



Cardiac CT for the diagnosis of CAD

Carmen P. Lydell MD, FRCPC

Cardiothoracic Imaging, Diagnostic Radiology
Foothills Medical Centre, University of Calgary

OUTLINE:

- 1. What is Cardiac CTA?
  - Techniques
  - Patient preparation
- 2. Where does CT fit in?
  - When can or should it be used?

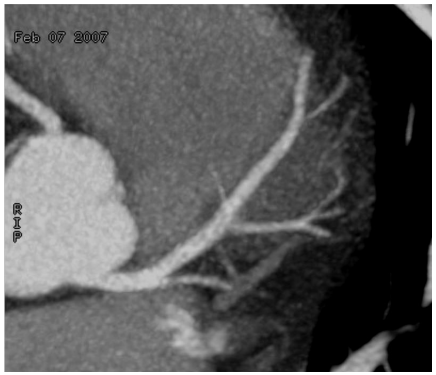
Cardiac CT:

- Enhanced arterial phase CT images through the thorax optimized for assessment of the coronary arteries.

(Anomalous RCA from left sinus-malignant course)

Components of Exam:

- CORONARY ARTERIES:
  - Calcium Score:
    - Non enhanced images
    - Calcified plaque
  - Coronary CT Angiogram:
    - Arterial phase enhanced images
    - Non-calcified plaque



Cardiac CT:

- Freezes cardiac motion to allow visualization of coronary arteries.
- Non-invasive assessment with resolution close to coronary cath.
- Very dependent on technologies that are rapidly changing and improving

(Vein graft to PDA)

Techniques:

- Cardiac imager must be involved at each step
  - Protocolling- appropriateness criteria
  - Patient prep
  - Image acquisition
  - Image analysis

Image acquisition

*Goal:

- Attempt to freeze cardiac motion

- Acquire images over multiple heart beats, preferably when the heart is most still

- Follow ECG in order to establish timing of systole and diastole

CT Parameters: ECG-gating Retrospective vs. Prospective

Figure 1

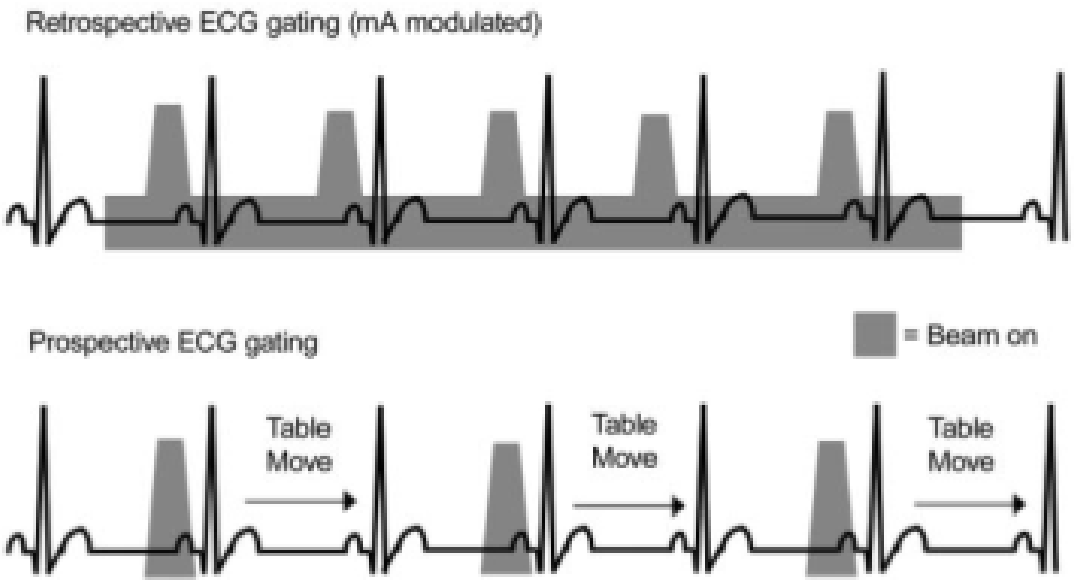
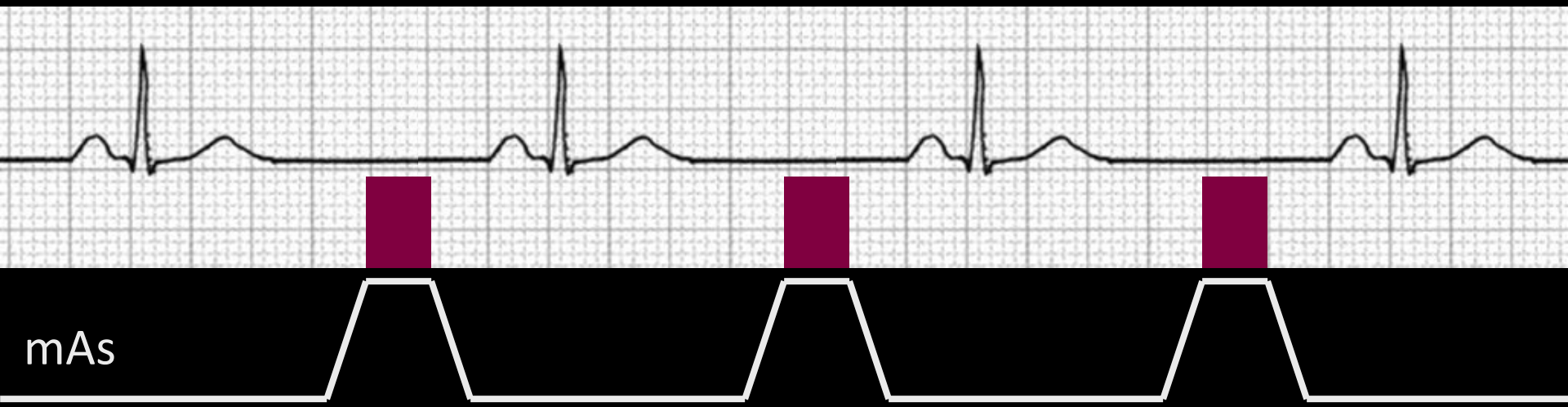


Figure 1: Model shows retrospective ECG gating versus prospective ECG gating. With retrospective gating, the intensity-modulated x-ray beam is on for the entirety of the R-R intervals during imaging. With prospective gating, the x-ray beam is on for about 26% of every other R-R interval.

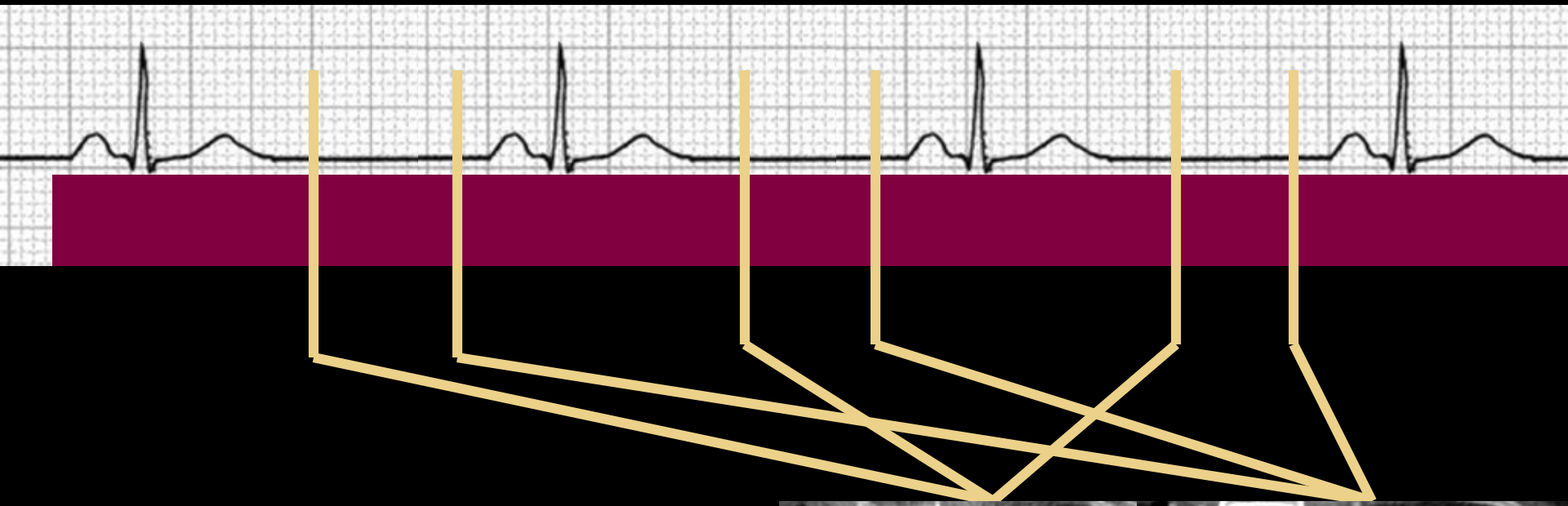
- Radiology: Volume 248: Number 2—August 2008

Prospective ECG Gating

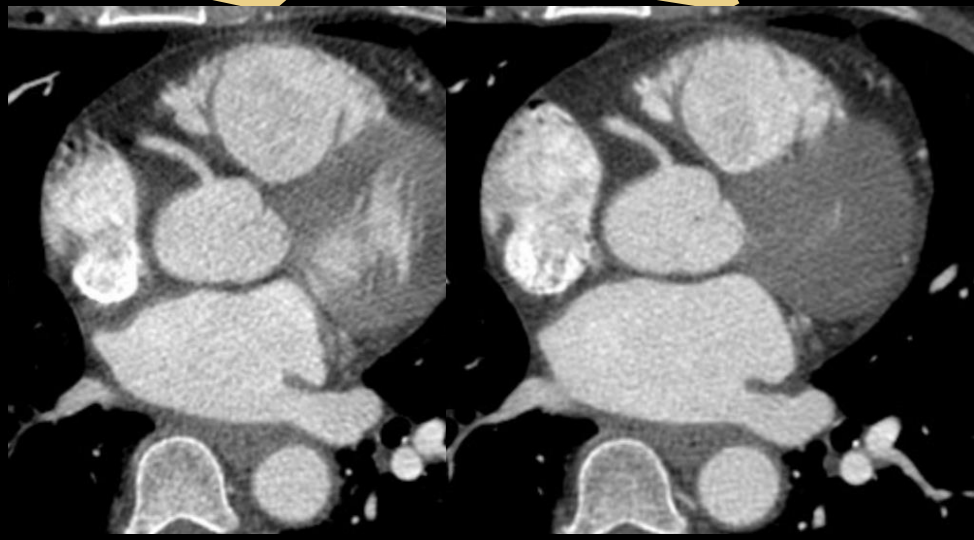


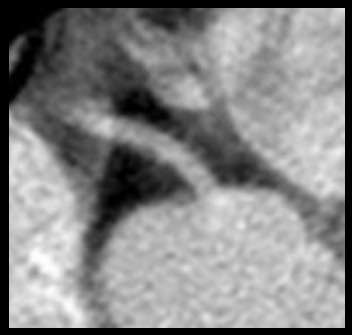
- Advantages
  - Low radiation
- Disadvantages
  - Susceptible to HR irregularities

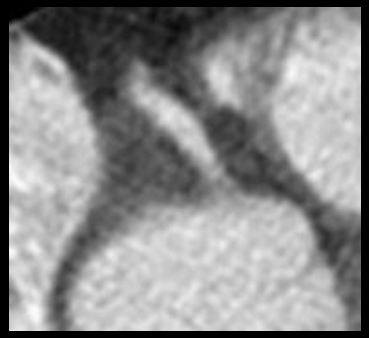
Retrospective ECG Gating

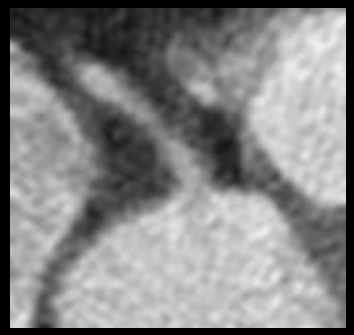


- 1. Select images with least motion
- 2. Function
- 3. Increased radiation

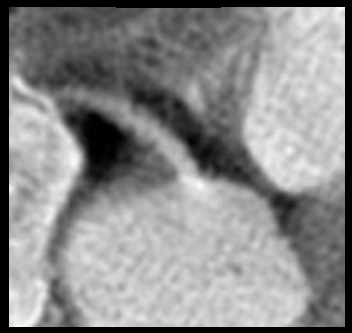




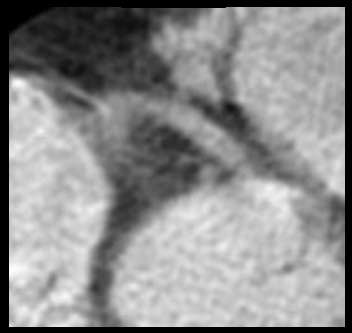




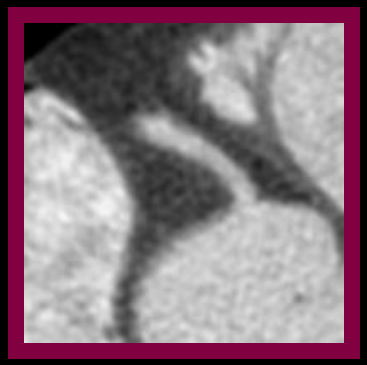
55



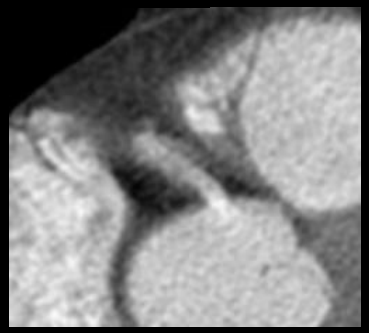
65



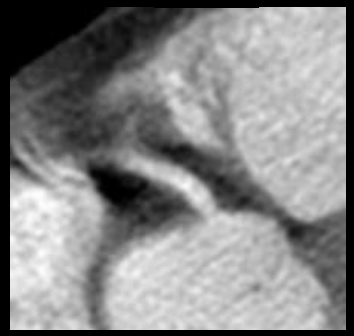
75



85



95



Patient Preparation:

- Heart Rate:
  - Target HR: 55-60
    - Slower heart rate→ longer time in diastole
    - Often anxious on table and with flush of contrast
    - Oral B-Blocker (metoprolol or bisoprolol)
    - IV B-Blockers useful for small reductions in HR
    - ECG: Arrhythmia, heart block, and atrial fibrillation

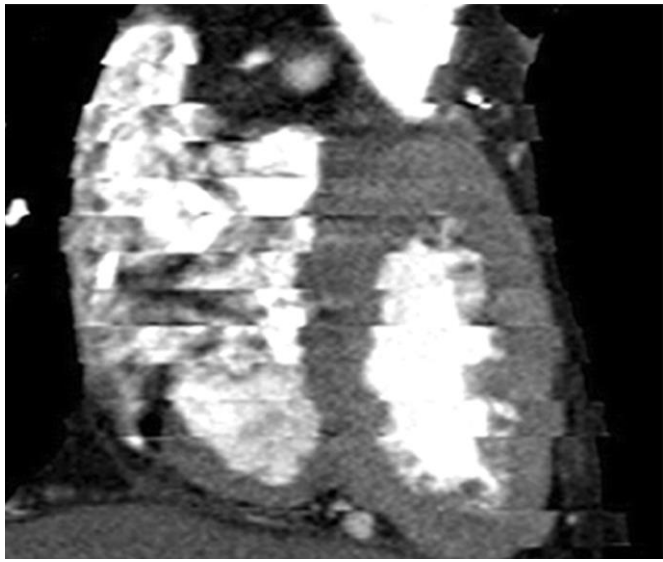
(Artefact in RCA from high HR)

Patient Preparation:

Breath-hold: (64 MDCT scanner)

- Retrospective:
  - 6-12 sec; 6-8 heart beats
- Prospective:
  - 8-12 sec; 8-14 heartbeats

(320-MDCT- 1-2 sec)



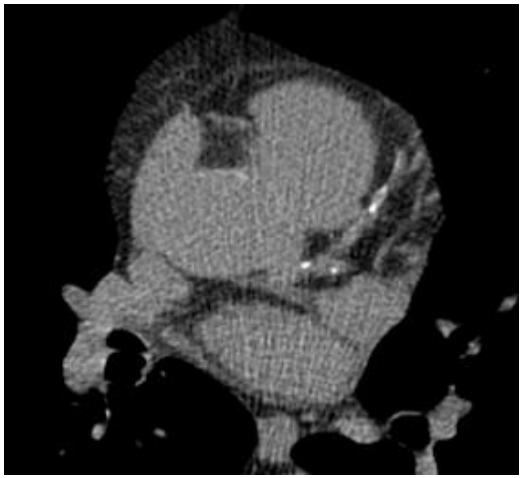
(Artefact from poor breath hold)

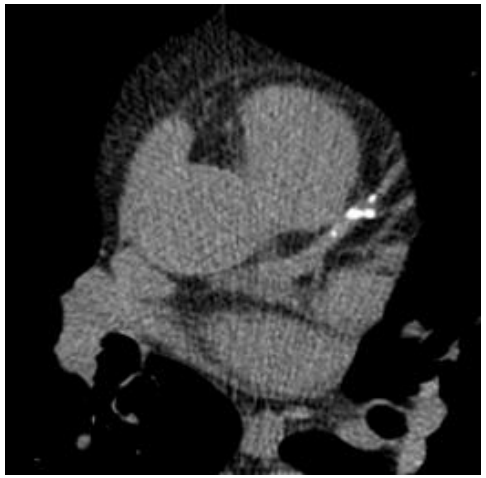
Patient Preparation:

- Nitroglycerin spray
  - Dilates coronary arteries
  - Contraindications:
    - Viagra
    - Glaucoma
    - Severe aortic stenosis
- IV contrast
  - 60-80 cc

Limitations:

- Calcified atherosclerotic plaque
  - Blooming artefact: over-estimation of stenosis
  - may not be best test for elderly and diabetics
- Body habitus
  - BMI >40





Technological Advances:

- Improvements in technology have led to improved image quality:
  - Multidetector CT:
  - 1→4→16 → 64 detectors… 320
    - Better Spatial resolution
    - Better Temporal resolution
    - Decreased Radiation Dose

Image Quality:

- Spatial resolution:
  - 16 MDCT: 0.8 - 1 mm
  - 64 MDCT: 0.5 mm
  - Cardiac cath: 0.2 mm

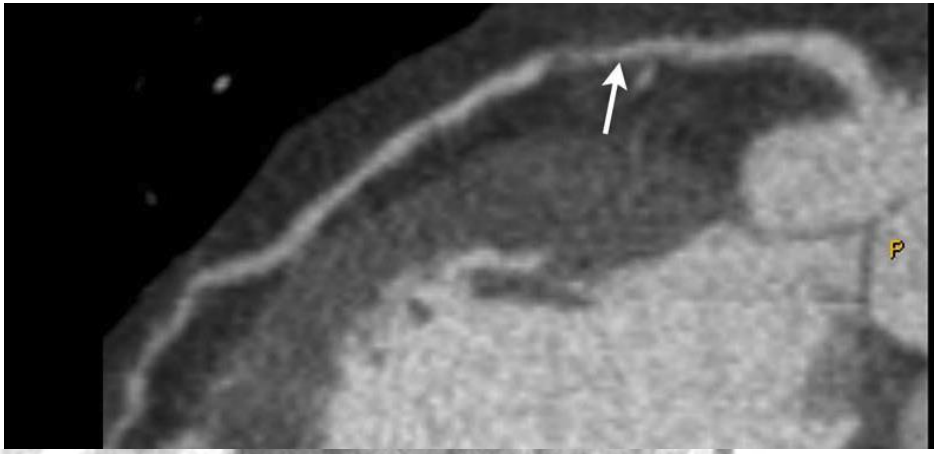


Image Quality:

Temporal Resolution:

- Important because we are imaging a moving object!
  - Can scan a higher heart rates
  - Shorter scan time
    - Lower radiation dose
  - Relates to:
    - ½ of gantry rotation time (180 degrees of rotation)

Radiation Dose:

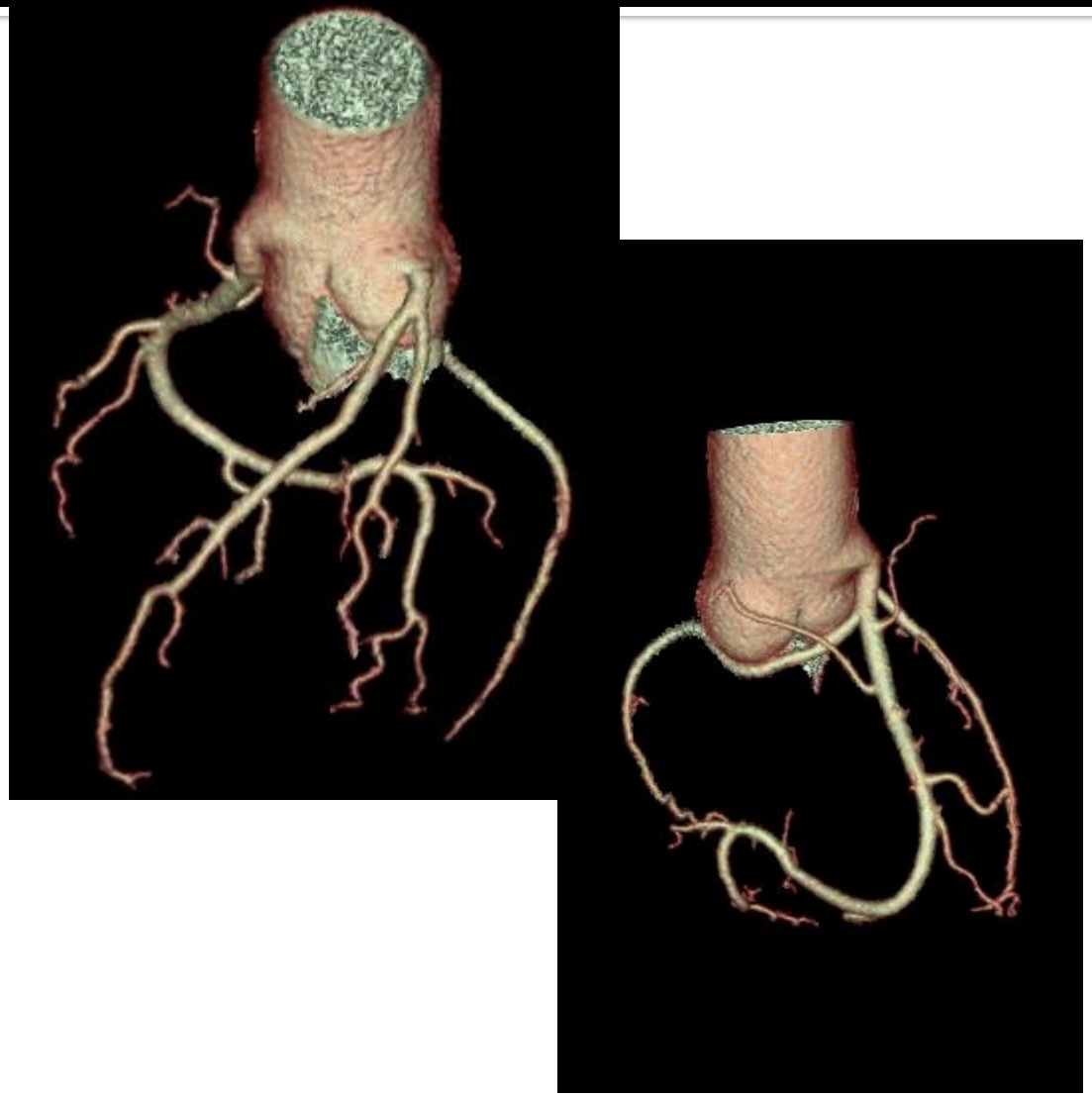
Cardiac CT previously reported: 6-25 mSv

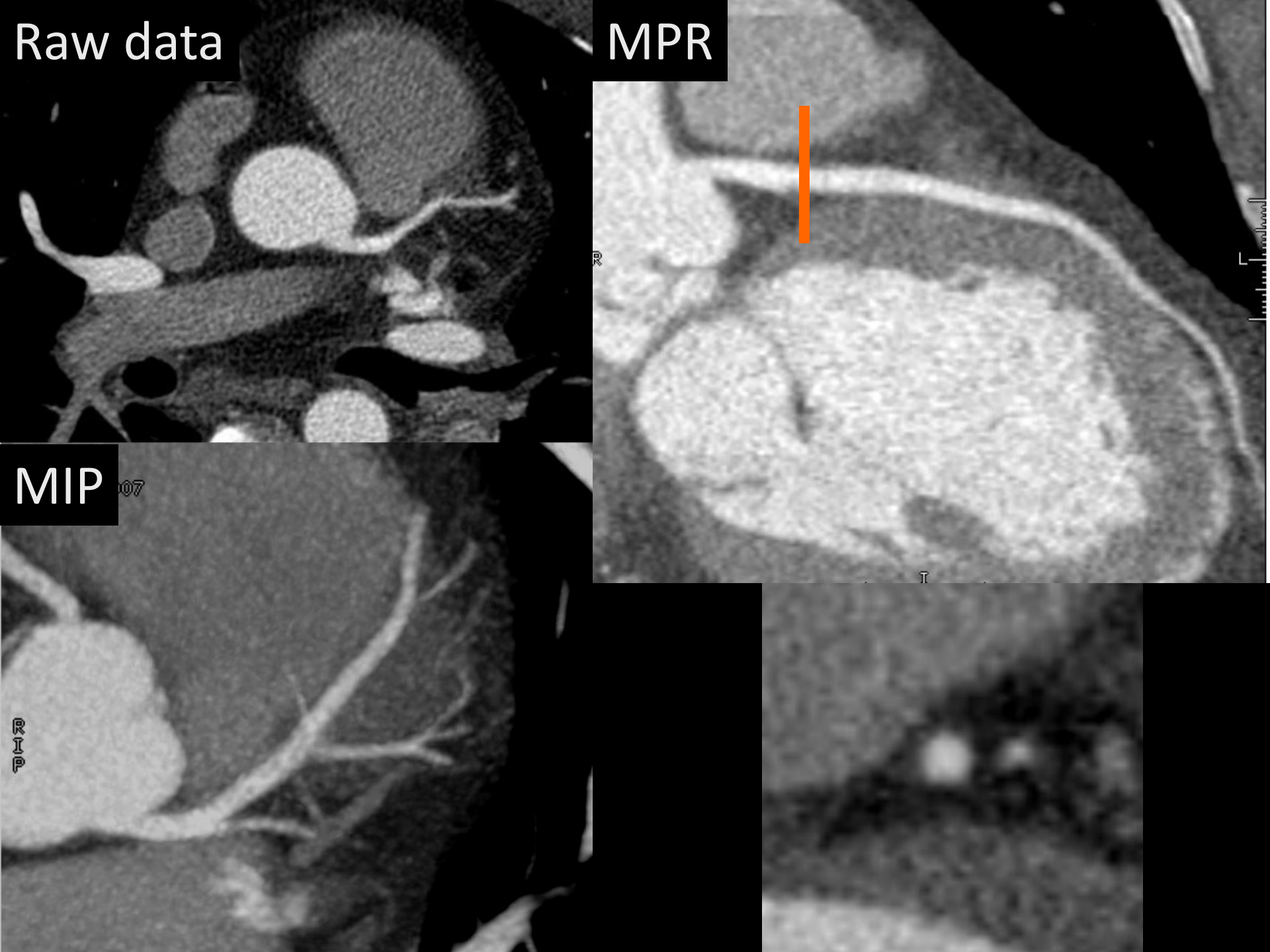
- at FMC: 1.5-9 mSv
- More complex patients being assessed with retrospective scanning or entire thorax
- Background exposure of living in Calgary: 3 mSv/year

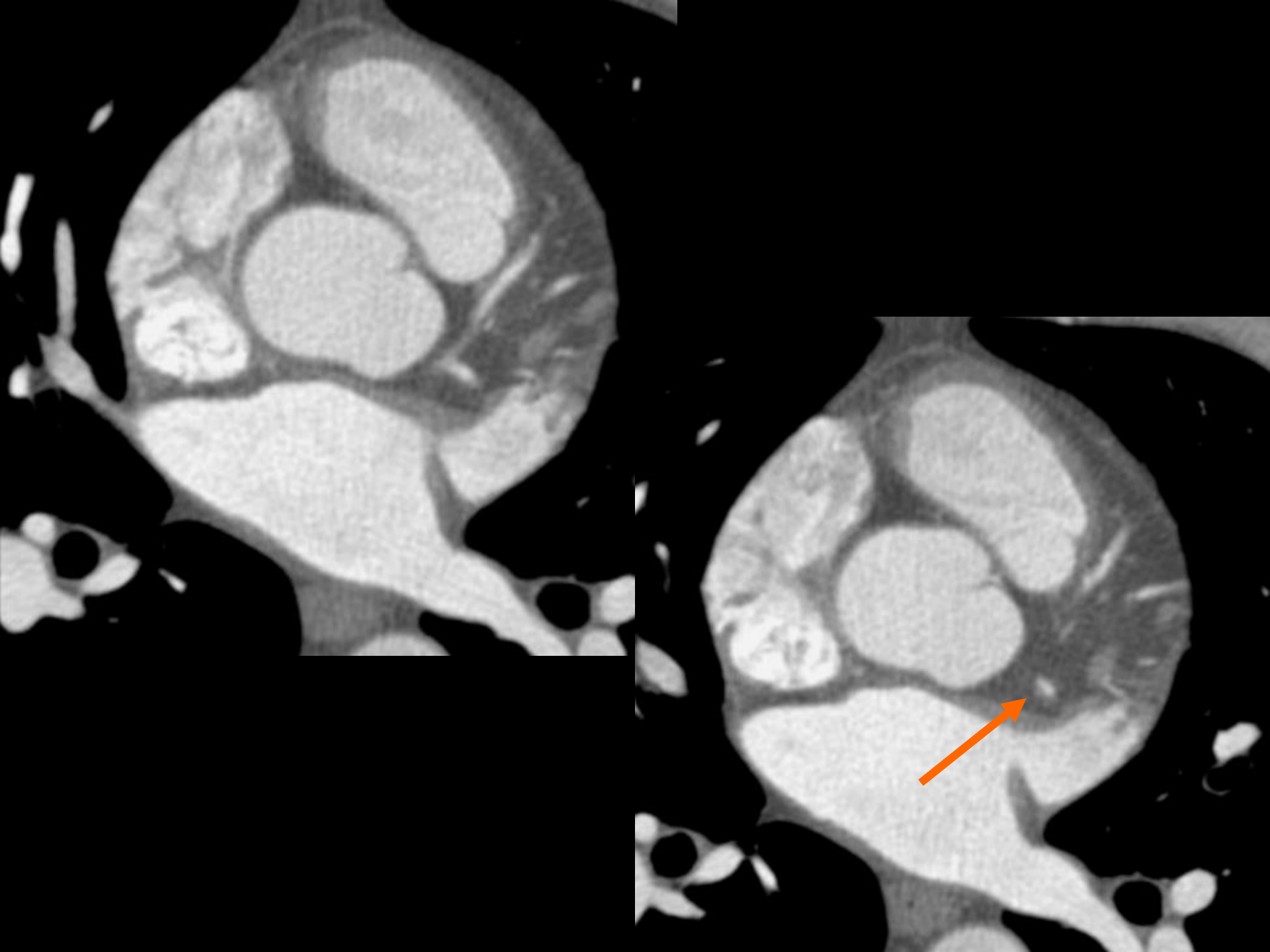
Imaging Procedures	Modality	Effective Dose (mSv)*
Cardiac procedures		
Calcium scoring	Electron beam CT	1.0–1.3
	Multiple-row detector CT	1.5–6.2†
Cardiac CT angiography	Electron beam CT	1.5–2.0
	Multiple-row detector CT	6†–25
Cardiac SPECT with ^{99m}Tc or ^{201}T1‡	Nuclear medicine	6.0–15.0
Coronary angiography (diagnostic)	Fluoroscopy	2.1†–6.0
Chest radiography	Radiography	0.1–0.2
Routine CT procedures		
Head CT	Multiple-row detector CT	1–2
Chest CT	Multiple-row detector CT	5–7
Abdominal and pelvic CT	Multiple-row detector CT	8–11

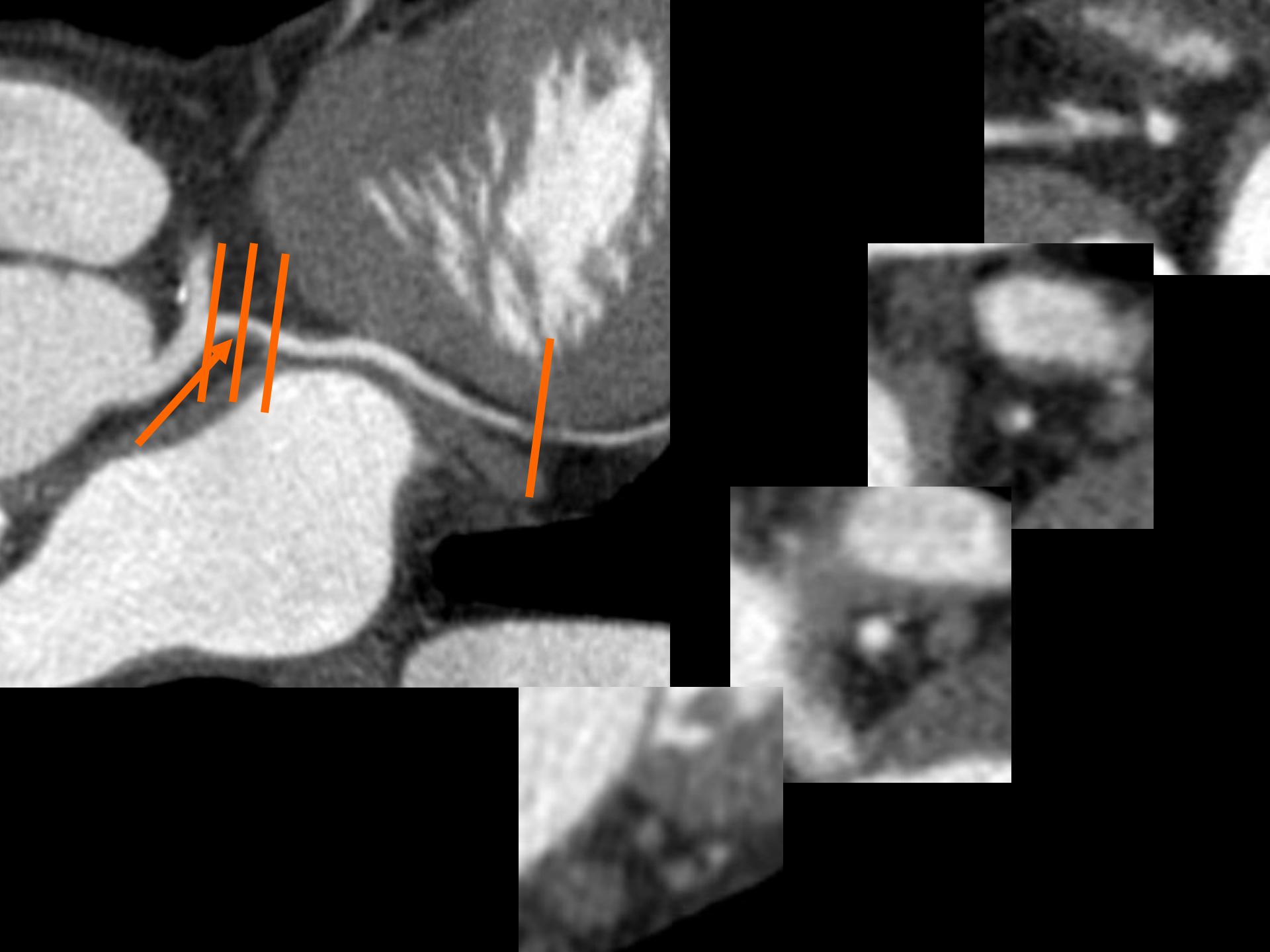
Image analysis:

- 3D reconstruction



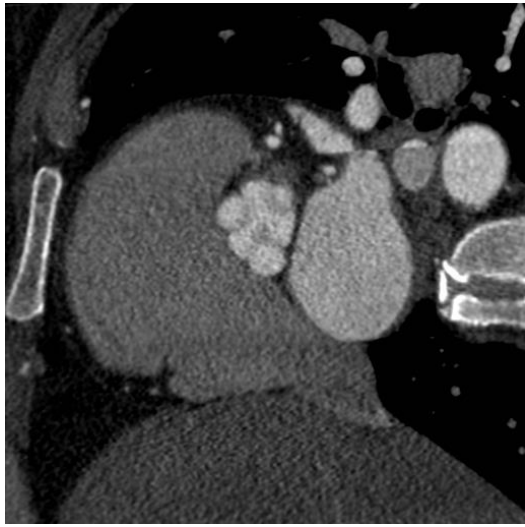

Raw data
MPR
MIP
R
L
T
RIP

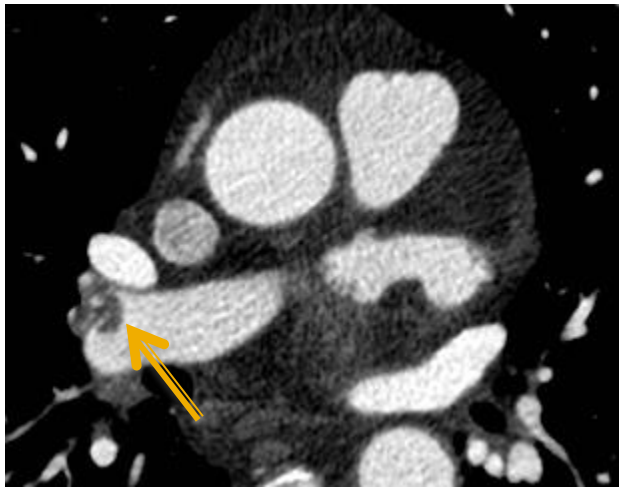


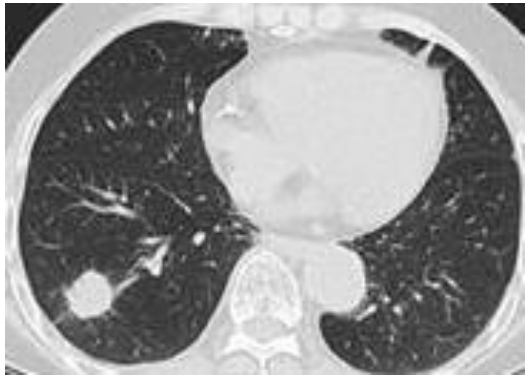


Extracoronary Findings

- Cardiac chambers / Pericardium
- Aorta & Pulmonary vessels
- Lung parenchyma
- Esophagus
- Upper abdomen
- Bones



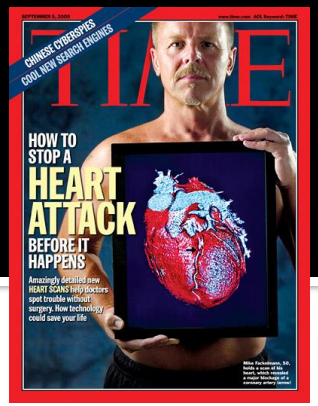




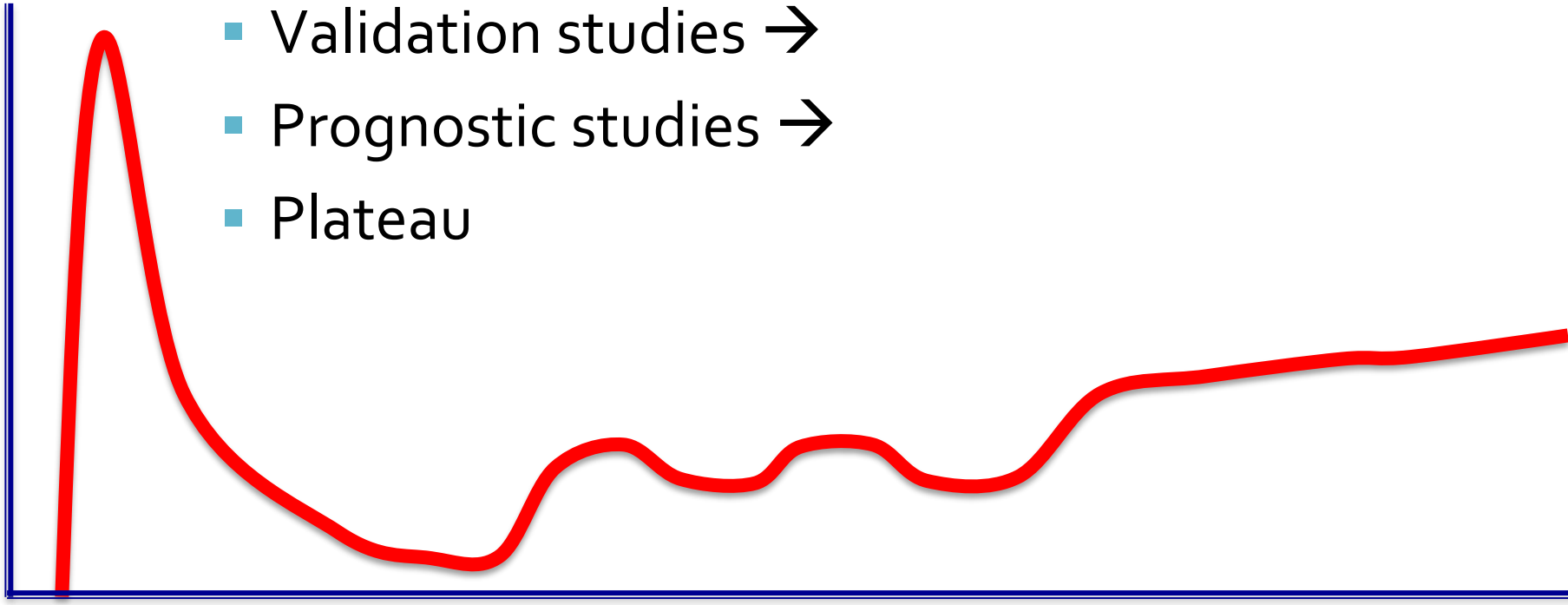
Coronary CTA:

- Another cardiac diagnostic imaging exam…
  - Not the definitive test
  - But is an appropriate test in certain settings
- Anatomic vs physiologic information
  - Nuclear
  - Stress echo
  - Stress MRI
- Non-invasive but also non-therapeutic
  - Catheter angiography

Coronary CTA:



- Evolution of a diagnostic test…
  - Initial excitement, high profile→
  - Disappointment, challenges and limitations→
  - Validation studies →
  - Prognostic studies →
  - Plateau



Diagnostic Performance of CCTA:

Four (4) Prospective Multicenter Studies

	Sensitivity	Specificity	PPV	NPV
ACCURACY	**95**	83	64	**99**
N=230, Stable Chest Pain; No known CAD; No exclusion criteria; CAD prevalence 13%				
Europe	**99**	64	85	**97**
N=360, Acute and Stable Chest Pain; No known CAD; CAD prevalence 68%				
MEDIC	**95**	91	71	**99**
N=415 (83), No known CAD; 20-80% pretest LK of CAD				
CorE64	85	90	91	83
N=291, Stable Chest Pain; Known / No Known CAD; Exclude CACS >600; CAD prevalence 56%				

Source: Budoff et al. J Am Coll Cardiol 2008; Miller et al. N Eng J Med 2008; Meijboom et al. J Am Coll Cardiol 2009

Diagnosis of Obstructive CAD

Test	Sensitivity	Specificity
Exercise ECG treadmill[1]	68%	77%
Exercise Echo treadmill[2]	86%	81%
Dobutamine Echo[2]	~85%	~85%
Exercise nuclear treadmill[3]	87%	73%
Pharmacologic nuclear[3]	89%	75%
Coronary CTA[4]	**94%**	**83%**

1. ACC/AHA 2002 Guideline Update for Exercise Testing
2. ACC/AHA/ASE 2003 Guideline Update for the Application of Echocardiography
3. ACC/AHA/ASNC Guidelines for the Clinical Use of Cardiac Radionuclide Imaging
4. ACCURACY study

Prognostic studies of Coronary CTA

- Shift from studies of identifying the prognostic role of CCTA
- Outcomes measured by:
  - major adverse cardiovascular events (MACE):
    - Death (all cause mortality)
    - MI
    - Readmission for unstable angina
    - coronary revascularization.

Journal of the American College of Cardiology
© 2011 by the American College of Cardiology Foundation
Published by Elsevier Inc.

Vol. 57, No. 10, 2011
ISSN 0735-1097/$36.00
doi:10.1016/j.jacc.2010.10.011

Cardiac Imaging

Prognostic Value of Cardiac Computed Tomography Angiography

A Systematic Review and Meta-Analysis

Hulten et al. JACC 2011

Study Characteristics:

- 18 studies
- Symptomatic patients - suspected to be attributable to CAD
- 9,592 patients
  - 6,035 positive CCTA findings
  - 3,557 normal CCTA findings
- Median follow-up: 20 months
- Mean age: 59

Definitions:

- Normal (or negative) CCTA study:
  - no, minimal
- Nonobstructive CAD:
  - < 50% stenosis of any coronary artery
- Obstructive CAD:
  - > 50% stenosis of any coronary artery.

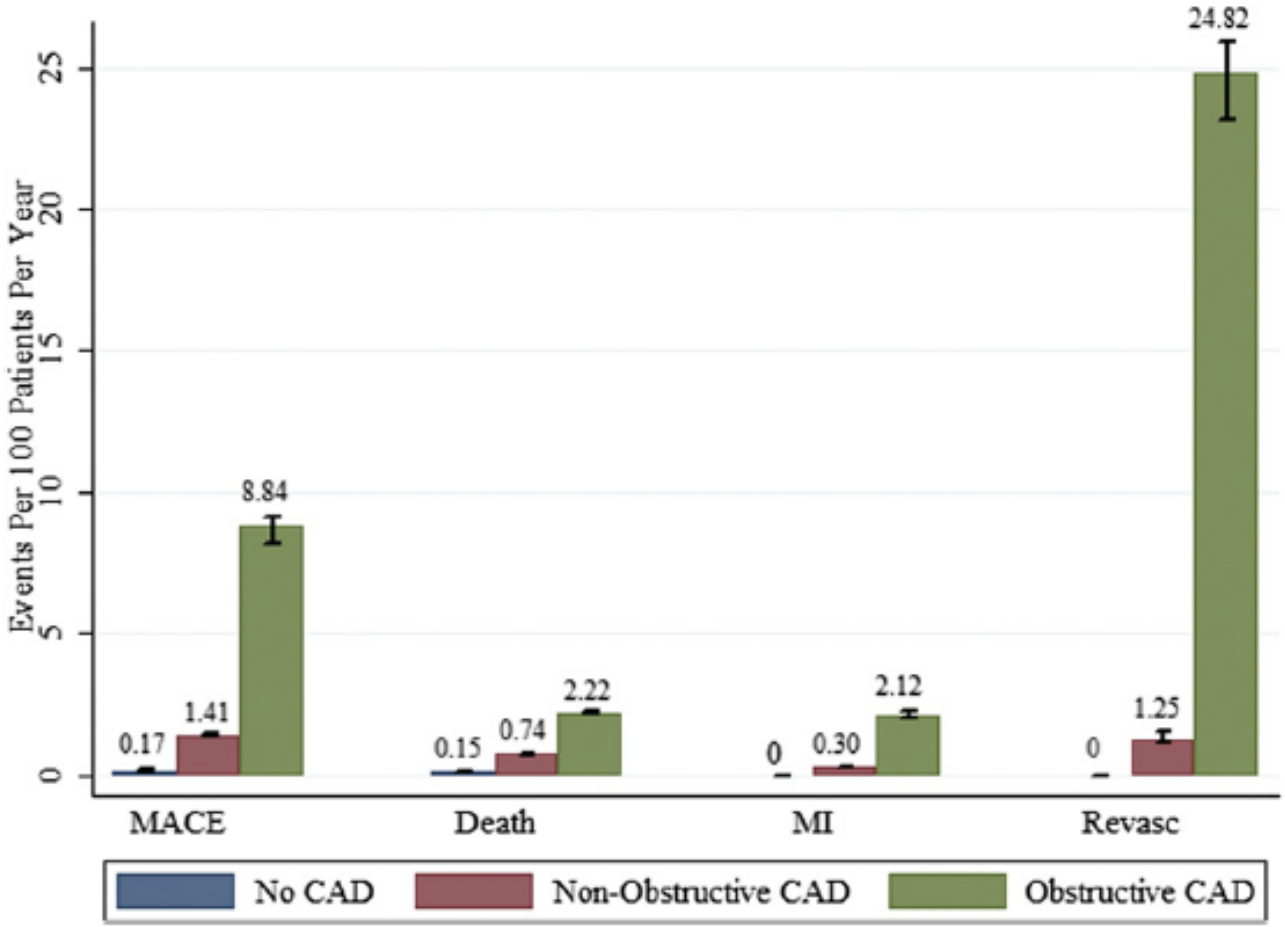
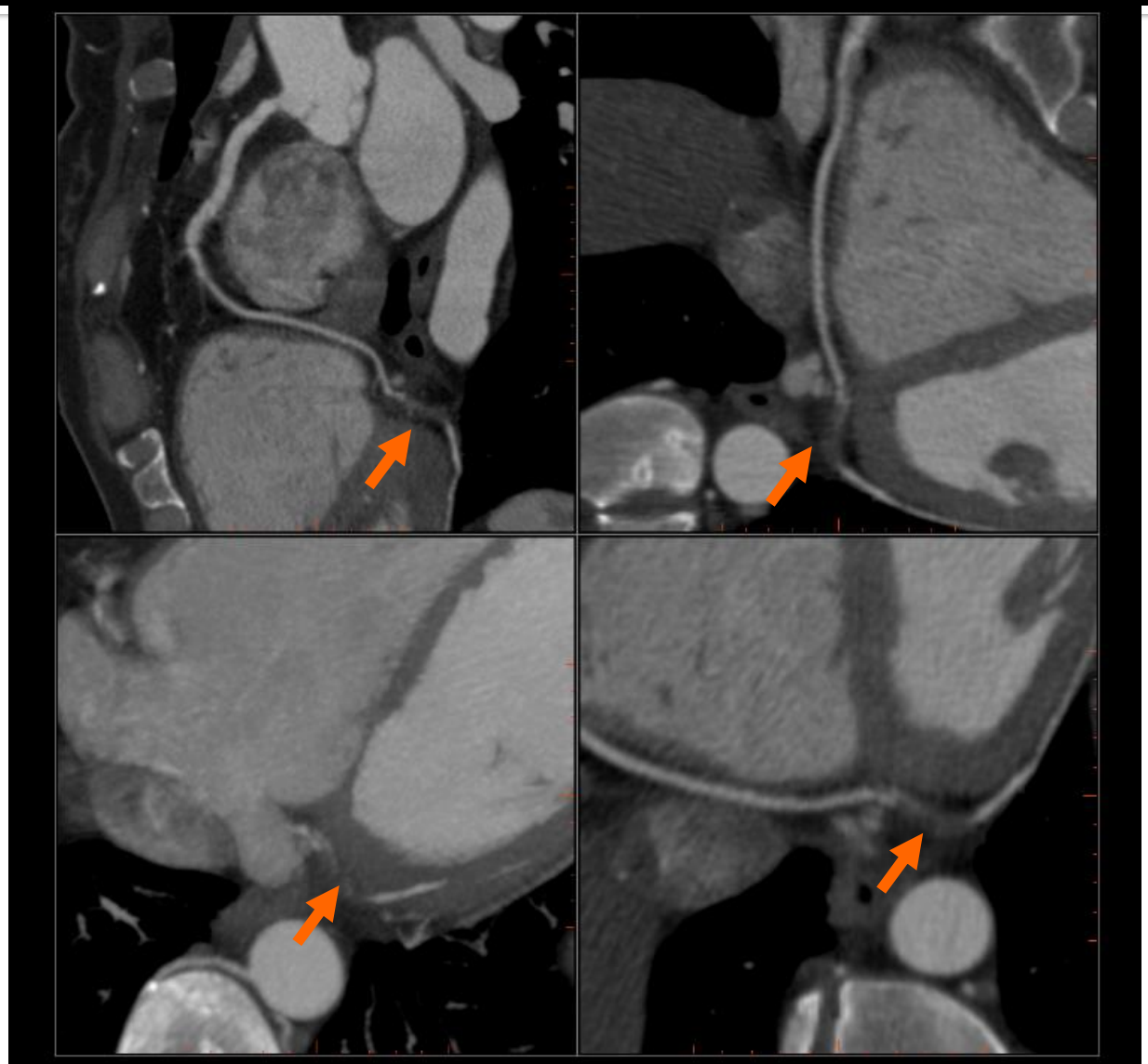


Figure 2 **Annual Event Rates Stratified by Cardiac Computed Tomography Angiography Result**

For " NO or Minimal CAD" patients:

- Low event rate of 0.17%
  - No definite CAD-specific
    - all 23 events were all-cause mortality
  - excellent prognosis
  - less than the background event rate among healthy low-risk individuals (1%).

High-grade stenosis posterolateral branch (PLB), Right dominant system.



CT in ER: ROMICAT II

- Randomized controlled multi-centered clinical trial of Coronary CTA in ED
- 987 patients (low-risk presentation)

The NEW ENGLAND JOURNAL of MEDICINE

HOME | ARTICLES & MULTIMEDIA | ISSUES | SPECIALTIES & TOPICS | FOR AUTHORS | CME

ORIGINAL ARTICLE

Coronary CT Angiography versus Standard Evaluation in Acute Chest Pain

Udo Hoffmann, M.D., M.P.H., Quynh A. Truong, M.D., M.P.H., David A. Schoenfeld, Ph.D., Eric T. Chou, M.D., Pamela K. Woodard, M.D., John T. Nagurney, M.D., M.P.H., J. Hector Pope, M.D., Thomas H. Hauser, M.D., M.P.H., Charles S. White, M.D., Scott G. Weiner, M.D., M.P.H., Shant Kalanjian, M.D., Michael E. Mullins, M.D., Issam Mikati, M.D., W. Frank Peacock, M.D., Pearl Zakroysky, B.A., Douglas Hayden, Ph.D., Alexander Goehler, M.D., Ph.D., Hang Lee, Ph.D., G. Scott Gazelle, M.D., M.P.H., Ph.D., Stephen D. Wiviott, M.D., Jerome L. Fleg, M.D., and James E. Udelson, M.D. for the ROMICAT-II Investigators

N Engl J Med 2012; 367:299-308 | July 26, 2012 | DOI: 10.1056/NEJMoa1201161

Comments open through August 1, 2012

CT in ER: ROMICAT II

- Primary endpoints:
  - Length of stay in hospital-
    - Reduced time to discharge by 7.6h
    - Greater number of patients discharged directly from the ED (47% vs 12%)
    - Improved clinical decision making
  - No difference in major adverse cardiovascular events at 28 days.
- Secondary endpoints:
  - Number of diagnostic investigations were increased in CT arm
  - Costs were unchanged in CT arm
  - Radiation dose was slightly higher in CT arm

CT in ER ROMICAT II sub-study

2y follow-up:

- No / minimal CAD (183 patients)-
  - No MACE
- Non-obstructive (<50% stenosis) (117 patients):
  - 30 days-4 (1.3)
  - 1 year: 4 (1.3)
  - 2 year: 5 (1.8)

Guidelines:

Journal of the American College of Cardiology
© 2010 by the American College of Cardiology Foundation
Published by Elsevier Inc.

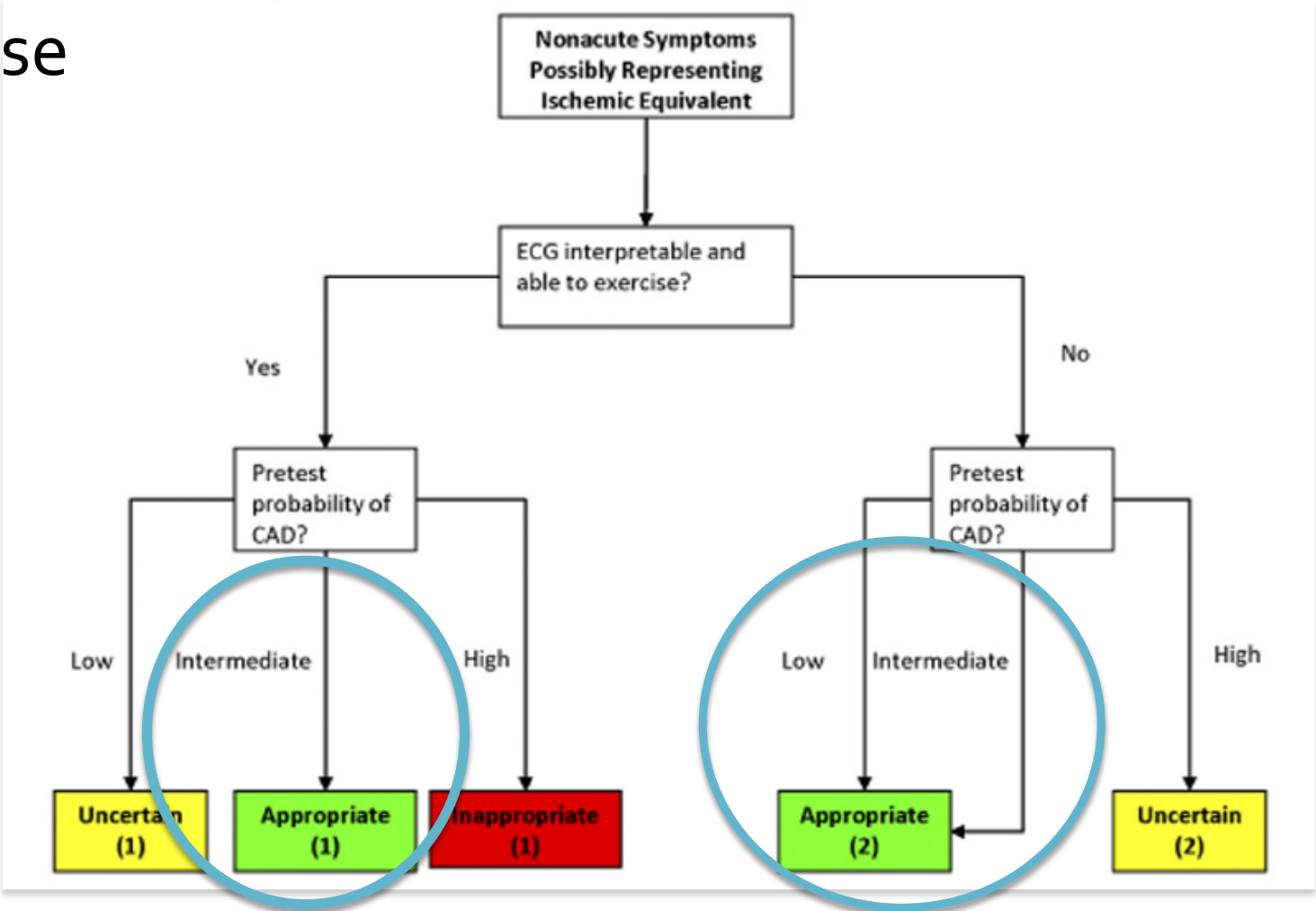
Vol. 56, No. xx, 2010
ISSN 0735-1097/$36.00
doi:10.1016/j.jacc.2010.07.005

APPROPRIATE USE CRITERIA

ACCF/SCCT/ACR/AHA/ASE/ASNC/SCAI/SCMR 2010 Appropriate Use Criteria for Cardiac Computed Tomography

Stable ischemic heart disease

- Symptomatic patients Without Known Heart Disease



Appropriate Use Criteria | February 2014

ACCF/AHA/ASE/ASNC/HFSA/HRS/SCAI/SCCT/SCMR/STS 2013 Multimodality Appropriate Use Criteria for the Detection and Risk Assessment of Stable Ischemic Heart Disease

Stable symptomatic Patients:

- trend toward functional imaging over CCTA as a primary test

Refer to pages 16 and 17 for relevant definitions, in particular Table A and text for age, sex, symptom presentation, and risk factors relevant to each pre-test probability category

Indication Text		Exercise ECG	Stress RNI	Stress Echo	Stress CMR	Calcium Scoring	CCTA	Invasive Coronary Angiography
1.	• Low pre-test probability of CAD • ECG interpretable AND able to exercise	A	R	M	R	R	R	R
2.	• Low pre-test probability of CAD • ECG uninterpretable OR unable to exercise		A	A	M	R	M	R
3.	• Intermediate pre-test probability of CAD • ECG interpretable AND able to exercise	A	A	A	M	R	M	R
4.	• Intermediate pre-test probability of CAD • ECG uninterpretable OR unable to exercise		A	A	A	R	A	M
5.	• High pre-test probability of CAD ECG interpretable AND able to exercise	M	A	A	A	R	M	A
6.	• High pre-test probability of CAD • ECG uninterpretable OR unable to exercise		A	A	A	R	M	A

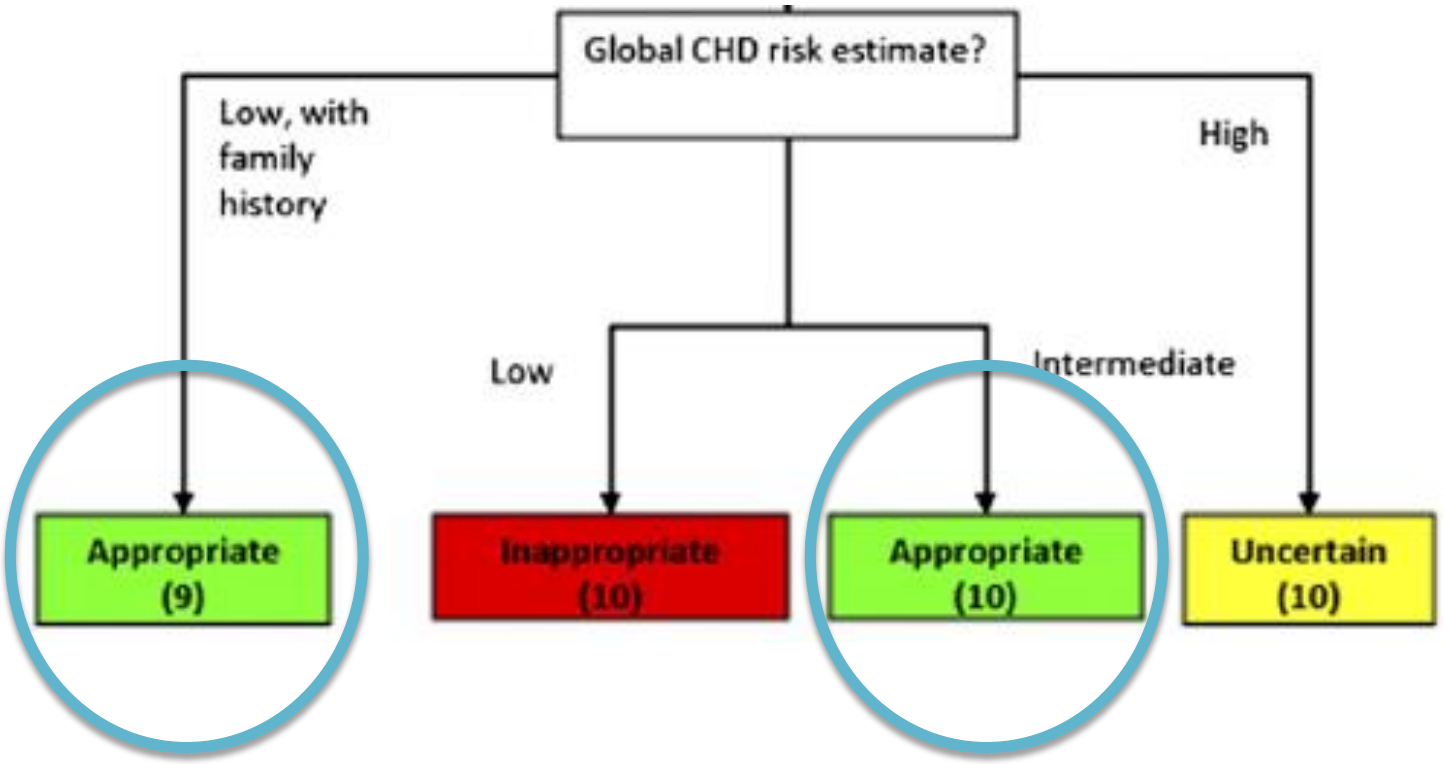
Sequential Testing (≤90 Days): Uncertain Prior Results

- Appropriate if uncertain or abnormal functional test such as exercise ECG or stress imaging study.

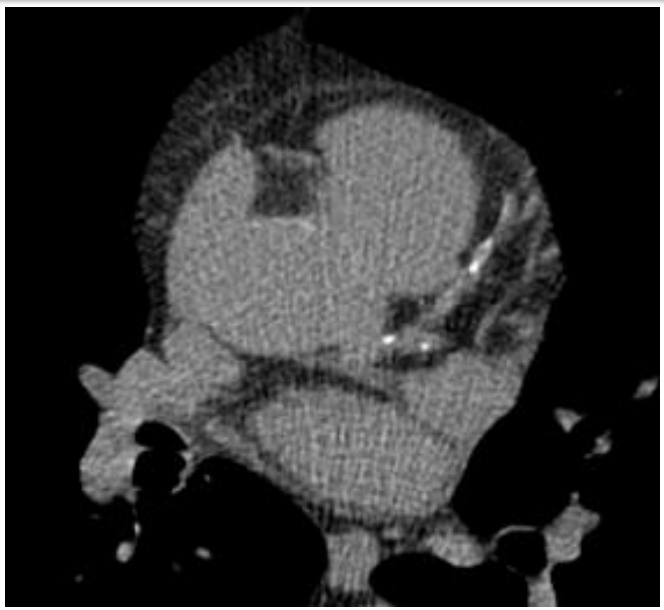
Indication text		Exercise ECG	Stress RNI	Stress Echo	Stress CMR	Calcium Scoring	CCTA	Invasive Coronary Angiography
Equivocal, Borderline, or Discordant Prior Noninvasive Evaluation Where Obstructive CAD Remains a Concern								
30.	• Prior exercise ECG test		A	A	A	R	A	M
31.	• Prior stress imaging study (assumes not repeat of same type of stress imaging)	R	M	M	M	R	A	A
32.	• Prior CCTA	M	A	A	A			A
Prior Coronary Angiography (Invasive or Noninvasive)								
33.	• Coronary stenosis or anatomic abnormality of unclear significance found on cardiac CCTA	M	A	A	A			A
34.	• Coronary stenosis or anatomic abnormality of unclear significance on previous coronary angiography	M	A	A	A	R	R	

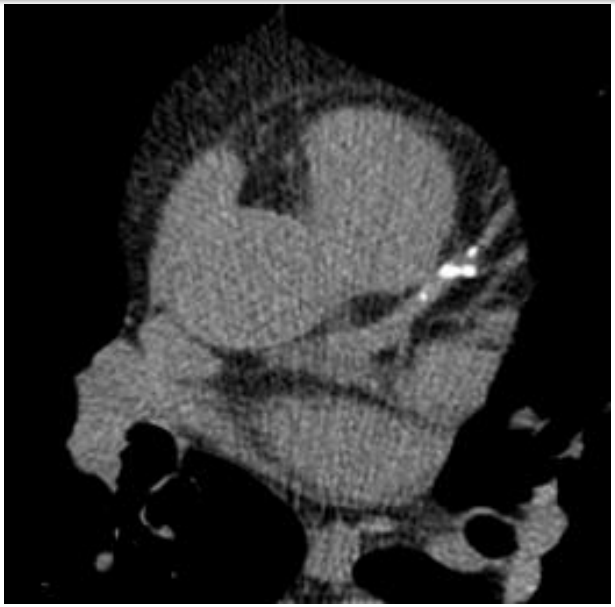
Detection of CAD/Risk Assessment: Asymptomatic individuals

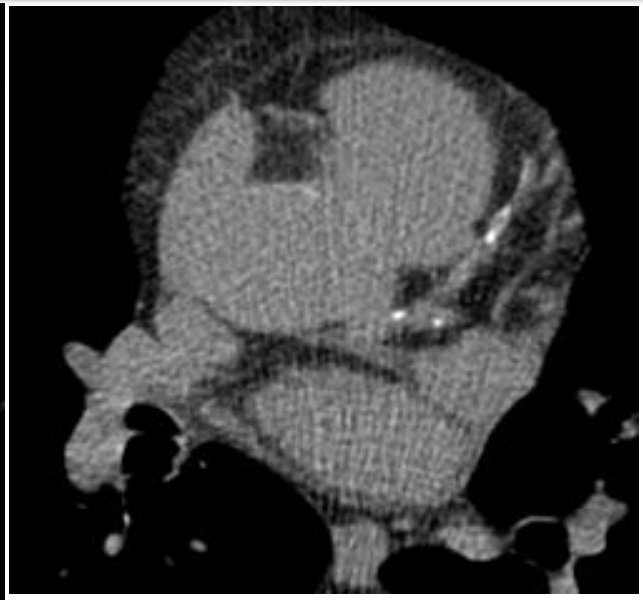
- Without Known Heart Disease
- Calcium Scoring

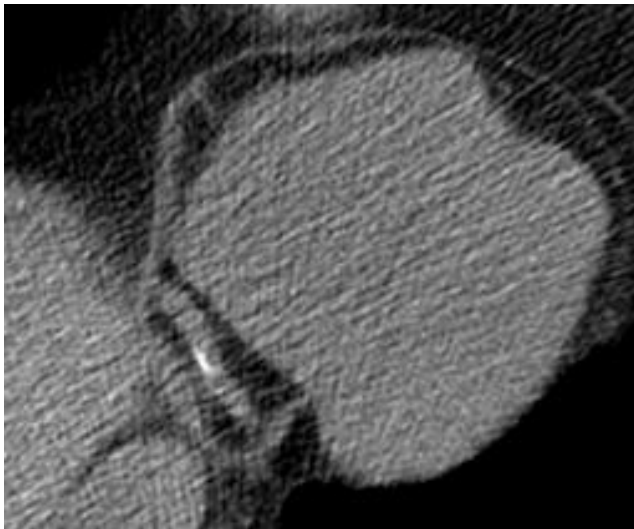


Calcium Score:









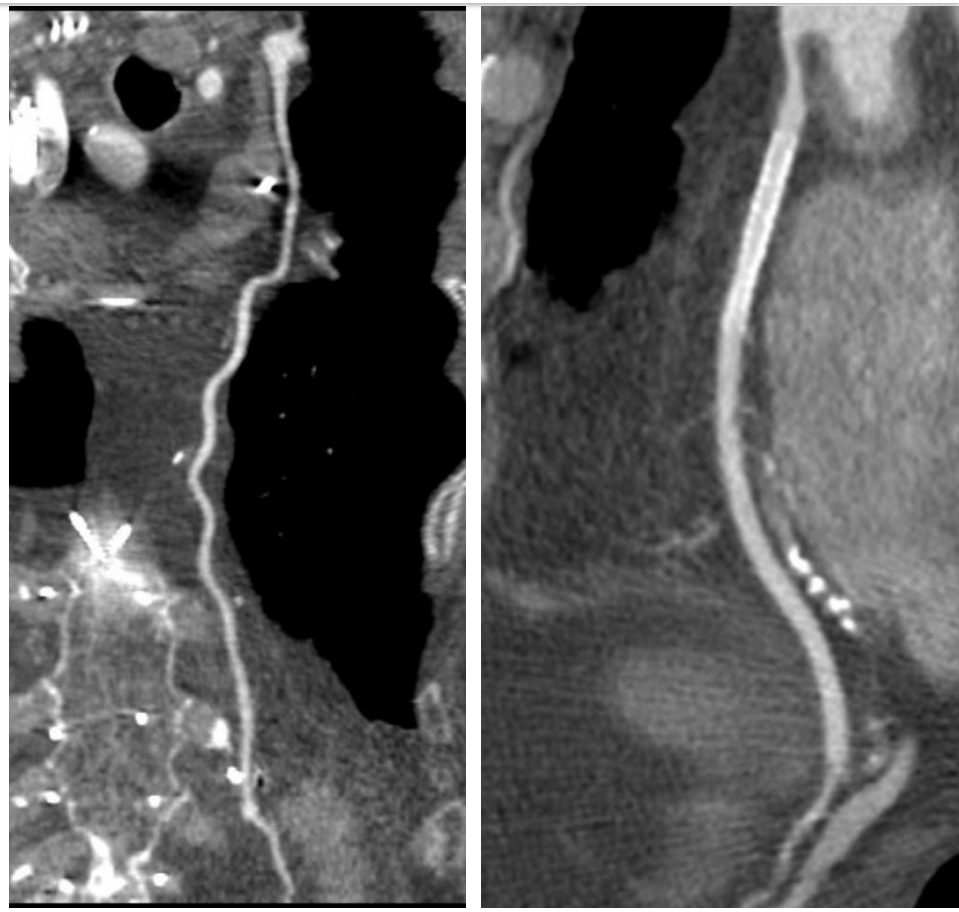
ACCF/SCCT/ACR/AHA/ASE/ASNC/SCAI/SCMR 2010 Appropriate Use Criteria for Cardiac Computed Tomography

	Indication	Appropriate Use Score (1–9)
	Risk Assessment Postrevascularization (PCI or CABG)—Asymptomatic—Prior Coronary Stenting	
43.	• Prior left main coronary stent with stent diameter ≥3 mm	A (7)
	Evaluation of Cardiac Structure and Function—Adult Congenital Heart Disease	
46.	• Assessment of anomalies of coronary arterial and other thoracic arteriovenous vessels	A (9)
47.	• Assessment of complex adult congenital heart disease	A (8)
	Evaluation of Cardiac Structure and Function—Evaluation of Ventricular Morphology and Systolic Function	
49.	• Evaluation of left ventricular function • Following acute MI or in HF patients • Inadequate images from other noninvasive methods	A (7)
50.	• Quantitative evaluation of right ventricular function	A (7)
51.	• Assessment of right ventricular morphology • Suspected arrhythmogenic right ventricular dysplasia	A (7)
	Evaluation of Cardiac Structure and Function—Evaluation of Intra- and Extracardiac Structures	
53.	• Characterization of native cardiac valves • Suspected clinically significant valvular dysfunction • Inadequate images from other noninvasive methods	A (8)
54.	• Characterization of prosthetic cardiac valves • Suspected clinically significant valvular dysfunction • Inadequate images from other noninvasive methods	A (8)
56.	• Evaluation of cardiac mass (suspected tumor or thrombus) • Inadequate images from other noninvasive methods	A (8)
57.	• Evaluation of pericardial anatomy	A (8)
58	• Evaluation of pulmonary vein anatomy • Prior to radiofrequency ablation for atrial fibrillation	A (8)
59.	• Noninvasive coronary vein mapping • Prior to placement of biventricular pacemaker	A (8)
60.	• Localization of coronary bypass grafts and other retrosternal anatomy • Prior to reoperative chest or cardiac surgery	A (8)

Different Uses:

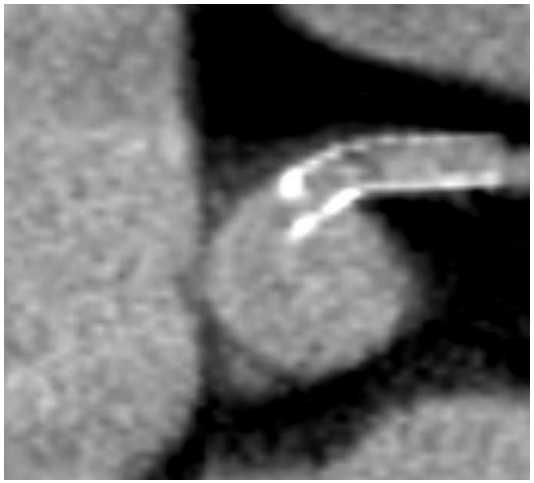
ACCF/SCCT/ACR/AHA/ASE/ASNC/SCAI/SCMR
2010 Appropriate Use Criteria
for Cardiac Computed Tomography

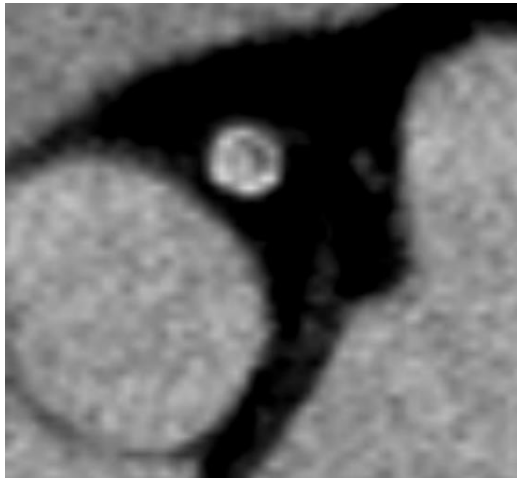
- Bypass grafts



Different Uses:

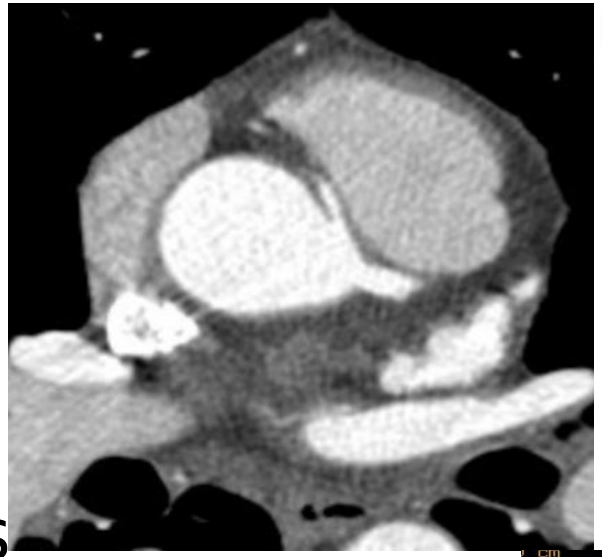
- Bypass grafts
- Stents (>3mm)

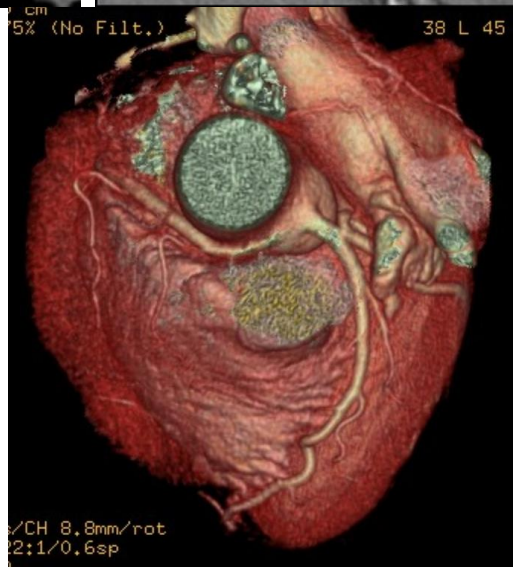




Different Uses:

- Bypass grafts
- Stents
- Coronary anomalies





Different Uses:

- Bypass grafts
- Stents
- Coronary anomalies
- Cardiac Masses / Pericardium

(Left atrial myxoma)

(LV thrombus)

Different Uses:

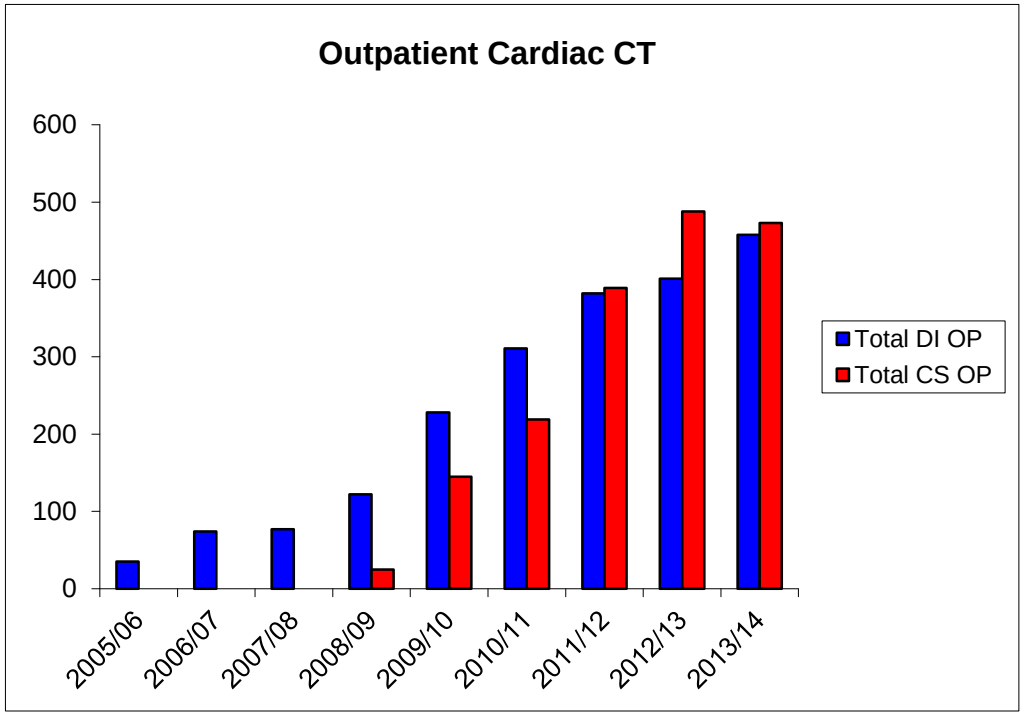
- Bypass grafts
- Stents
- Coronary anomalies
- Cardiac Masses / Pericardium
- Adult congenital heart disease

(Left atrial myxoma)

(LV thrombus)

Out-patient volumes:

- 2012-13: 889
- 2013-14 (to Dec): 930



Summary

- Role of coronary CTA is still evolving
  - Acute chest pain
  - Stable chest pain
- Very good at ruling out coronary disease
  - if positive, another test may be required.
  - Useful when another functional exam is abnormal or equivocal.

Future Directions:

- Coronary CT FFR
- CT perfusion

FACULTY OF HEALTH SCIENCES
AARHUS UNIVERSITY

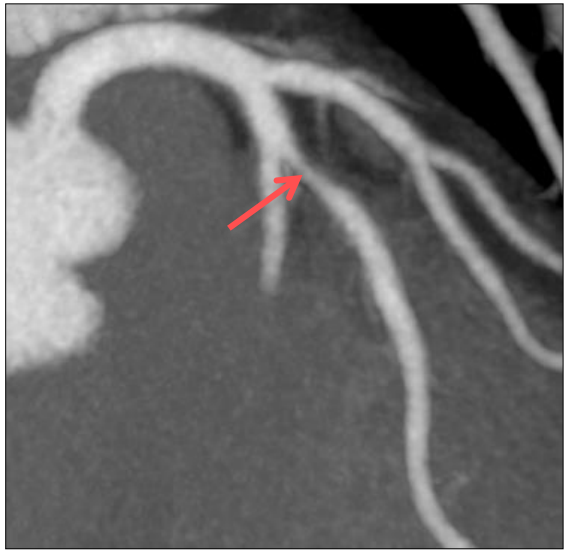
Diagnostic performance of non-invasive fractional flow reserve derived from coronary CT angiography in suspected coronary artery disease: The NXT trial

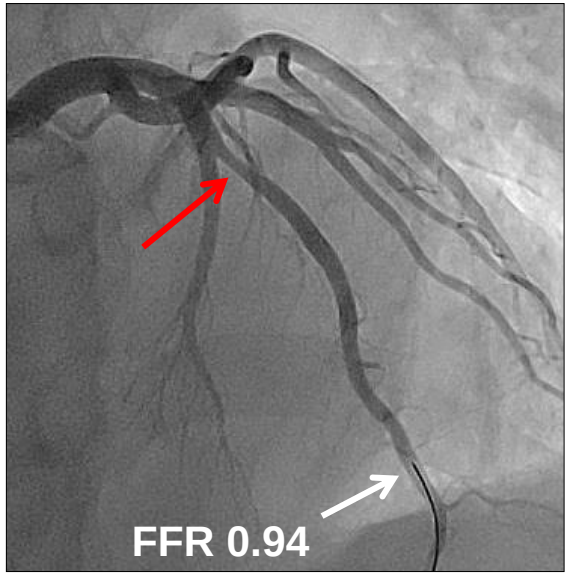
Bjarne L. Nørgaard, Jonathon Leipsic, Sara Gaur, Sujith Seneviratne, Brian S. Ko, Hiroshi Ito, Jesper M. Jensen, Laura Mauri, Bernard De Bruyne, Hiram Bezerra, Kazuhiro Osawa, Mohamed Marwan, Christoph Naber, Andrejs Erglis, Seung-Jung Park, Evald H. Christiansen, Anne Kaltoft, Jens F. Lassen, Hans Erik Bøtker, Stephan Achenbach

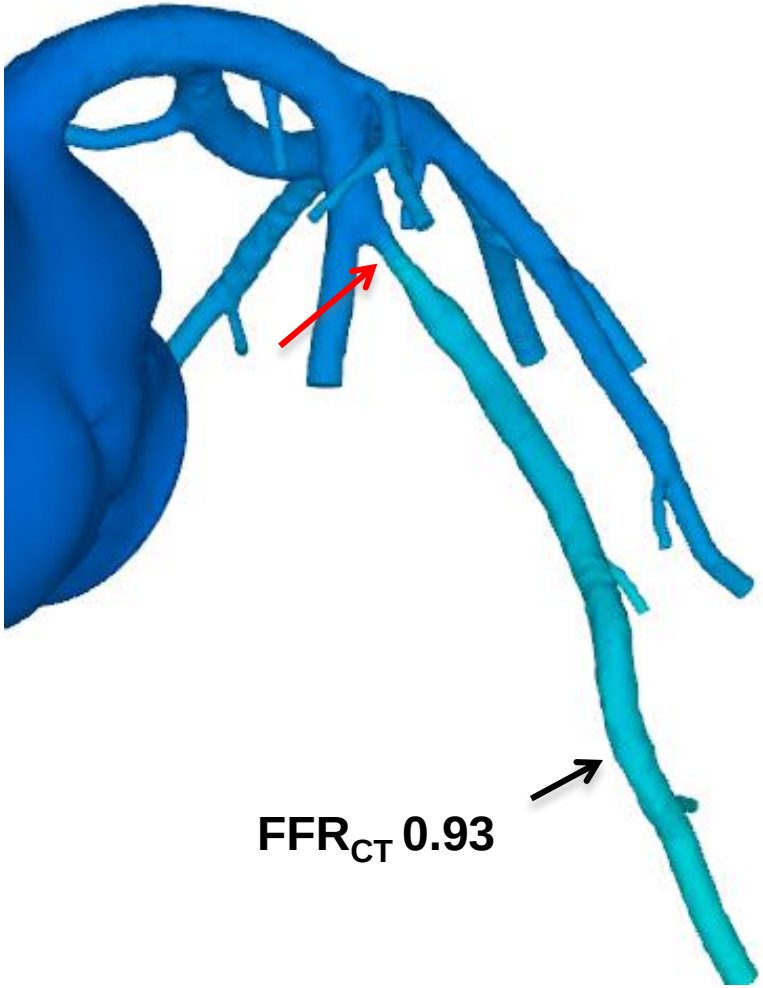
For the NXT Investigators

Case Example

LAD stenosis 70-90%







FFR_{CT} Model

CORE 320

CTA
50% Stenosis

+

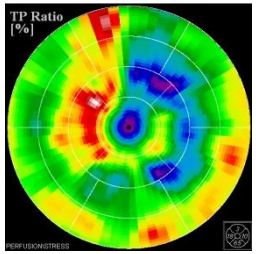
CTP
Perfusion Defect

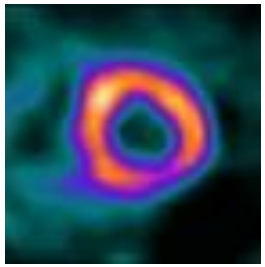
VS

QCA
50% Stenosis

+

SPECT
Perfusion Defect





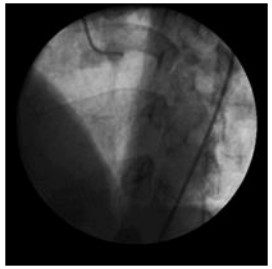
CTA
50% Stenosis

+

CTP
Perfusion Defect

VS

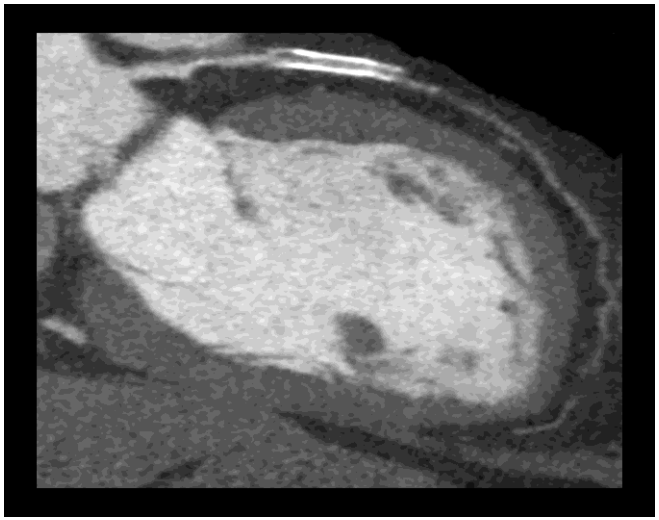
QCA
50% Stenosis

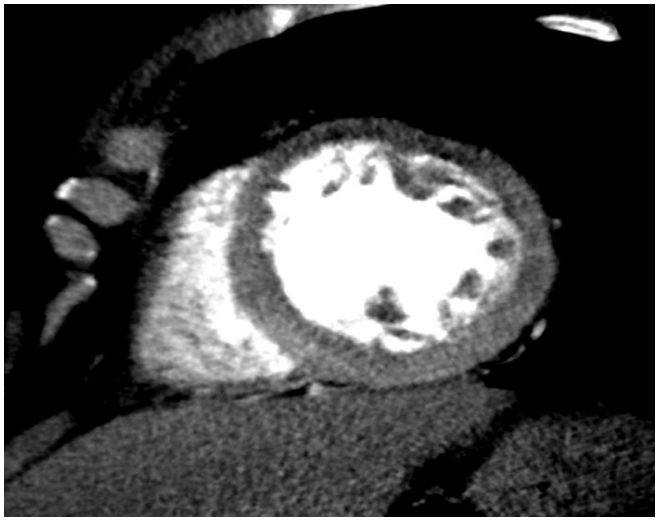


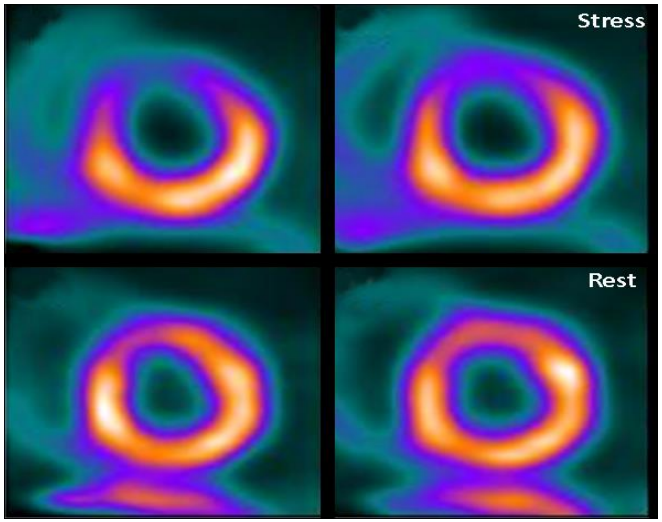
Source: Rochitte et al. Nov 2013

CORE 320

CORE320 Complete Dataset







Scenario 2:

- For Asymptomatic patients risk factor assessment using calcium scoring is appropriate in:
  - Intermediate risk patients
  - Low risk patients with family history

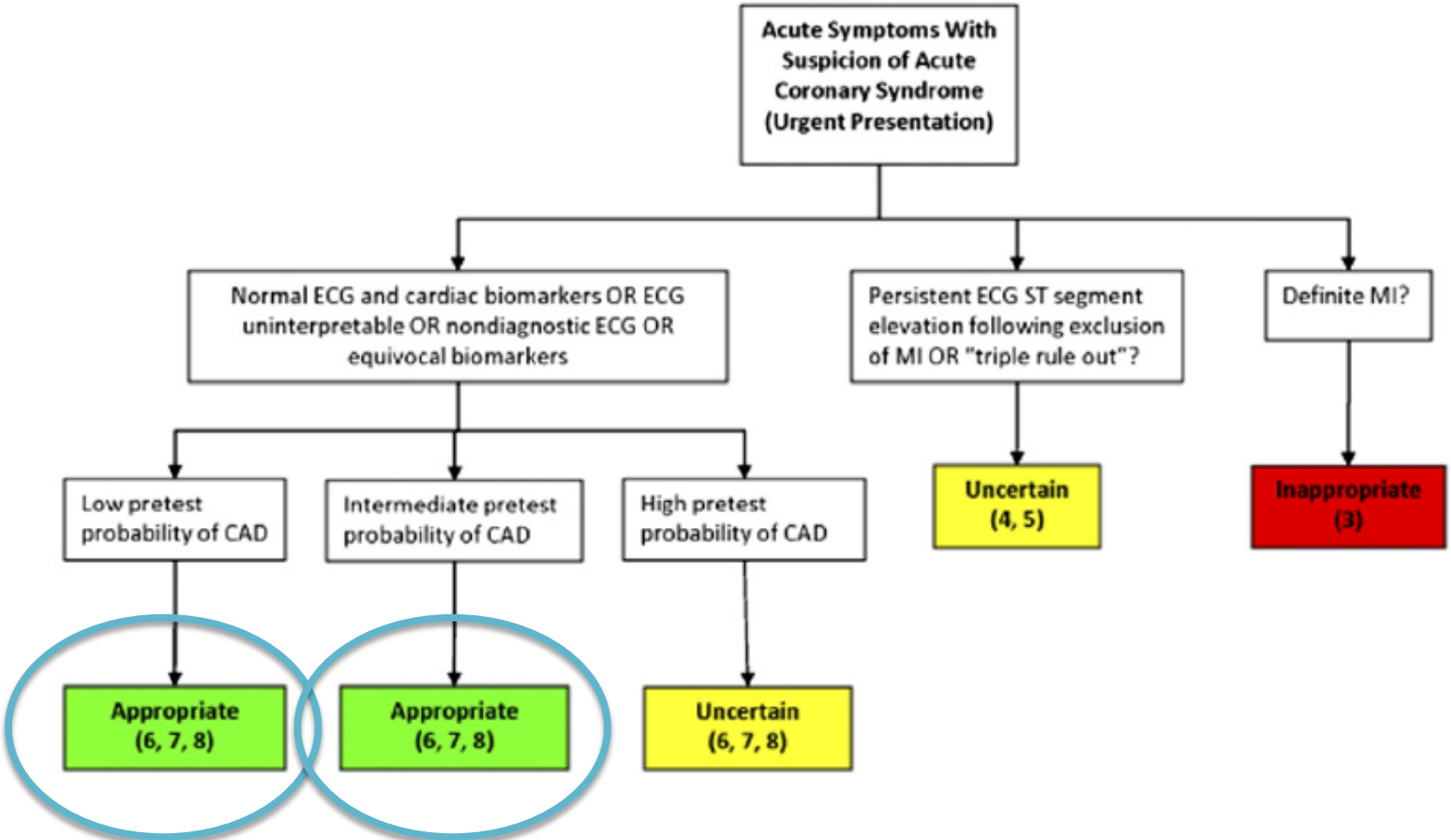
Journal of the American College of Cardiology
© 2010 by the American College of Cardiology Foundation
Published by Elsevier Inc.
Vol. 56, No. xx, 2010
ISSN 0735-1097/$36.00
doi:10.1016/j.jacc.2010.07.005

APPROPRIATE USE CRITERIA

ACCF/SCCT/ACR/AHA/ASE/ASNC/SCAI/SCMR 2010 Appropriate Use Criteria for Cardiac Computed Tomography

Detection of CAD in Symptomatic Patients: Acute Presentation

- Without Known Heart Disease



Journal of the American College of Cardiology
Published by Elsevier Inc.

Vol. 56, No. xx, 2010
ISSN 0735-1097/$36.00
doi:10.1016/j.jacc.2010.07.005

APPROPRIATE USE CRITERIA

ACCF/SCCT/ACR/AHA/ASE/ASNC/SCAI/SCMR 2010 Appropriate Use Criteria for Cardiac Computed Tomography

Summary:

- " In general, use of CCT angiography for diagnosis and risk assessment in patients with low or intermediate risk or pretest probability for coronary artery disease (CAD) was viewed favorably"

- " Testing in high-risk patients, routine repeat testing, and general screening in certain clinical scenarios were viewed less favorably."

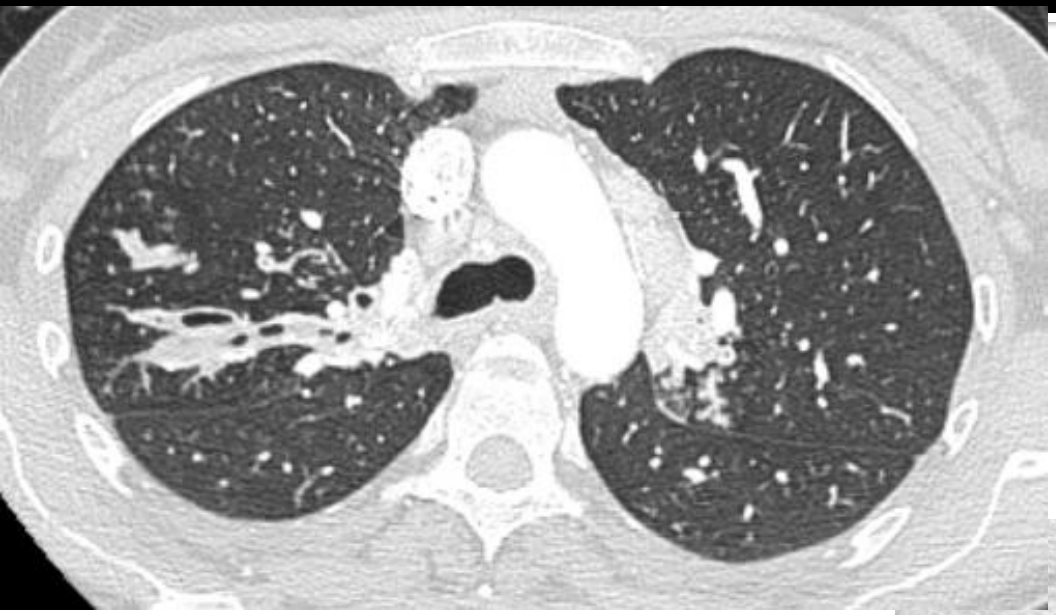
Summary:

- Use of noncontrast computed tomography (CT) for calcium scoring was rated as appropriate within intermediate- and selected low-risk patients.
- Appropriate applications of CCT are also within the category of cardiac structural and functional evaluation.

Anomalous origin of Right Coronary Artery

- Coronary anomalies are reported in 0.3-1.3% of population.
- Most are not felt to be hemodynamically significant.
- Malignant Course:
  - Carry risk of sudden death; artery impinged upon RVOT during exercise
    - Interarterial Course: Right> Left

Extracoronary Findings:
History- 49 y woman with dyspnea on excertion



Another Meta-analysis

Journal of the American College of Cardiology
© 2011 by the American College of Cardiology Foundation
Published by Elsevier Inc.

Vol. 57, No. 24, 2011
ISSN 0735-1097/$36.00
doi:10.1016/j.jacc.2010.12.043

Cardiac Imaging

Meta-Analysis and Systematic Review of the Long-Term Predictive Value of Assessment of Coronary Atherosclerosis by Contrast-Enhanced Coronary Computed Tomography Angiography

Fabian Bamberg, MD, MPH,*† Wieland H. Sommer, MD,† Verena Hoffmann, PHD,‡
Stephan Achenbach, MD,§ Konstantin Nikolaou, MD,† David Conen, MD, MPH,‖
Maximilian F. Reiser, MD,† Udo Hoffmann, MD, MPH,* Christoph R. Becker, MD†

Radiation Dose:

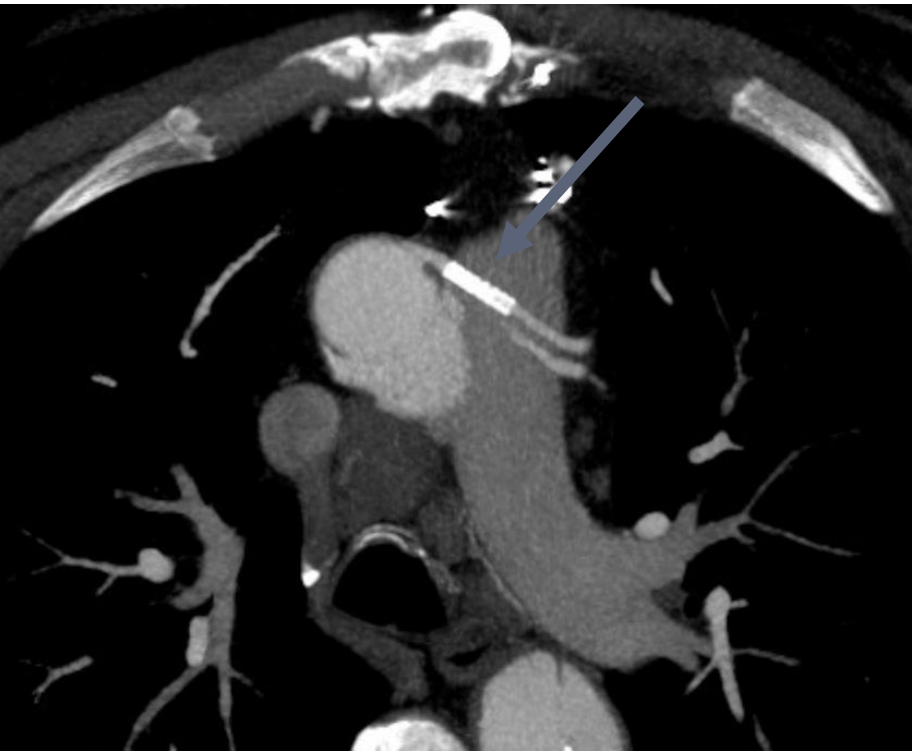
- Effective Dose (mSv)
  - Effective Dose= DLP x CT (chest) conversion coefficient (0.017)
    - DLP for entire scan
      - (scout, timed-dose, aortic root localization run)
      - DLP= CTDI x Z-axis scan length

Evaluation of bypass grafts

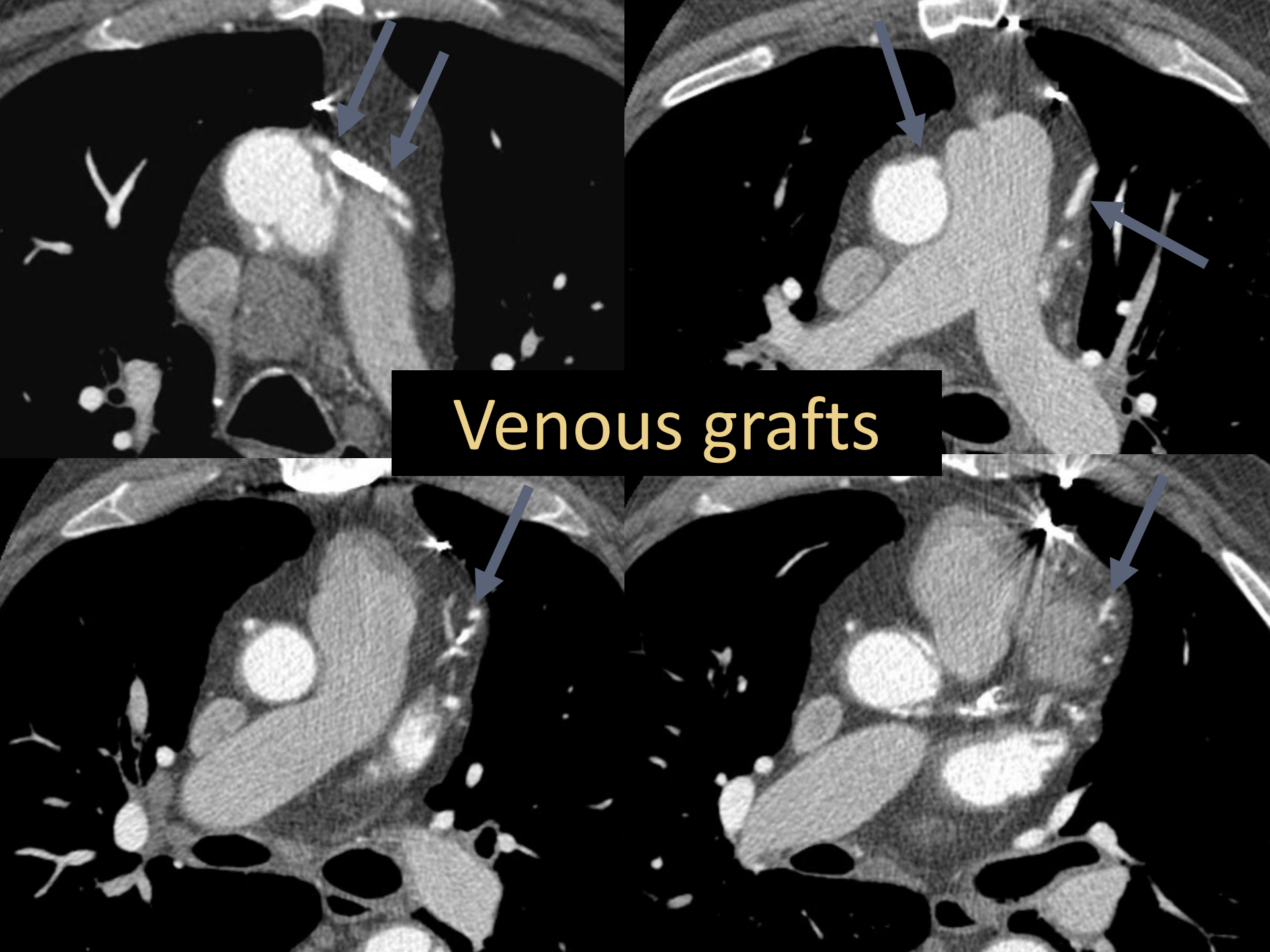
- Why it is easier
  - Larger size of vessels
  - Less cardiac motion
  - Less calcification in grafts
- Why it is harder
  - Clip artifact
  - Native coronaries heavily calcified

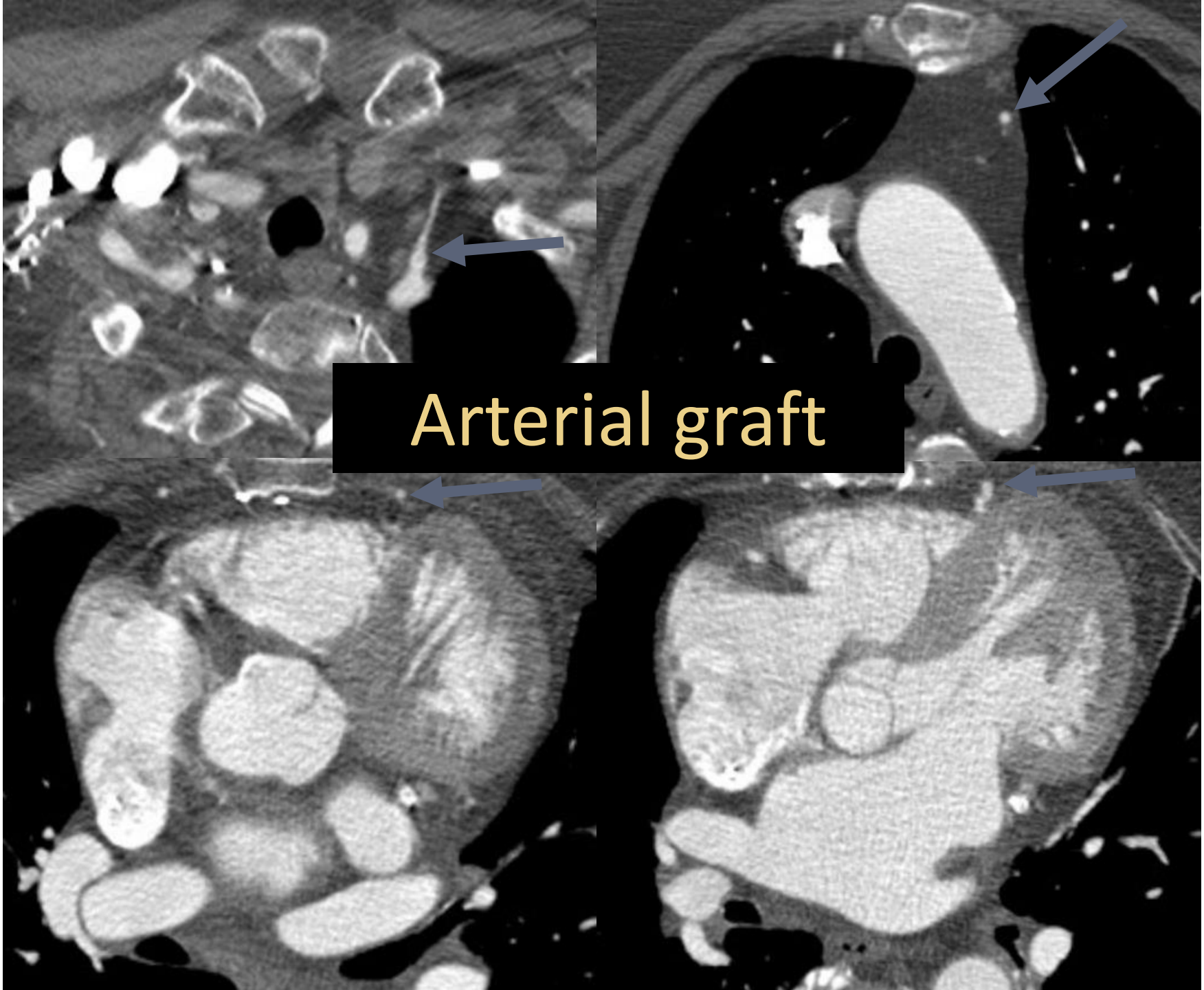
Grafts

Venous



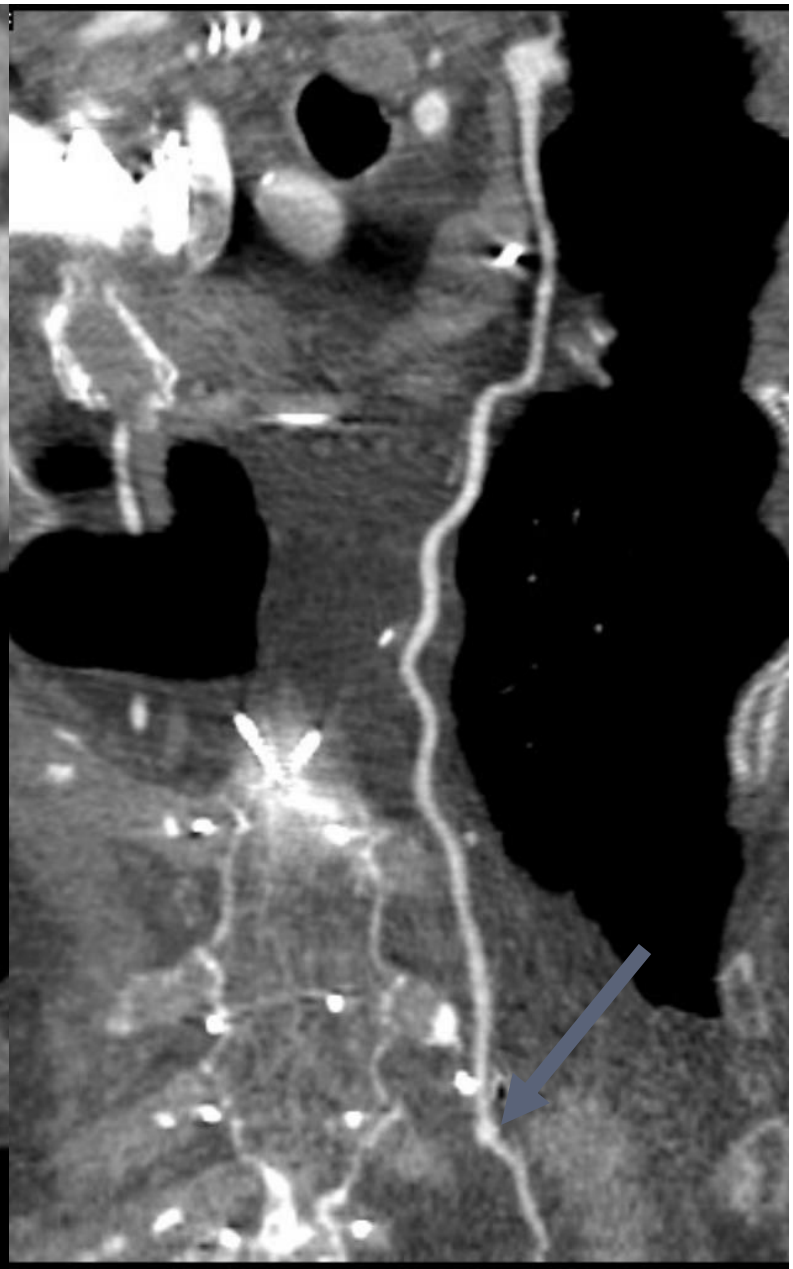
Arterial


Venous grafts


Arterial graft

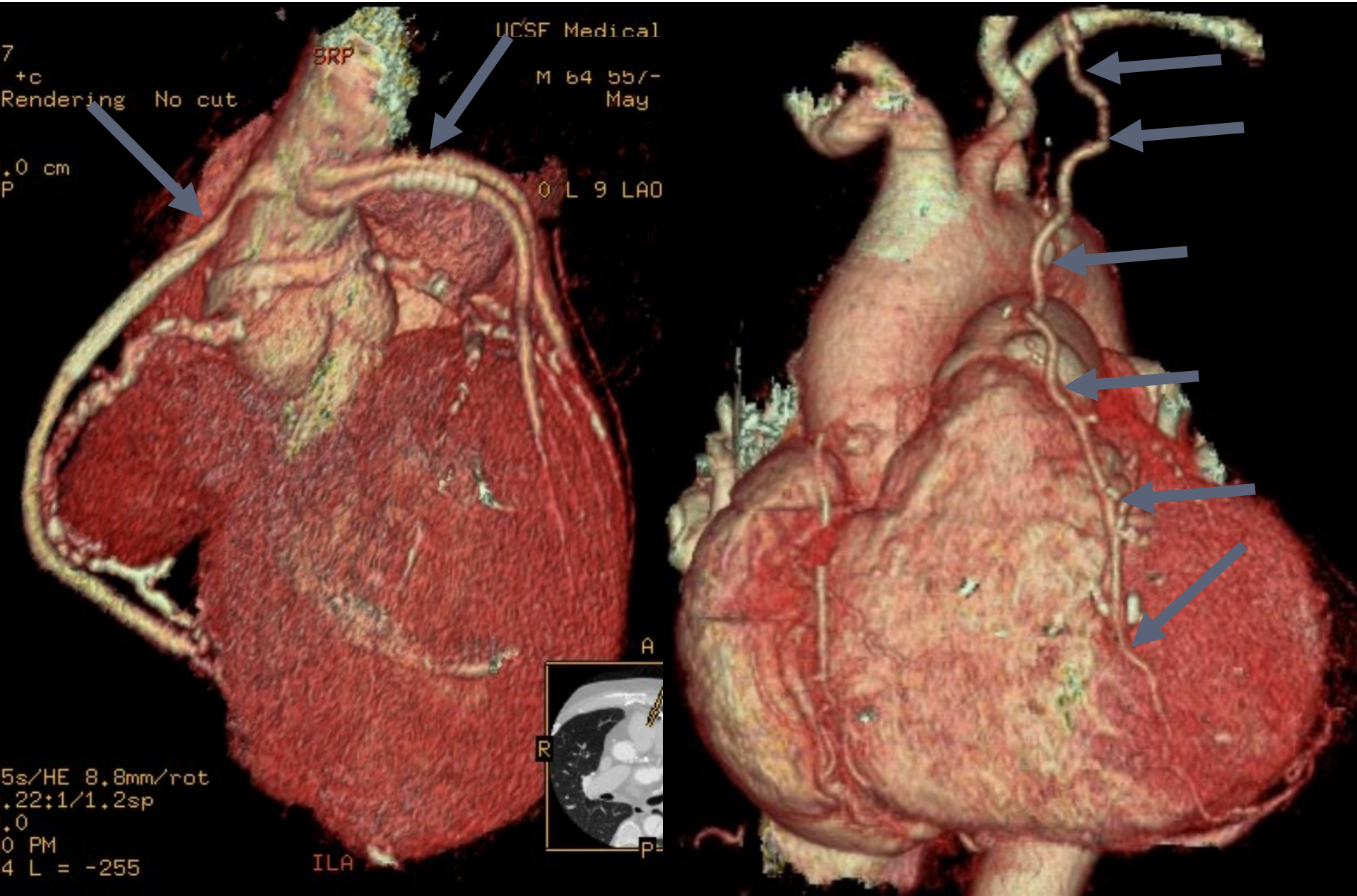
Venous

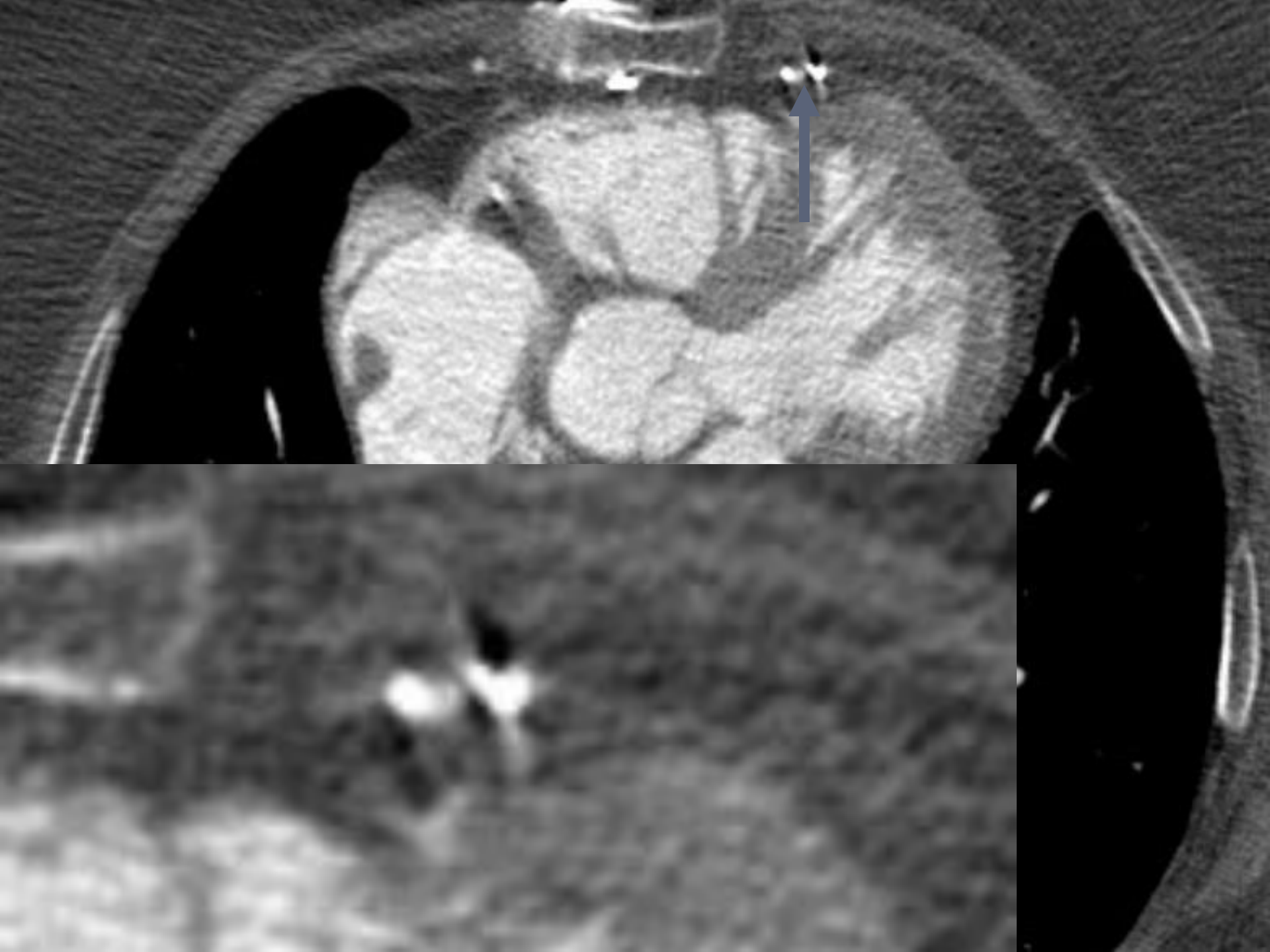
Arterial



Venous

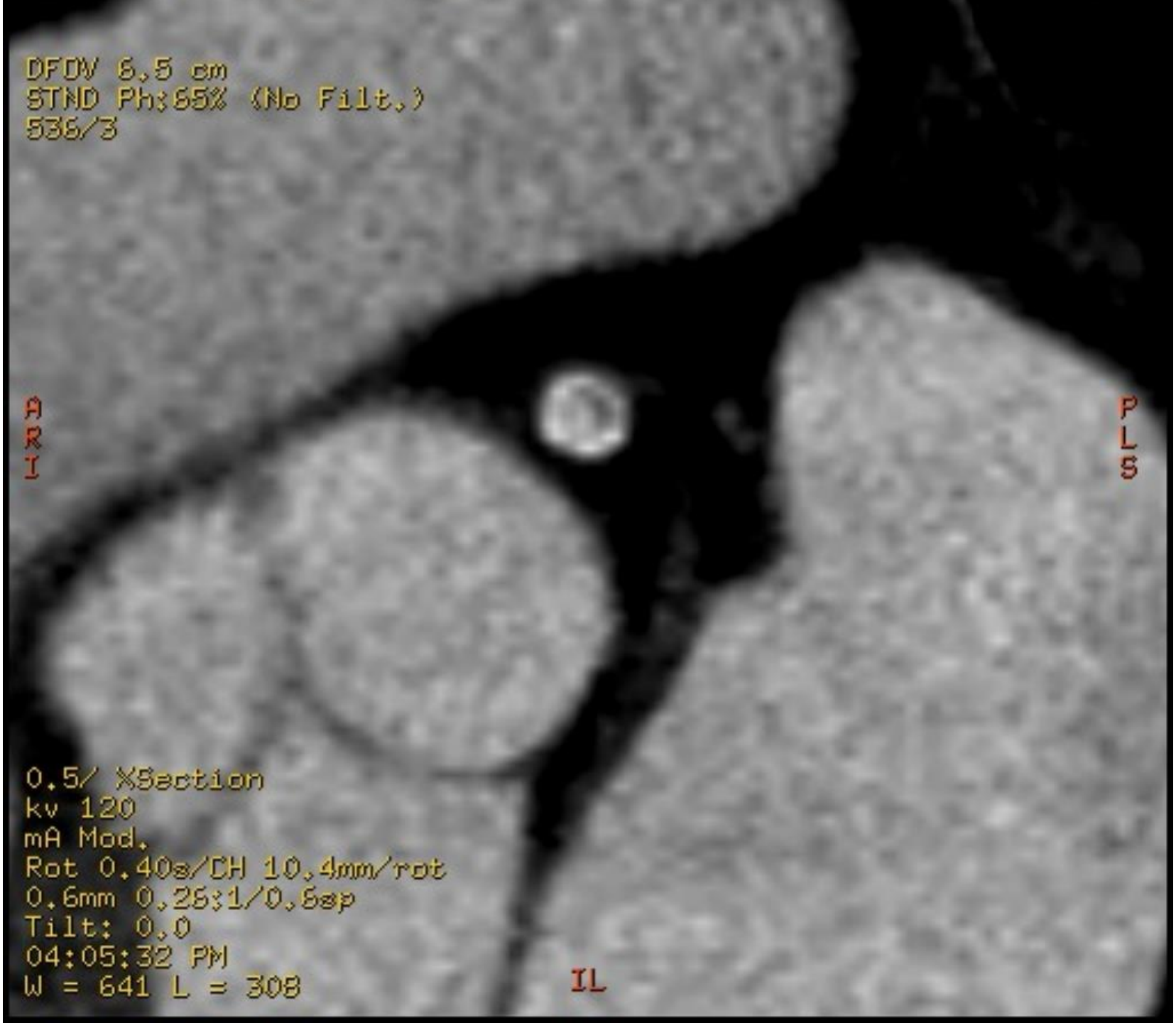
Arterial





Stent patency:


Left Main Artery Angle: 275.0
Jan 29 2007
DFOV 6.5 cm
STND Ph:65% (No Filt.)
536/1
R
L
kv 120
mA Mod.
Rot 0.40s/CH 10.4mm/rot
0.6mm 0.25:1/0.6sp
Tilt: 0.0
04:05:32 PM
W = 647 L = 293
I

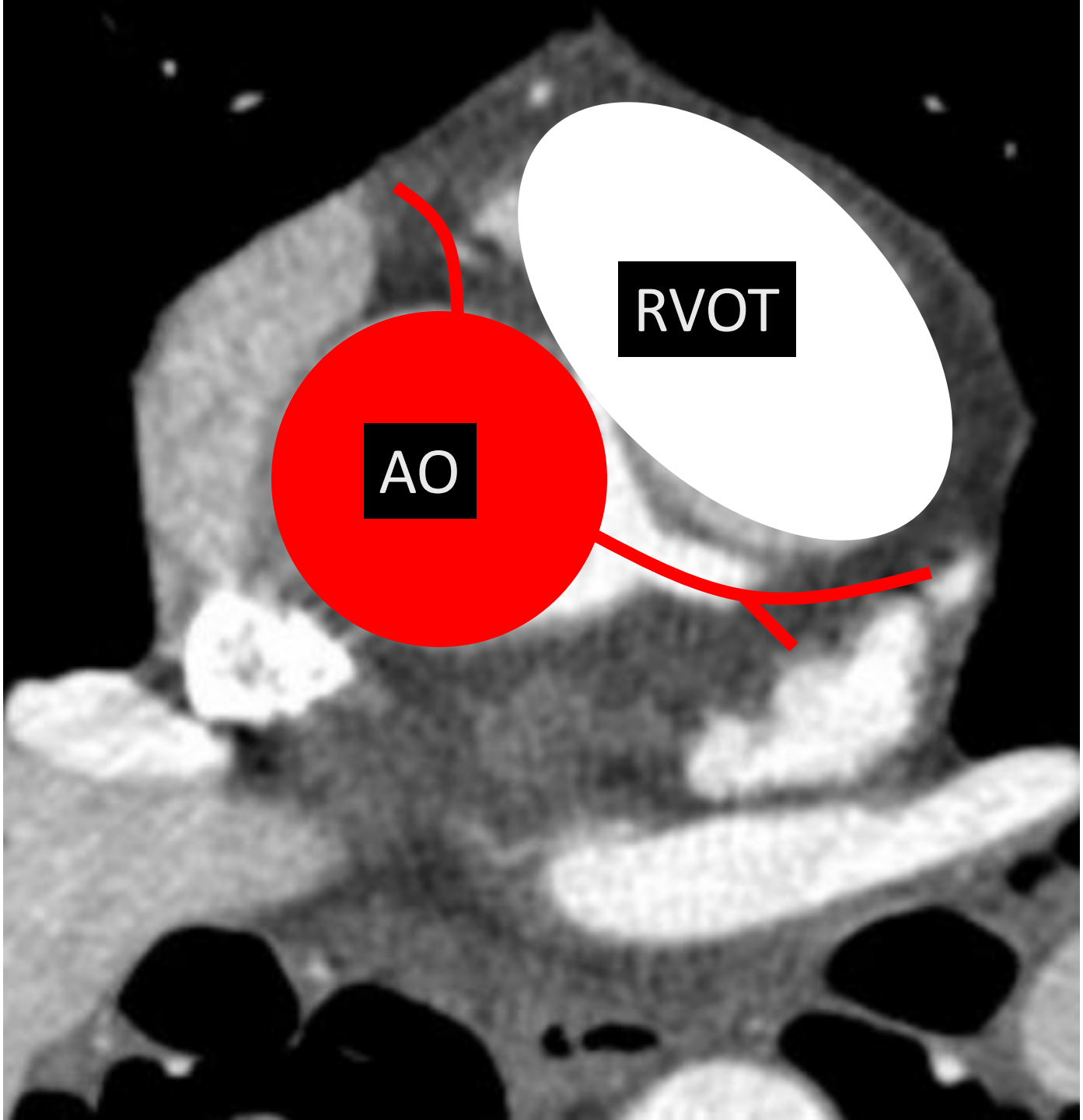

DFOV 6.5 cm
STND Ph:65% (No Filt.)
536/3
A
R
I
P
L
S
0.5/ XSection
kv 120
mA Mod.
Rot 0.40s/CH 10.4mm/rot
0.6mm 0.25:1/0.6sp
Tilt: 0.0
04:05:32 PM
W = 641 L = 308
IL

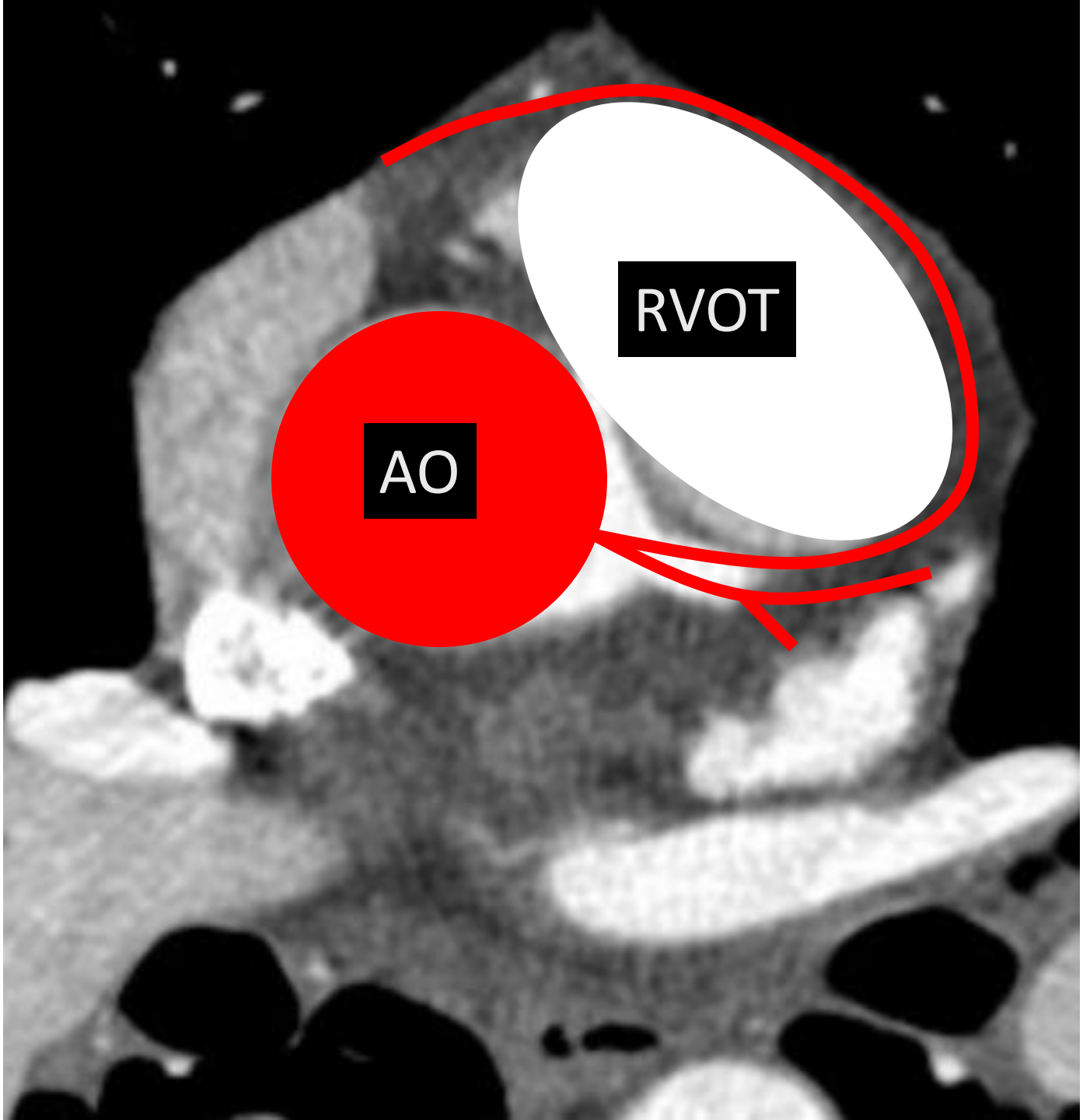
Coronary anomalies

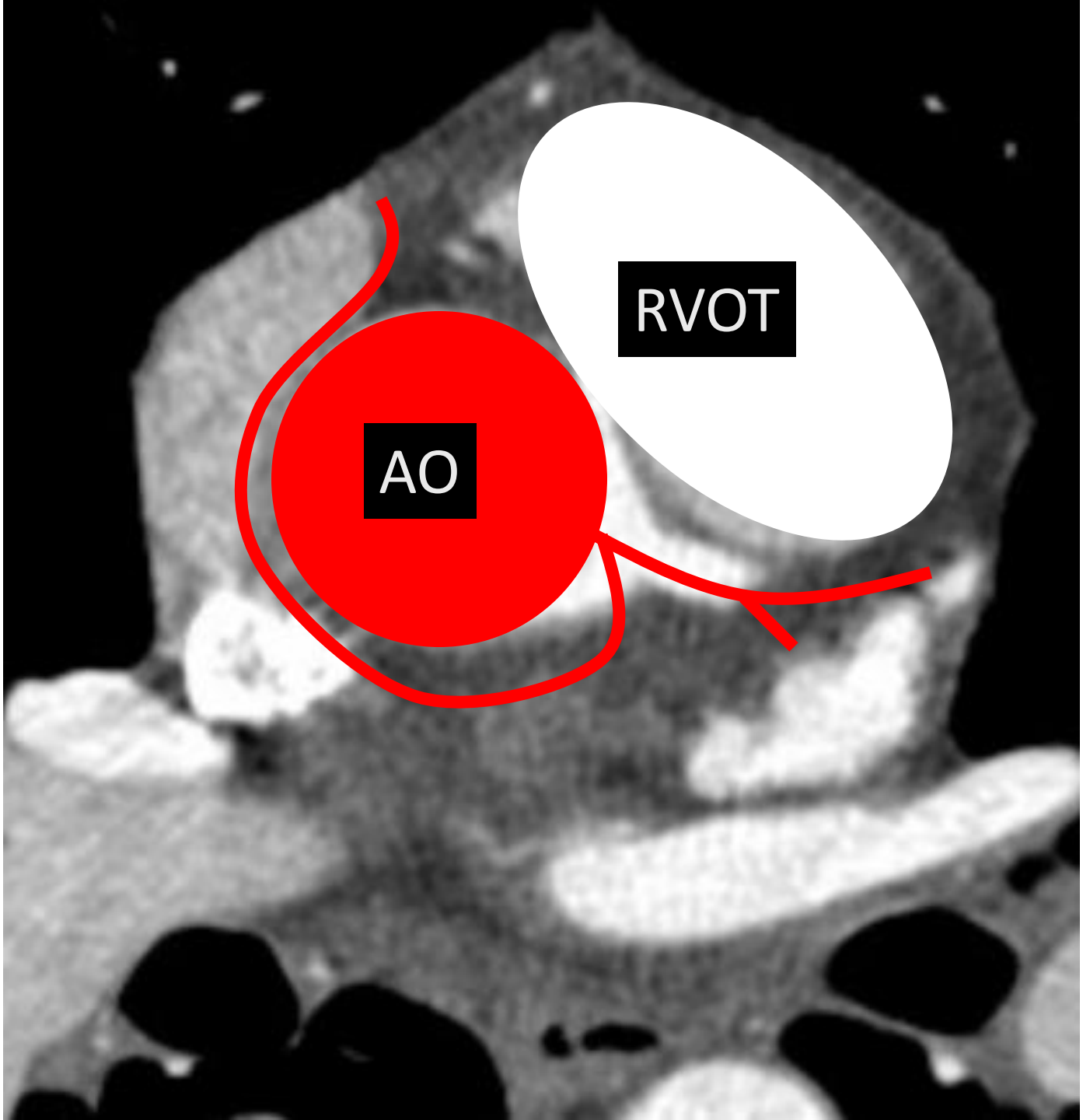
Coronary anomalies

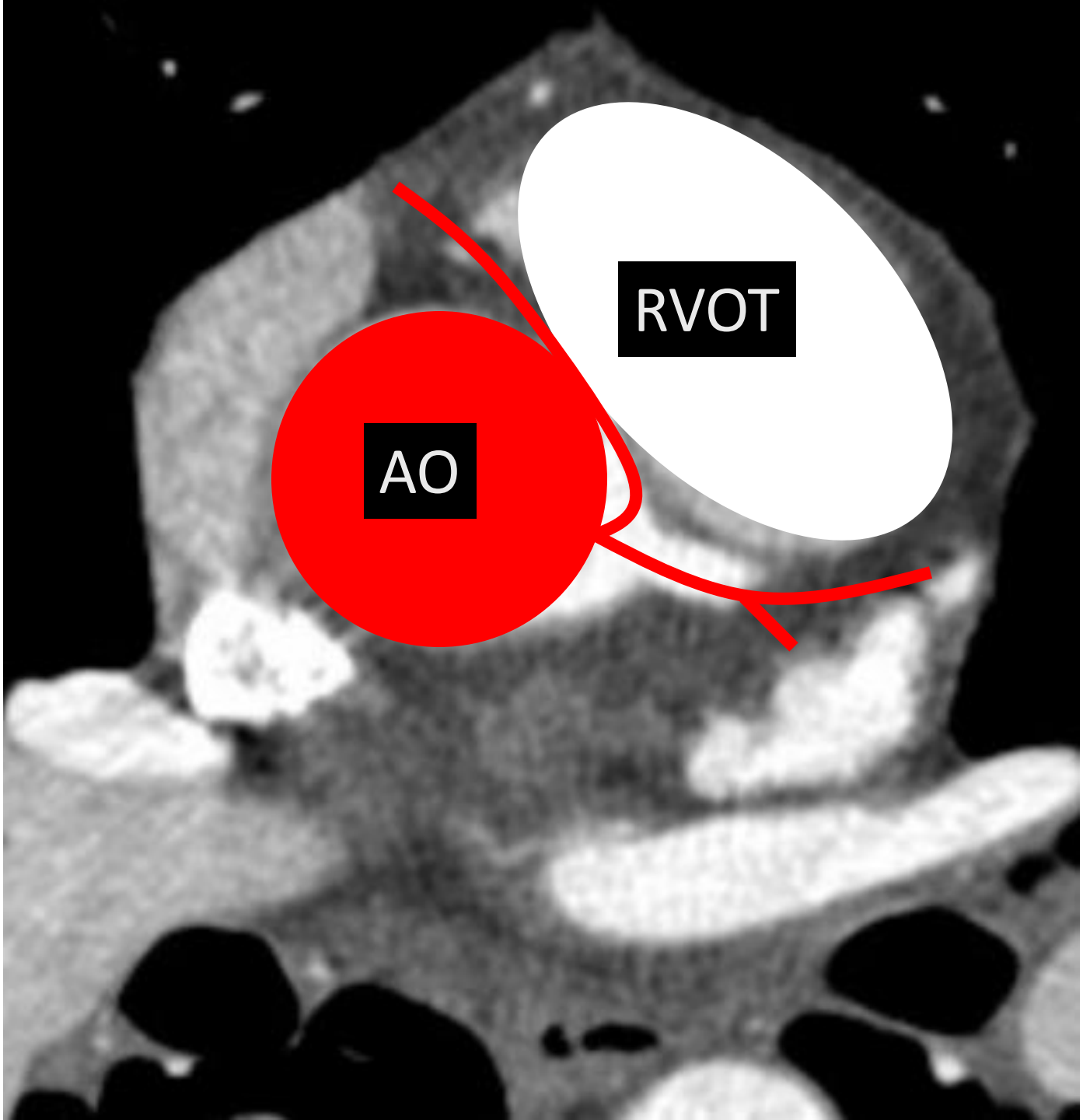
Shi. Eur Radiol. 2004; 14: 2172

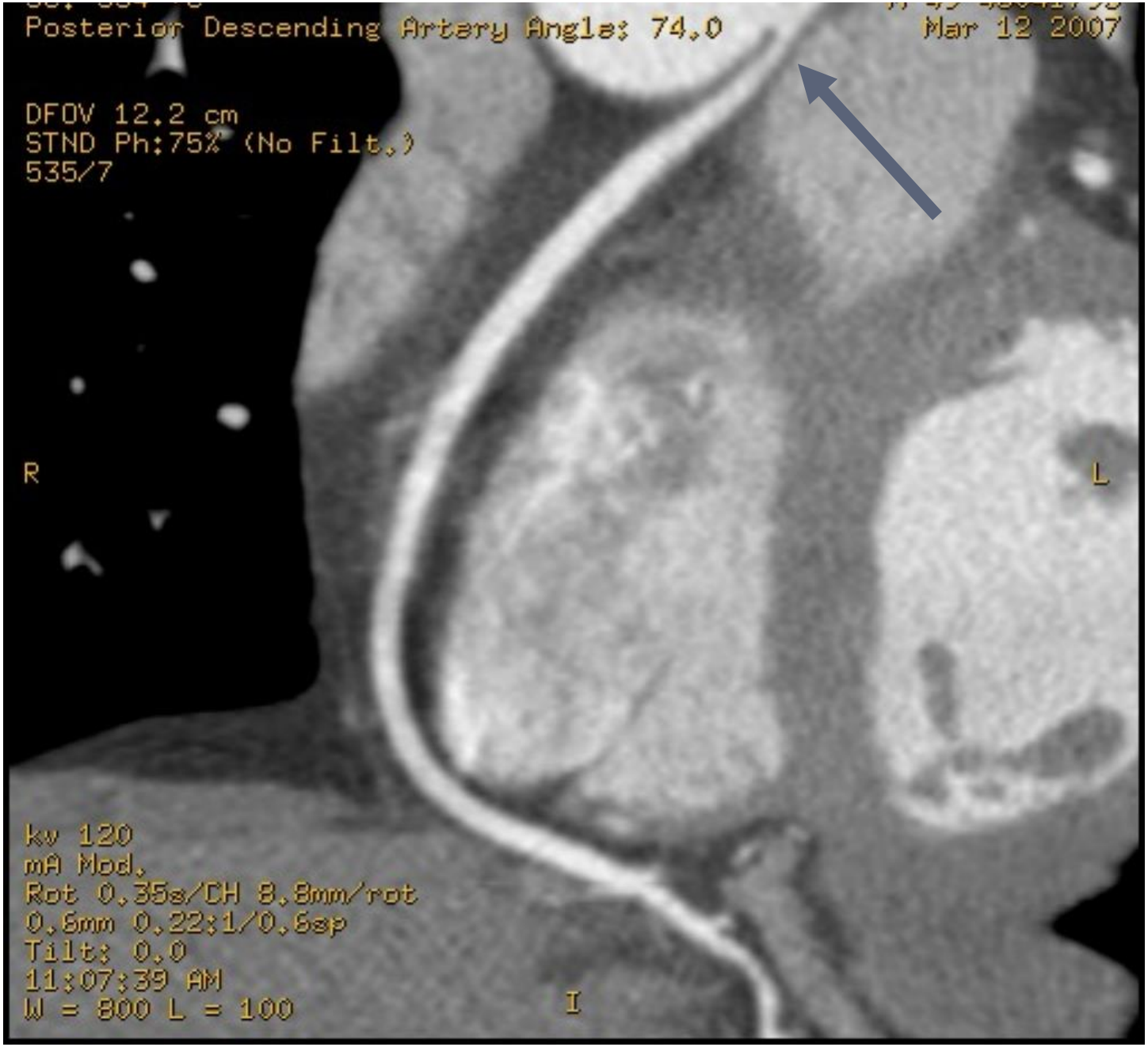
- 6.6% incidence (suspected CAD)
- 56% malignant course
- 100% diagnosis with MDCT
- 53% diagnosis with angiography
- Limitations of angio
  - Two dimensional modality
  - Selective canalization required

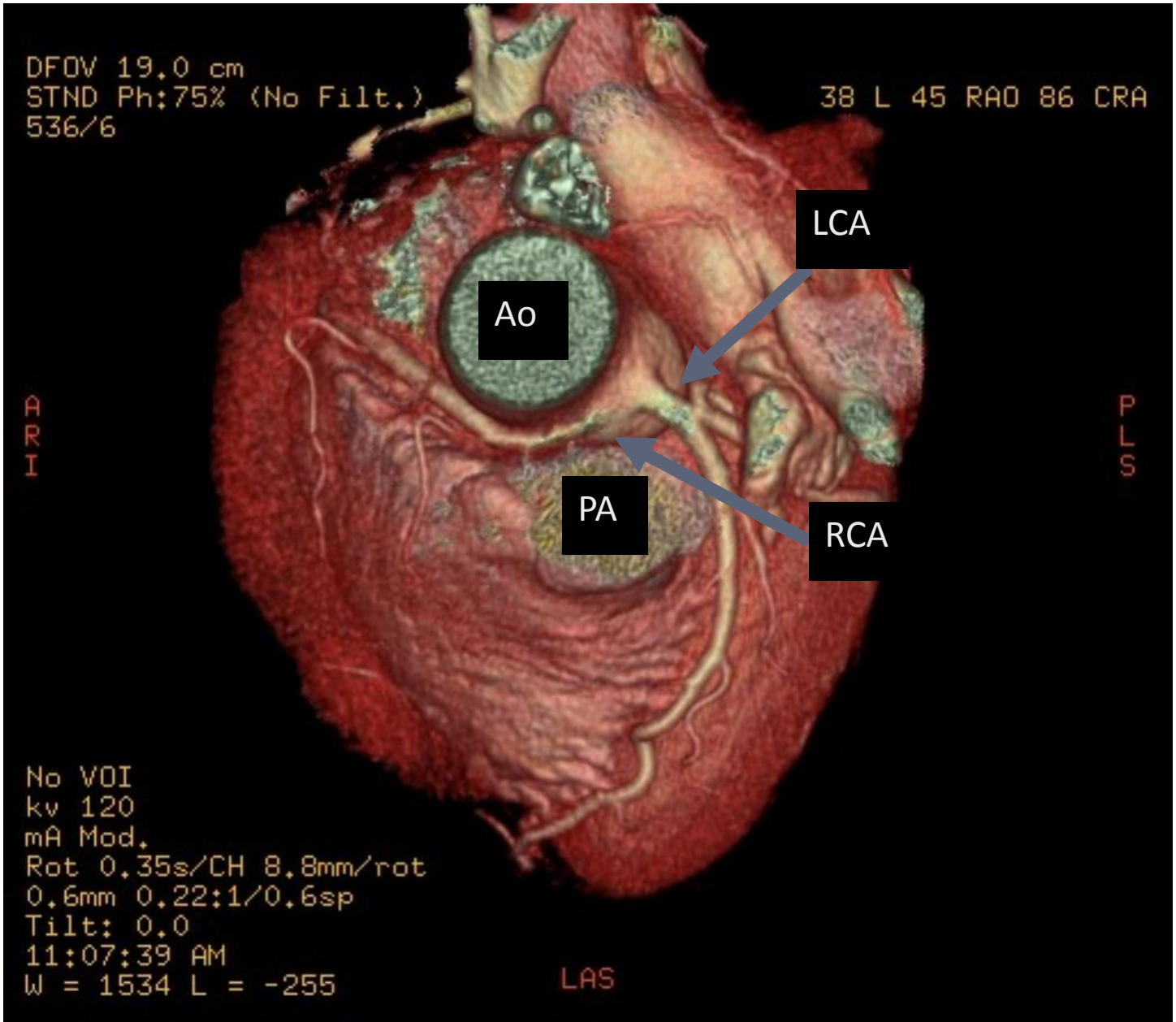

RVOT
AO

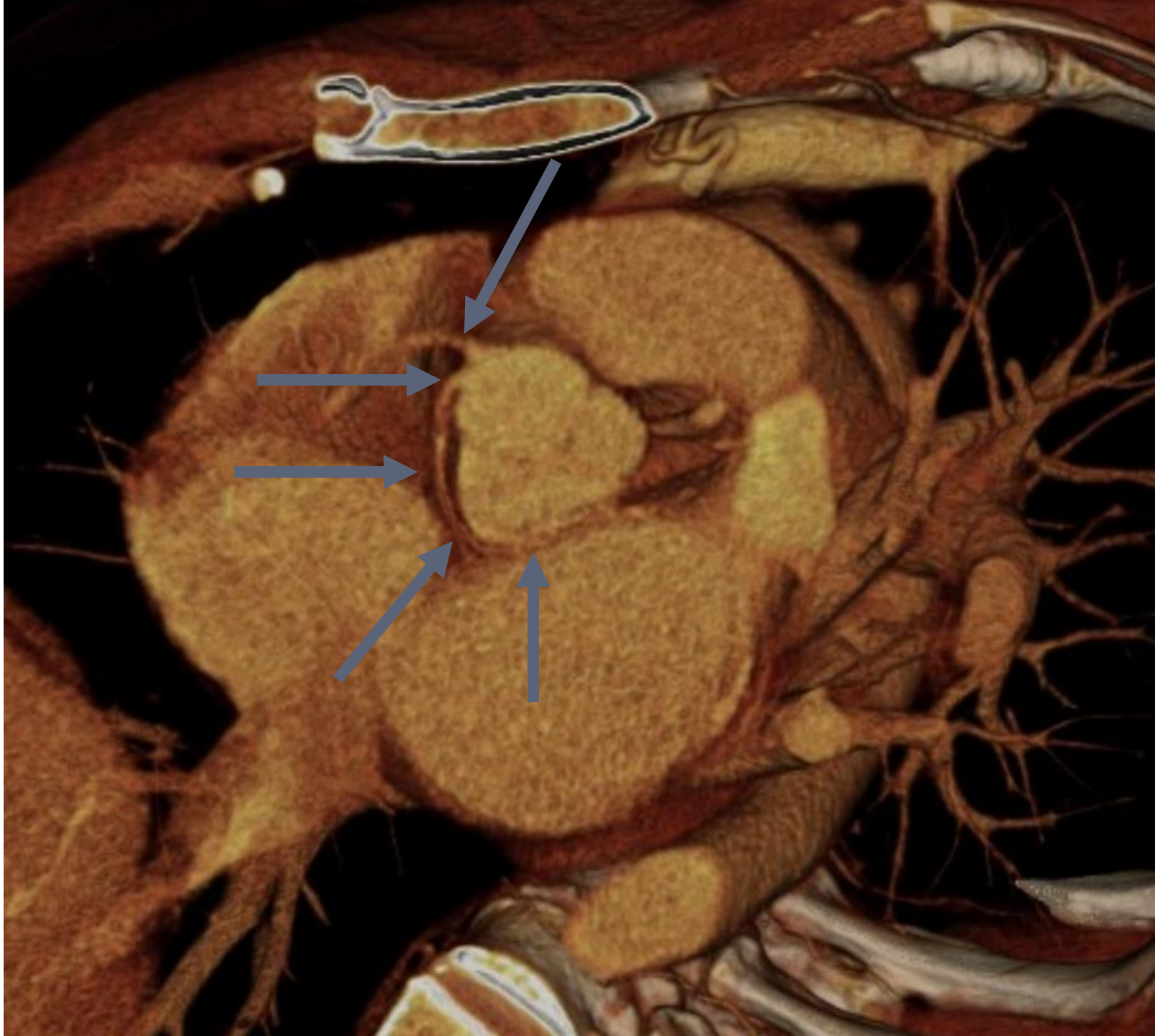

RVOT
AO


RVOT
AO


RVOT
AO


Posterior Descending Artery Angle: 74.0
Mar 12 2007
DFOV 12.2 cm
STND Ph:75% (No Filt.)
535/7
R
L
kv 120
mA Mod.
Rot 0.35s/CH 8.8mm/rot
0.6mm 0.22:1/0.6sp
Tilt: 0.0
11:07:39 AM
W = 800 L = 100
I


DFOV 19.0 cm
STND Ph:75% (No Filt.)
536/6
38 L 45 RAO 86 CRA
LCA
Ao
A
R
I
P
L
S
PA
RCA
No VOI
kv 120
mA Mod.
Rot 0.35s/CH 8.8mm/rot
0.6mm 0.22:1/0.6sp
Tilt: 0.0
11:07:39 AM
W = 1534 L = -255
LAS

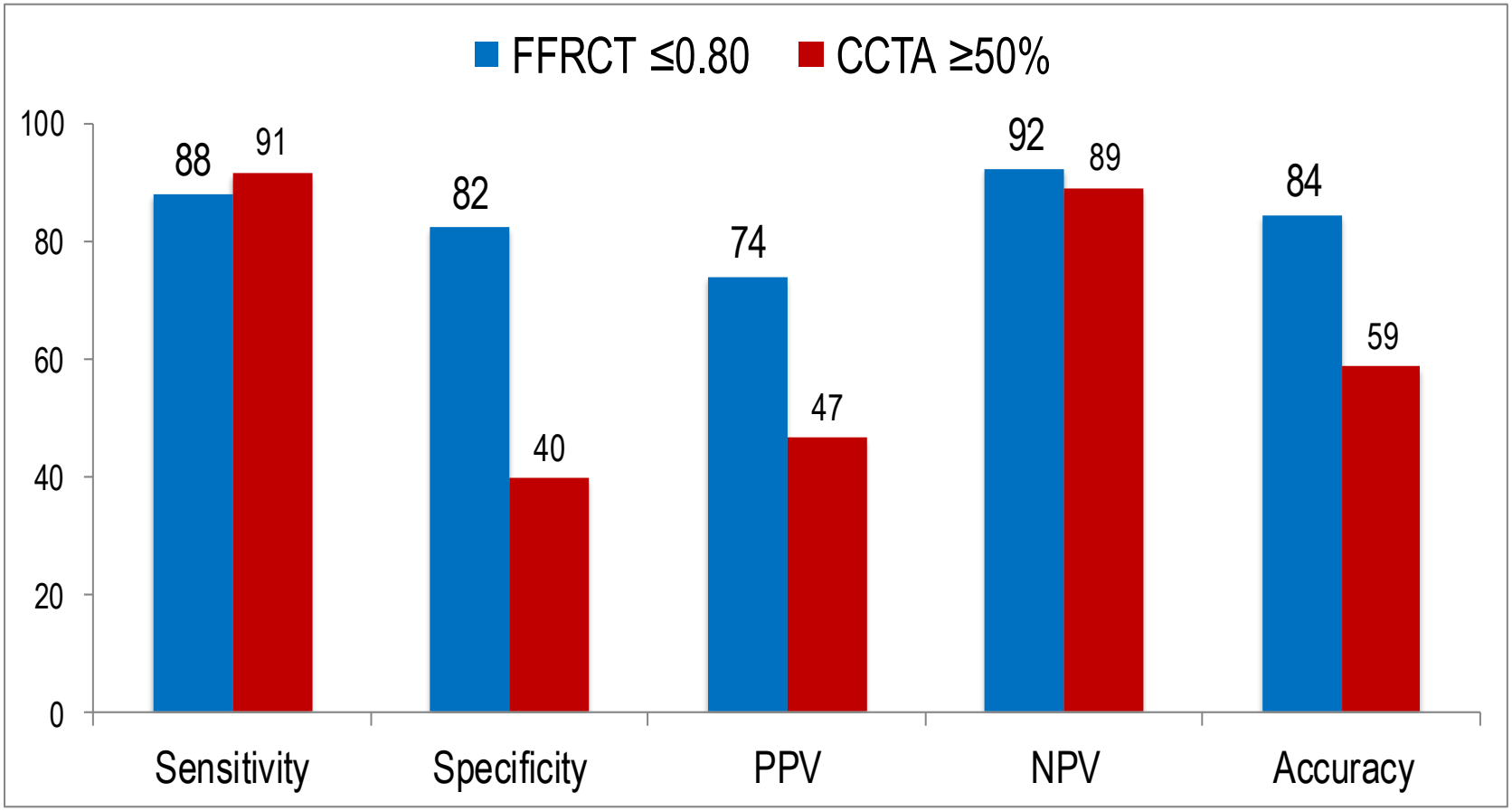


Diagnosis of Ischemia-Causing Coronary Stenoses by Noninvasive Fractional Flow Reserve Computed From Coronary Computed Tomographic Angiograms

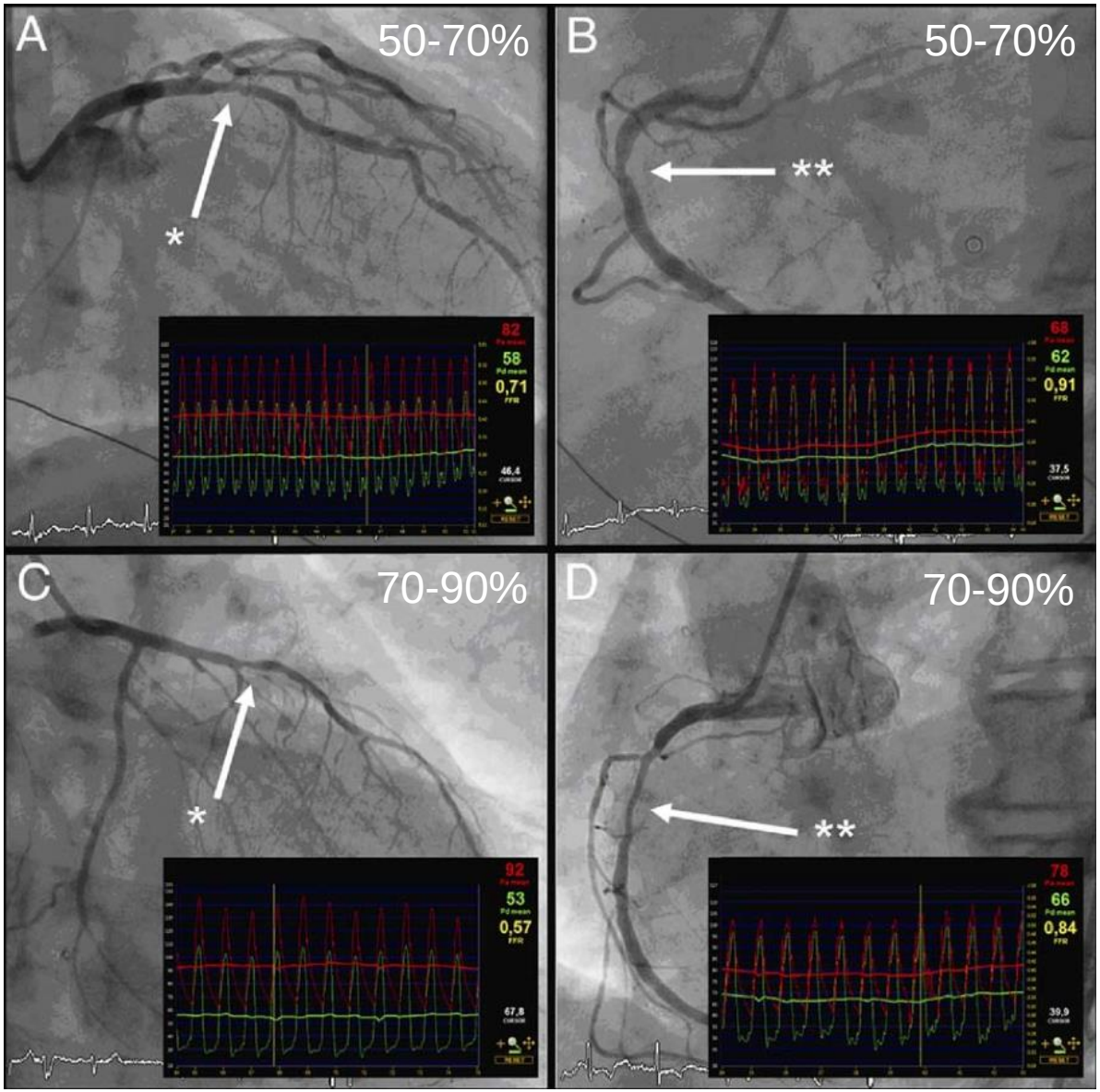
Results From the Prospective Multicenter DISCOVER-FLOW (Diagnosis of Ischemia-Causing Stenoses Obtained Via Noninvasive Fractional Flow Reserve) Study

Bon-Kwon Koo, MD, PhD,* Andrejs Erglis, MD, PhD,† Joon-Hyung Doh, MD, PhD,‡ David V. Daniels, MD,§ Sanda Jegere, MD,‖ Hyo-Soo Kim, MD, PhD,* Allison Dunning, MD,¶ Tony DeFrance, MD,# Alexandra Lansky, MD,** Jonathan Leipsic, BSc, MD,†† James K. Min, MD‡‡

Seoul and Goyang, South Korea; Riga, Latvia; Palo Alto, San Francisco, and Los Angeles, California; New York, New York; New Haven, Connecticut; and Vancouver, British Columbia, Canada



What about intermediate stenoses?



Source: Tonino PA et al. J Am Coll Cardiol

Angiographic Versus Functional Severity of Coronary Artery Stenoses in the FAME Study

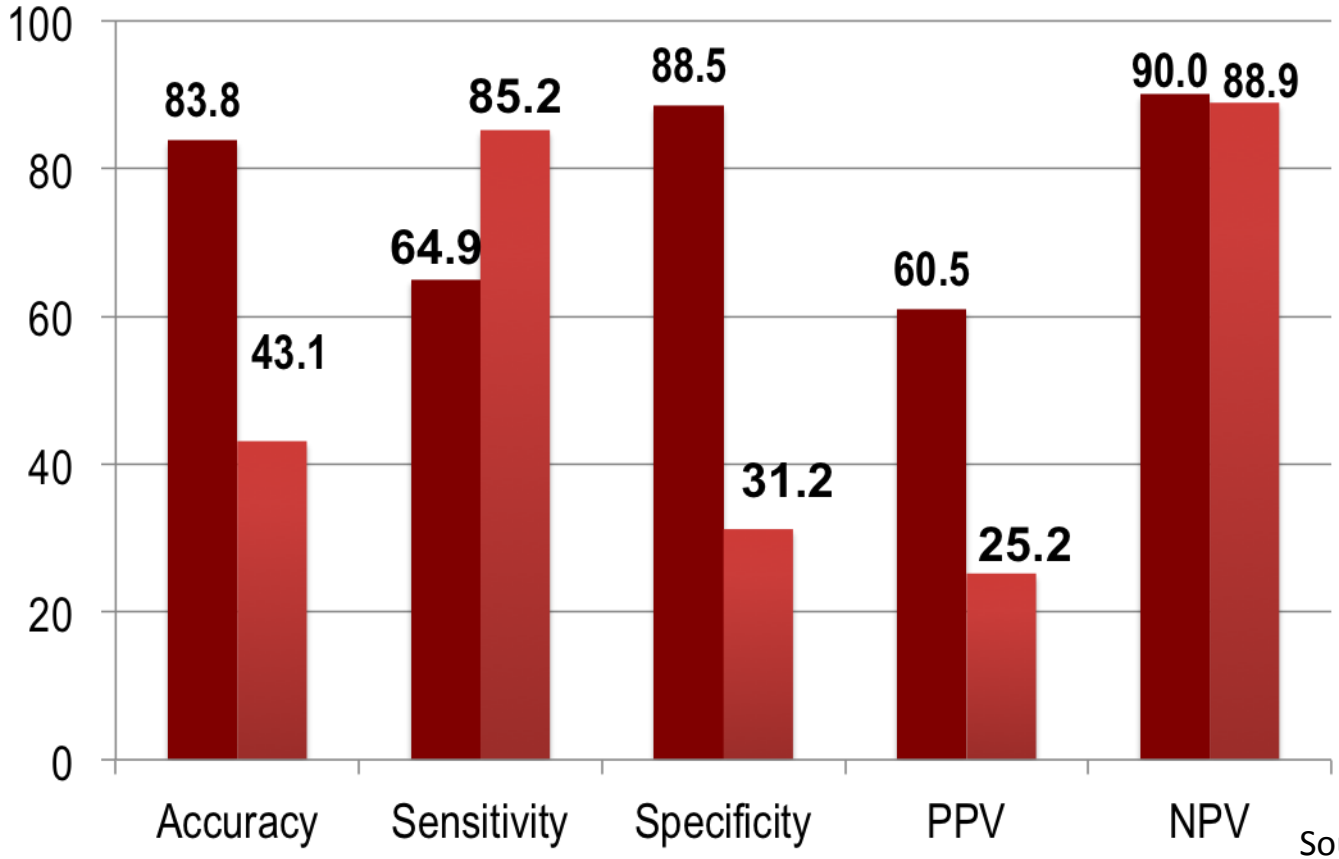
Fractional Flow Reserve Versus Angiography in Multivessel Evaluation

	% Stenosis by Angiography*		
	50% to 70% (n = 620, 47%)	71% to 90% (n = 513, 39%)	91% to 99% (n = 96, 15%)
FFR >0.80	402 (65)	104 (20)	7 (4)
FFR ≤0.80	218 (35)	409 (80)	189 (96)
Mean FFR for all lesions	0.81 ± 0.12	0.67 ± 0.15	0.52 ± 0.15
Mean FFR >0.80	0.89 ± 0.05	0.87 ± 0.05	0.87 ± 0.04
Mean FFR ≤0.80	0.68 ± 0.10	0.62 ± 0.13	0.51 ± 0.13

Source: Tonino et al JACC 2010

Diagnostic Performance of FFRCT for 30-69% Stenoses by CCTA

FFR_{CT}	Accuracy	Sensitivity	Specificity	PPV	NPV
$FFR_{CT} \leq 0.80$	83.8	64.9	88.5	60.5	90.0
CCTA	43.1	85.2	31.2	25.2	88.9



Source: Leipsic et al RSNA 2011

The DeFACTO Study

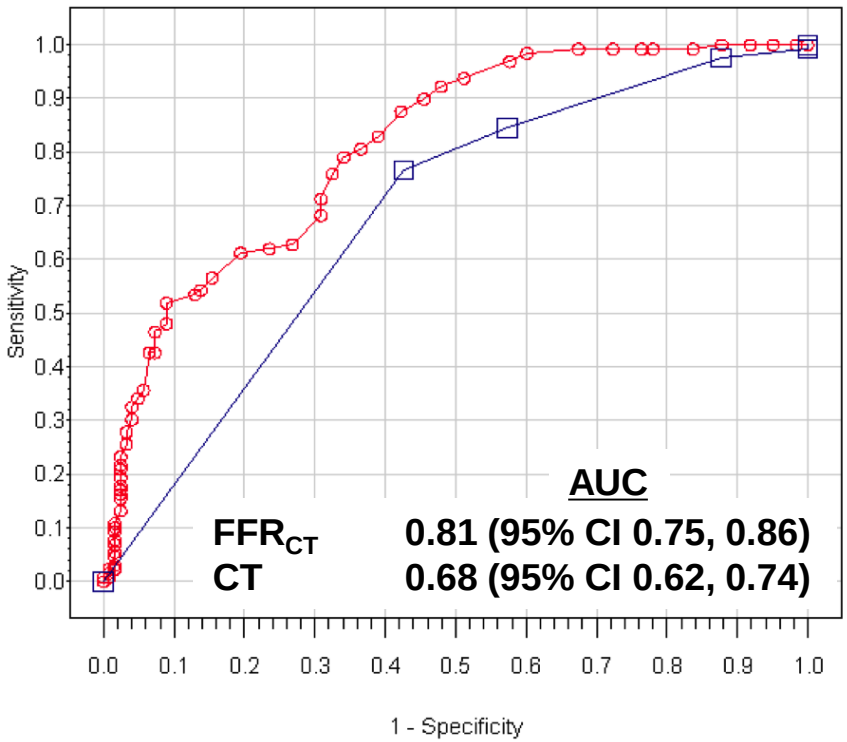
(**De**termination of **F**FR by **A**natomic **CT** Angi**O**graphy)

- 17-center international study of 252 patients undergoing CCTA and invasive FFR to evaluate the *diagnostic performance of* FFR_{CT} compared to coronary CT alone using invasively measured FFR as the reference standard

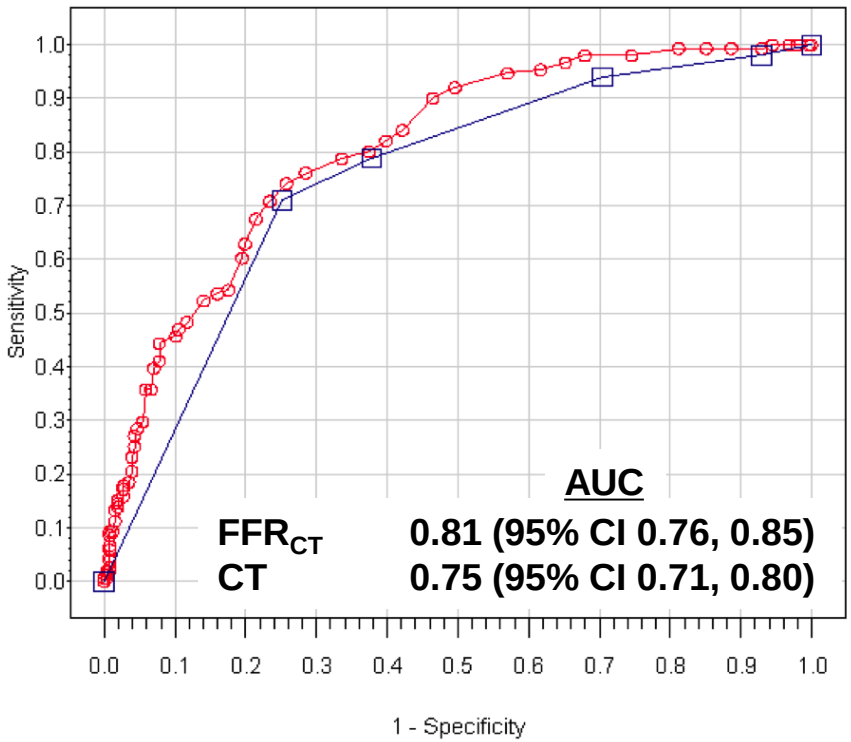
Source: Min, Leipsic, Berman et al. JAMA 2012: 308 (12): 1237-1245

Discrimination (total patient population, n=252)

Per-Patient



Per-Vessel



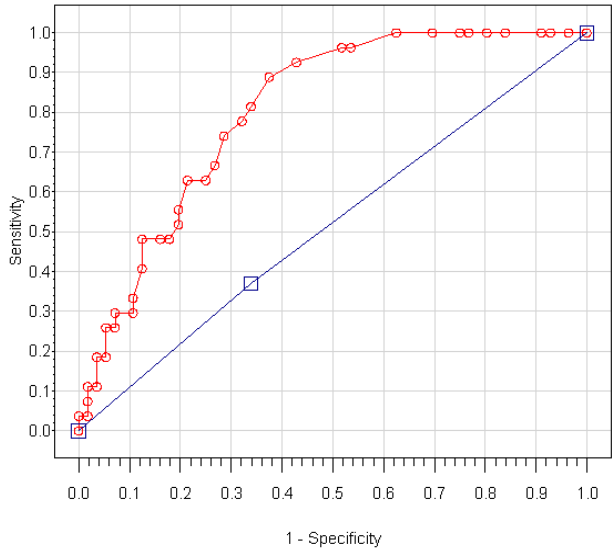
- **Greater discriminatory power for FFR$_{CT}$ versus CT stenosis**
  - Per-patient (Δ 0.13, p<0.001)
  - Per-vessel (Δ 0.06, p<0.001)

*AUC = Area under the receiver operating characteristics curve

DeFACTO
Determination of Fractional Flow Reserve by Anatomic Computed Tomographic Angiography

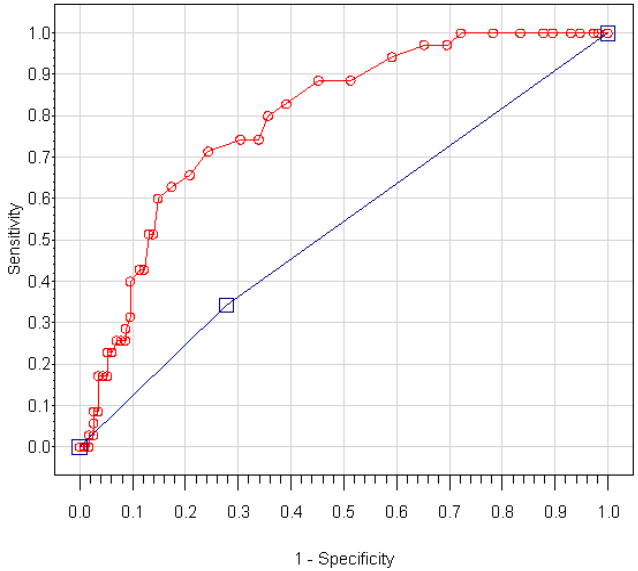
Intermediate stenosis: Discrimination

Per-Patient



	AUC
FFR_{CT}	0.80 (95% CI 0.70, 0.89)
CT	0.52 (95% CI 0.50, 0.64)

Per-Vessel



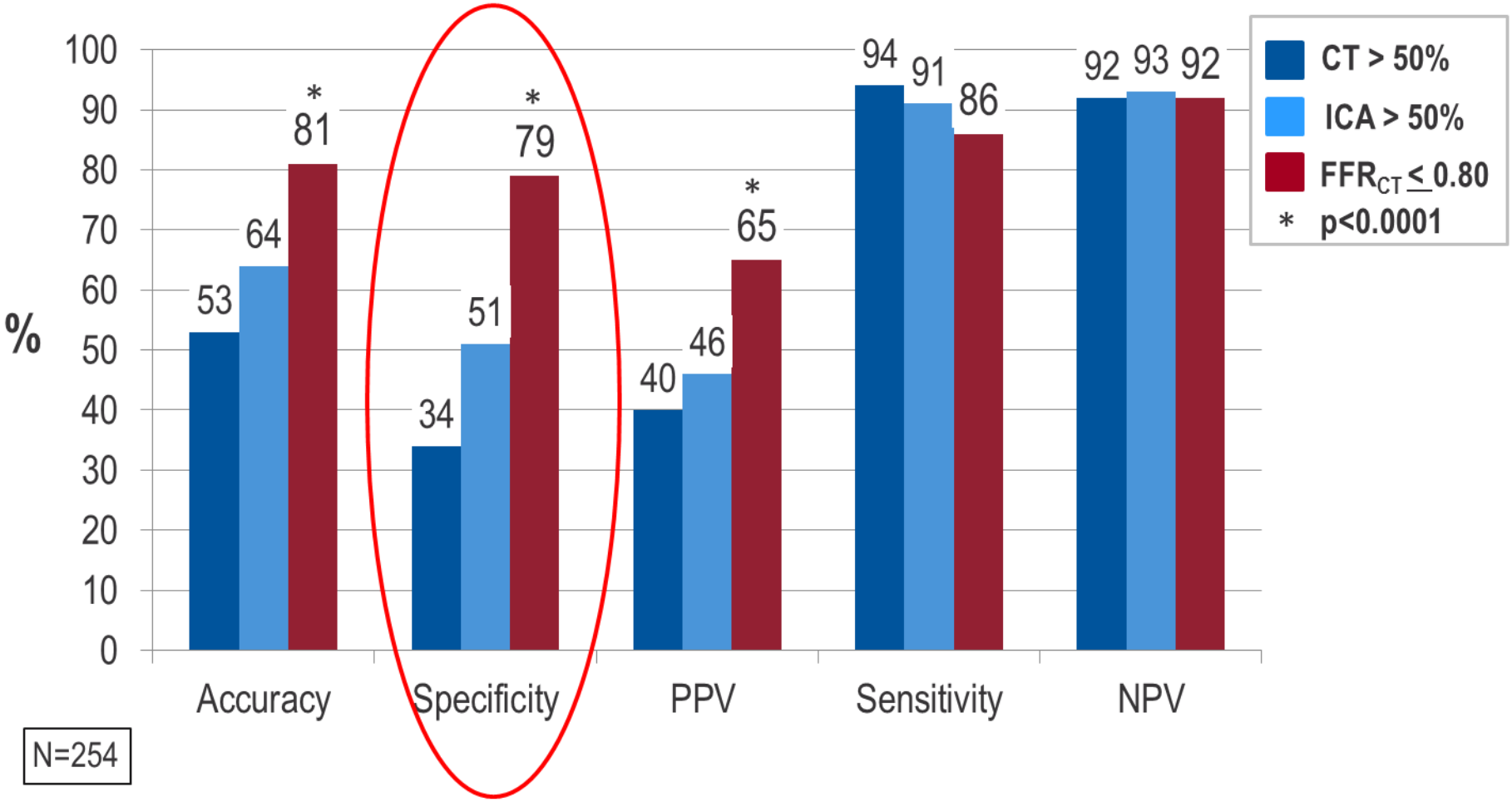
	AUC
FFR_{CT}	0.80 (95% CI 0.71, 0.87)
CT	0.53 (95% CI 0.50, 0.62)

- **Greater discriminatory power for FFR_{CT} versus CT stenosis**
  - Per-patient (Δ 0.29, p<0.0001)
  - Per-vessel (Δ 0.26, p<0.0001)

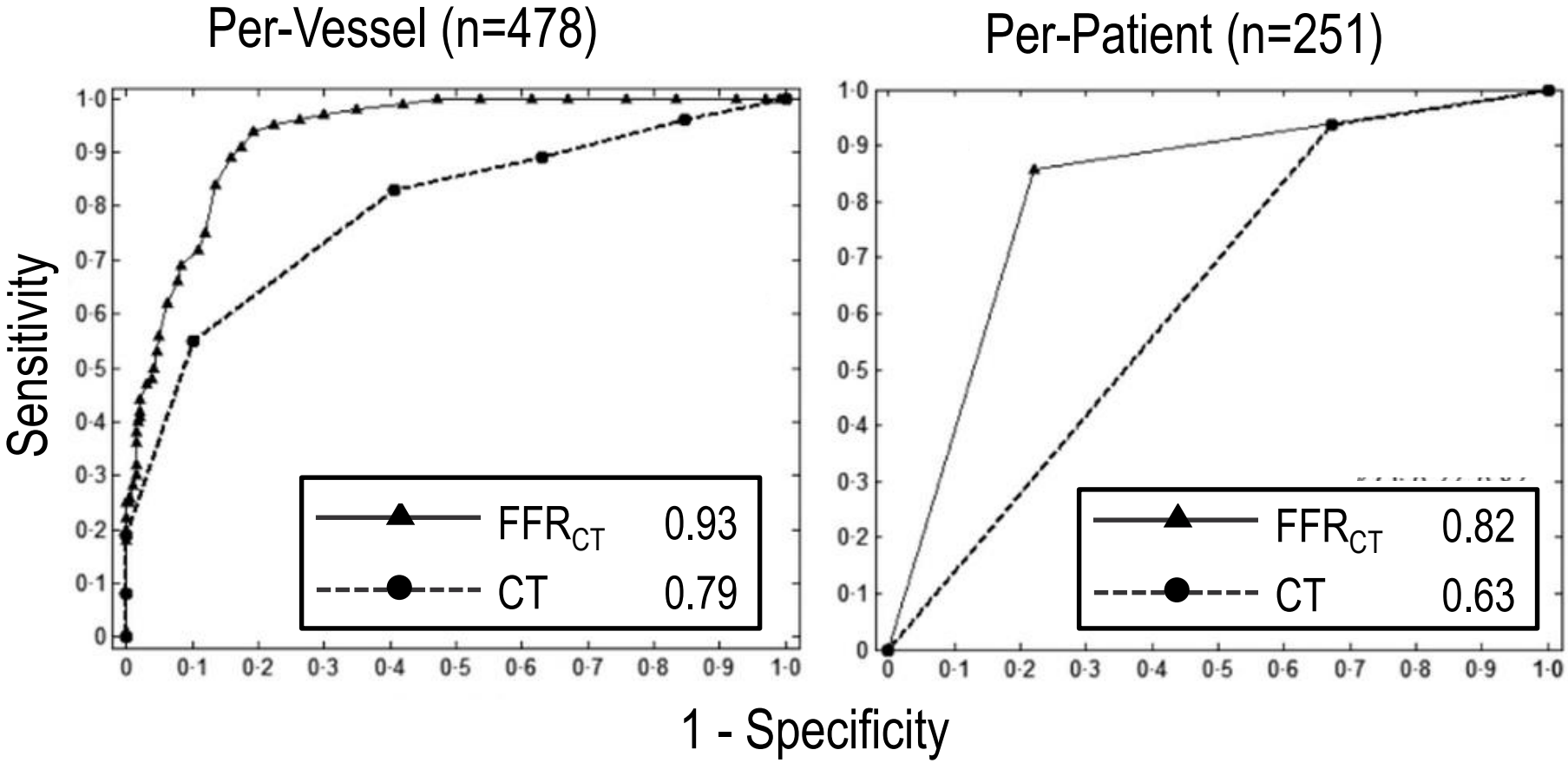
* Nakazato et al . Circ Imaging 2013

DeFACTO
Determination of Fractional Flow Reserve by Anatomic Computed Tomographic Angiography

Per-Patient Diagnostic Performance



Discrimination of Ischemia*



Greater discriminatory power for FFR$_{CT}$ versus CT stenosis

Vessel (Δ 0.14, p<0.001) Patient (Δ 0.19, p<0.001)

*Area under the receiver operating characteristics curve

FACULTY OF HEALTH SCIENCES
AARHUS UNIVERSITY

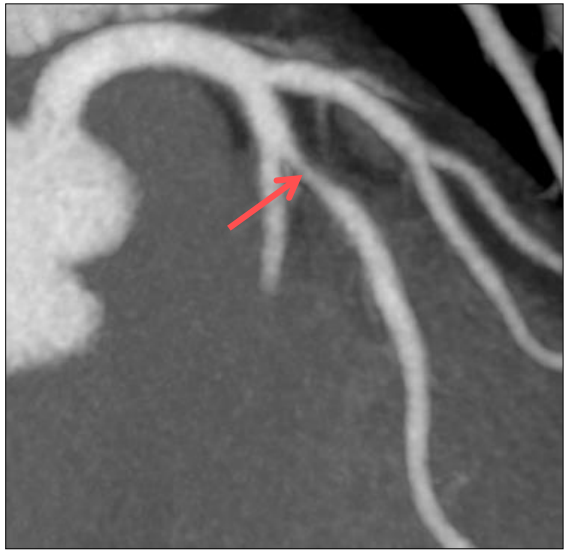
Diagnostic performance of non-invasive fractional flow reserve derived from coronary CT angiography in suspected coronary artery disease: The NXT trial

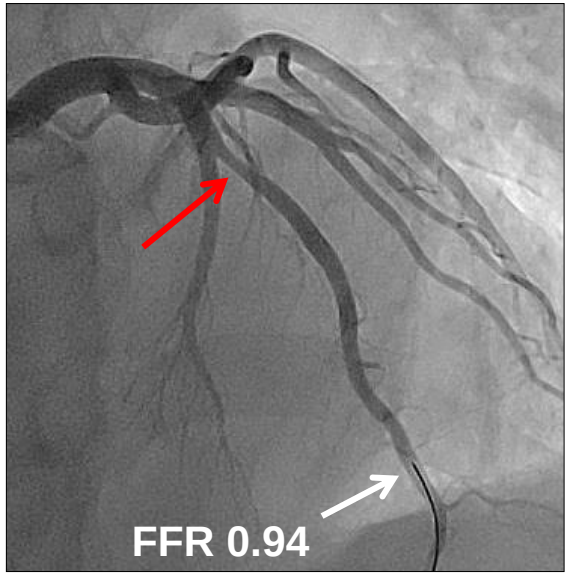
Bjarne L. Nørgaard, Jonathon Leipsic, Sara Gaur, Sujith Seneviratne, Brian S. Ko, Hiroshi Ito, Jesper M. Jensen, Laura Mauri, Bernard De Bruyne, Hiram Bezerra, Kazuhiro Osawa, Mohamed Marwan, Christoph Naber, Andrejs Erglis, Seung-Jung Park, Evald H. Christiansen, Anne Kaltoft, Jens F. Lassen, Hans Erik Bøtker, Stephan Achenbach

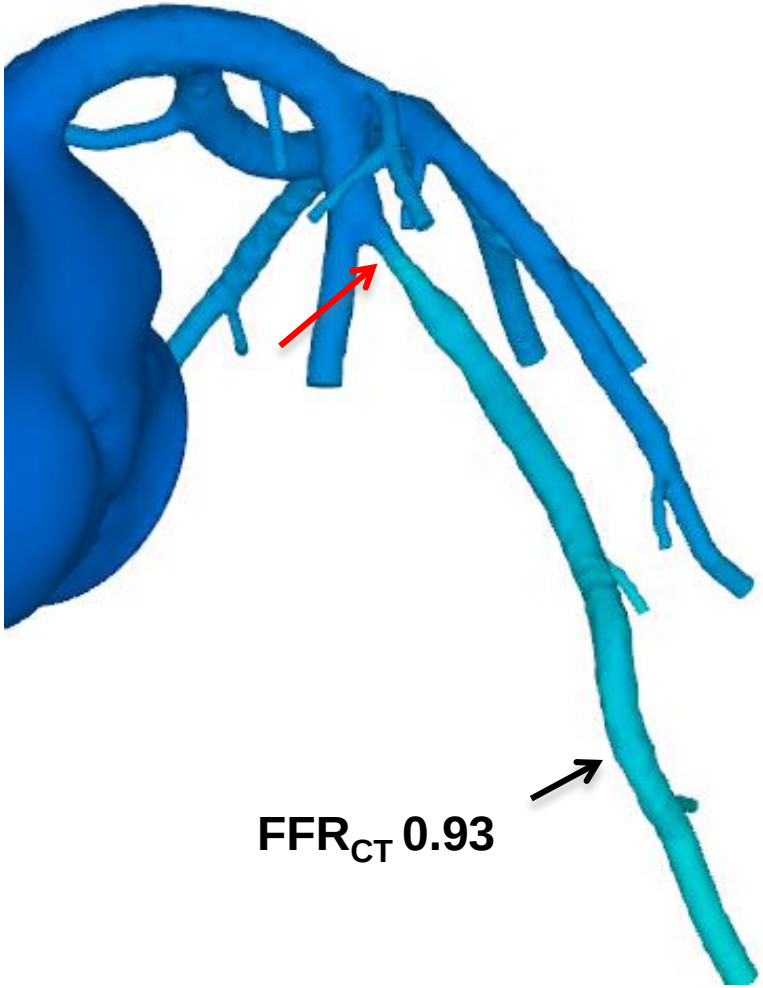
For the NXT Investigators

Case Example

LAD stenosis 70-90%







FFR_{CT} Model

CORE 320

CTA
50% Stenosis

+

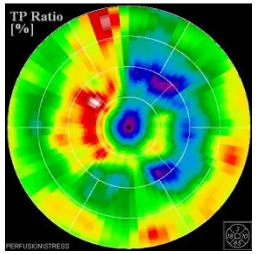
CTP
Perfusion Defect

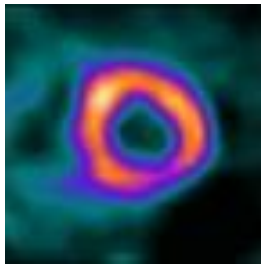
VS

QCA
50% Stenosis

+

SPECT
Perfusion Defect





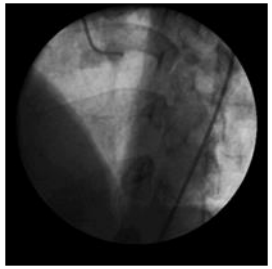
CTA
50% Stenosis

+

CTP
Perfusion Defect

VS

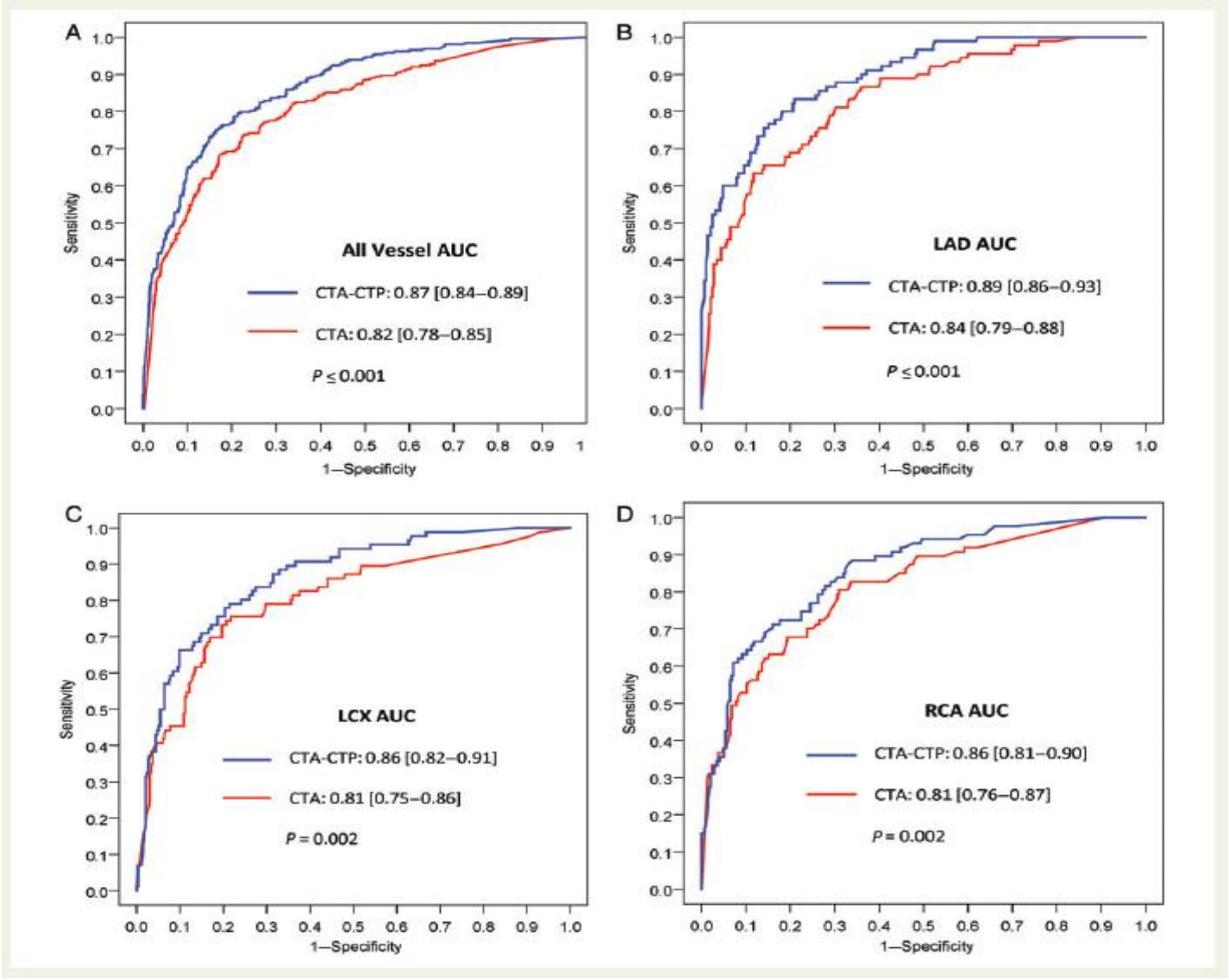
QCA
50% Stenosis



Source: Rochitte et al. Nov 2013

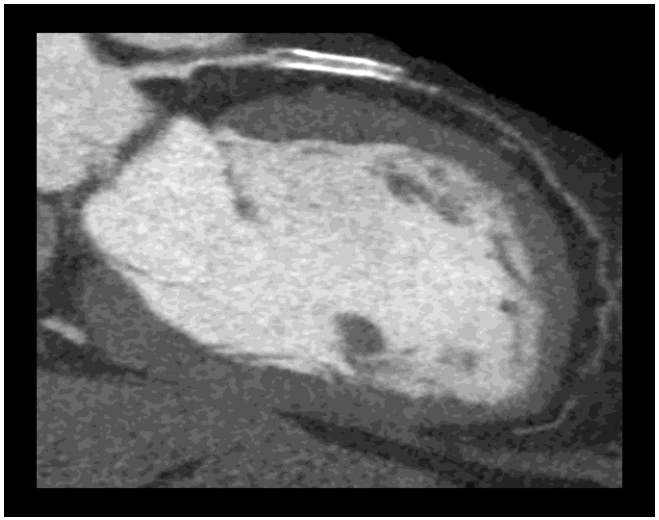
CORE 320

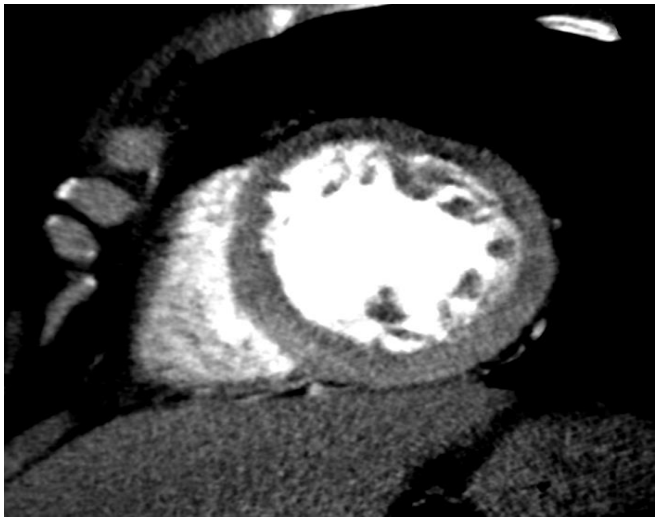
Improved Accuracy Beyond CCTA across all Vascular Territories

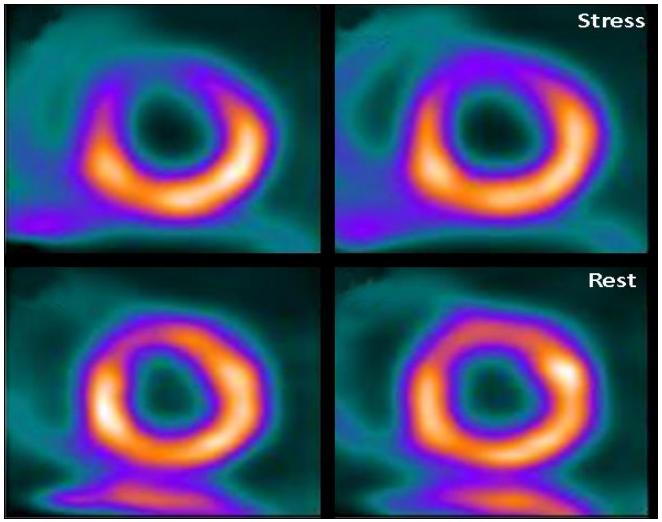


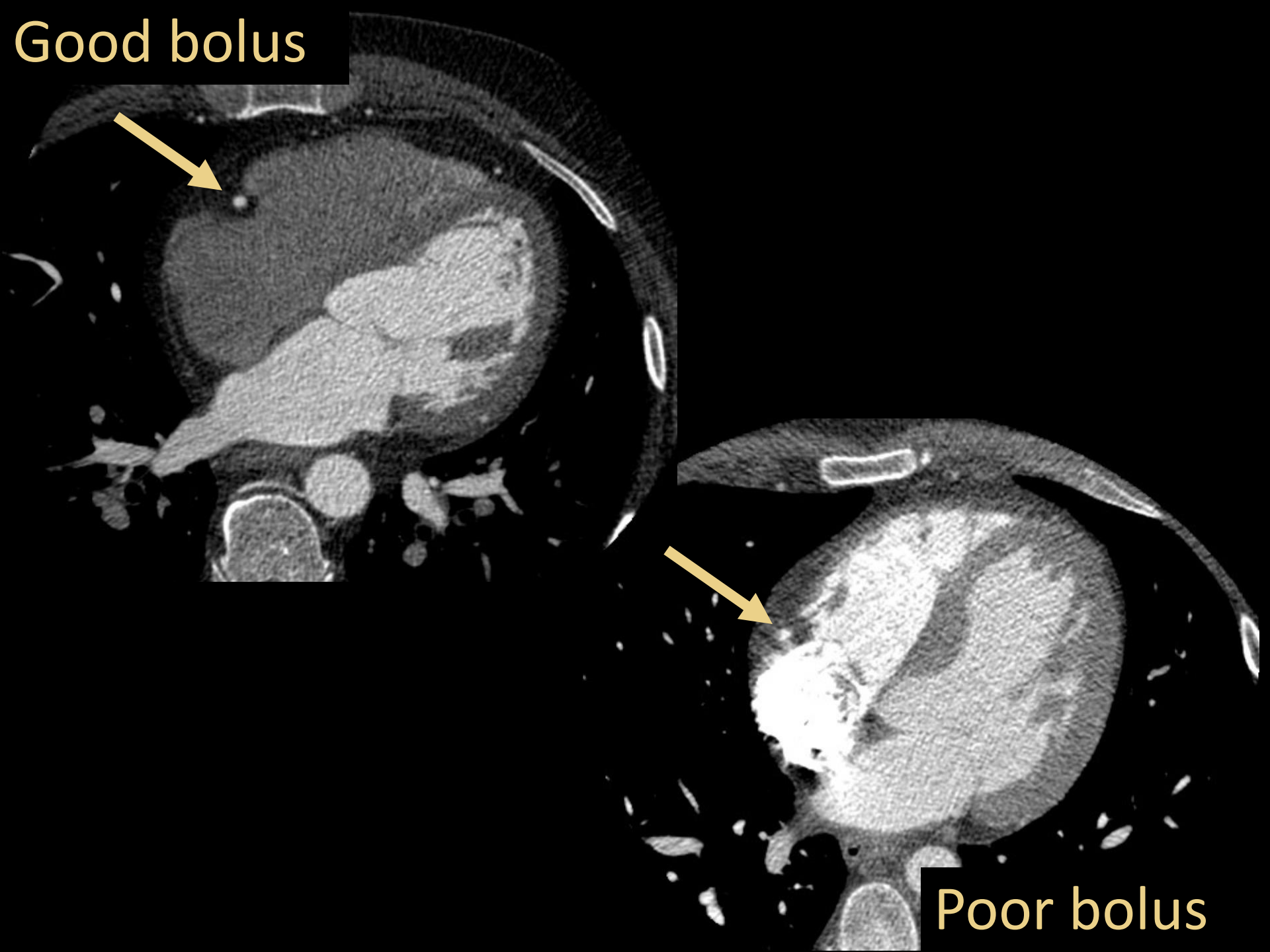
Source: Rochitte et al EHJ 2013

CORE320 Complete Dataset








Good bolus
Poor bolus

JACC Journals

From: ACCF/AHA/ASE/ASNC/HFSA/HRS/SCAI/SCCT/SCMR/STS 2013 Multimodality Appropriate Use Criteria for the Detection and Risk Assessment of Stable Ischemic Heart Disease: A Report of the American College of Cardiology Foundation Appropriate Use Criteria Task Force, American Heart Association, American Society of Echocardiography, American Society of Nuclear Cardiology, Heart Failure Society of America, Heart Rhythm Society, Society for Cardiovascular Angiography and Interventions, Society of Cardiovascular Computed Tomography, Society for Cardiovascular Magnetic Resonance, and Society of Thoracic Surgeons

J Am Coll Cardiol. 2014;63(4):380-406. doi:10.1016/j.jacc.2013.11.009

Figure Legend:

Symptomatic

Table 12 Characteristics of tests commonly used to diagnose the presence of coronary artery disease

	Diagnosis of CAD	
	Sensitivity (%)	Specificity (%)
Exercise ECG [a, 91, 94, 95]	45–50	85–90
Exercise stress echocardiography[96]	80–85	80–88
Exercise stress SPECT[96, 99]	73–92	63–87
Dobutamine stress echocardiography[96]	79–83	82–86
Dobutamine stress MRI[b, 100]	79–88	81–91
Vasodilator stress echocardiography[96]	72–79	92–95
Vasodilator stress SPECT[96, 99]	90–91	75–84
Vasodilator stress MRI[b, 98, 100–102]	67–94	61–85
Coronary CTA[c, 103–105]	95–99	64–83
Vasodilator stress PET[97, 99, 106]	81–97	74–91

CAD = coronary artery disease; CTA = computed tomography angiography; ECG = electrocardiogram; MRI = magnetic resonance imaging; PET = positron emission tomography; SPECT = single photon emission computed tomography.

[a] Results without/with minimal referral bias.

[b] Results obtained in populations with medium-to-high prevalence of disease without compensation for referral bias.

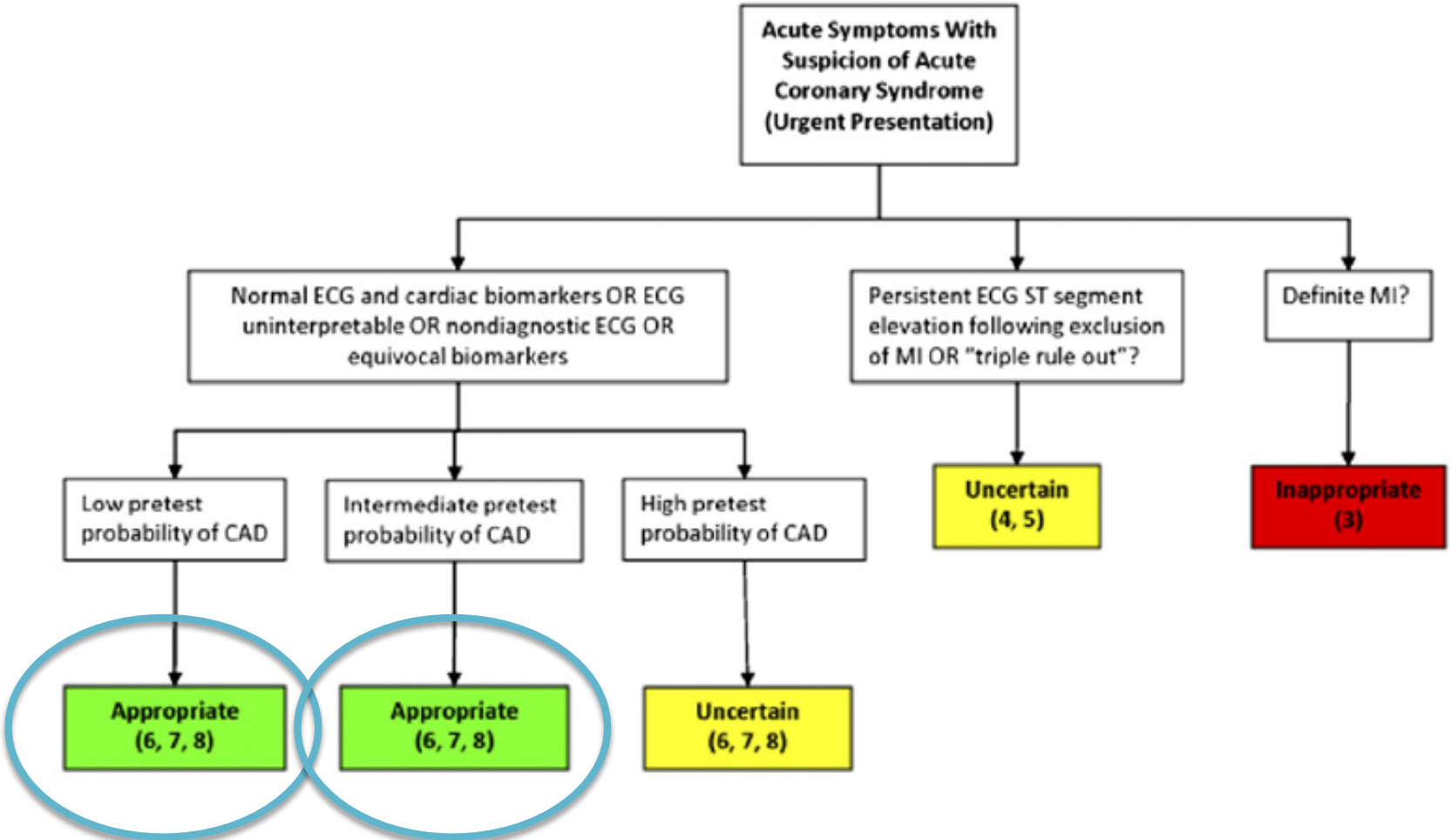
[c] Results obtained in populations with low-to-medium prevalence of disease.

Coronary CTA:

- Where are we now?
- Strengths:
  - Sensitivity
  - Ruling out CAD
  - Accessibility→ ED
- Weaknesses:
  - Ionizing radiation
  - Patient preparation

Detection of CAD in Symptomatic Patients: Acute Presentation

- Without Known Heart Disease



Radiation Dose:

Cardiac CT previously reported: 6-25 mSv

- at FMC: 1.5-9 mSv
- More complex patients being assessed with retrospective scanning or entire thorax
- Background exposure of living in Calgary: 3 mSv/year

Imaging Procedures	Modality	Effective Dose (mSv)*
Cardiac procedures		
Calcium scoring	Electron beam CT	1.0–1.3
	Multiple-row detector CT	1.5–6.2†
Cardiac CT angiography	Electron beam CT	1.5–2.0
	Multiple-row detector CT	6†–25
Cardiac SPECT with ^{99m}Tc or ^{201}T1‡	Nuclear medicine	6.0–15.0
Coronary angiography (diagnostic)	Fluoroscopy	2.1†–6.0
Chest radiography	Radiography	0.1–0.2
Routine CT procedures		
Head CT	Multiple-row detector CT	1–2
Chest CT	Multiple-row detector CT	5–7
Abdominal and pelvic CT	Multiple-row detector CT	8–11

Validation Studies:

- Coronary CTA is a highly sensitive exam for detection of coronary artery disease.
- When used in appropriate population has an excellent negative predictive value.

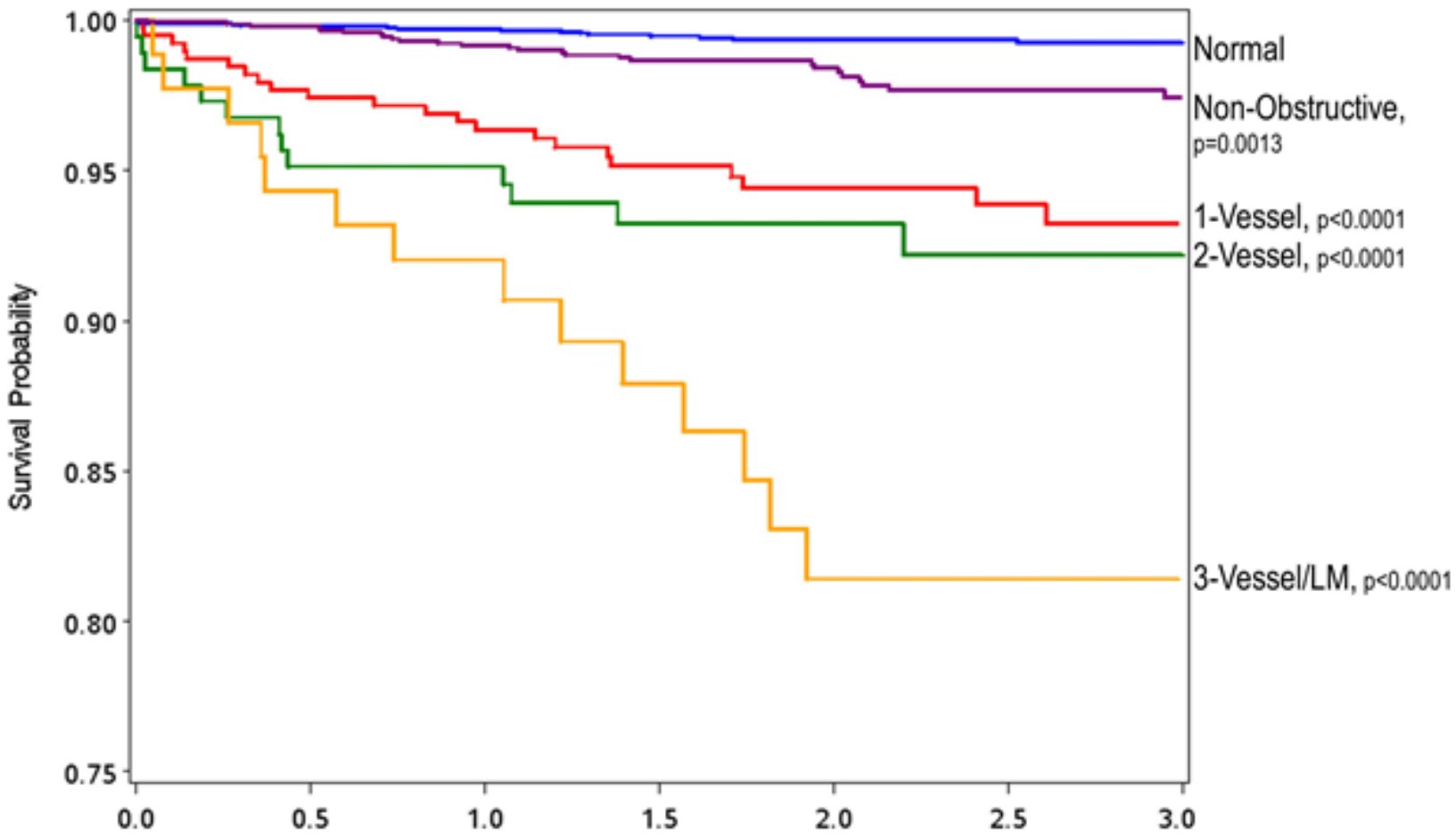
For Abnormal CCTA findings:

- MACE rate for positive versus negative CCTA findings was 8.8% vs 0.17% per year (p 0.05)
  - predominantly revascularization
- For death or MI, average annualized event rate was 3.2% versus 0.15% (p 0.05) for positive versus negative scans.
- After stratifying by nonobstructive CAD and obstructive CAD, incrementally increasing cardiovascular events (MI and revascularization) and all-cause mortality rates occurred with increasing severity of CAD.

Sequential Testing (≤90 Days): Abnormal Prior Test/Study)

Indication Text		Exercise ECG	Stress RNI	Stress Echo	Stress CMR	Calcium Scoring	CCTA	Invasive Coronary Angiography
23.	• Abnormal rest ECG findings (potentially ischemic in nature such as LBBB, T-wave inversions) • Low global CAD risk		A	A	M	R	M	R
24.	• Abnormal rest ECG findings (potentially ischemic in nature such as LBBB, T-wave inversions) • Intermediate to high global CAD risk		A	A	A	R	M	M
25.	• Abnormal prior exercise ECG test		A	A	A	R	A	A
26.	• Abnormal prior stress imaging study (assumes not repeat of same type of stress imaging)	R	M	M	M	R	A	A
27.	• Obstructive CAD on prior CCTA study	M	A	A	A			A
28.	• Obstructive CAD on prior invasive coronary angiography	M	A	A	A	R	R	
29.	• Abnormal prior CCT calcium (Agatston Score >100)	A	A	A	M		M	R

MACE-Free Survival Based upon the Presence of Non-Obstructive, and Obstructive 1-, 2- and 3-vessel CAD for Individuals Without Modifiable CAD Risk Factors



Source: Leipsic et al. AHA 2012, Radiology June 2013