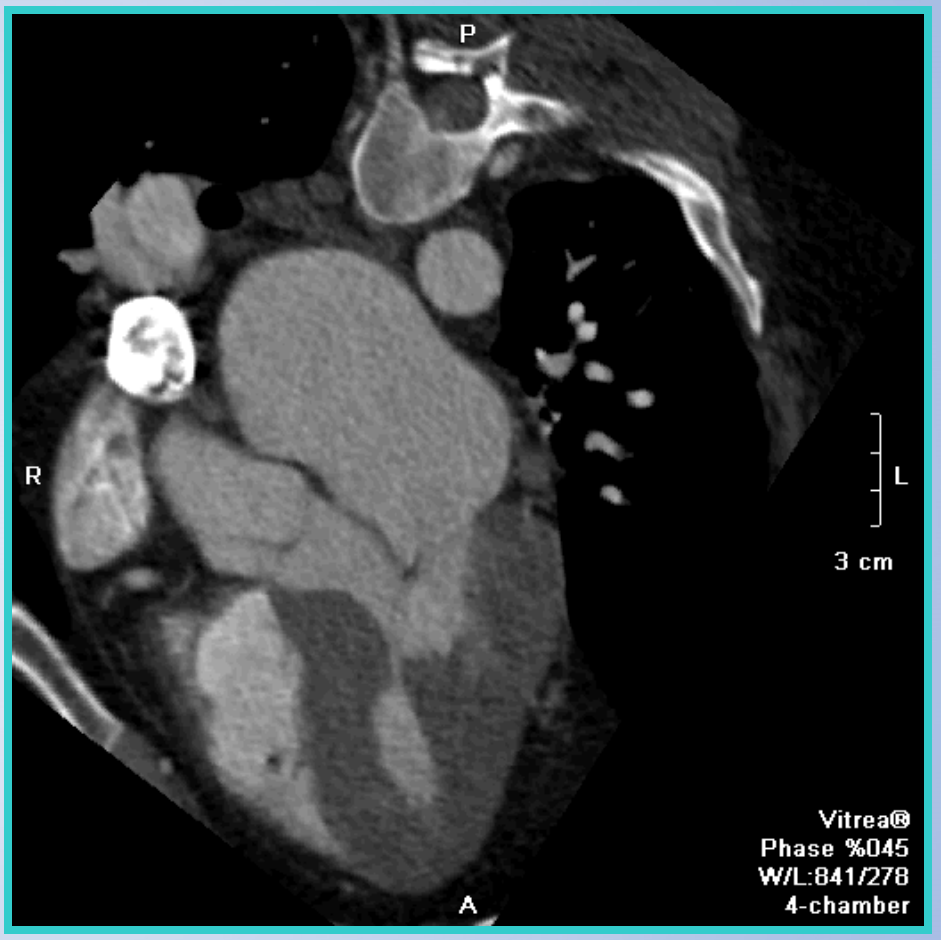
(+) Allows recon at multiple phases in R-R interval

(+) Allows ECG editing (to recover from ectopic beats)

(+) Cardiac motion

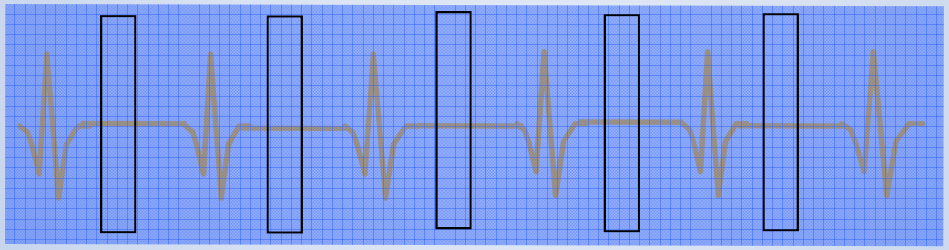

R
L
506/11
kv 120
mA Mod.
Rot 0.40s/CH 10.4mm/rot
0.6mm 0.26:1/0.6sp 0.4/MIP
Tilt: 0.0


R
L
506/12
kv 120
mA Mod.
Rot 0.40s/CH 10.4mm/rot
0.6mm 0.26:1/0.6sp 0.4/MIP
Tilt: 0.0


P
R
L
3 cm
A
Vitrea®
Phase %045
W/L:841/278
4-chamber

Synchronization with cardiac motion

- **Retrospective Gating**



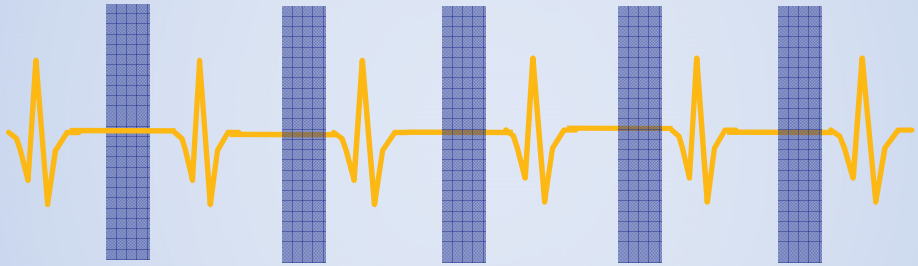
(+) Allows recon at multiple phases in R-R interval

(+) Allows ECG editing (to recover from ectopic beats)

(-) Higher radiation dose!

Synchronization with cardiac cycle

- **Prospective ECG Triggering**



(-) One image (recon phase) per anatomic level for each R-R interval

(+) Low radiation dose!

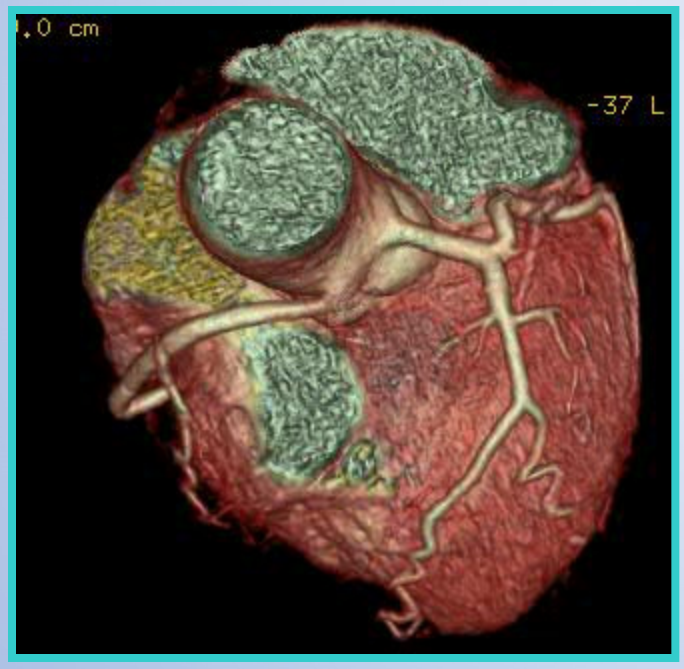
MDCT in Clinical Practice

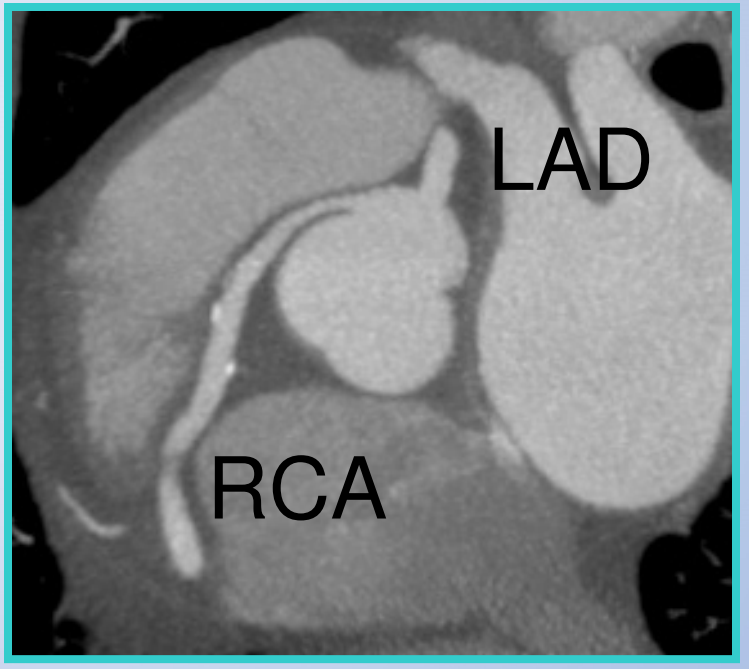
✓ 'Reference' Standard

- Anomalous coronary vessels
- Coronary fistula, aneurysms

Coronary anatomy

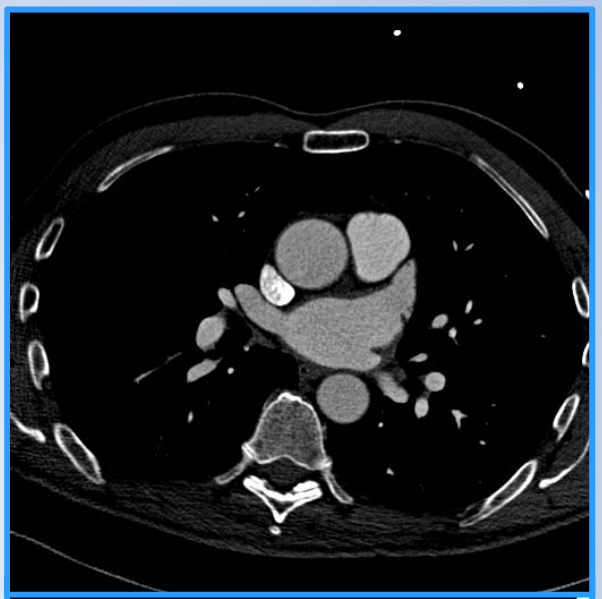
Evaluation of Intra-Cardiac Structures (Use of CT Angiogram)	
• Evaluation of suspected coronary anomalies	A (9)

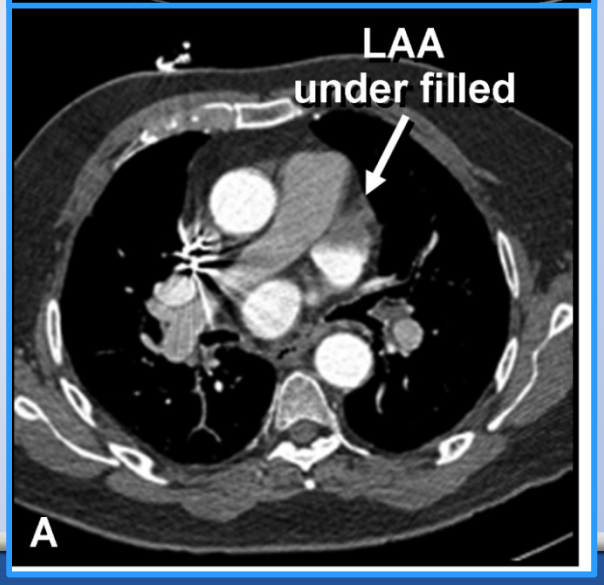




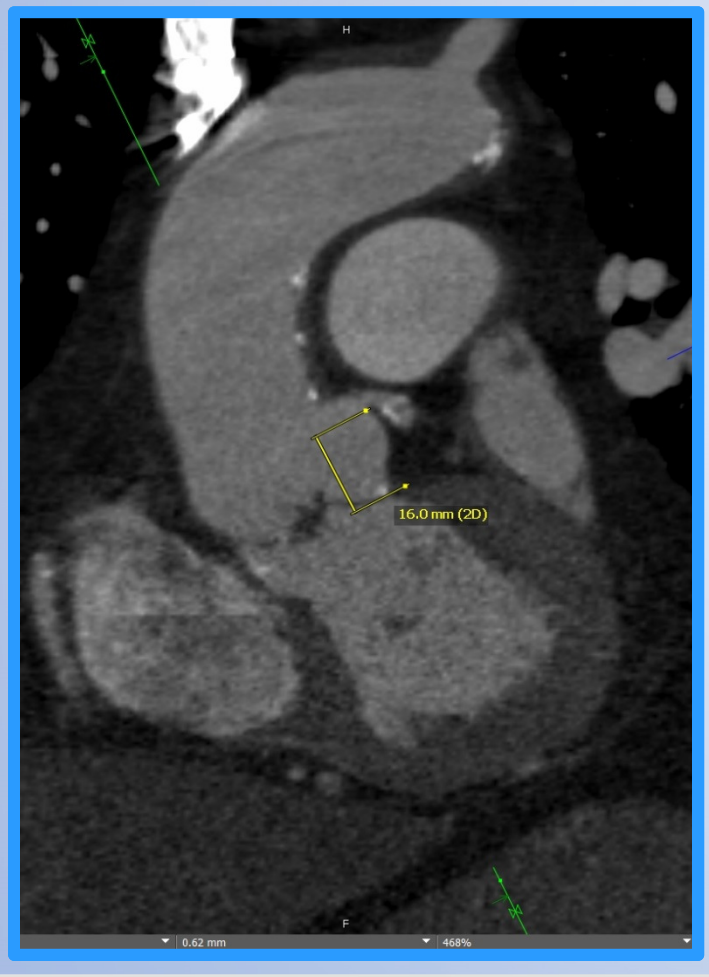
Coronary Anomalies

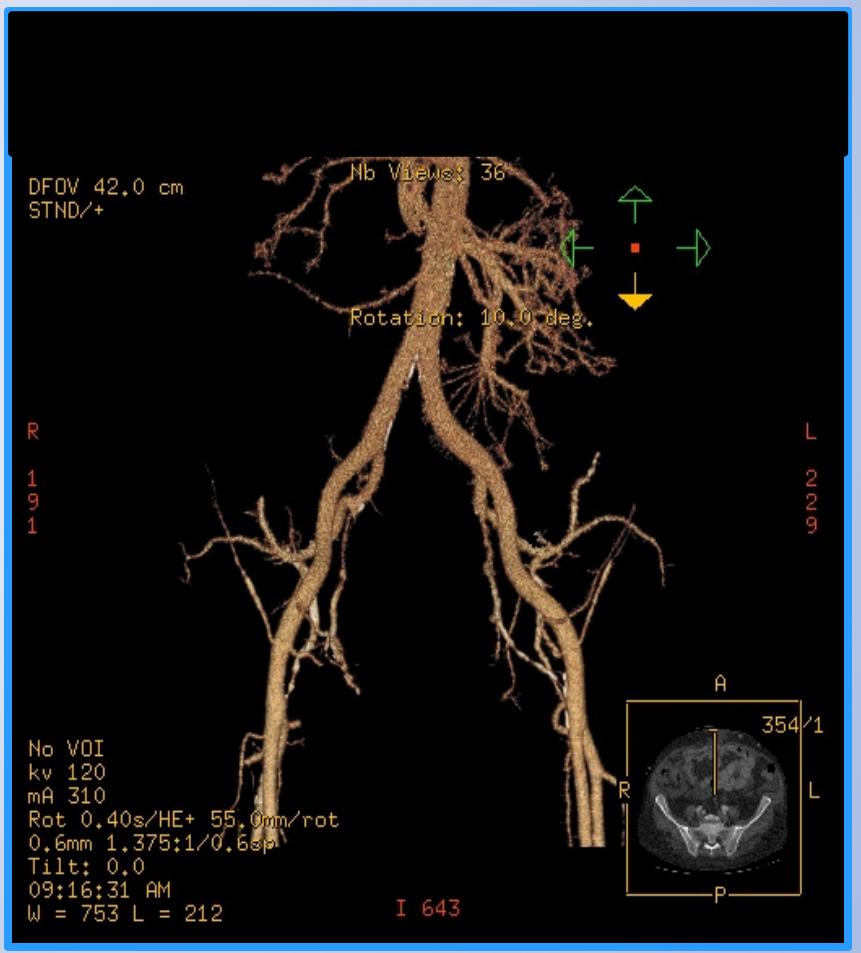
CT Scenarios





Identification of L main ostia and peripheral vessel assessment.





MDCT in Clinical Practice

✓ 'Reference' Standard

- Anomalous coronary vessels
- Coronary fistula, aneurysms

✓ Coronary Disease

- Great for ruling out CAD

ELSEVIER

European Journal of Radiology xxx (2007) xxx–xxx

www.elsevier.com/locate/ejrad

Review

Diagnostic value of 64-slice CT angiography in coronary artery disease: A systematic review

Zhonghua Sun [a,*], ChengHsun Lin [b], Robert Davidson [c], Chiauhuei Dong [b], Yunchan Liao [b]

[a] *Discipline of Medical Imaging, Department of Imaging and Applied Physics, Curtin University of Technology, Perth, Western Australia, Australia*

[b] *Department of Radiological Technology, Central Taiwan University of Science and Technology, Taichung, Taiwan, ROC*

[c] *Discipline of Medical Radiations, RMIT University, Victoria 3083, Australia*

Received 7 April 2007; received in revised form 4 July 2007; accepted 4 July 2007

Excluding CAD

High sensitivity

High NPV

Table 1
Study characteristics of 64-slice CT angiography in CAD

Reference/country of origin	Year of publication	No. of patients	Mean age	Suspected CAD (%)	Known CAD (%)	Mean HR	No. of cases β-blocker (%)	No. of detectors
Raff et al. [10]/USA	2005	70	59	NS	54	65	100	64 × 0.6
Leber et al. [14]/Germany	2005	59	64	83	17	62	36	64 × 0.6
Leschka et al. [15]/Switzerland	2005	67	60	NS	70	66	60	64 × 0.6
Pugliese et al. [16]/Italy	2005	35	61	100		58	77	64 × 0.6
Fine et al. [17]/USA	2006	66	62	83	17	NS	NS	64 × 0.6
Plass et al. [18]/Switzerland	2006	50	66	NS	80	65	60	64 × 0.6
Ropers et al. [19]/Germany	2006	84	58	NS	31	59	74	64 × 0.6
Ong et al. [21]/Malaysia	2006	134	53/57[a]	51	49	62	NS	64 × 0.6
Schuijf et al. [22]/Netherlands	2006	60	60	42	58	60	72	64 × 0.5
Muhlenbruch et al. [23]/Germany	2006	51	59	NS	88	61	NS	64 × 0.6
Ehara et al. [24]/Japan	2006	69	67	28	72	72	22	64 × 0.6
Nilolaou et al. [25]/Germany	2006	68	64	60	40	61	NS	64 × 0.6
Scheffel et al. [26]/Switzerland	2006	30	63	50	50	70	0	64 × 0.6
Meijboom et al. [27]/Netherlands	2007	104	58/59[a]	32	68	NS	63	64 × 0.6
Oncel et al. [28]/Turkey	2007	80	56	100		58	54	64 × 0.6

- 64 MDCT vs. ICA
- Sensitivity 97%, NPV 98%

Sun, Z - 2007 Eur Jour of Radiology

Promise

The NEW ENGLAND JOURNAL of MEDICINE

ORIGINAL ARTICLE

Outcomes of Anatomical versus Functional Testing for Coronary Artery Disease

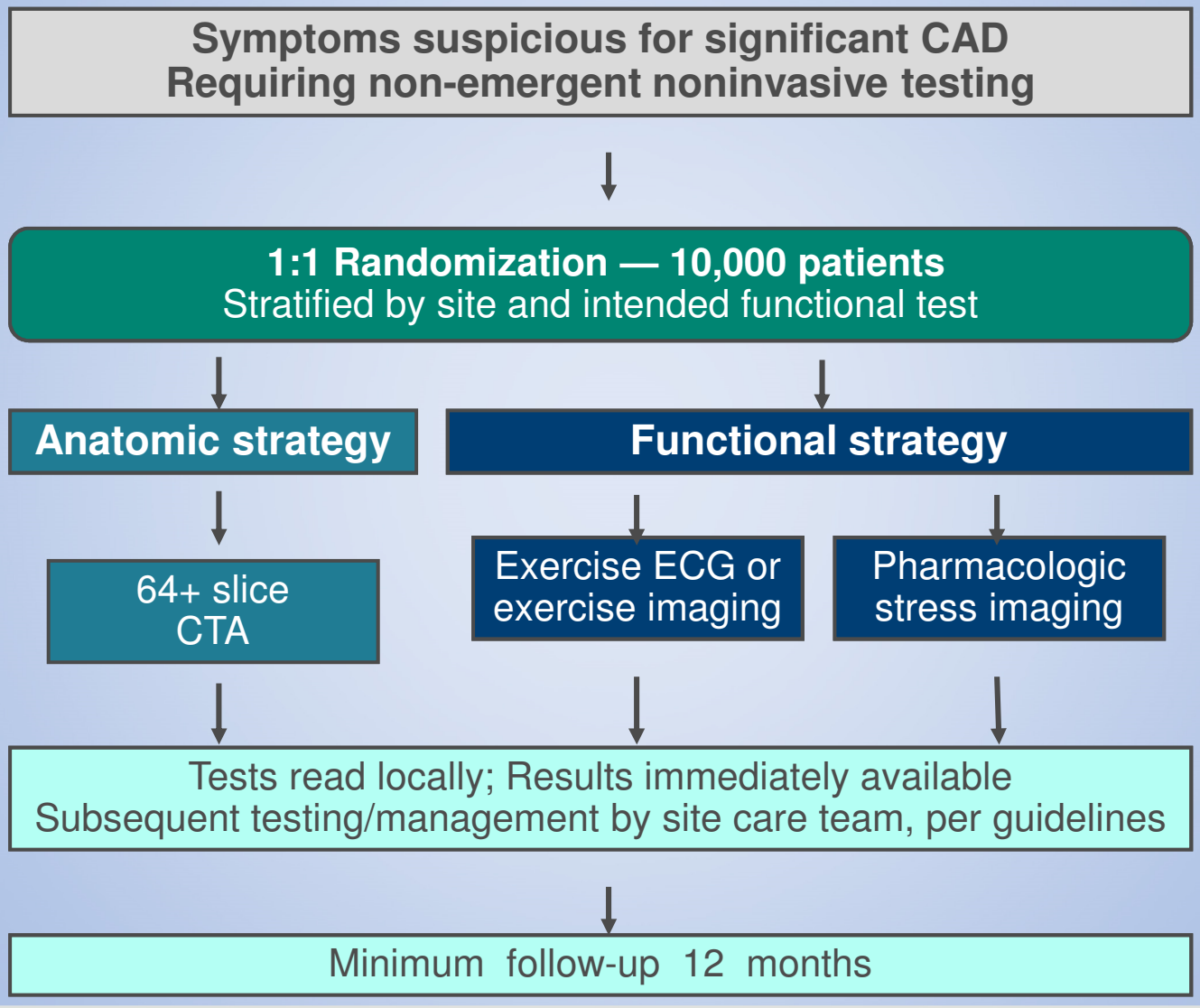
Pamela S. Douglas, M.D., Udo Hoffmann, M.D., M.P.H., Manesh R. Patel, M.D., Daniel B. Mark, M.D., M.P.H., Hussein R. Al-Khalidi, Ph.D., Brendan Cavanaugh, M.D., Jason Cole, M.D., Rowena J. Dolor, M.D., Christopher B. Fordyce, M.D., Megan Huang, Ph.D., Muhammad Akram Khan, M.D., Andrzej S. Kosinski, Ph.D., Mitchell W. Krucoff, M.D., Vinay Malhotra, M.D., Michael H. Picard, M.D., James E. Udelson, M.D., Eric J. Velazquez, M.D., Eric Yow, M.S., Lawton S. Cooper, M.D., M.P.H., and Kerry L. Lee, Ph.D., for the PROMISE Investigators*

ABSTRACT

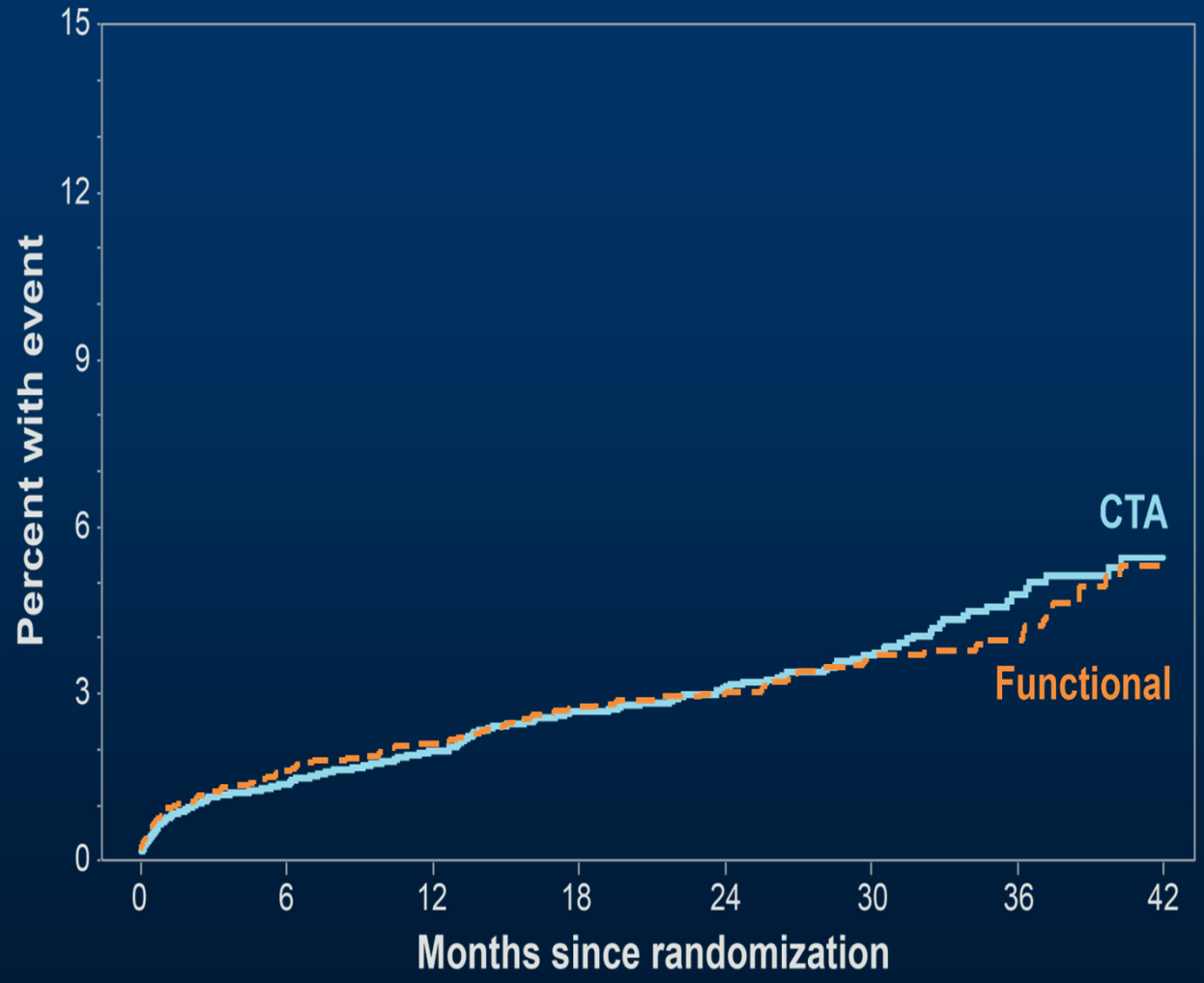
BACKGROUND

Many patients have symptoms suggestive of coronary artery disease (CAD) and are often evaluated with the use of diagnostic testing, although there are limited data from randomized trials to guide care.

PROMISE Trial Design

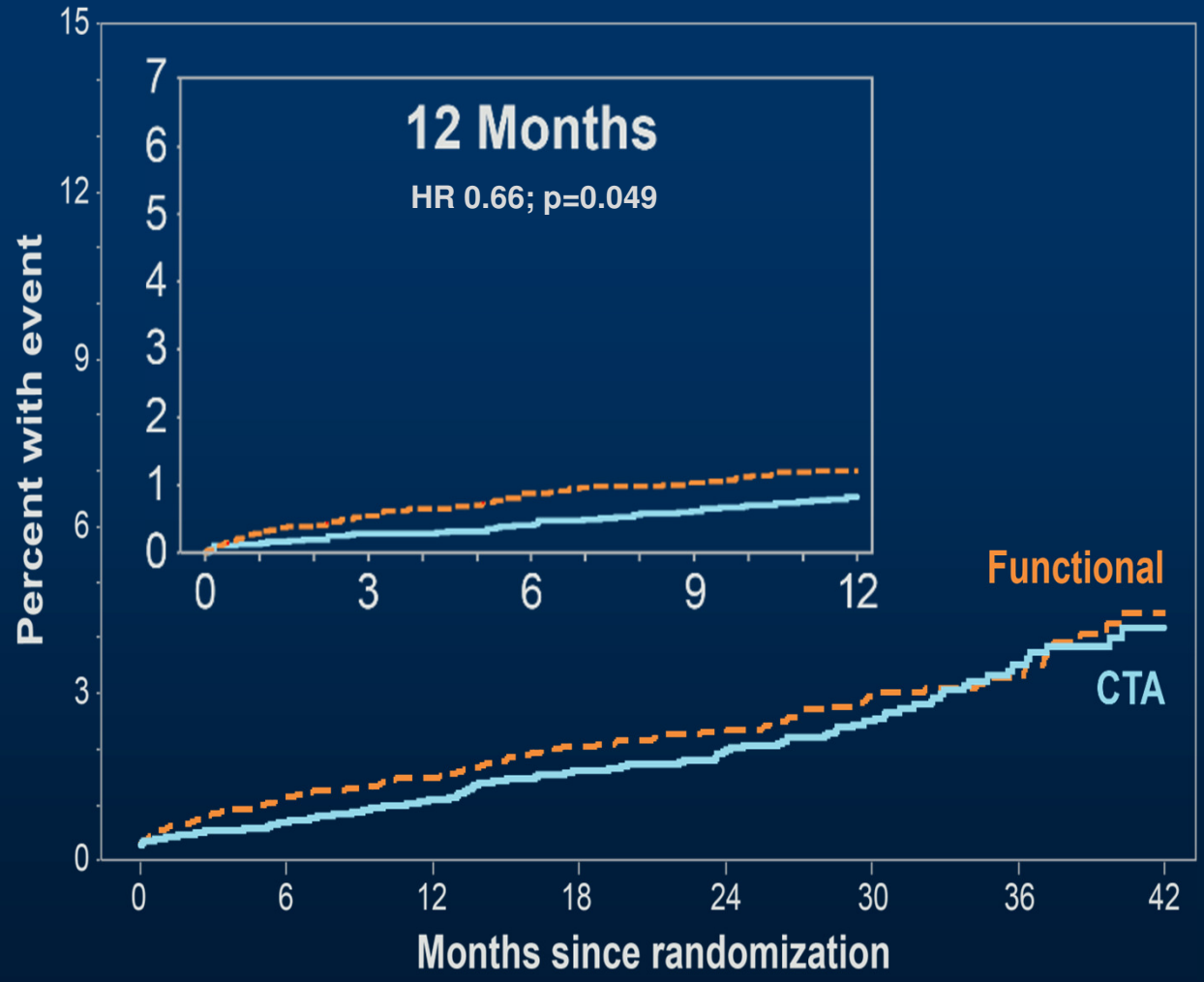


Primary Endpoint:
MI, Unstable Angina, Major Complications



# at risk	Baseline (0)	6 Mo.	12 Mo.	18 Mo.	24 Mo.	30 Mo.	36 Mo.	42 Mo.
CTA	4996	4703	4362	3551	2652	1705	902	269
Functional	5007	4536	4115	3331	2388	1518	832	258

Secondary Endpoint:
Death or Non-fatal MI



# at risk	Baseline (0)	6 Mo.	12 Mo.	18 Mo.	24 Mo.	30 Mo.	36 Mo.	42 Mo.
CTA	4996	4739	4409	3599	2686	1732	918	276
Functional	5007	4563	4148	3365	2415	1540	846	262

Case – Chest pain in the hospital

58 y/o woman

Substernal chest discomfort 2 mos

Emotion and sometimes exertion

Today 15 min chest and back pain at rest → ED

Postmenopausal

Prior smoker >15 yrs ago

No FH

No meds

Mild HTN

Exam: no murmur
BP 142/88
Troponin: <.01
Creat: 0.8

What to Do?

Exercise MPI

Acute Chest Pain (in Reference to Rest Perfusion Imaging)		
7.	• Intermediate pre-test probability of CAD • ECG – no ST elevation AND initial cardiac enzymes negative	**A (9.0)**

Stress Echo

Acute Chest Pain		
7.	• Intermediate pre-test probability of CAD • ECG-no dynamic ST changes AND serial cardiac enzymes negative	A (8)

Coronary CTA

Acute Chest Pain (Use of CT Angiogram)		
6.	• Intermediate pre-test probability of CAD • No ECG changes and serial enzymes negative	A (7)

A Randomized Controlled Trial
of Mu
Tomo

197 Low risk patients
CTA vs Standard of Care

James A. Goldstein, MD, FACC, Michael J. Gallagher, MD, William W. O'Neill, MD, FACC,
Michael A. Ross, MD, FACEP, Brian J. O'Neil, MD, FACEP, Gilbert L. Raff, MD, FACC
Royal Oak, Michigan

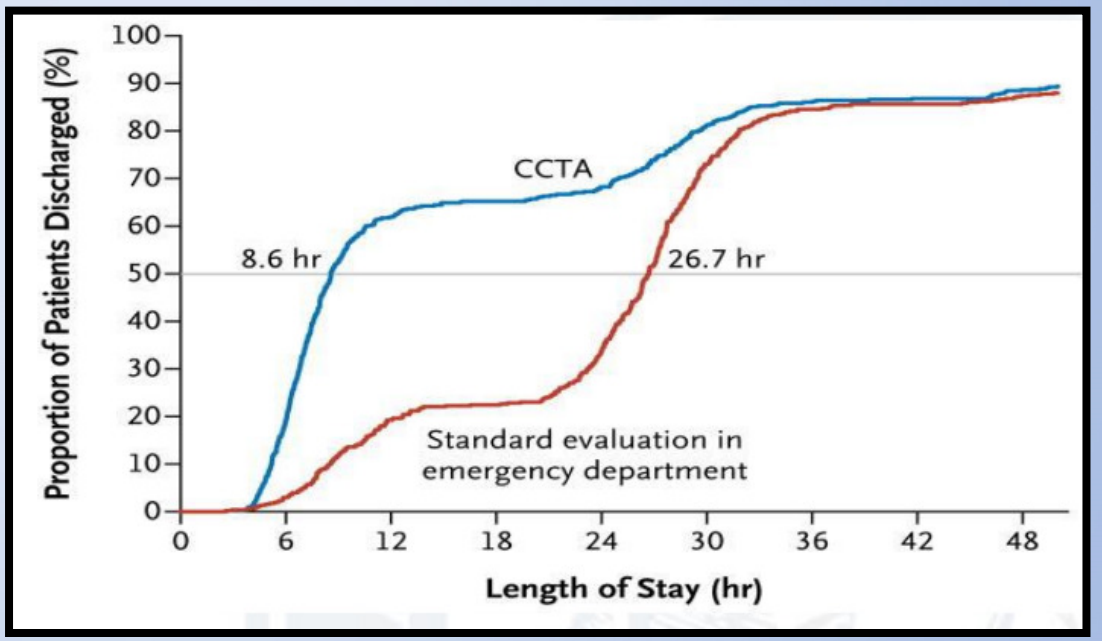
CTA – 67% normal and discharged
8% severe CAD → cath

Length of stay: lowered by 43%
12.5 hrs vs 22.1 hrs

Cost of care: lowered by 15%
$1586 vs $1872

Correct diagnosis
Safe, earlier discharge from ED
Similar or lower cost of care

Hoffman U JACC 2009
Goldstein JACC 2011
Litt NEJM 2012
Hoffman NEJM 2012

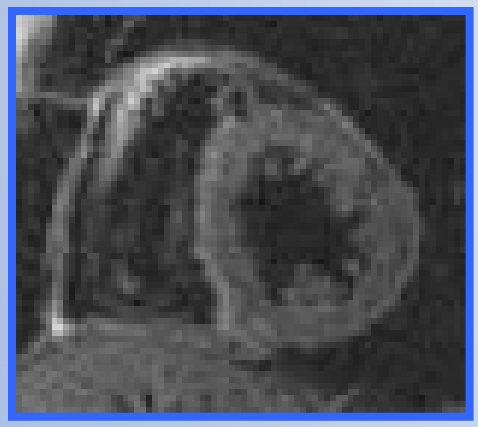


Take Home points

- CAC: Appropriate
  - Intermediate risk or Low risk but with family history of premature CAD
  - Absence of calcium does not equal absence of CHD risk
- CTA:
  - Excellent for exclusion of CAD.
  - Faster and cheaper than traditional evaluations in the ED.

Cardiac MRI

Black-Blood (Spin-Echo)



Still Images

Morphology
Edema

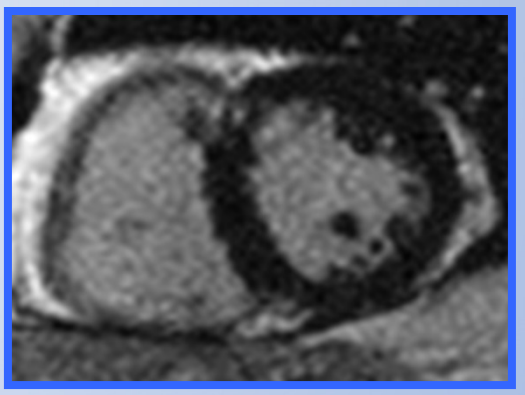
White-Blood

SSFP

Cine Imaging

Morphology
Function

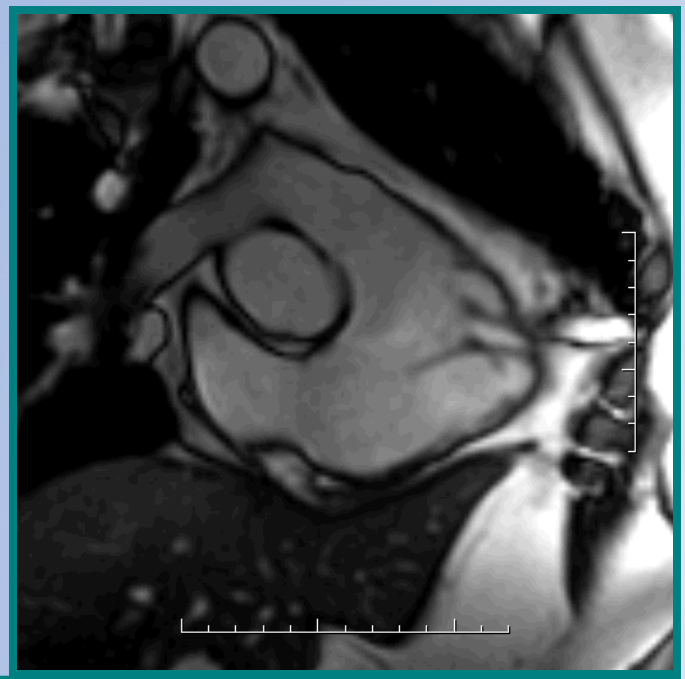
Delayed Enhancement

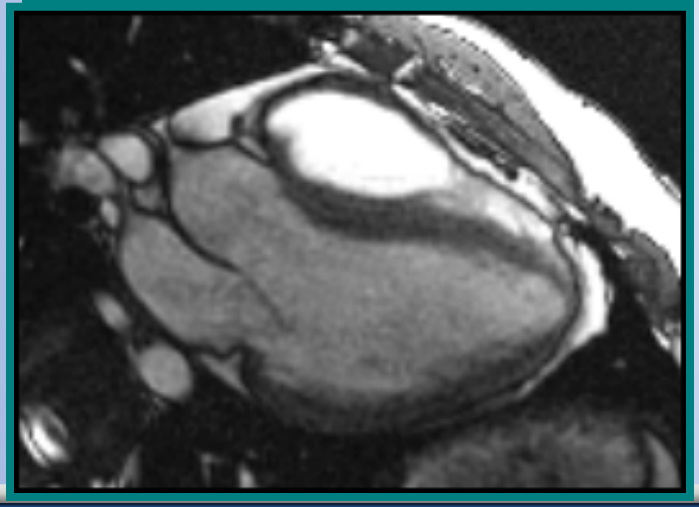


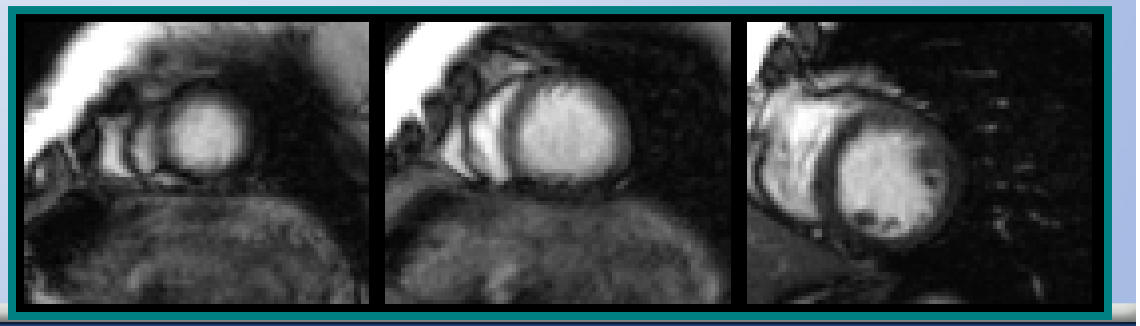
Still Images

Late Gadolinium
Enhancement

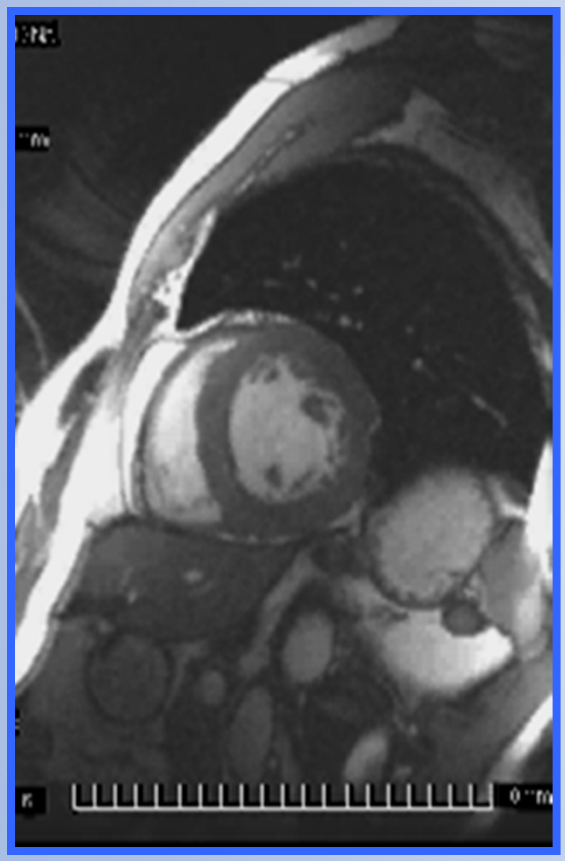
White blood = SSFP = 2D echo

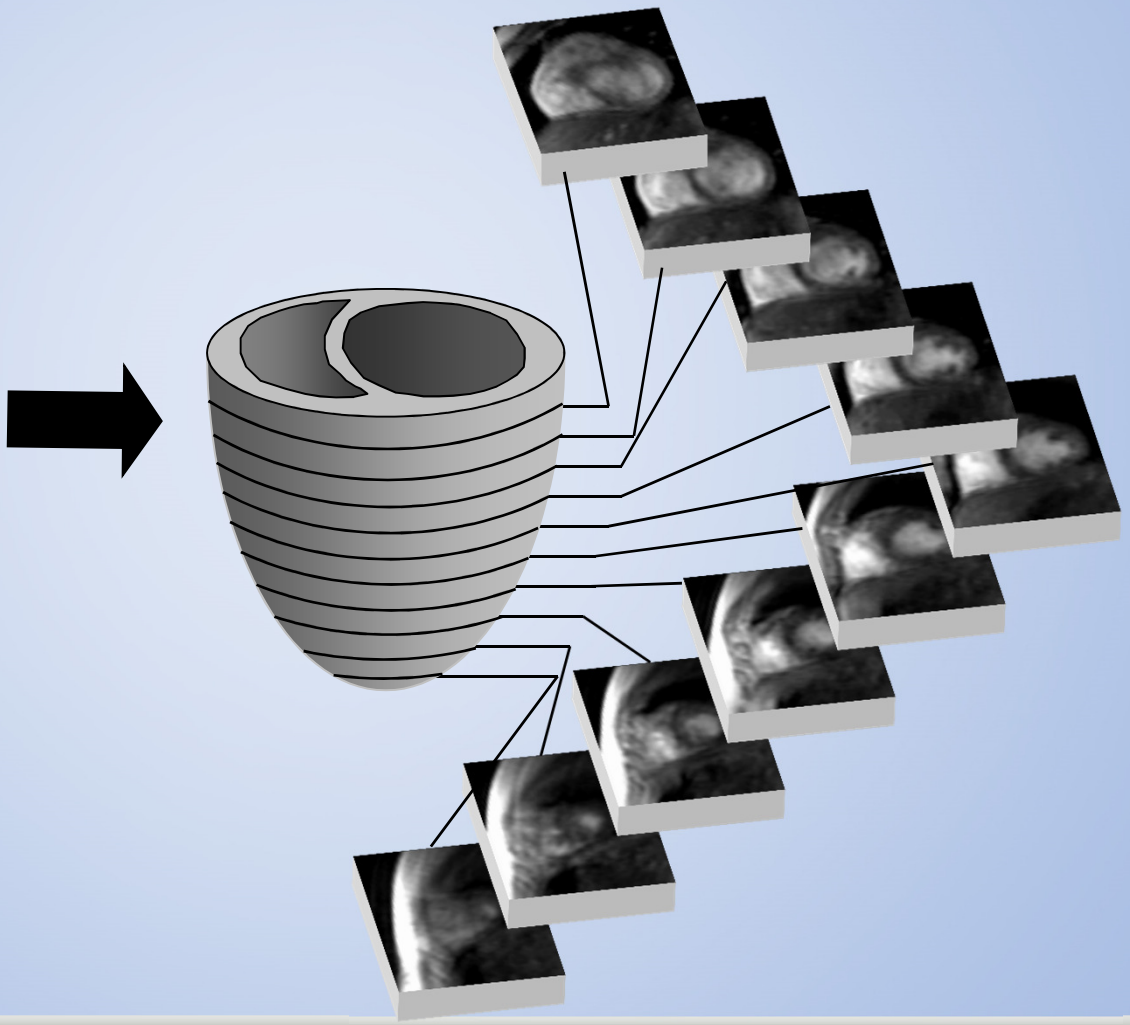






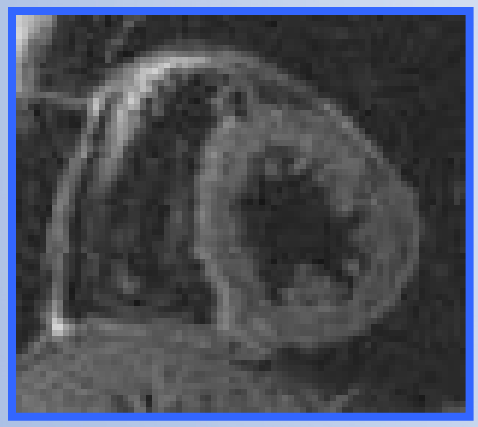
3D Short-Axis Scans are Integrated 2D Multiple Slices





Cardiac MRI

Black-Blood (Spin-Echo)



Still Images

Morphology
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Morphology
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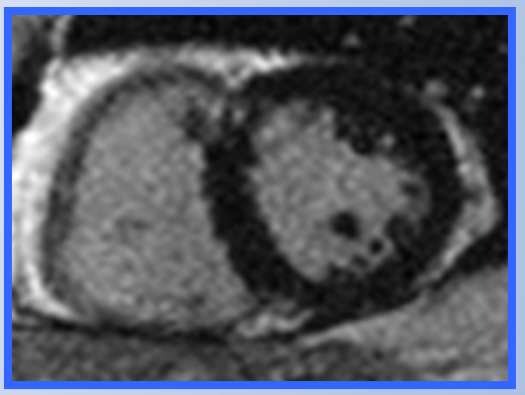
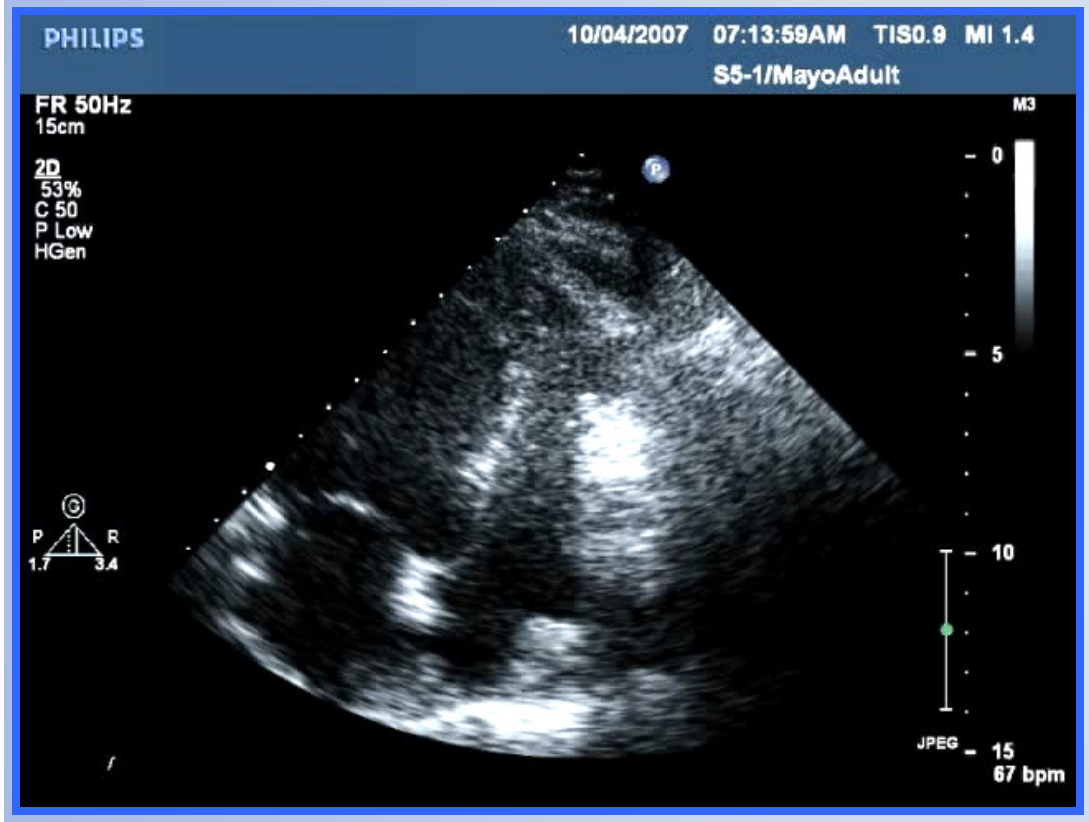
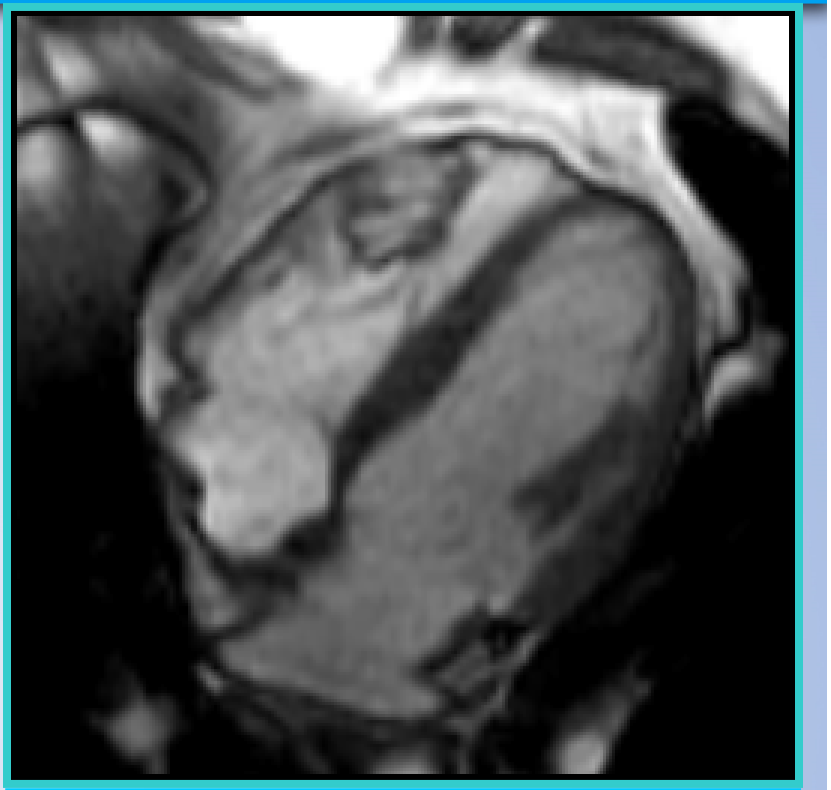
Delayed Enhancement

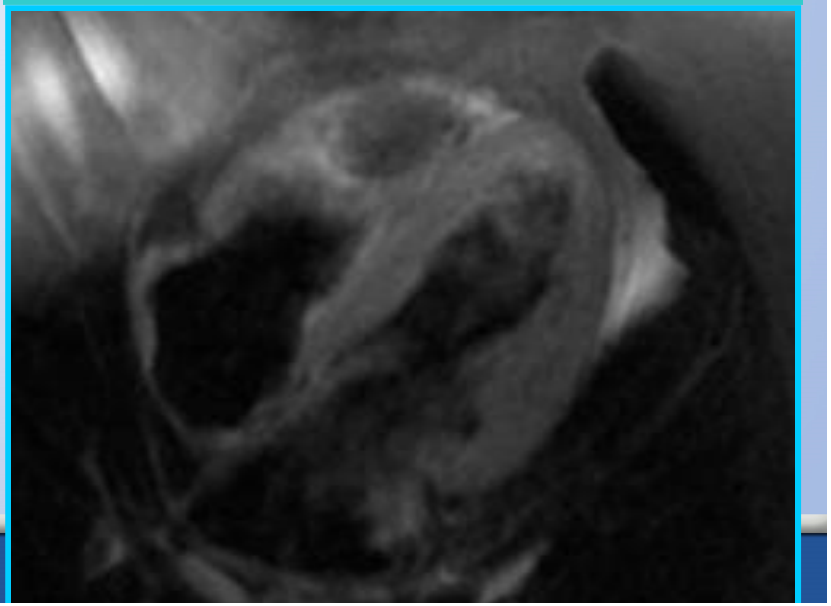


Still Images

Late Gadolinium
Enhancement

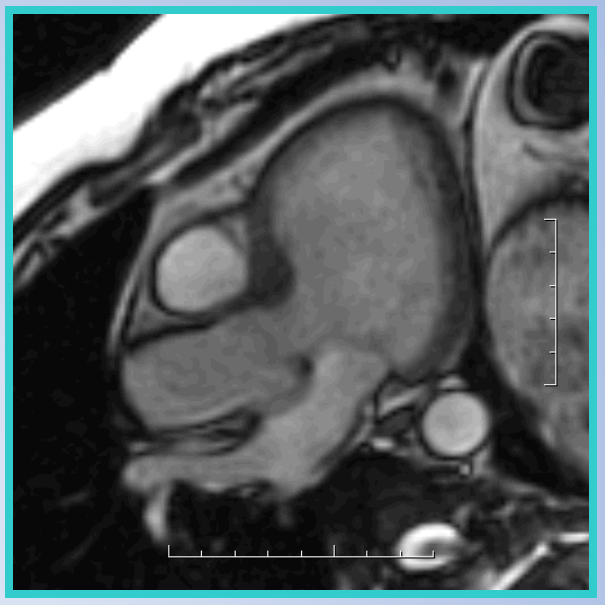

PHILIPS
10/04/2007 07:13:59AM TIS0.9 MI 1.4
S5-1/MayoAdult
FR 50Hz
15cm
2D
53%
C 50
P Low
HGen
M3
0
5
10
15
JPEG
67 bpm
P
R
1.7
3.4





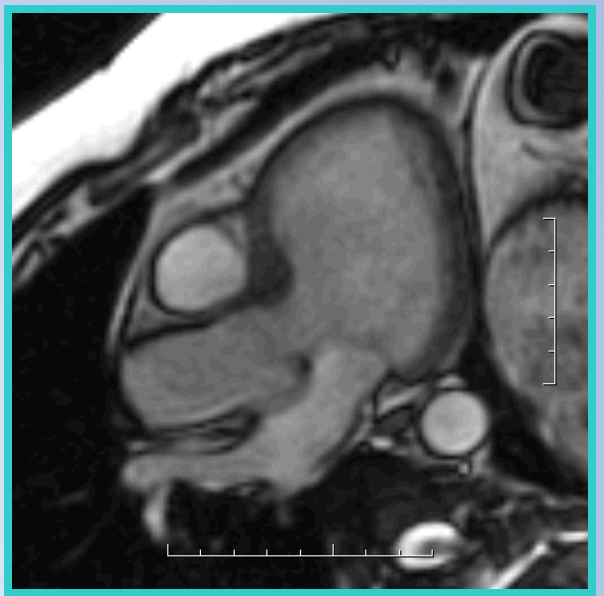
Acute MI

Day 3

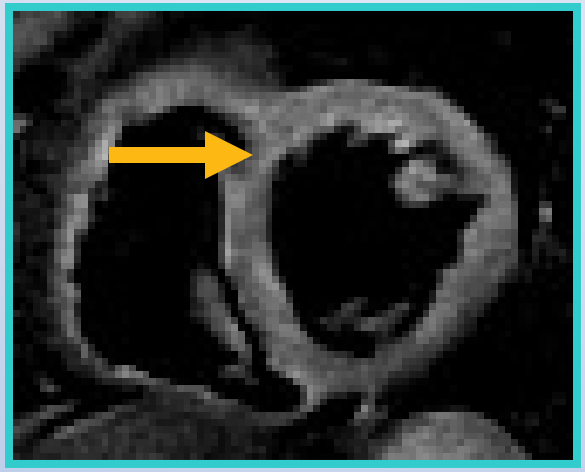


Acute MI

Day 3

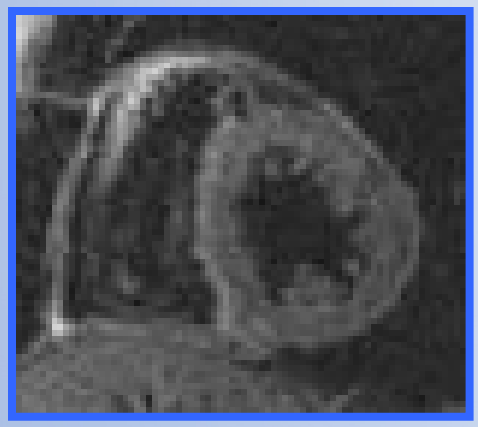


Follow-up
Day 43



Cardiac MRI

Black-Blood (Spin-Echo)



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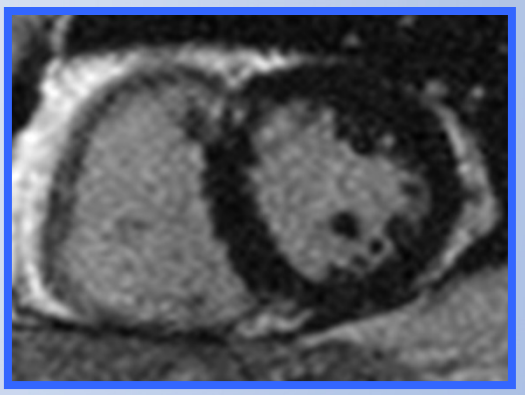


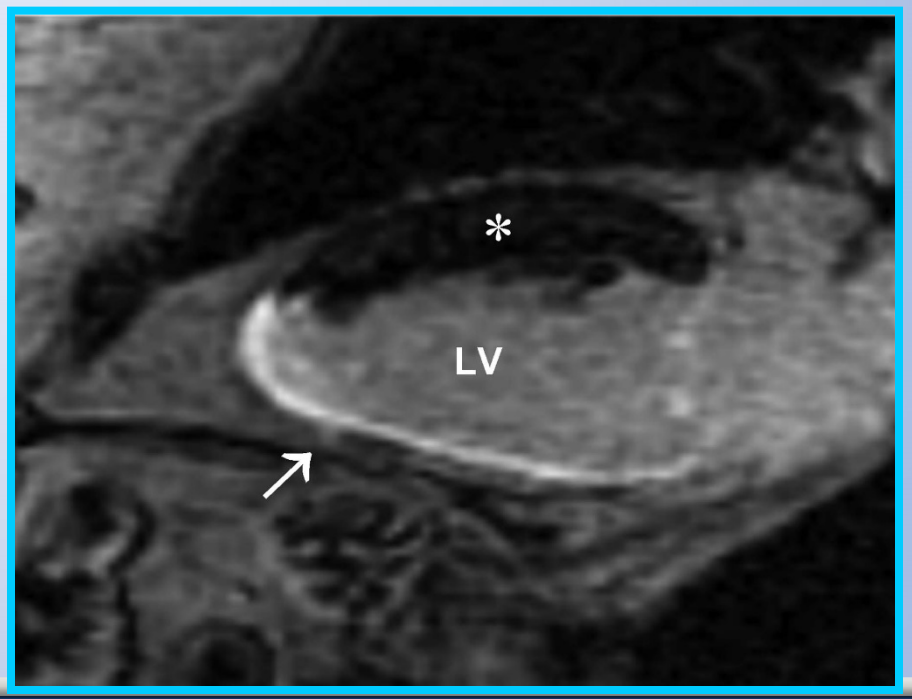
Still Images

Delayed
Enhancement

MR Angiography

Late Gadolinium Enhancement-

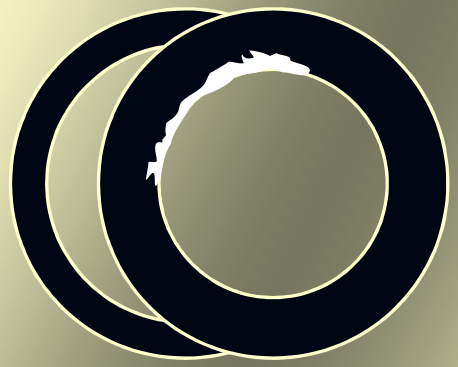
- Images obtained 10-15 minutes post-contrast (Gd)
- Normal myocardium – Black *
- Necrosis/scarring/inflammation – Hyperenhanced ⟶



Late Gadolinium enhancement Patterns

Ischemic

Subendocardial infarct

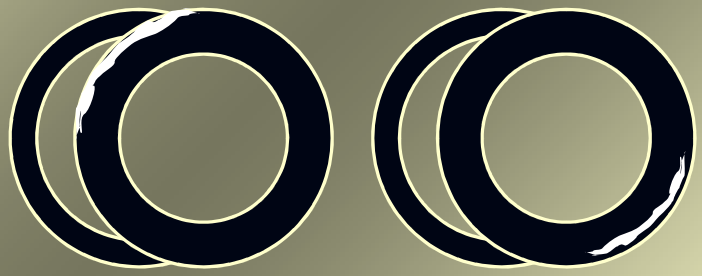


Transmural infarct

Nonischemic

Mid-wall HE

Epicardial HE



- Idiopathic dilated cardiomyopathy
- Myocarditis
- Hypertrophic cardiomyopathy
- Right ventricular pressure overload
- Sarcoidosis
- Myocarditis
- Anderson–Fabry disease

Shah DJ et al: Magnetic resonance of myocardial viability

Case 1
57-year-old woman

- Sudden onset of achy, continuous, substernal, 8/10 chest pain
- Radiating to back
- Pain came on at rest

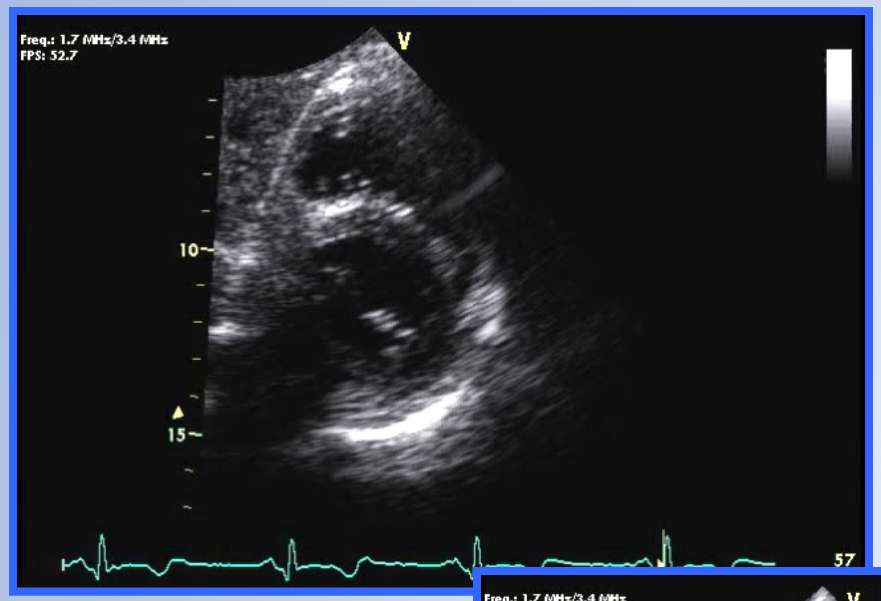
Cardiac Risk Factors

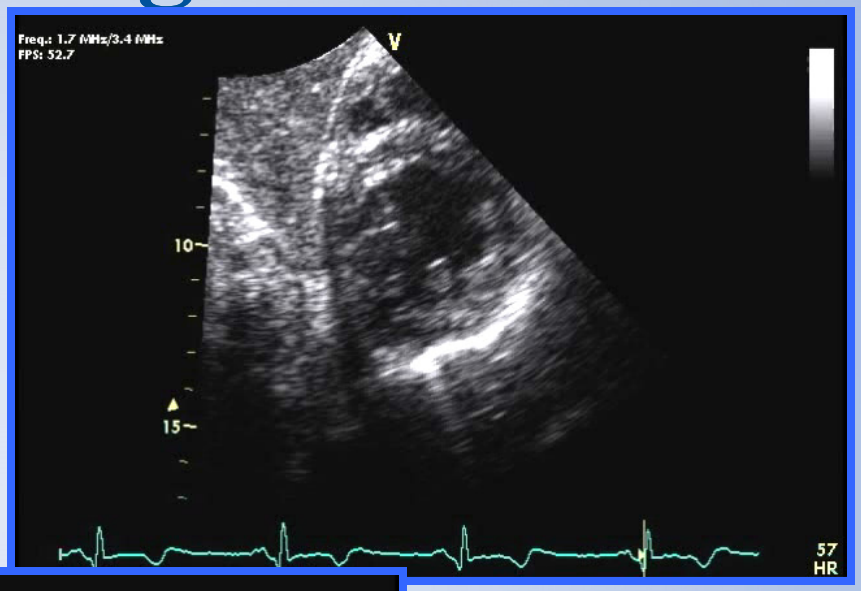
- Lifelong Smoker
- Hyperlipidemia

  (Diet controlled)
- Sedentery Lifestyle

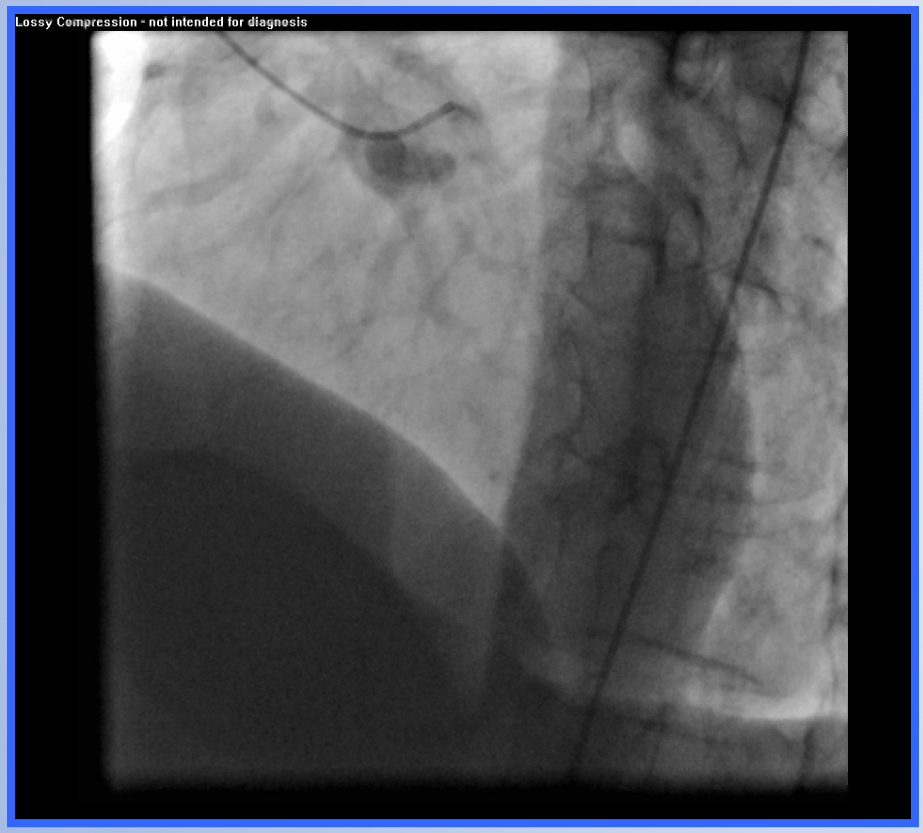
Troponin T - 0.56, 0.5 (3h), 0.36 (6h)

Echocardiogram

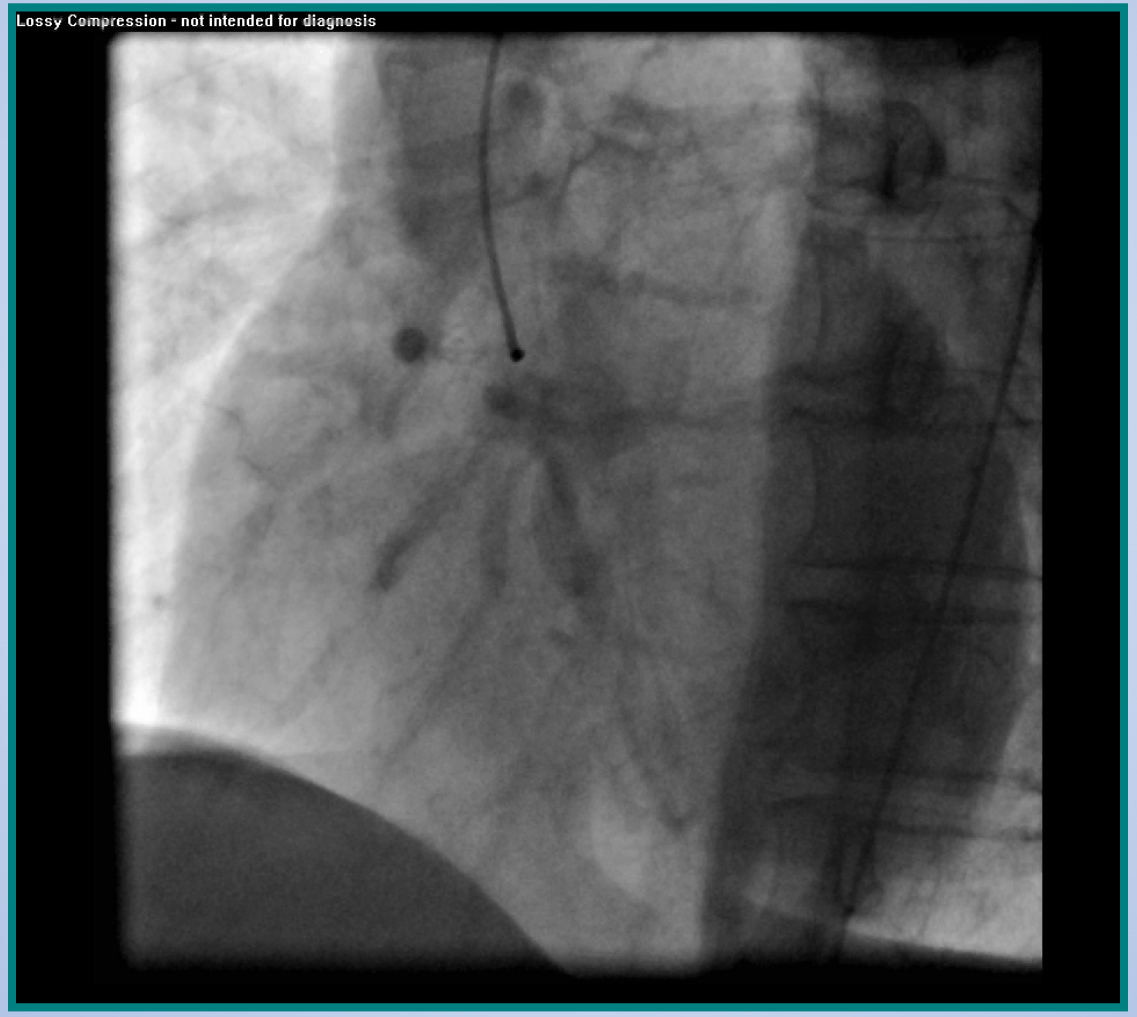




Cardiac Catheterization

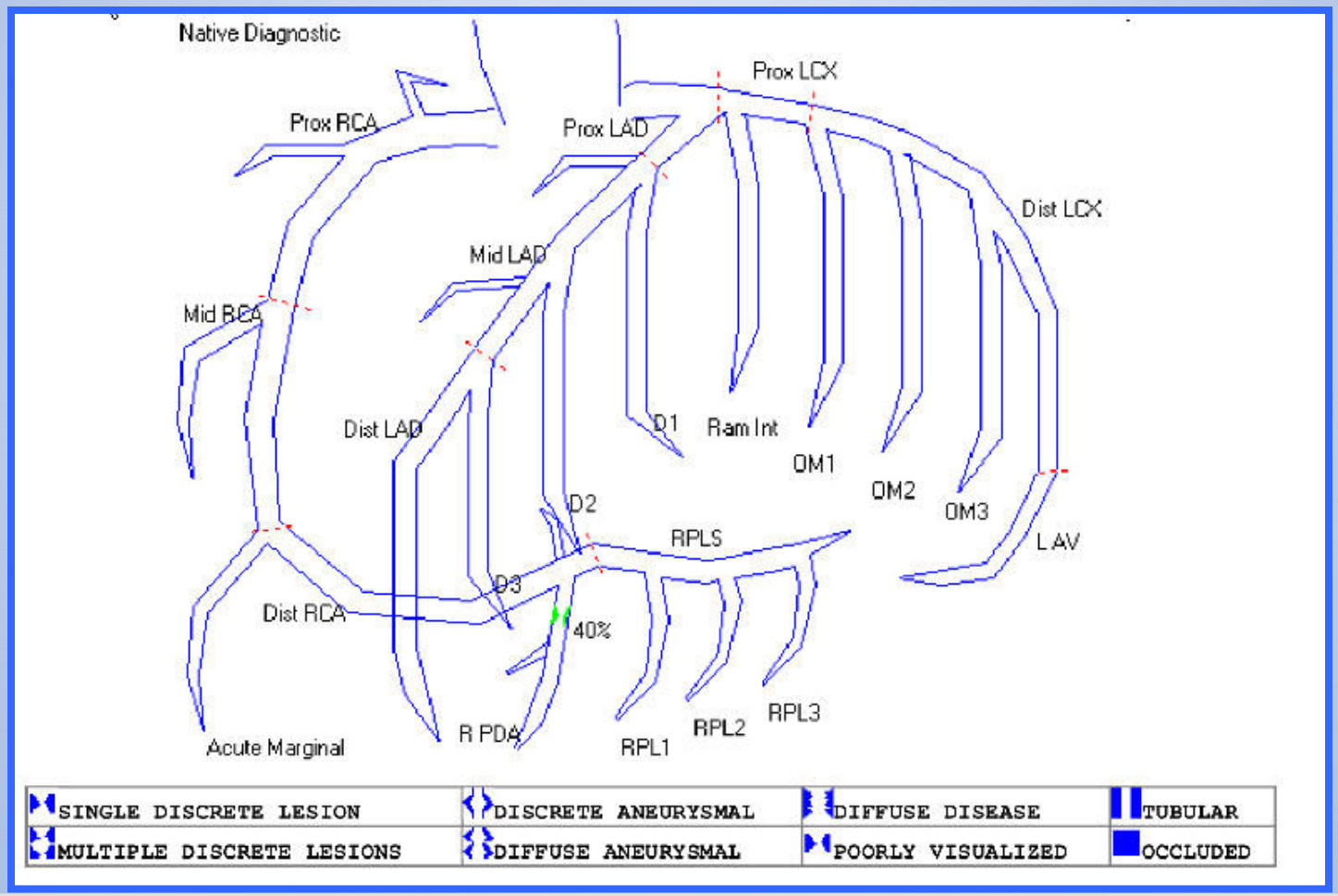


Cardiac Catheterization

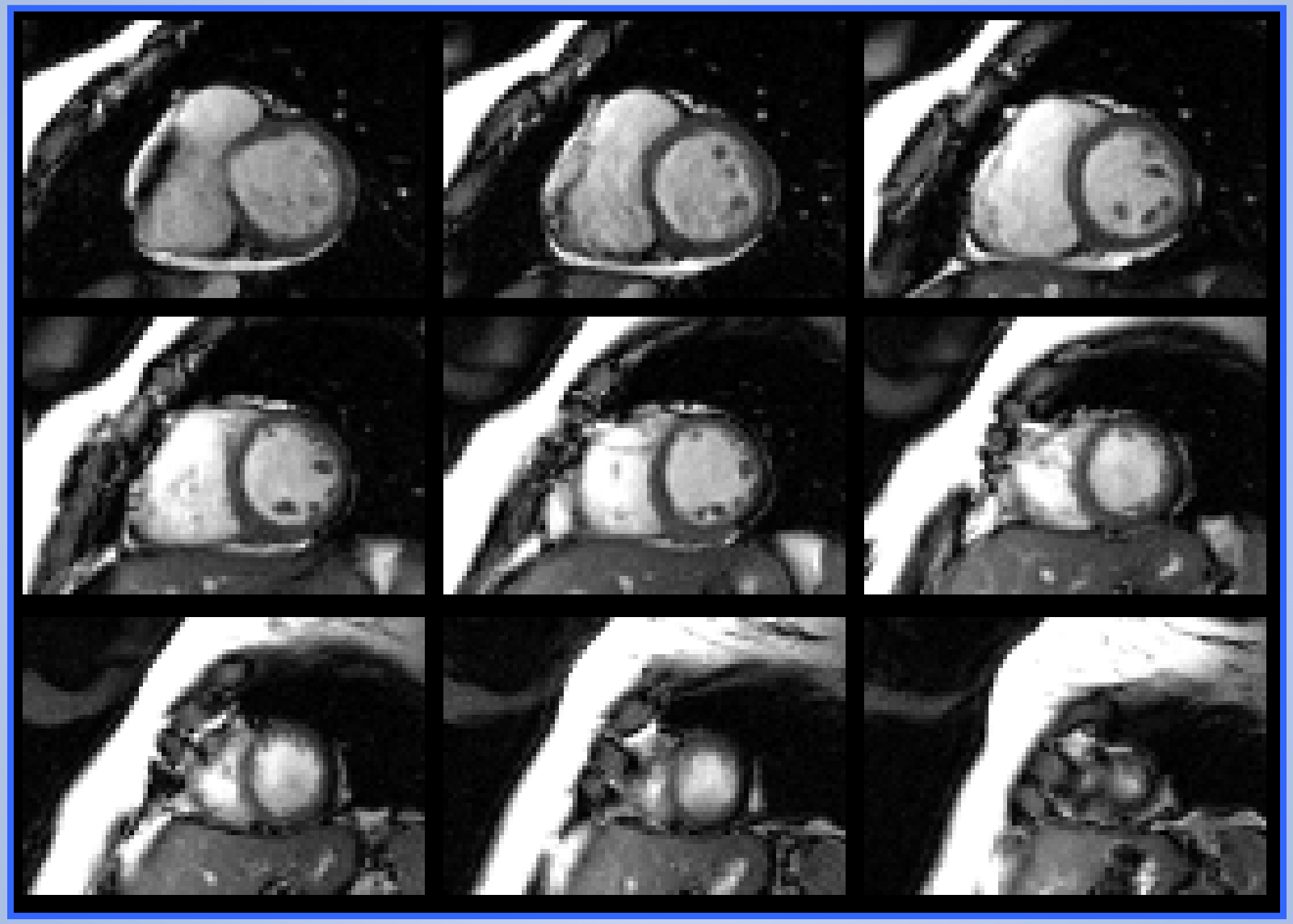


CORONARY SUMMARY

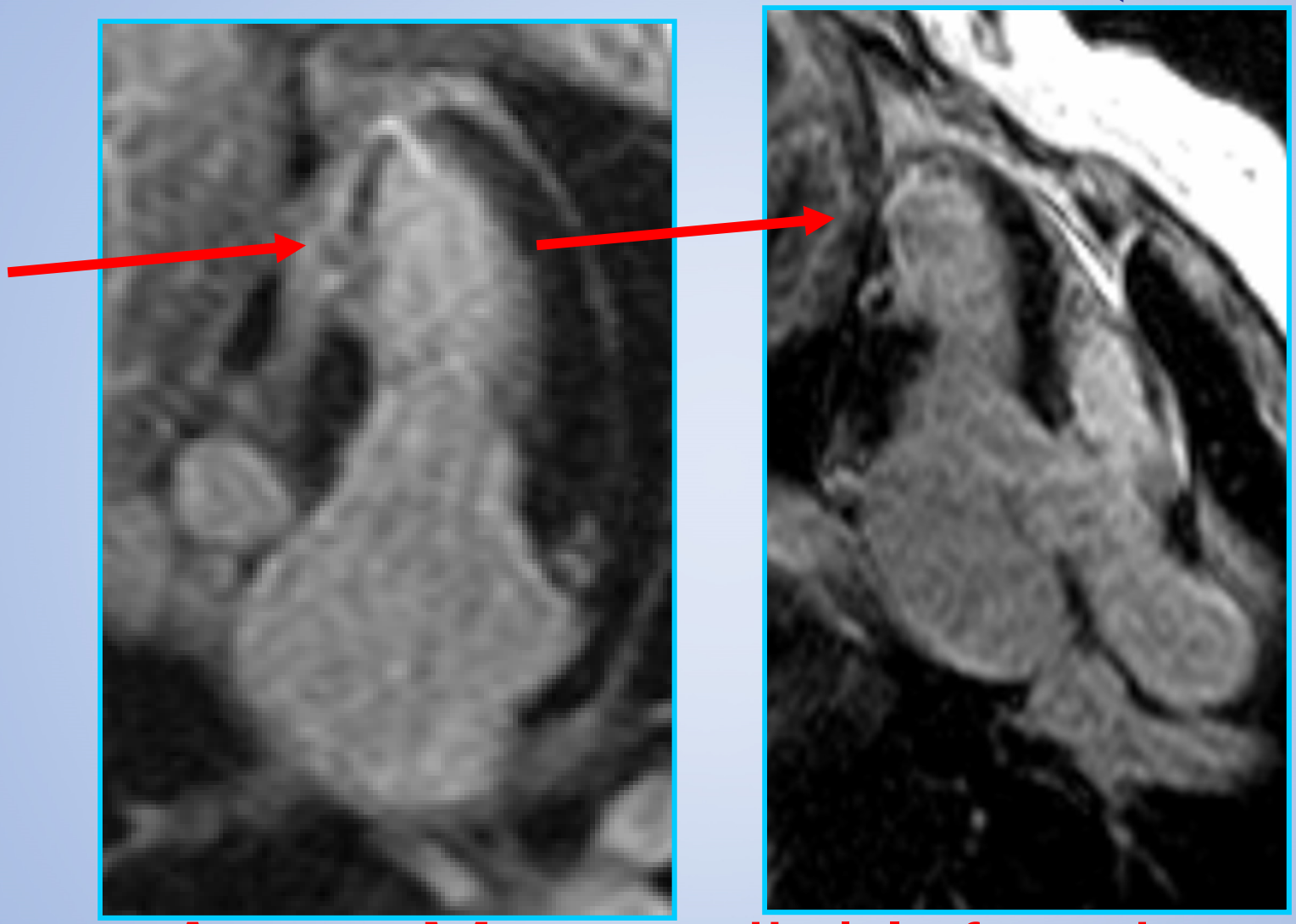
Coronary artery dominance is right. Normal left main coronary artery, left circumflex artery and left anterior descending artery.
The right posterior descending artery is 40% obstructed by a single discrete lesion.
Distal segment is normal size, diseased.
Coronary flow is subjectively diffusely a bit slow - this could be seen in myocarditis. Clinical correlation required.



Cardiac MRI



Late Gad Enhancement (LGE)

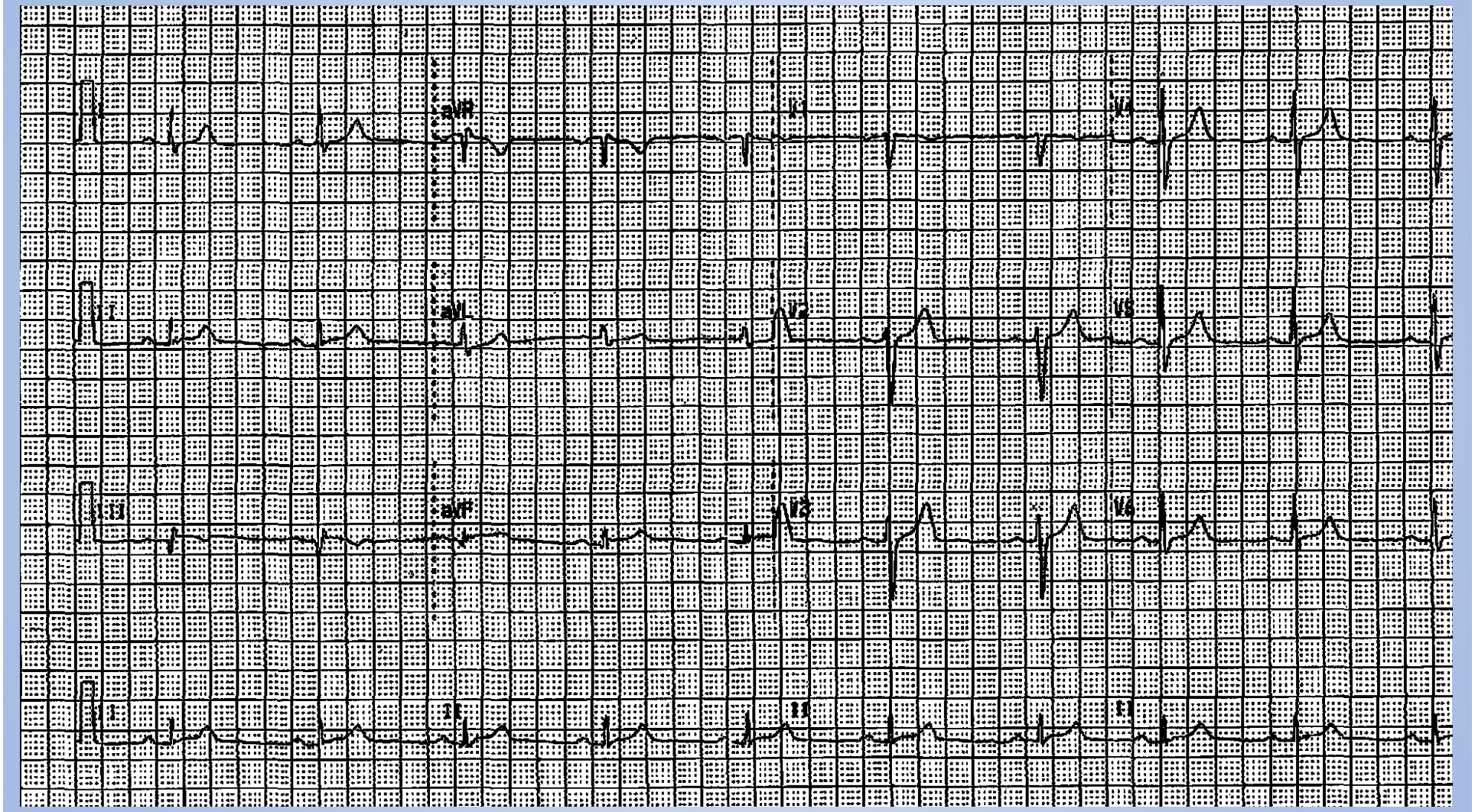


Acute Myocardial Infarction

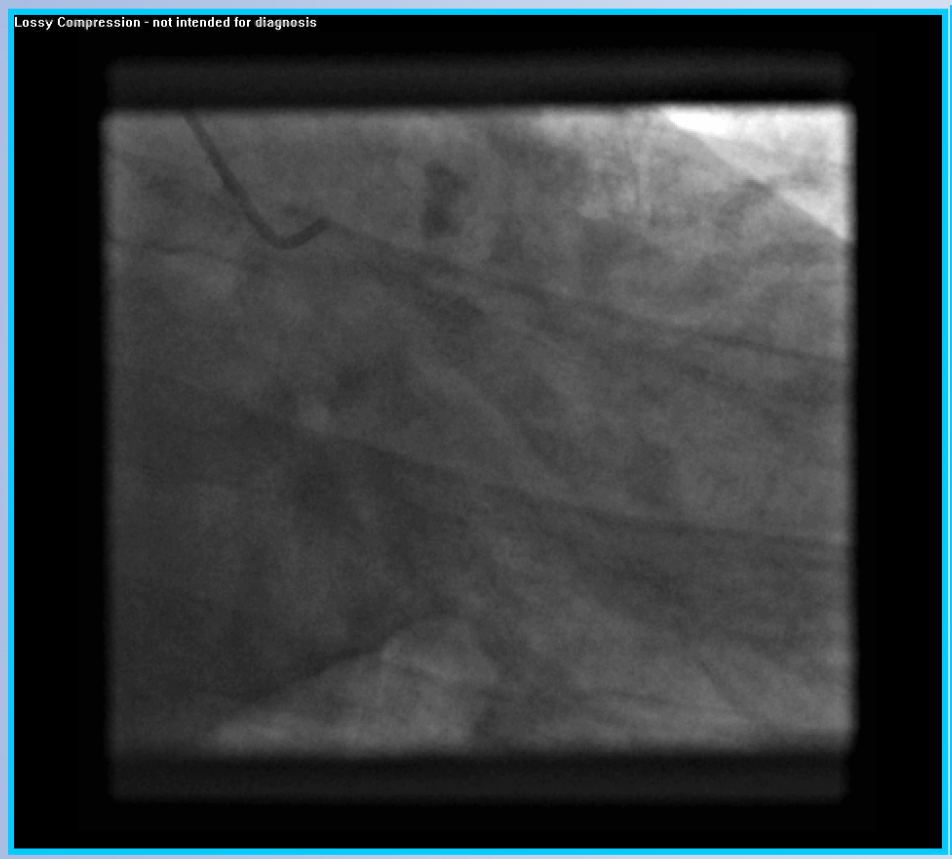
Case

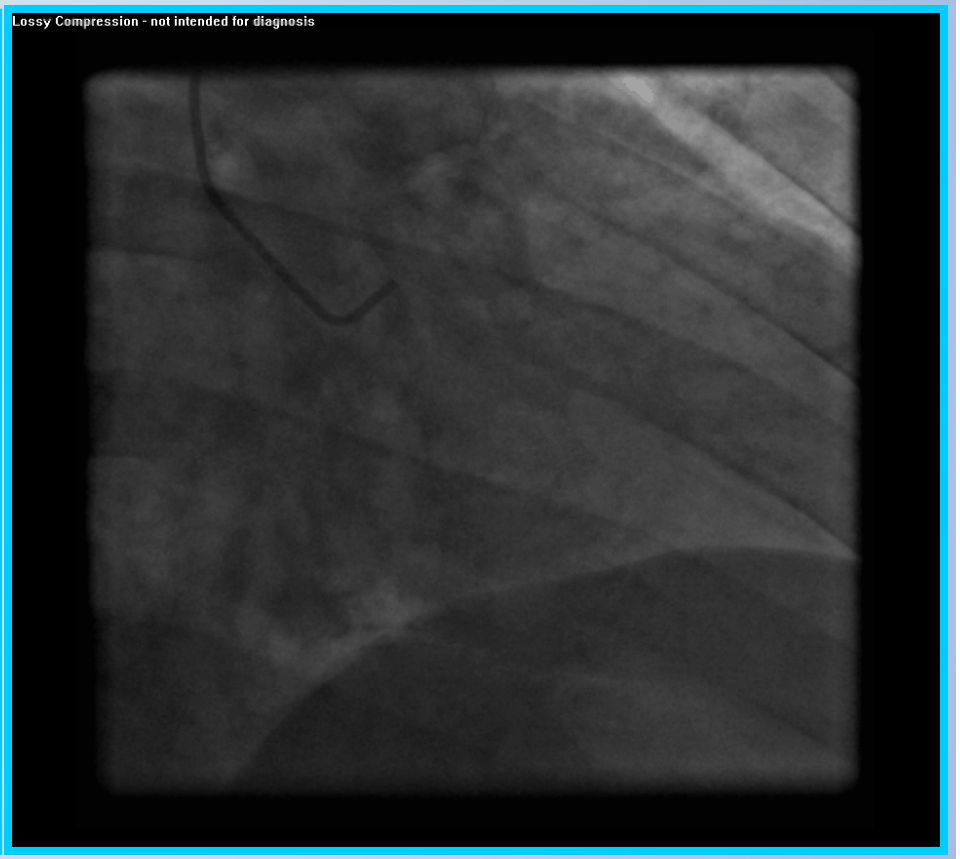
- 46 year old man presents to ED, 6:30 AM with 10/10 chest pain
  - Began 4:30 AM - Radiated to left arm
  - No SOB, no n/v
  - Feeling ill with episodic CP over past 2 weeks
- CAD risks
  - Mild hyperlipidemia at health fair – No treatment
  - 30 Pack year smoker

Initial ECG



Angiography Results

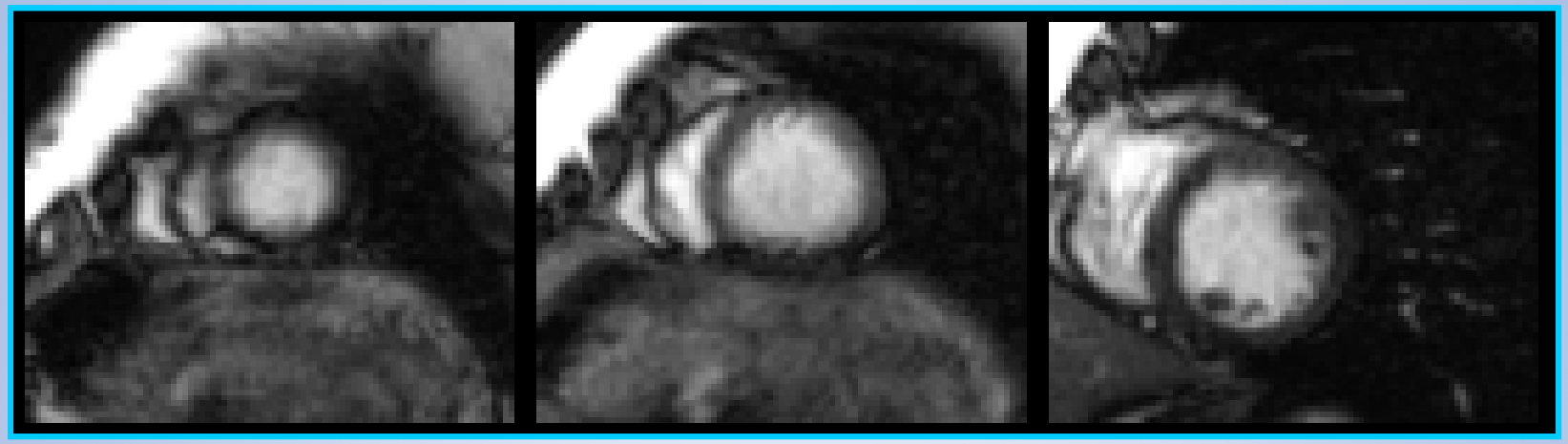


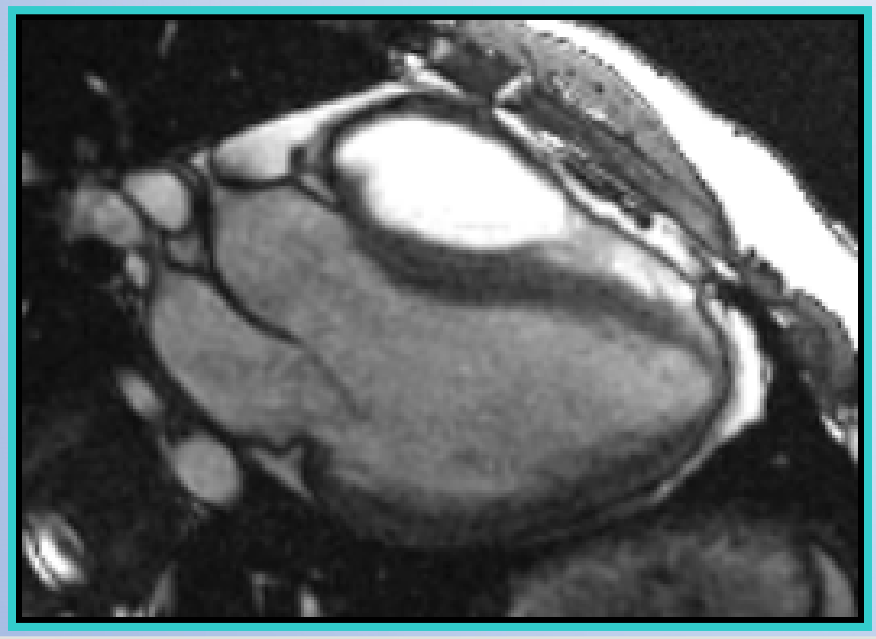


Troponin T Elevation:

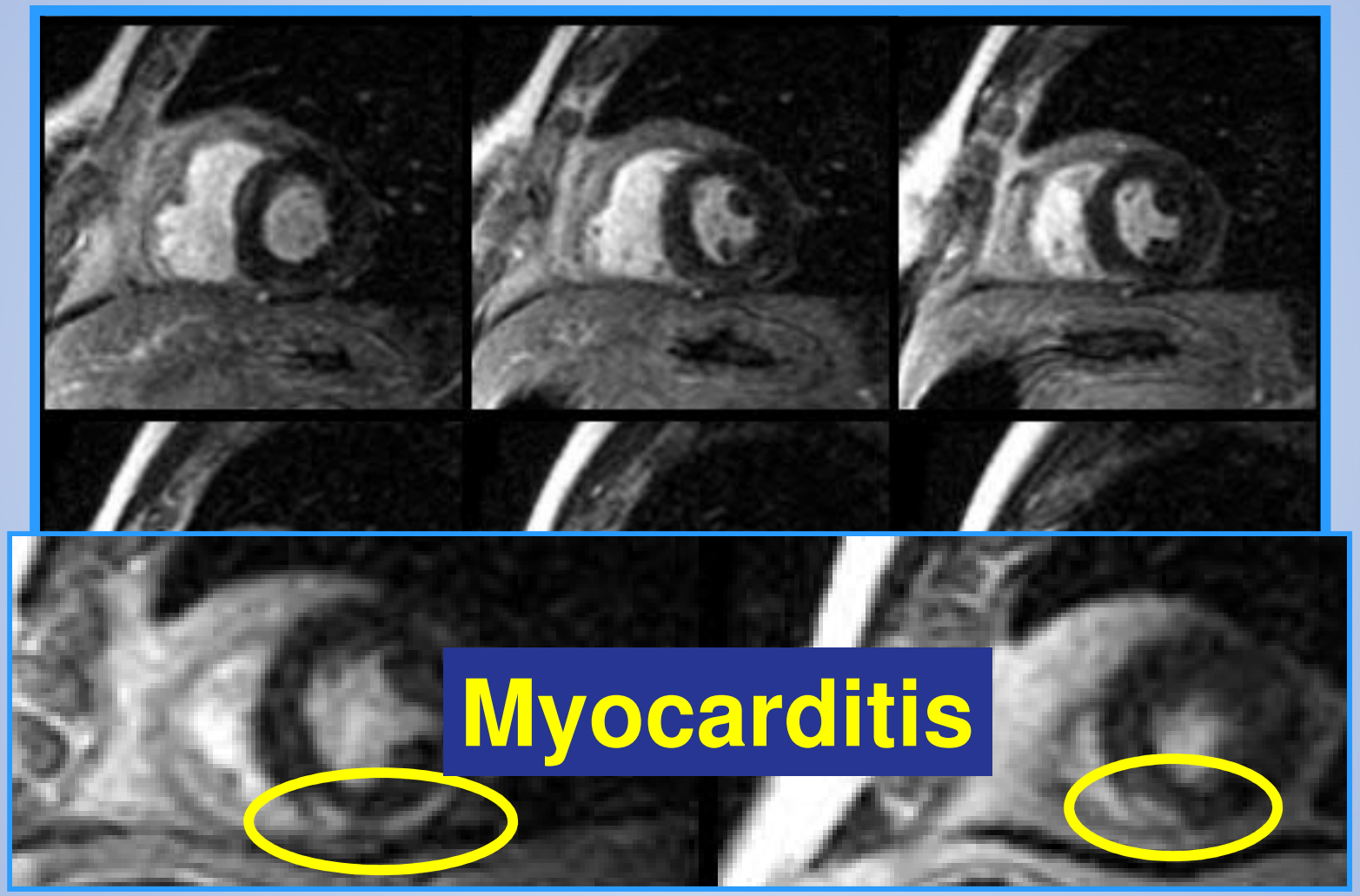
Baseline 0.44 3 hr 0.48 6 hr 0.49

Cardiac MRI





Late Gad Enhancement



Cardiac Troponin Etiologies

Plaque rupture mediated necrosis

- STEMI
- nSTEMI

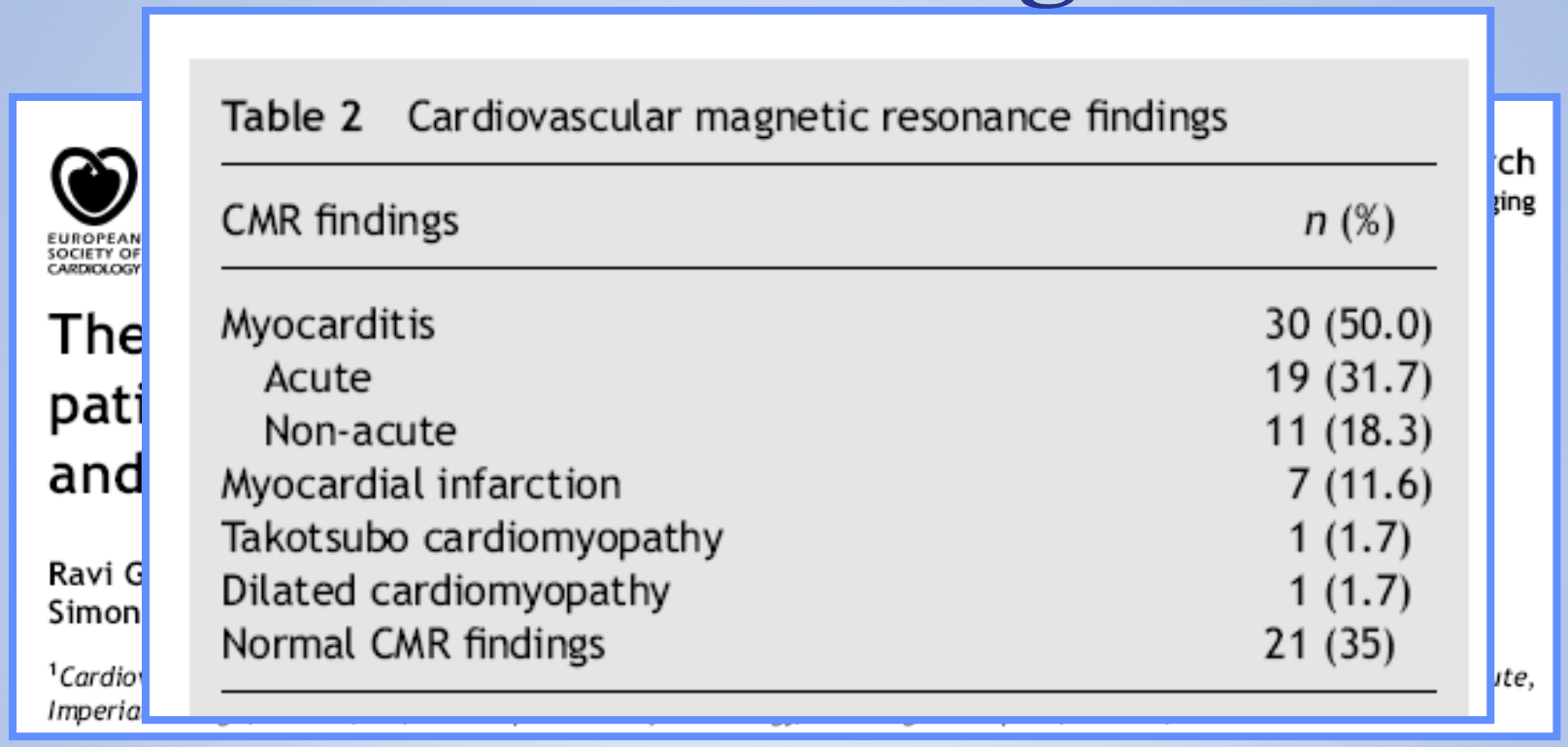
Alterations in coronary vasomotor tone

- Coronary spasm
- Subarachnoid hemorrhage
- Intracranial hemorrhage
- Apical Ballooning Syndrome
- Transplant vasculopathy

Sub-endocardial myocyte necrosis

- CHF
- Hypertensive crisis
- Acute pulmonary embolism
- Tachycardia-mediated – CHF, Pressure overload
- Volume-Pressure overload
  - (renal failure, CHF, fluid resuscitation)
- Anemia
- Hypotension
- Aortic Stenosis and / or Regurgitation
- Hypertrophic Cardiomyopathy
- Amyloid heart disease

Problem Solving Tool



EUROPEAN SOCIETY OF CARDIOLOGY

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Table 2 Cardiovascular magnetic resonance findings

CMR findings	*n* (%)
Myocarditis	30 (50.0)
Acute	19 (31.7)
Non-acute	11 (18.3)
Myocardial infarction	7 (11.6)
Takotsubo cardiomyopathy	1 (1.7)
Dilated cardiomyopathy	1 (1.7)
Normal CMR findings	21 (35)

Take Home points

- CMR and CTA offer alternative options for cardiovascular evaluation.
- CTA:
  - Excellent sensitivity/NPV for exclusion of CAD.
  - Faster and cheaper than traditional evaluations in the ED.

Take Home Points

- Cardiac MRI
  - LV/RV function without contrast
  - Cardiac Mass
  - Infarct and imaging in ACS
    - Elevated troponin without culprit
  - Non-ischemic cardiomyopathies Etiologies

THANK YOU!