Detection of Vulnerable Plaque: Non-Invasive Imaging Is More Clinically Relevant

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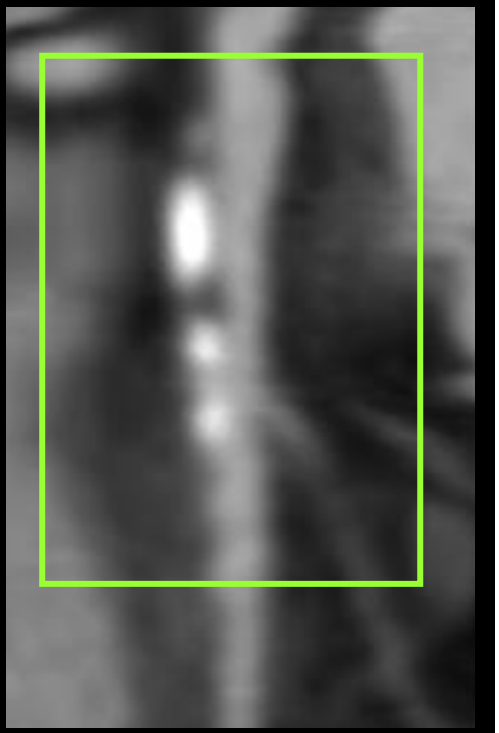
Can non-invasive methods effectively image “vulnerable” plaques?



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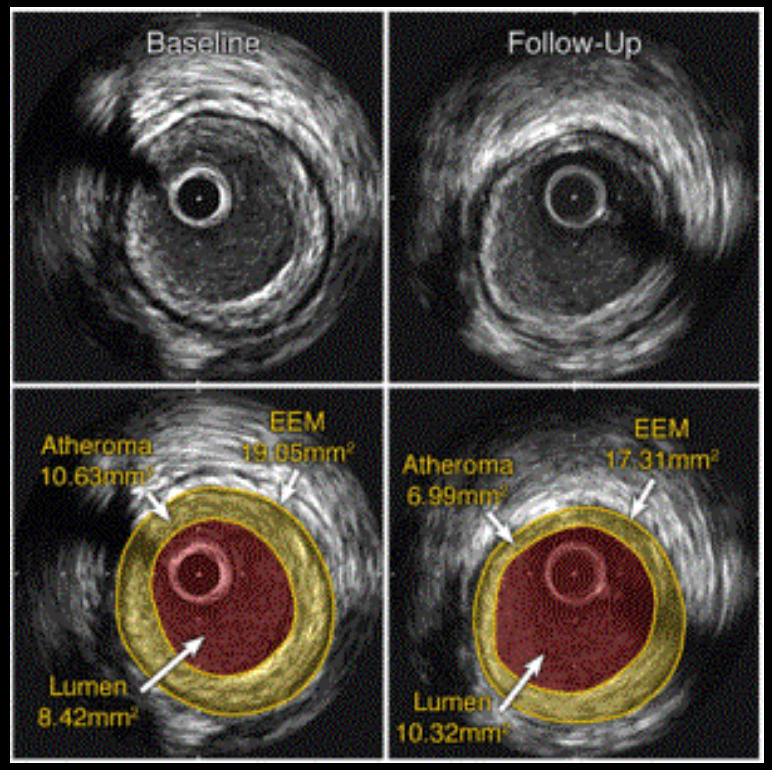
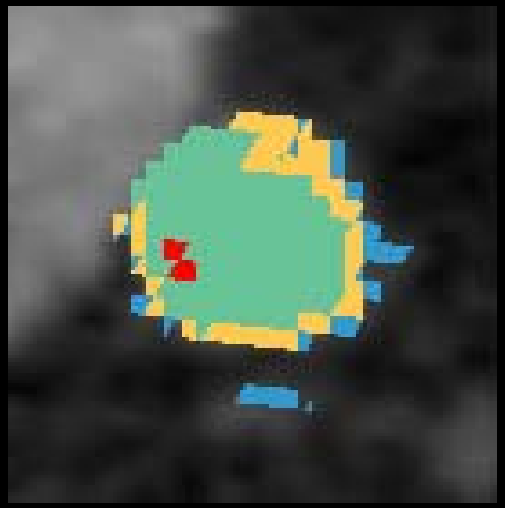
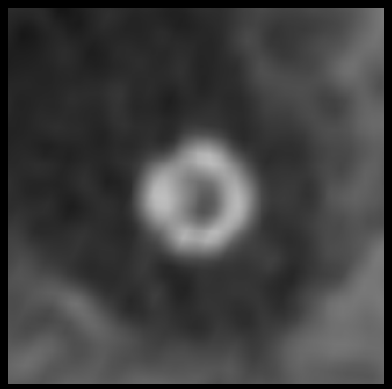
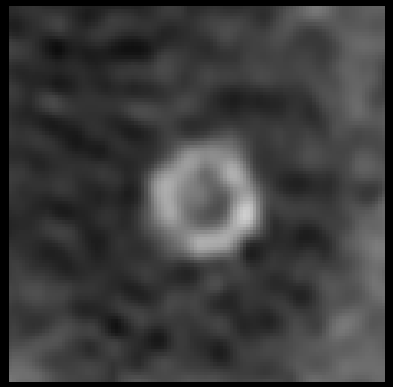


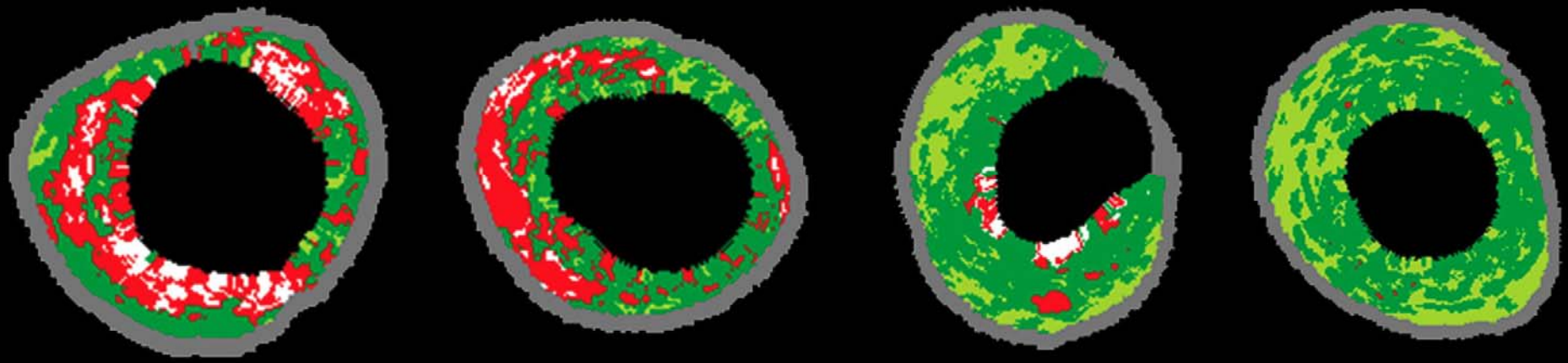






- ✓**Spatial resolution**
- ✓**Temporal resolution**
- ✓**Plaque composition**

Non-invasive imaging does not have the ability to identify important plaque features.



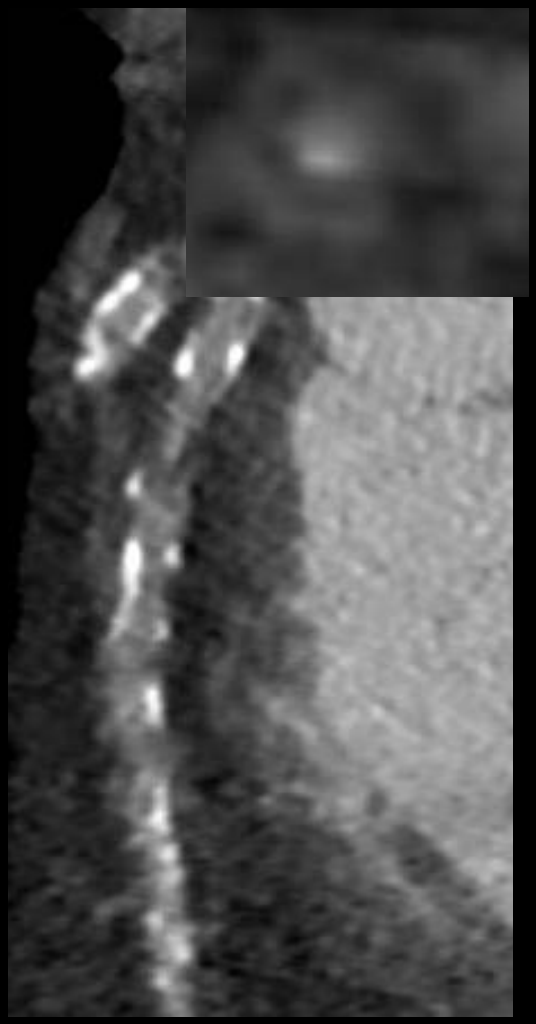
- Thin cap fibroatheroma
- Necrotic core
- Plaque rupture
- Plaque erosion
- Calcified nodule

Why is non-invasive imaging preferable for assessing ‘at-risk’ individuals?

REASON #1:

Non-invasive imaging offers measure of overall coronary artery plaque burden.

Plaque Characteristics by CCTA



	Sensitivity	Specificity	PPV	NPV
ACCURACY	94	83	48	99
N=230, Stable Chest Pain; No known CAD; No exclusion (CACS, HR, BMI); CAD prevalence 13%				
CorE64	85	90	91	83
N=291, Stable Chest Pain; No known and Known CAD; Exclusion CACS>600; CAD prevalence 56%				
Meijboom	99	64	85	97
N=360, Acute and Stable Chest Pain; No known CAD; CAD prevalence 68%				

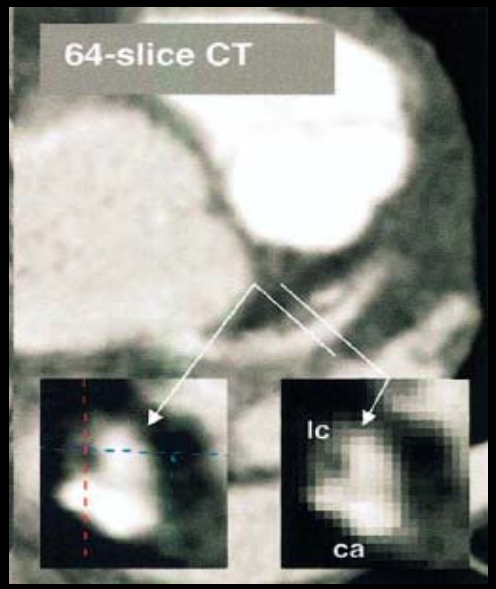
	Detected	Not Detected
Plaque thickness	1.5 ± 0.3 mm	0.9 ± 0.3 mm
Vessel size (EEM CSA)	4.5 ± 1.2 mm	3.6 ± 1.1 mm
% Plaque cross-sectional area	42 ± 16%	22 ± 5%

$p < 0.05$ for all categories.

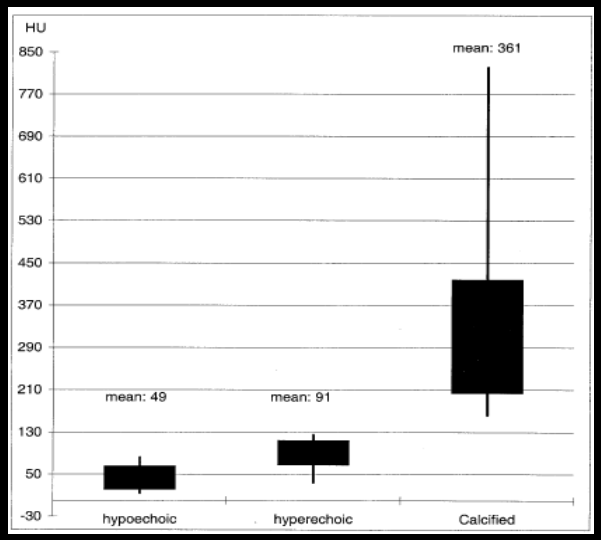
Budoff JACC 2008; Miller NEJM 2008; Meijboom JACC 2009; Leber JACC 2006

Plaque Features by CCTA

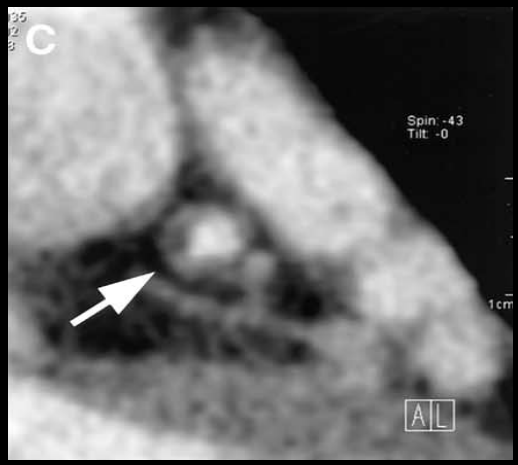
Volume (+/-)



Composition (+/-)



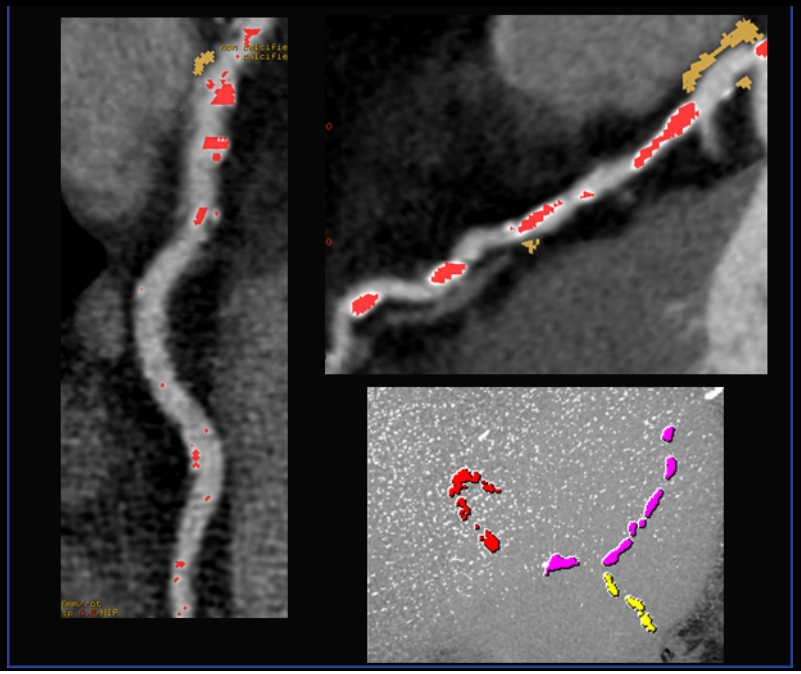
Remodeling (+)

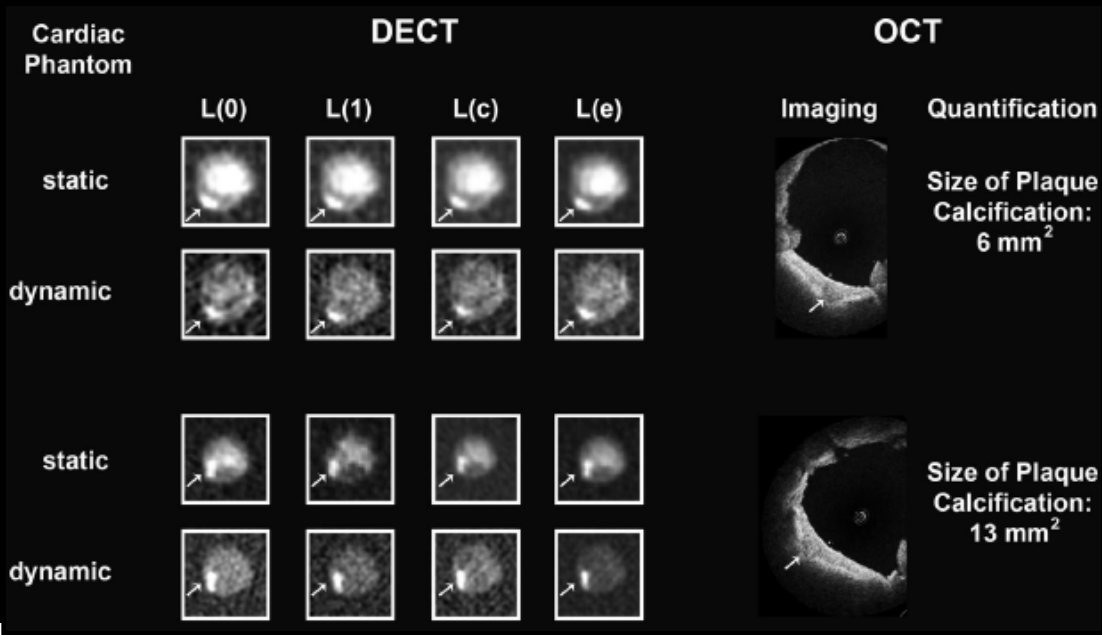


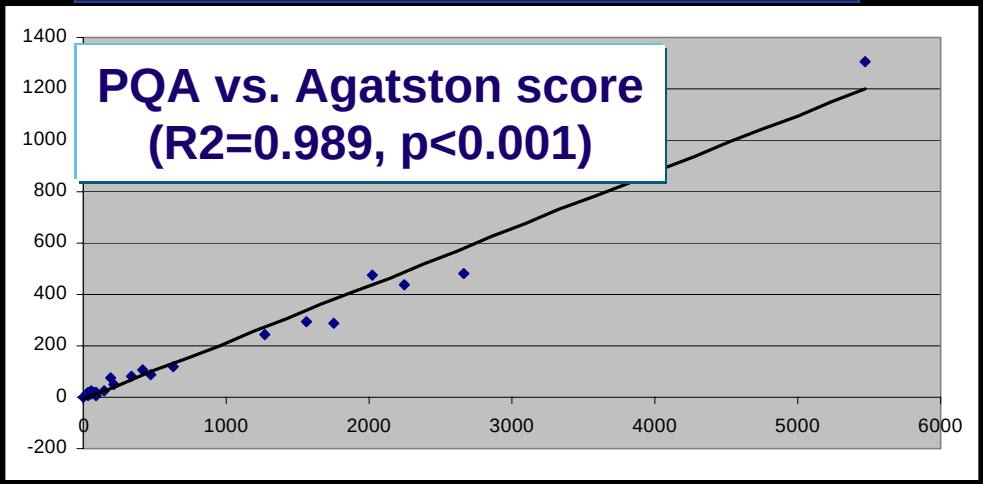
- Plaque volume/vessel r^2=0.69, p<0.001
  - Underestimates non-calcified
  - Overestimates calcified
- Interobserver variability
  - Any plaque (kappa = 0.75)
  - Plaque volume (kappa = 0.37)
- Overlap of HU for fibrous,and lipioid
- Remodeling generally high agreement

Leber JACC 2006; Leber JACC 2004; Hoffman JACC 2006

Plaque features by CCTA



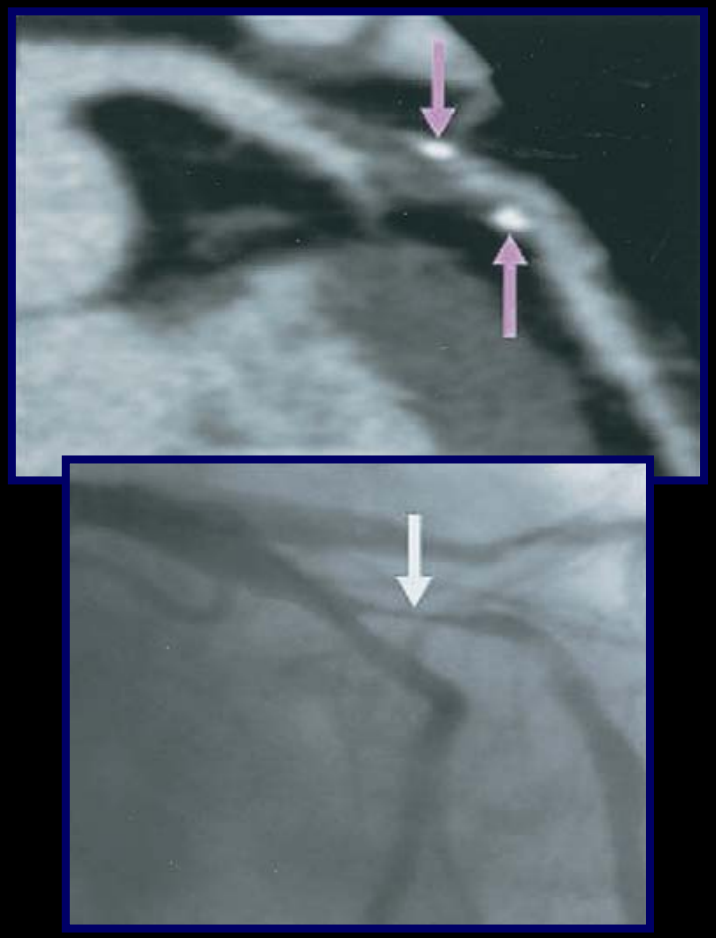


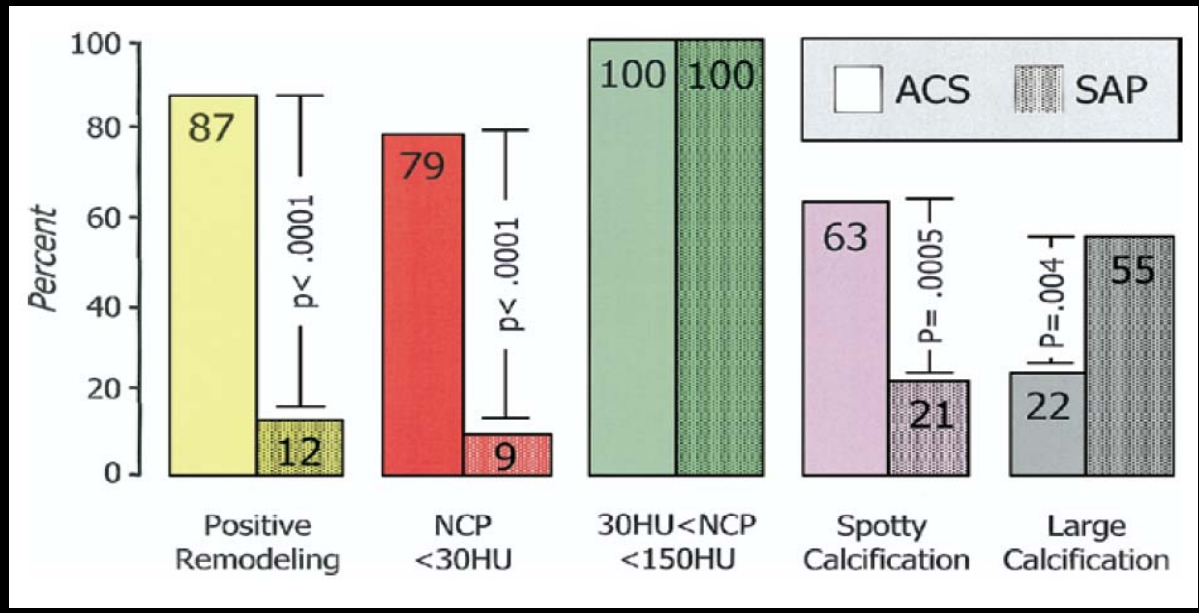


Dual Energy CCTA

CCTA Characteristics of Coronary Lesions in ACS

38 pts with ACS and 33 pts with SAP prior to PCI studied by CCTA.

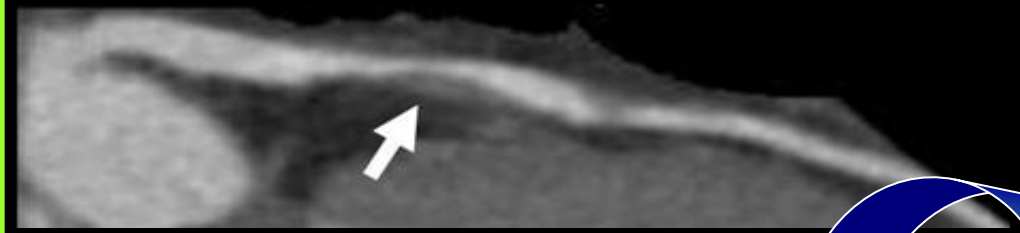




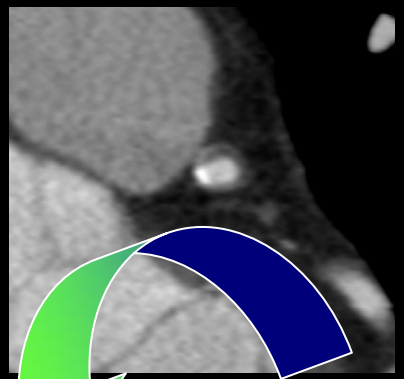
Positive remodeling, NCP<30 HU and spotty calcification more frequent in culprit ACS lesions than SAP.

Motoyama et al. AHJ 2006

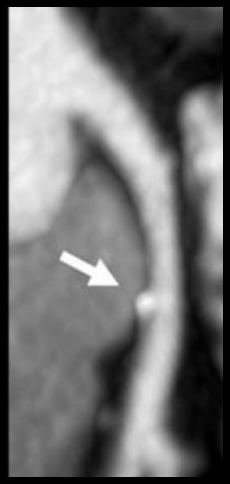
PLAQUE SEVERITY/VOLUME

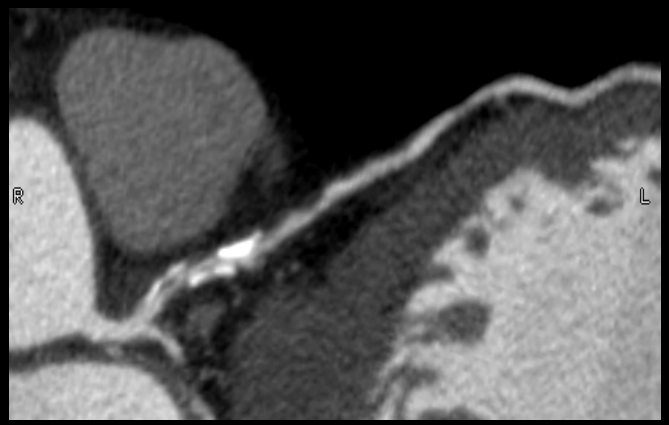


PLAQUE COMPOSITION/ REMODELING



PLAQUE LOCATION/ DISTRIBUTION



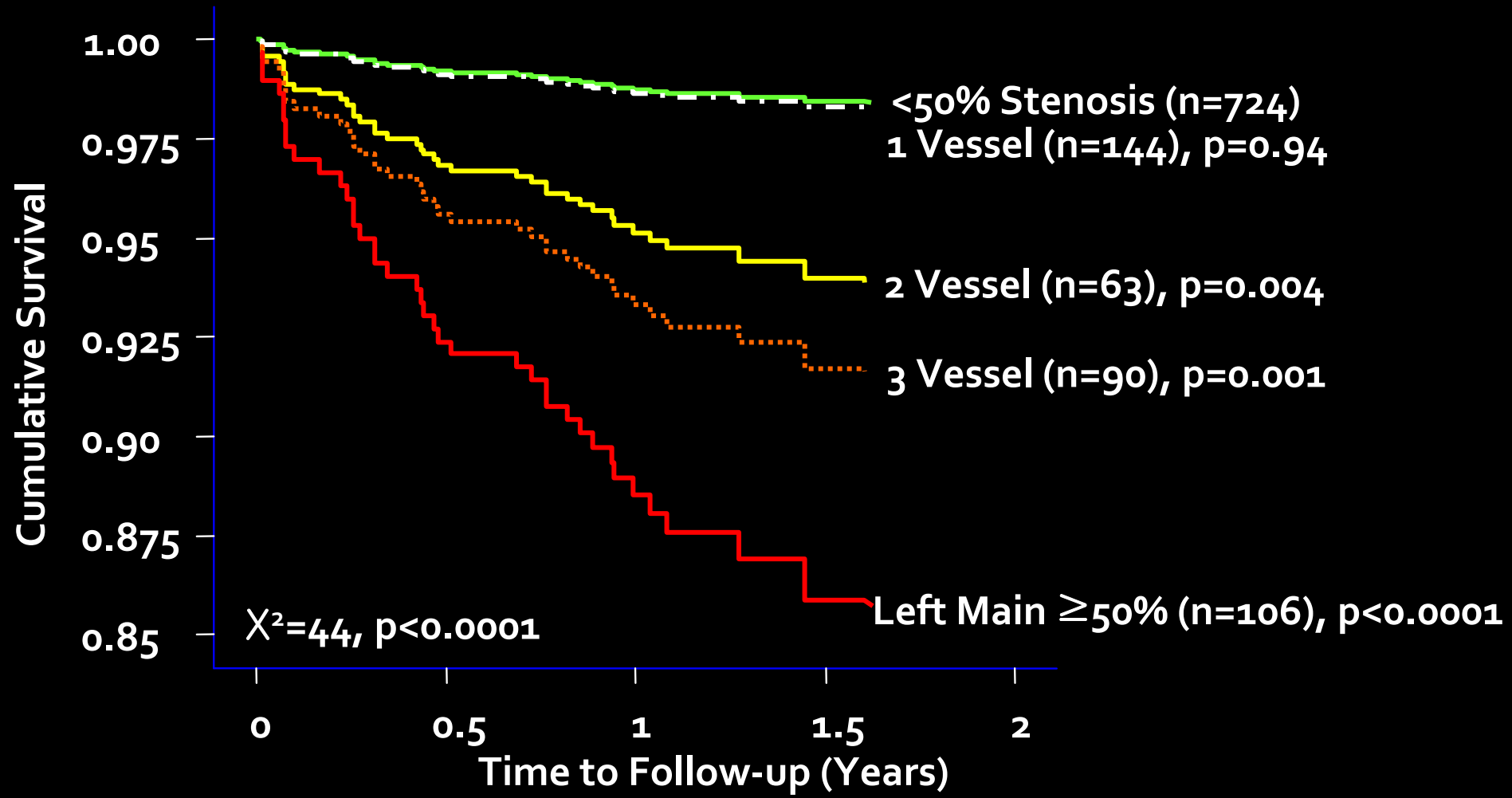


PATIENT –LEVEL PLAQUE BURDEN

REASON #2:

Non-invasive imaging is prognostically valuable for identifying ‘at-risk’ individuals BEFORE events occur.

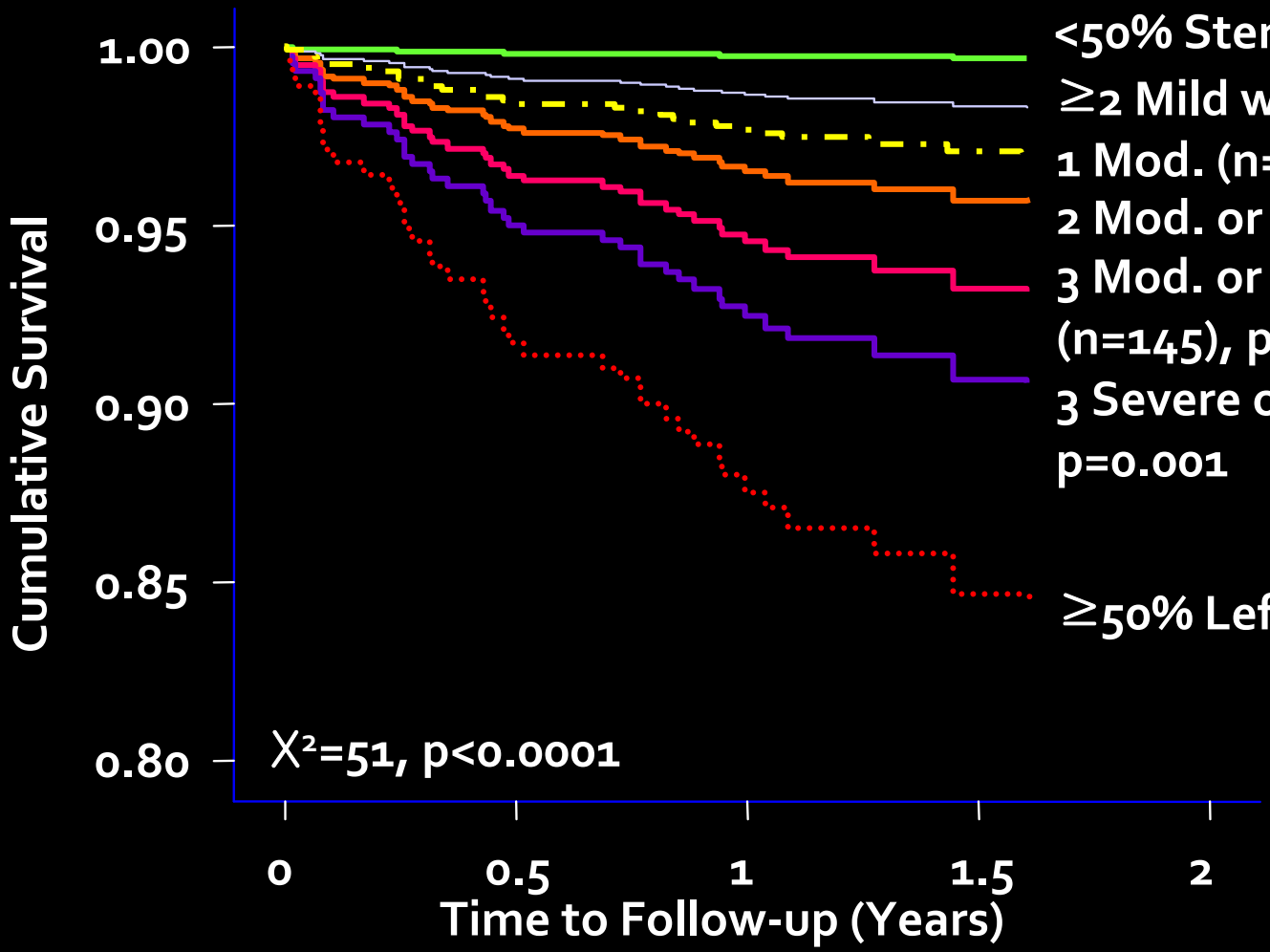
Plaque Severity



R-A p<0.001 (controlling for risk factors + chest pain).

Min et al. JACC 2007

Plaque Location



<50% Stenosis (n=422)

≥2 Mild w 1 Prox. (n=64), p=0.192

1 Mod. (n=212), p=0.065

2 Mod. or 1 Severe (n=101), p=0.013

3 Mod. or 2 Severe or ≥70% prox. LAD (n=145), p=0.002

3 Severe or 2 Severe w Prox. LAD (n=86), p=0.001

≥50% Left Main (n=106), p<0.0001

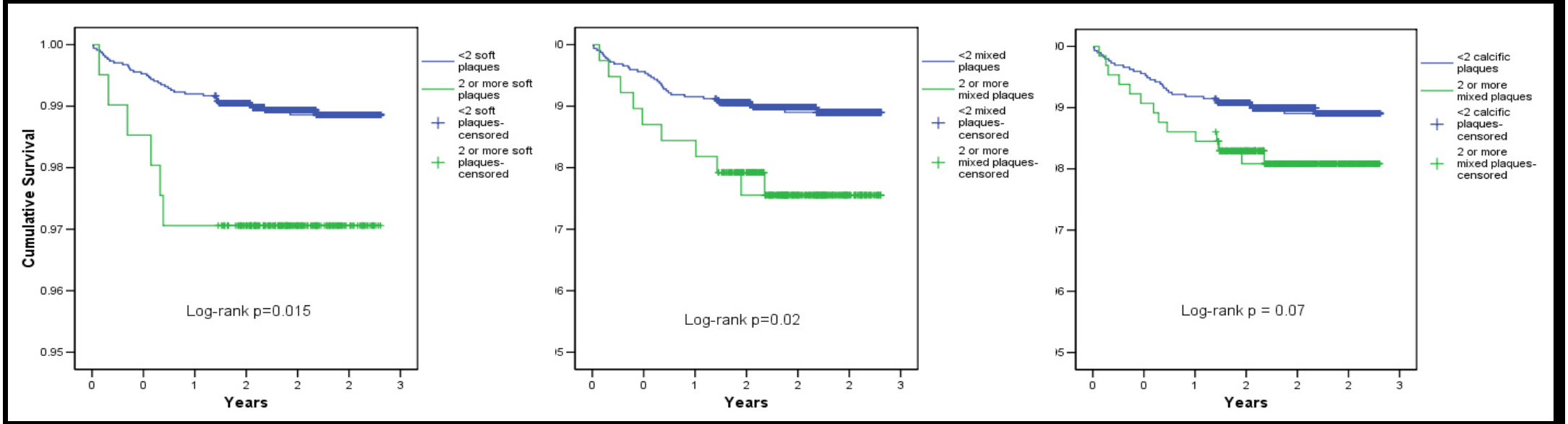
R-A p<0.0001 (adjusting for risk factors, chest pain, + dyspnea), Mild (30%-49%), Mod. (50%-69%), & Severe (≥70%).

Min et al. JACC 2007

Plaque Composition and Mortality

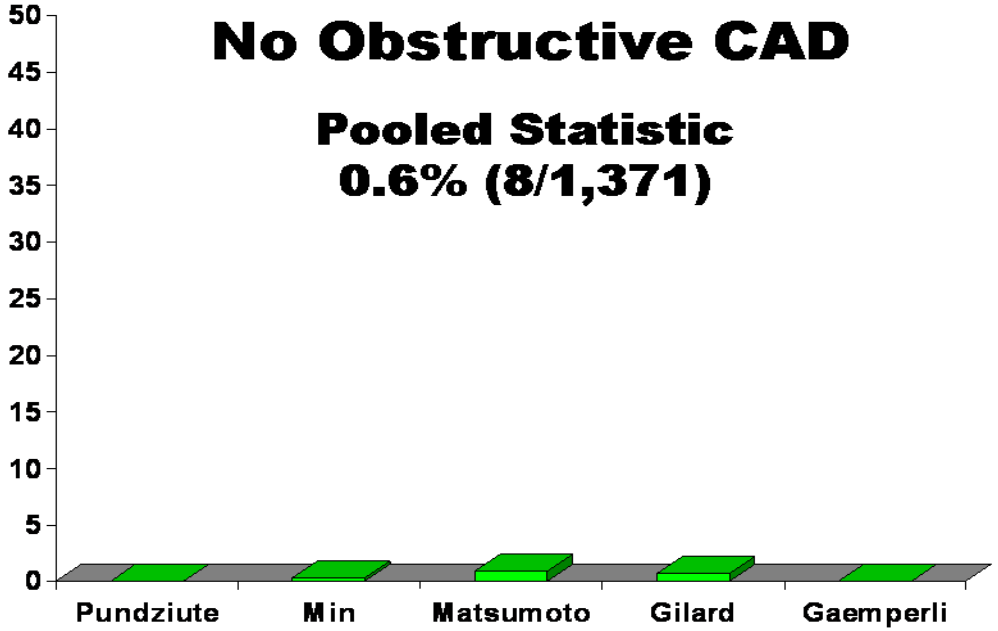
Two-center study of 3,576 patients without obstructive CAD followed for 2.3 years.

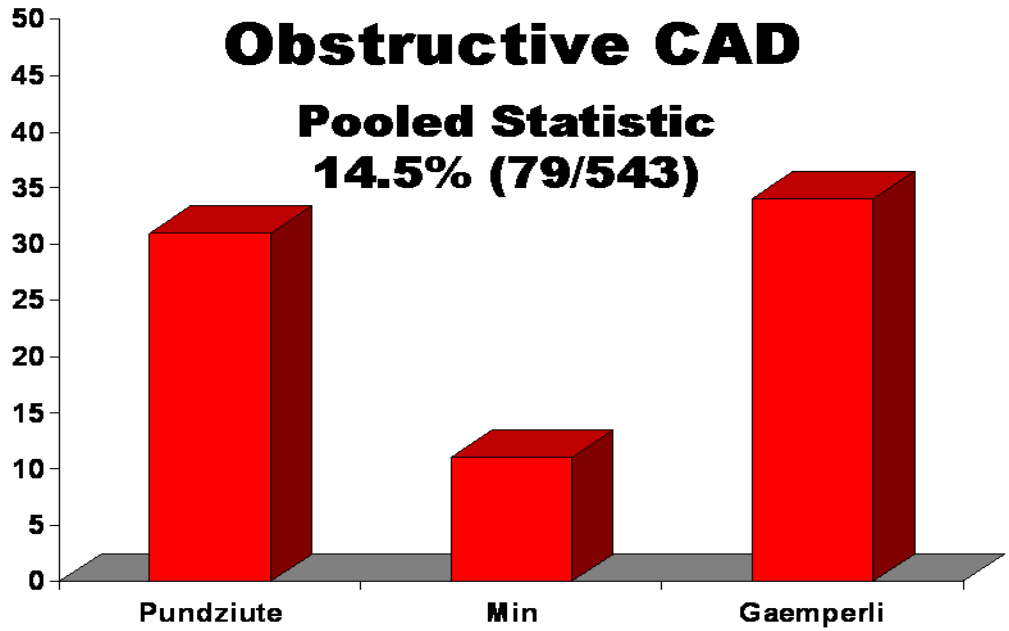
Non-obstructive – Non-calcified	Non-obstructive and Obstructive – Mixed	Obstructive – Calcified



Min, preliminary data

Prognosis by Non-invasive Imaging





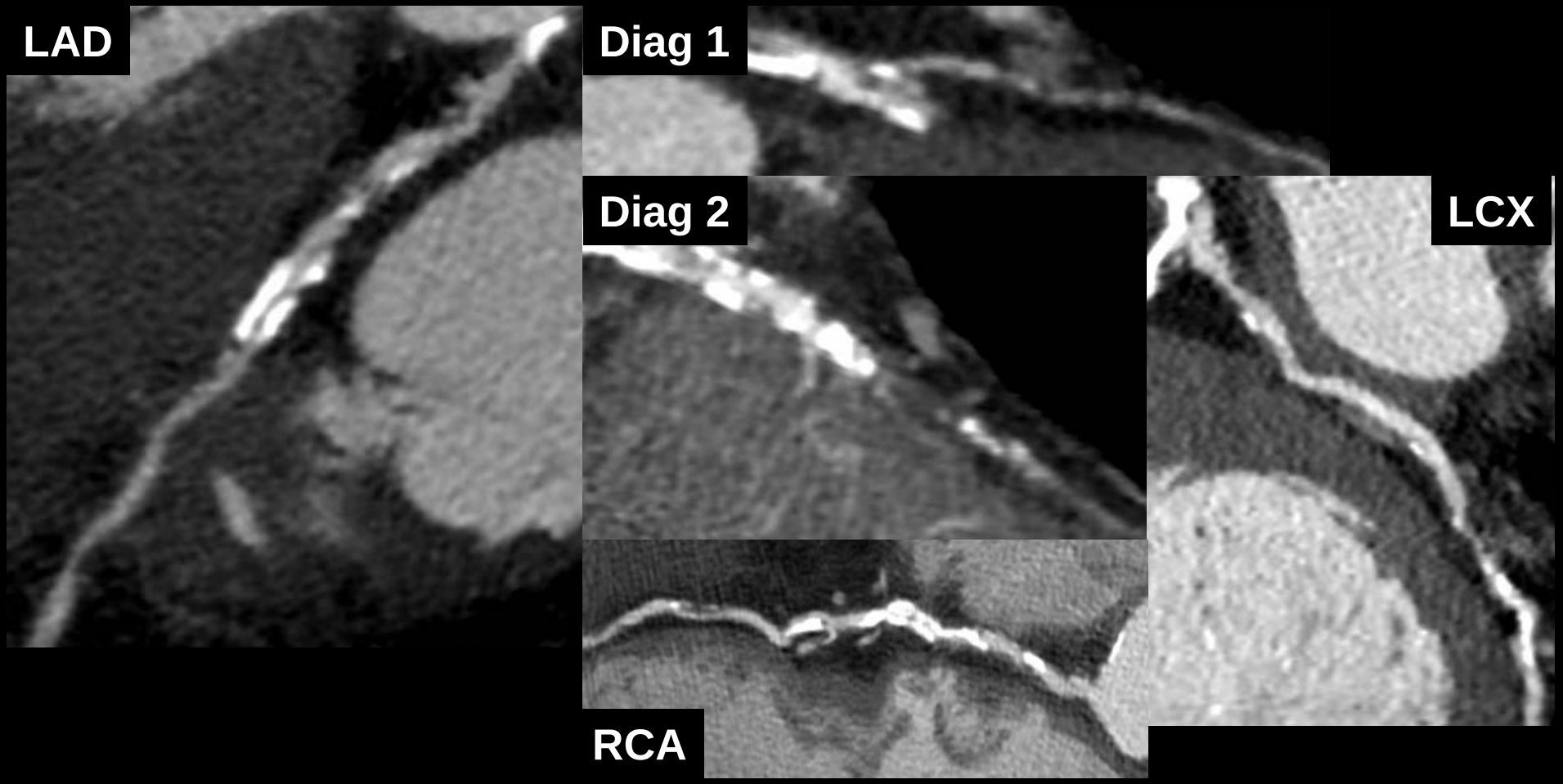
Courtesey of Leslee Shaw

Totality of Prognostic Data Associated with Invasive Plaque Imaging

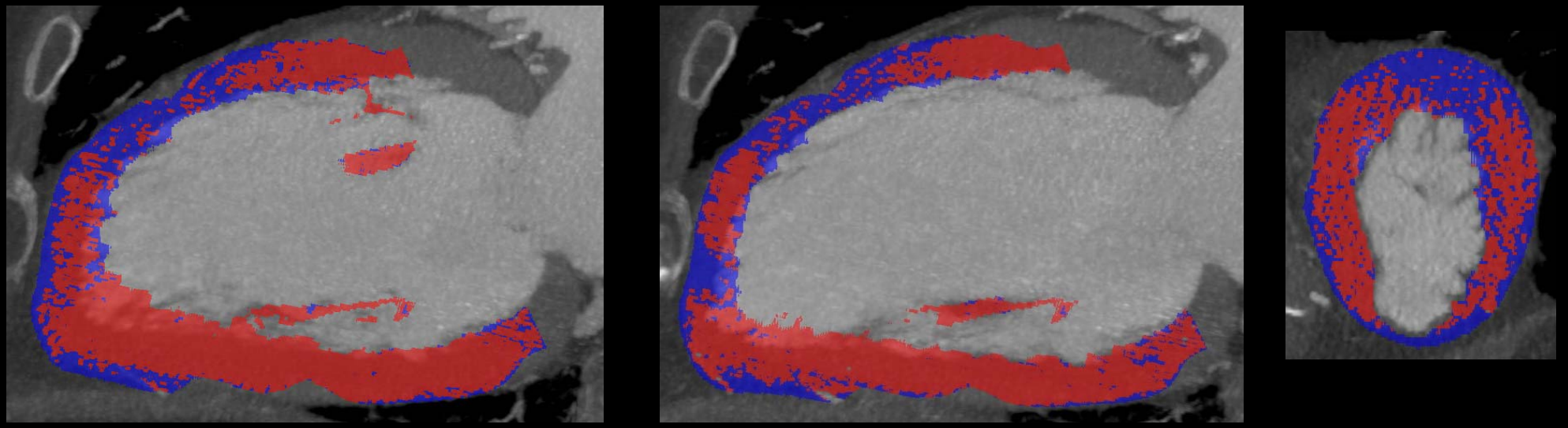
REASON #3:

Non-invasive imaging concurrently identifies other information capable of predicting risk.

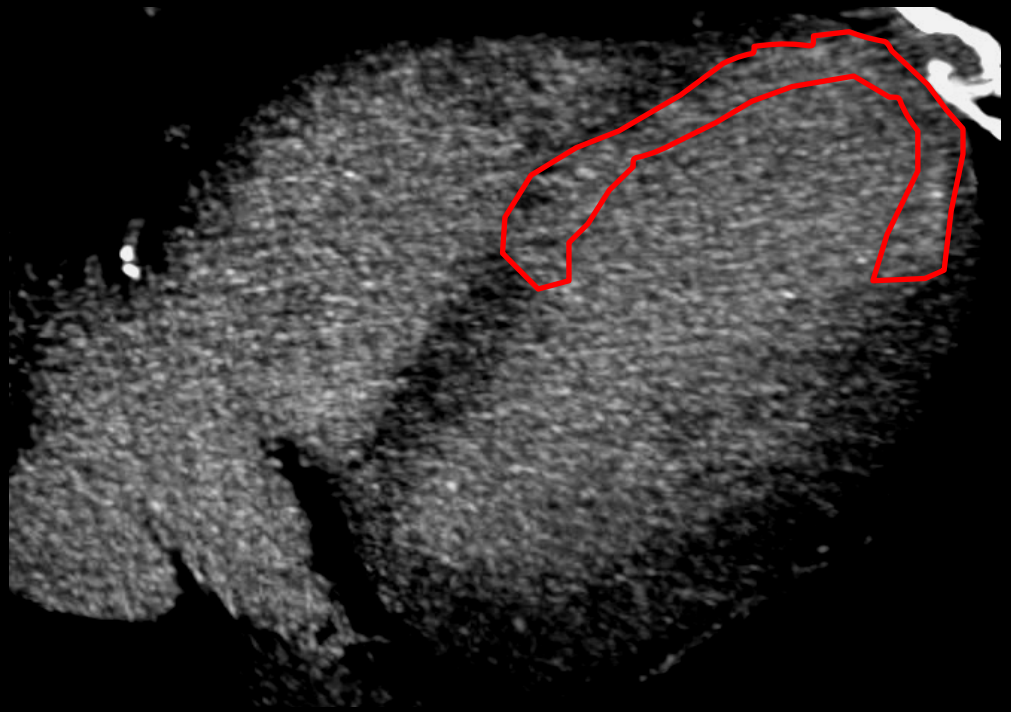
Which factors portend vulnerability?

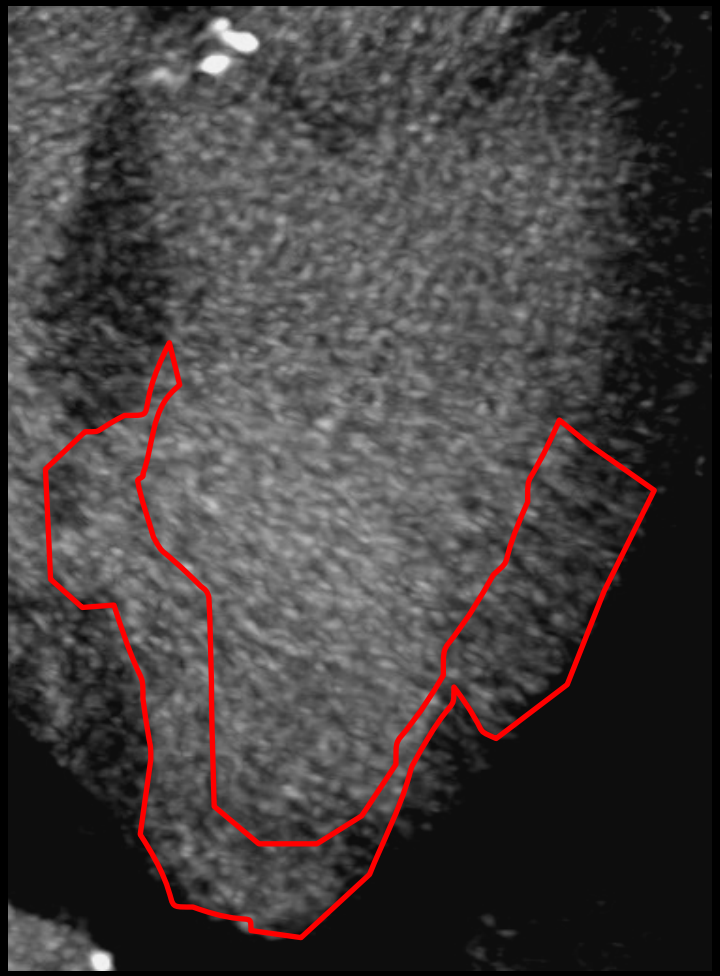


Perfusion



Myocardial scar





Function


AW VolumeShare 3
sdc
Patient List
Volume Viewer
Viewer
Filmer
S I A P L R
Review Steps
Save_State_layout_preset
Angiographic View
Tree VR
Coronary Analysis
Heart Graft
Cardiac Transparency
Auto Ejection Fraction
Protocols List
Auto Ejection Fraction
LV RV LA RA
ES: 46
ED: 124
V ml
0% 50% 100%
StrokeVolume 78.0 ml
Ejection Fraction 62.0 %
Cardiac Output 3354.0 ml/min
Myocardial Mass 97.3 g
ES Volume (35%) 46.0 ml
ED Volume (95%) 124.0 ml
PVR calculate
SVR calculate
BSA 1.9 m2
Heart Rate 43 bpm
Edit
Myocardium Analysis
Display less tools
VR
My Tools
Film/Save
Display
Segment
Report
Auto Select
Threshold
Remove Object
Advanced Processing
Exit
Hide Panels

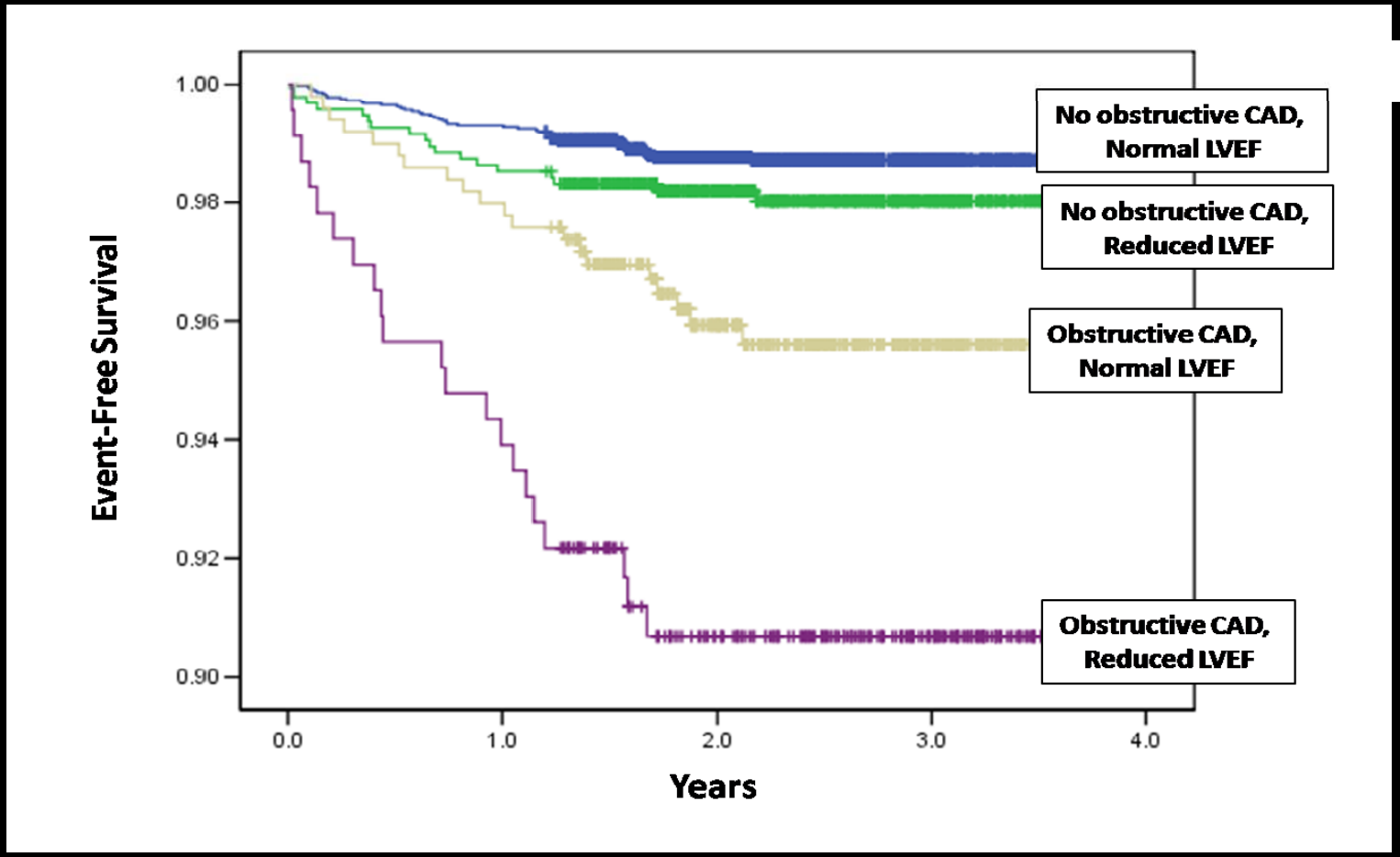
Incremental Value of Perfusion to Anatomy

517 pts undergoing CCTA and MPS studied for SSS≥4 or coronary stenosis≥50%

Van Werkhoven et al. JACC 2009

Incremental Value of LVEF to Anatomy

5,646 consecutive patients undergoing CCTA followed for 2.3 years.

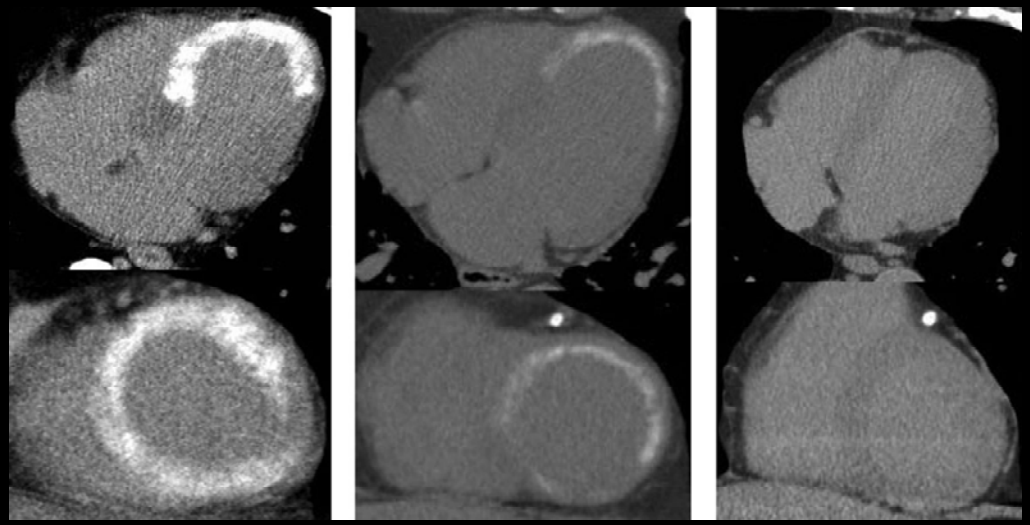


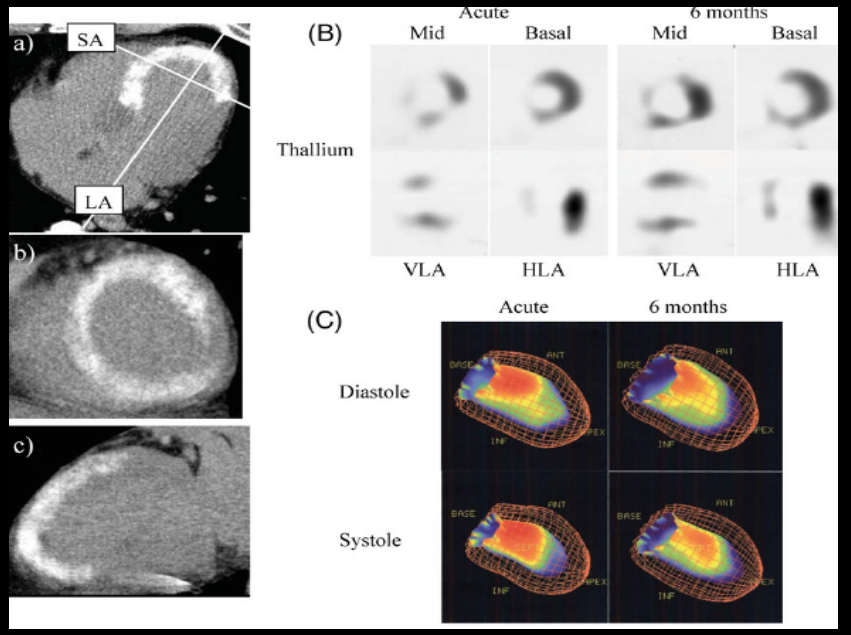
Min, preliminary data

Incremental Value of Scar to Anatomy

Adverse LV remodelling (p=0.001) and # of rehospitalizations for CHF (p=0.0017) higher in TM DE.

	TM DE (n=18)	SE DE (n=20)	No DE (n=14)	P value
Peak CKMB	497	182	85	0.0004
Myocardial blush grade 3	22%	67%	75%	0.001
LVEF	41%	53%	62%	0.0001





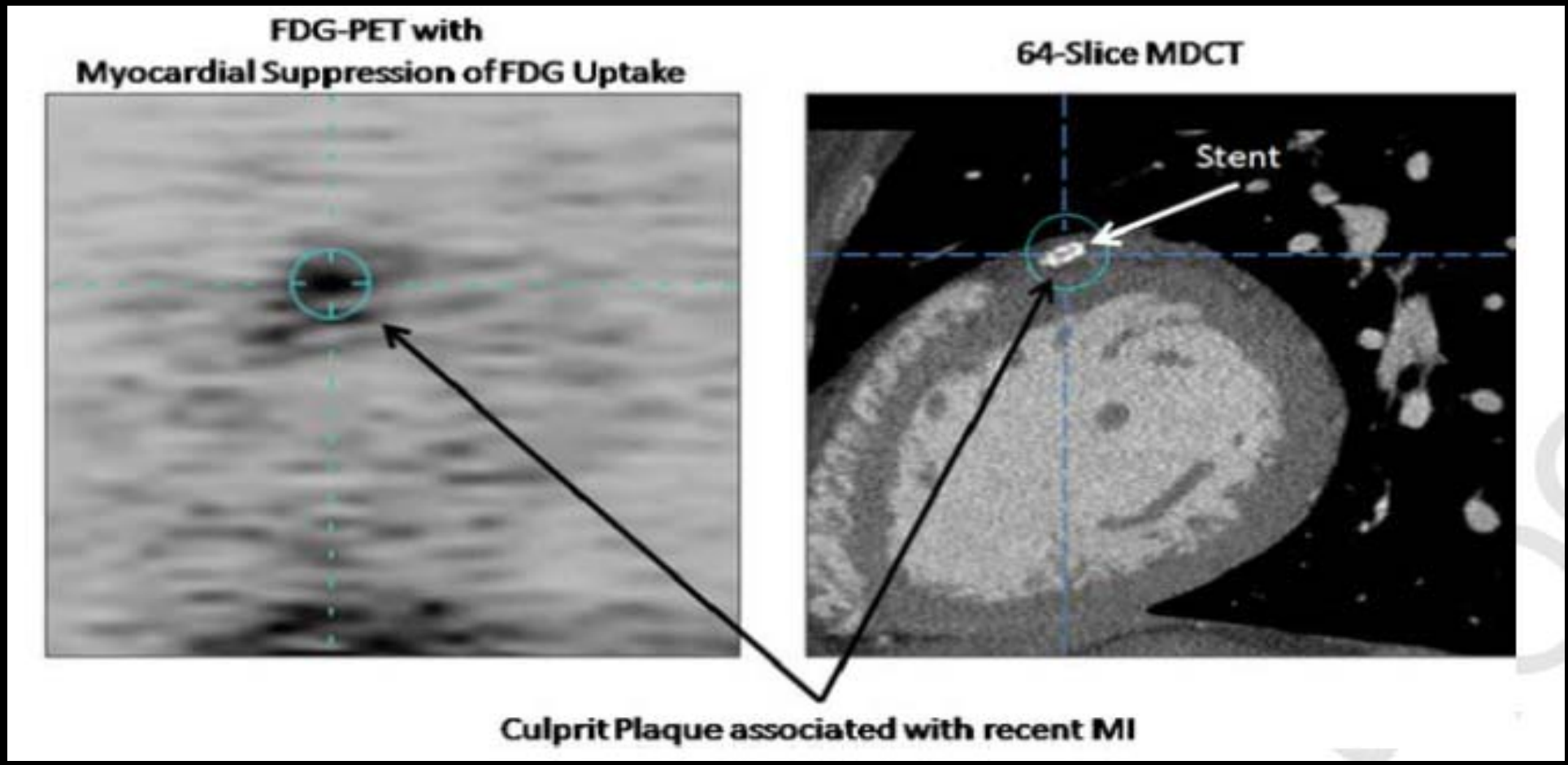
Sato et al. EHJ 2008

REASON #4:

Non-invasive imaging offers assessment beyond anatomy.

Inflammation and ACS (PET and CCTA)

Glycolytic activity by FDG uptake in the LM artery greater for pts with ACS than those who were stable (2.4 vs. 1.8, p 0.001).

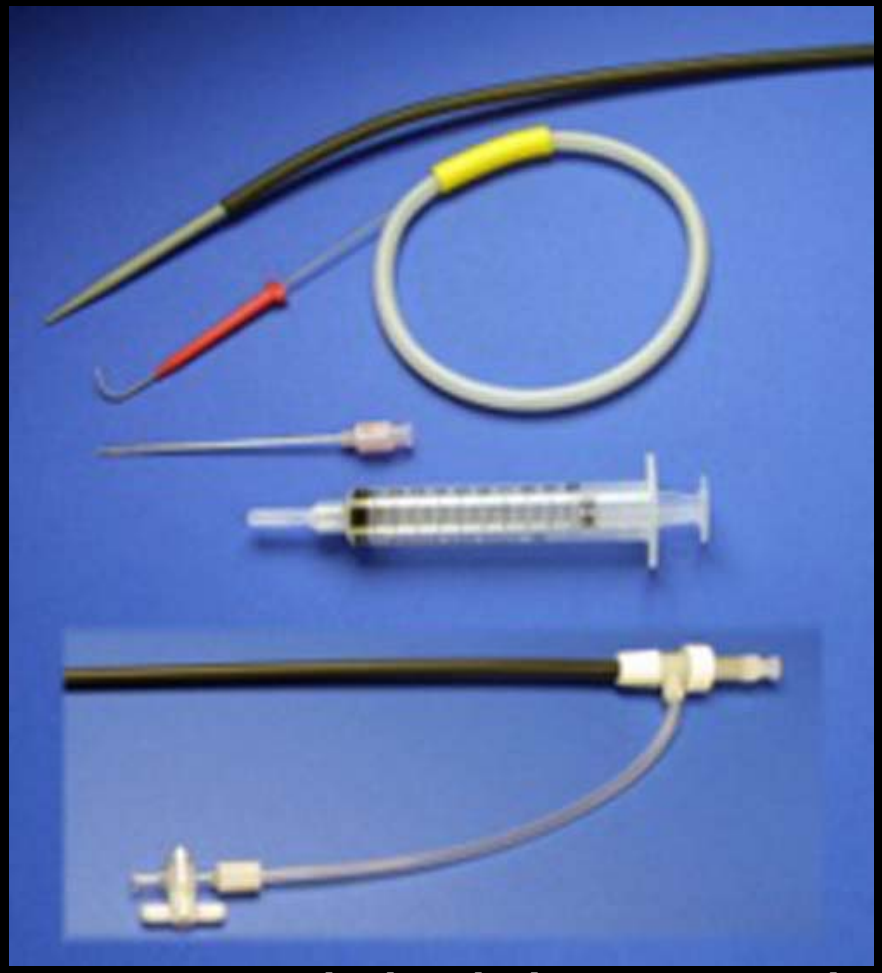


O'Donnell and Voros AHA Scientific Sessions 2007

REASON #5:

Non-invasive imaging by CCTA is safer than invasive imaging.

Near-term complications: Invasive Evaluation



- Complication Rate, IVUS
  - Any 1.1-2.9%
    - Spasm
  - Major 0.4%
    - Occlusion
    - Dissection
    - Guidewire entrapment

Hausmann D et al Circulation 1995; Batkoff BW et al. Cathet Cardiovasc Diagn 1996; Pinto FJ et al. Circulation 1993

Near-term complications: Non-invasive imaging

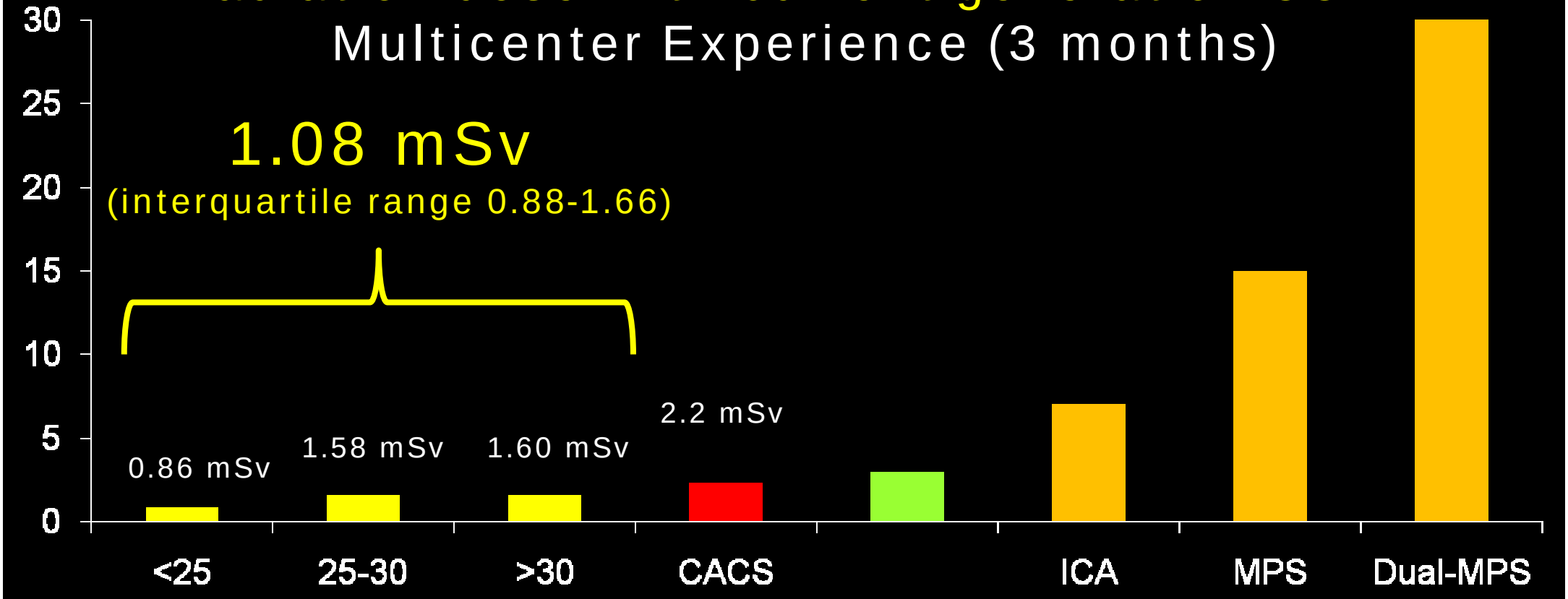
Complication*	Rate
Symptomatic bradycardia	0%
Hypotension	0%
Contrast-induced nephropathy	0%
Heart block	0%
Anaphylactic reaction	0%
Any complication	0%

*Using standard protocol involving 5mg increments of lopressor and iodixanol as contrast agent

Results from prospective multicenter ACCURACY trial, Budoff MJ et al. JACC 2008

Long-term Safety

Radiation dose with current generation CCTA:
Multicenter Experience (3 months)



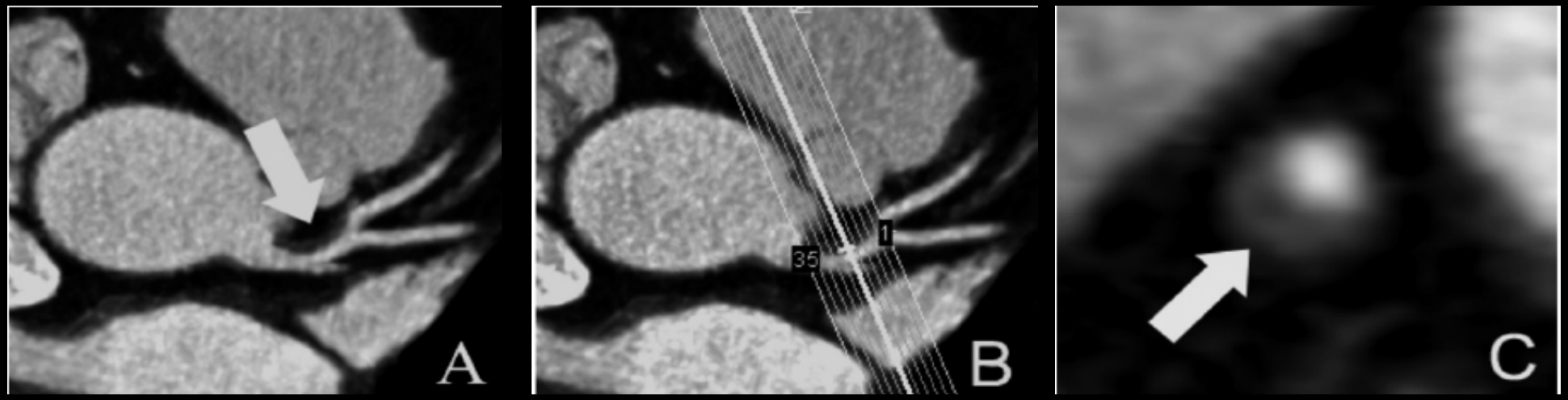
ICA dose 5X the CCTA.

REASON #6:

Non-invasive imaging by CCTA permits assessment of plaque progression.

Assessing Changes in Non-Calcified Atherosclerotic Plaque Volume in LM and LAD Over Time by 64-slice CCTA

50 patients with non-calcified plaque at baseline underwent f/u CCTA after 17±6 months. Mean plaque volumes were 92±81 mm3 at baseline MDCT and 115±110 mm3 on follow-up CCTA (p<0.001). Mean annualized volume change was 22% (95%CI, 14.7% vs. 29.7%). Weak but significant correlation to LDL levels for amount of baseline plaque volume, r=0.37, p<0.001)



Plaque areas manually traced. (PA = CSA – Luminal area)
Volume calculated by PA x (reconstruction increment)
Plaque volume = [PA1 + PA2 + ... PA30] x 0.5mm

Achenbach et al. AJC 2008

REASON #7:

You cannot invasively evaluate everyone.

Implicit in the evaluation of the "vulnerable" plaque is identification BEFORE clinical events occur

Non-invasive assessment of 'at-risk' *patients* is clinically more relevant than invasive assessment of 'at risk' *plaques*.

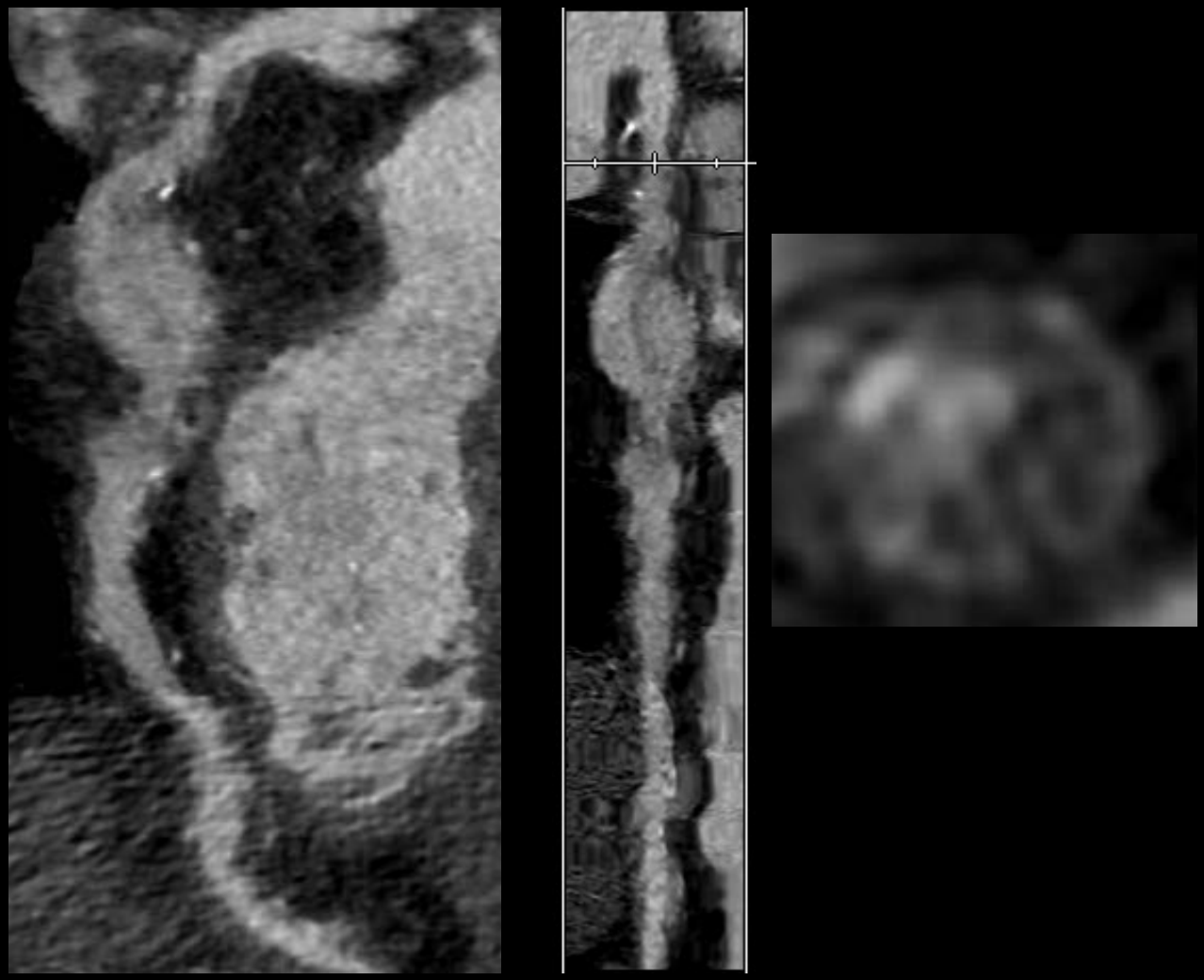
Thank you.

Non-invasive assessment of plaque vulnerability is preferable because:

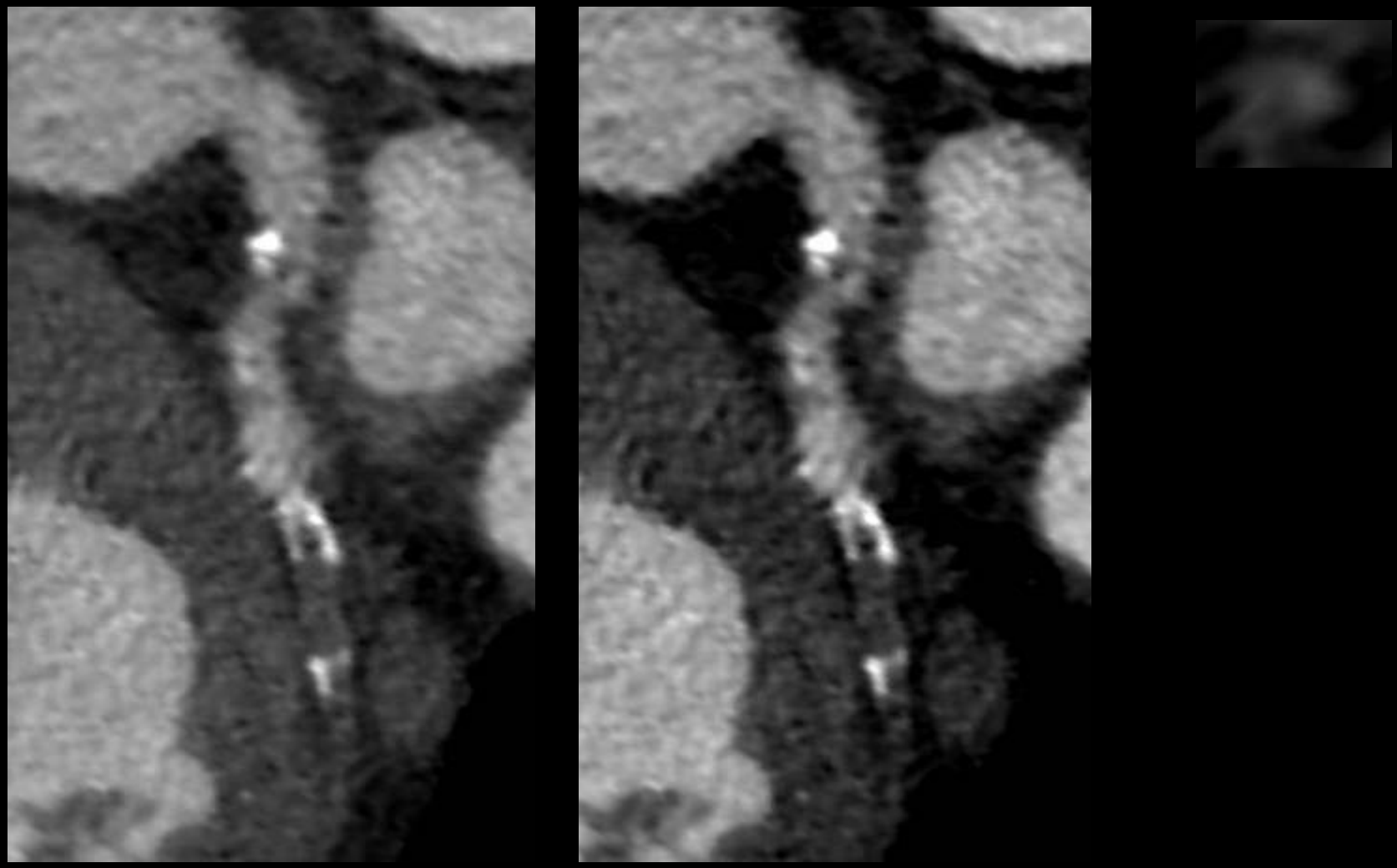
1. People will do it.
2. It is safer.
3. It permits serial assessment.
4. It permits assessment of overall plaque burden.
5. It is prognostic.
6. It offers data beyond plaque.
7. It permits concurrent evaluation of anatomy and physiology.

BEAL 2.5 mSv

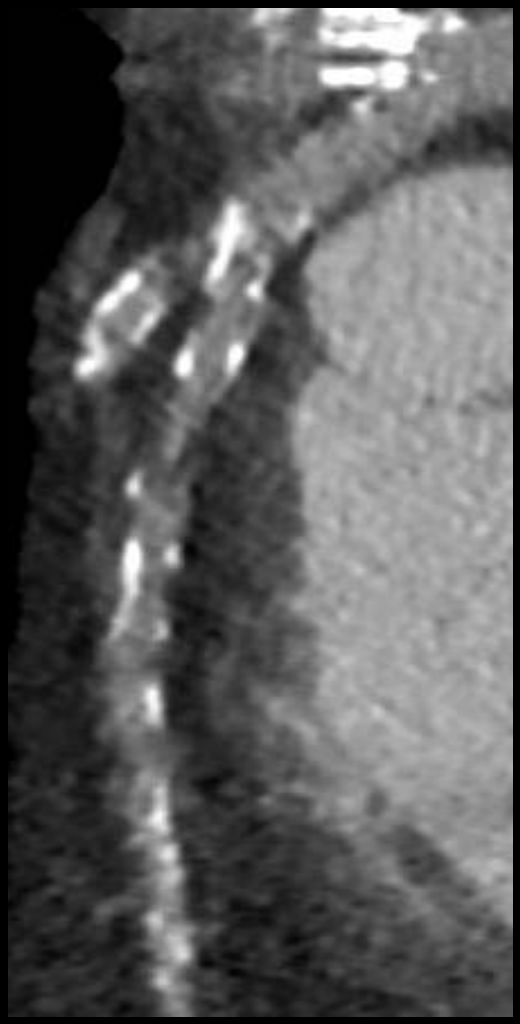
RCA aneurysm

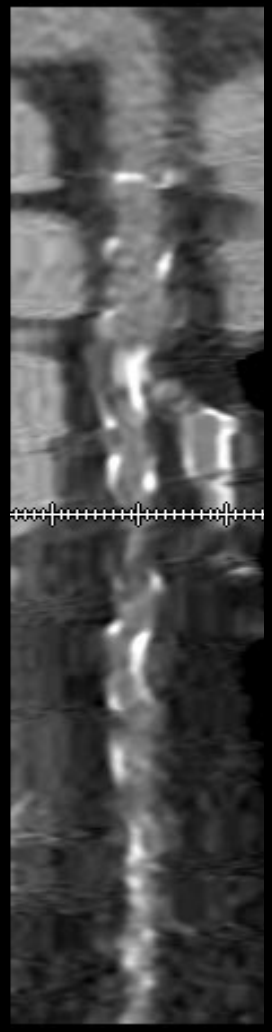


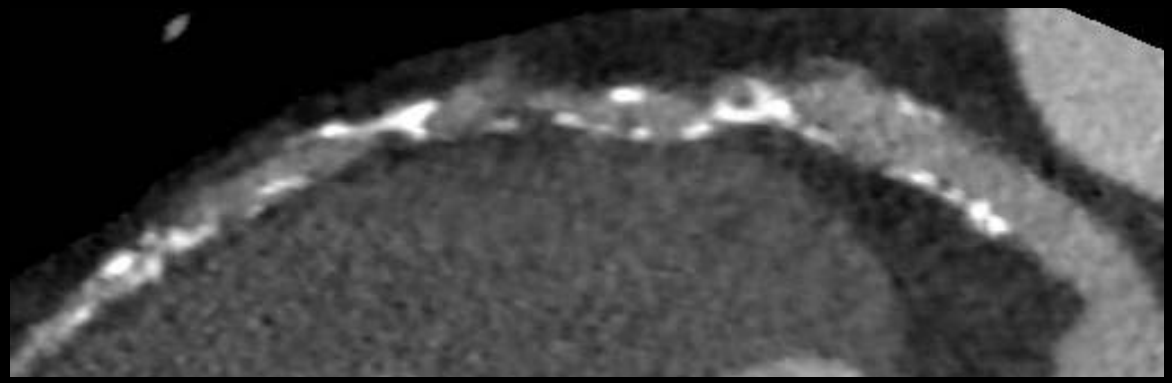
Totally occluded OM



Severely diseased LAD

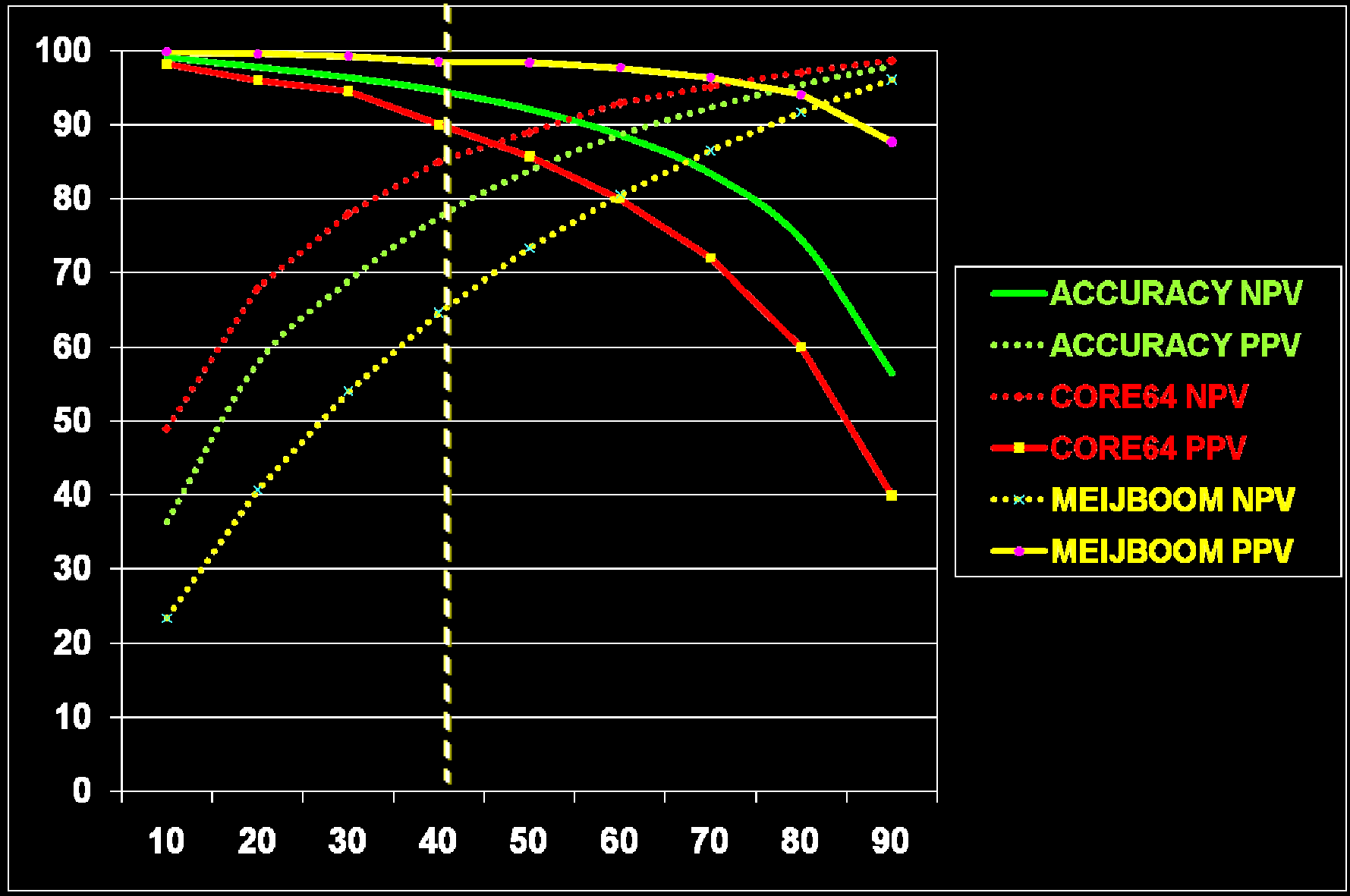


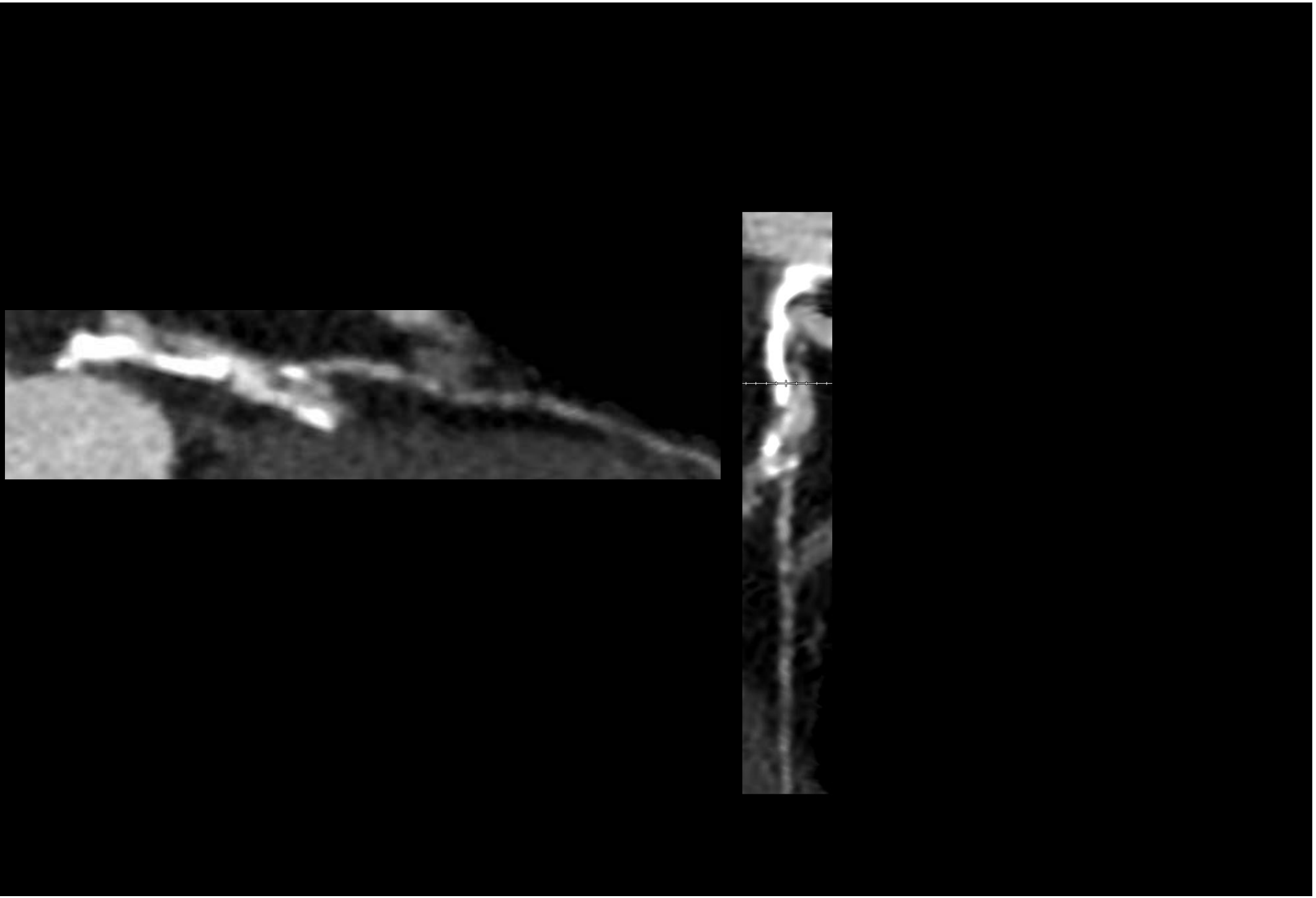


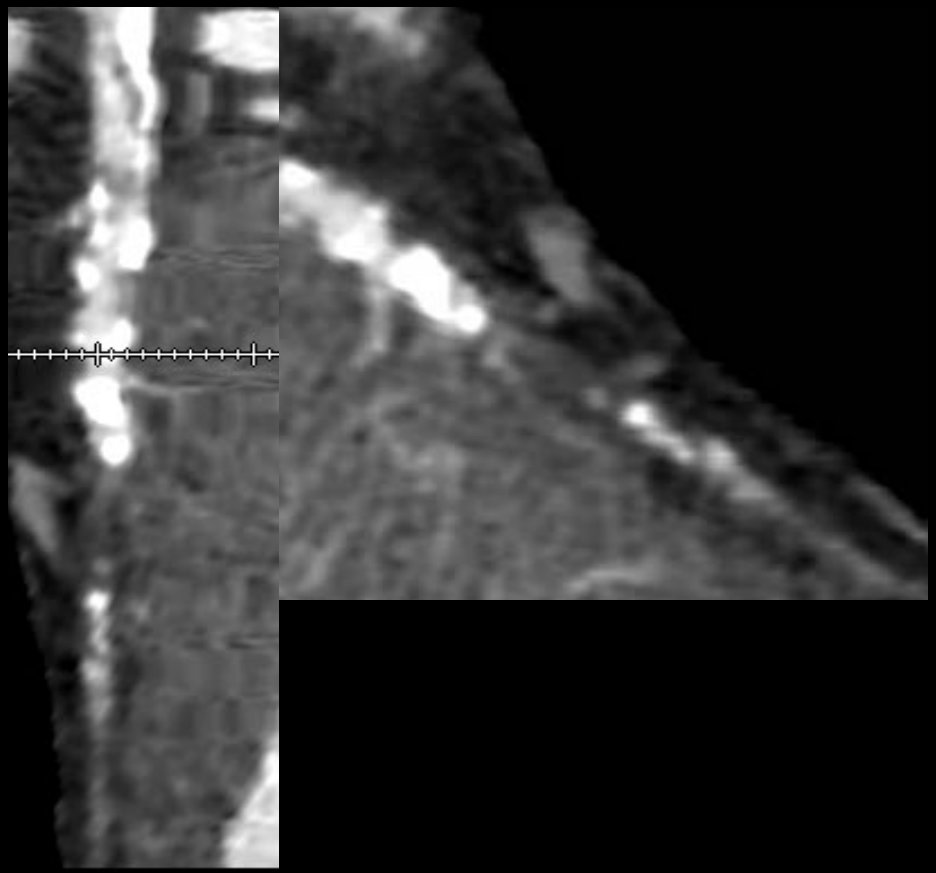


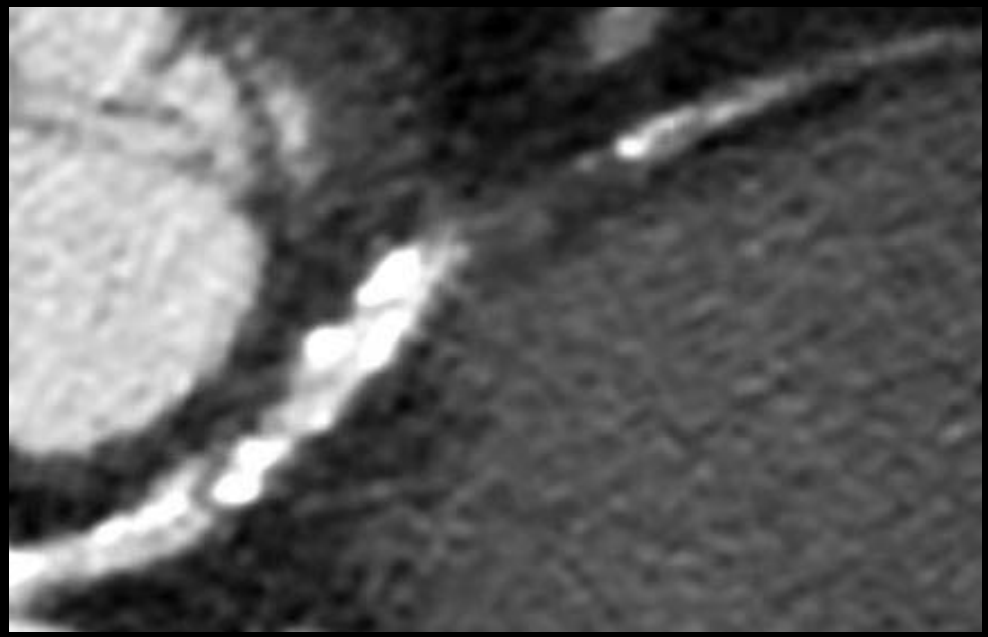
Chronic Total Occlusions

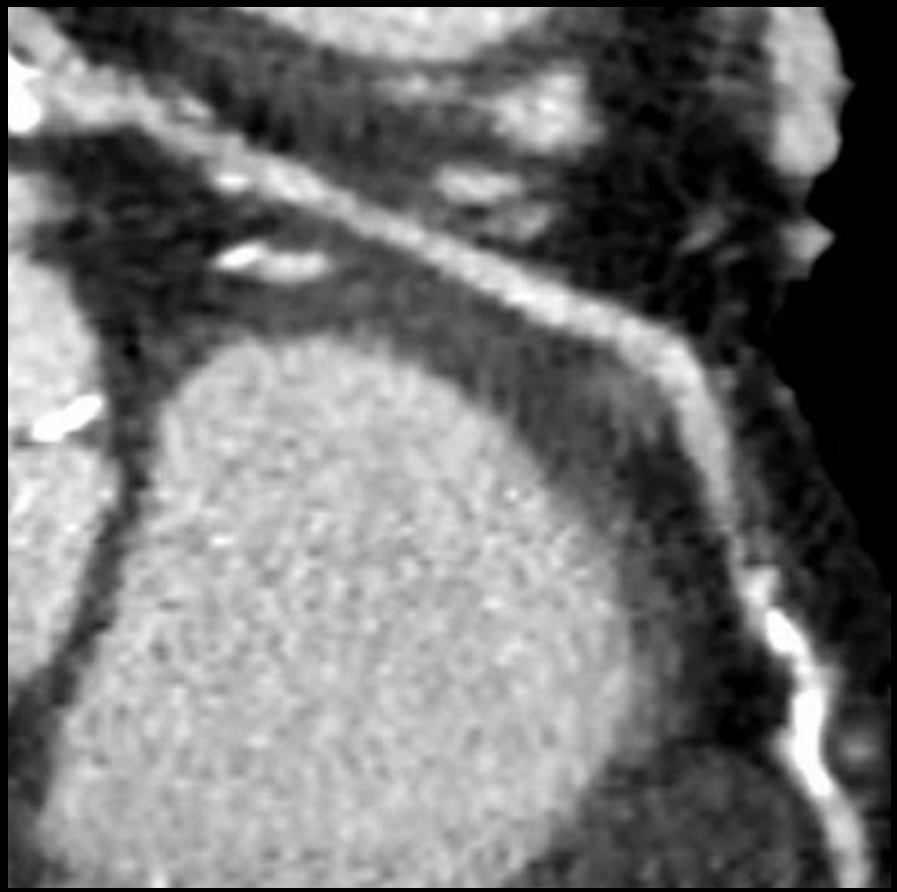
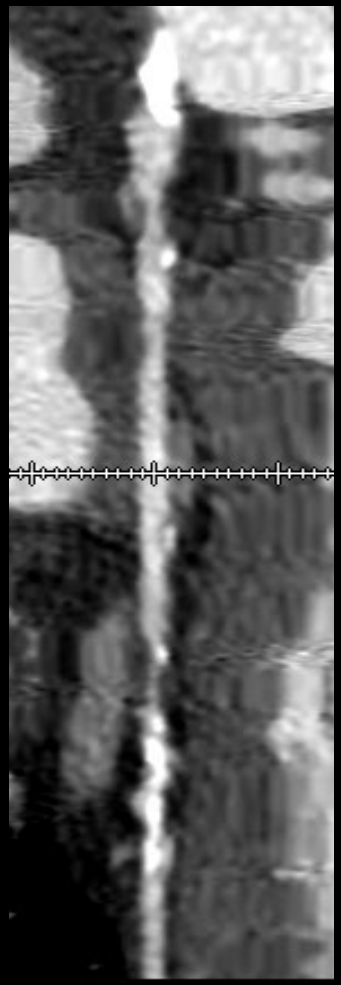
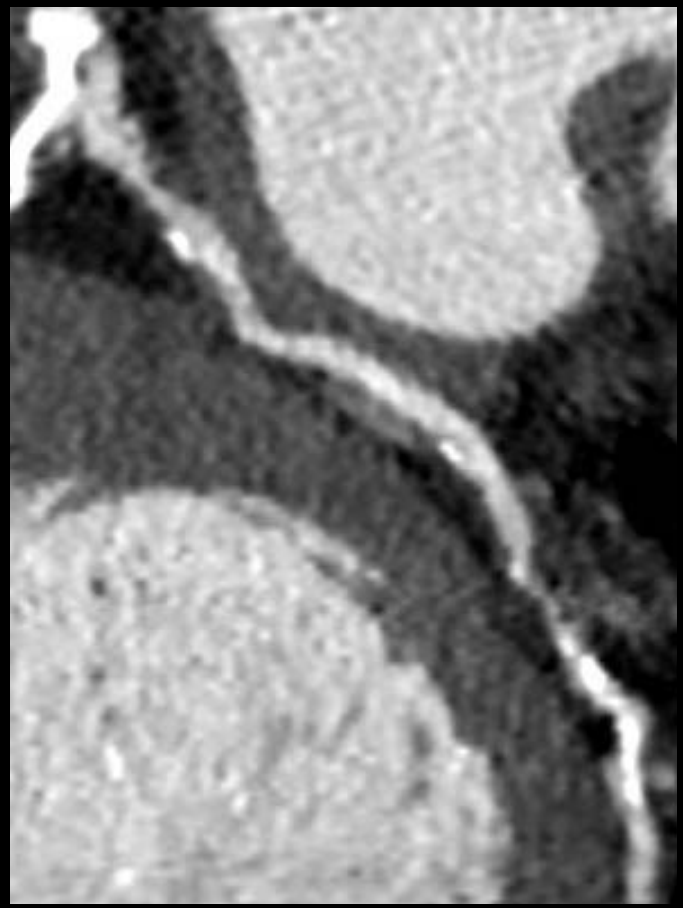
NPV / PPV based upon disease prevalence





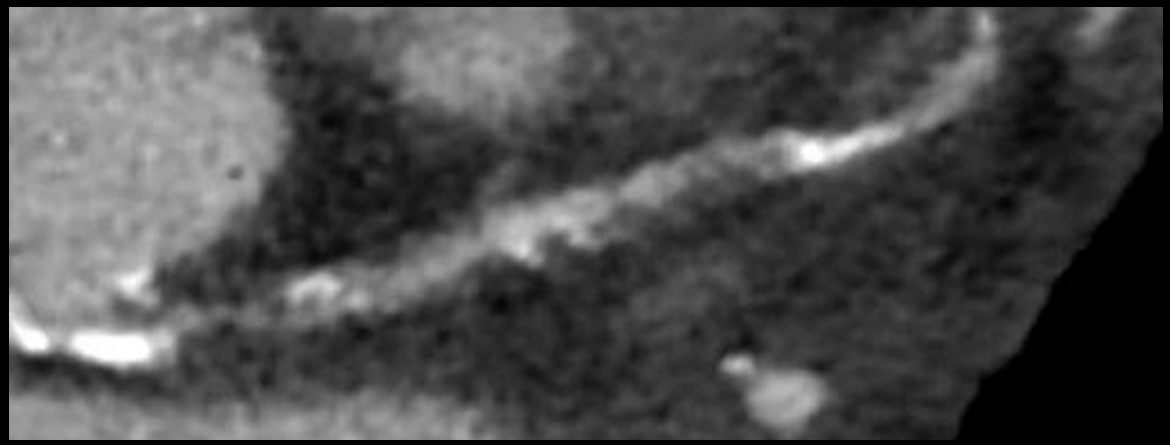


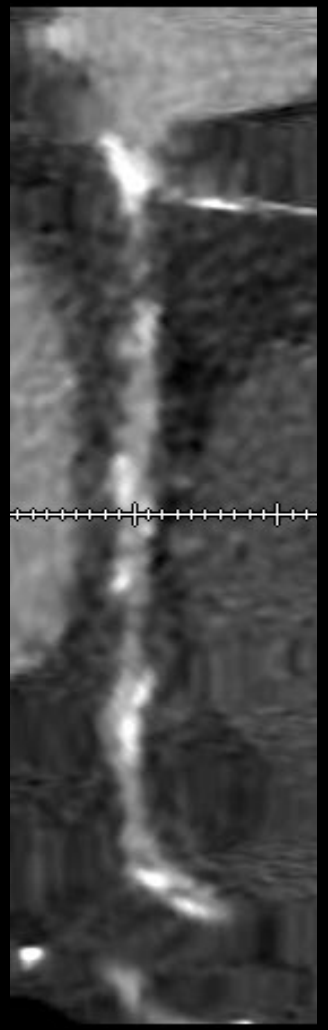


SVG to OM; SVG to RPL

LM and LAD





Plaque Composition

810 patients who underwent CCTA with non-obstructive CAD but with low dense plaques with CT HU density <68 HU, accompanied by mild-moderate coronary artery stenosis (25-75%). Follow-up 1,062+/-544 days for MACE (ACS, incl AMI and UA; cardiac death).

Only prior MI and low dense CT plaques predictive of MACE.
Low density plaques OR 4.60 (95% CI, 1.08-5.92)

Matsumoto et al. Circ J 2007

MDCT: CABG 64-row MDCT Studies

Author	# Pts	MDCT Rows	# Grafts	% Assessable	Basis	Sens	Spec	PPV	NPV
Pashka Eur Heart J 2006	31	64	96	94	Sten & Occl	97.8	89.3	90	87.7
Ropers et al Circulation. 2006	50	64	138	100	Sten	100	94	100	92
Dikkers J Cardio Imag 2006	34	64	69		Sten Occl	100 100	100 98.7		
Meyer J Am Coll Cardiol 2007	138	64	418		Sten & Occl	97	97	93	99

TAKE HOME POINT 1:

Spatial resolution is the most needed improvement to cardiac CT.

CASE #1: No known CAD

- 60 y/o female
  - H/o dyslidemia, HTN
  - Chest pain: exertional, better with rest

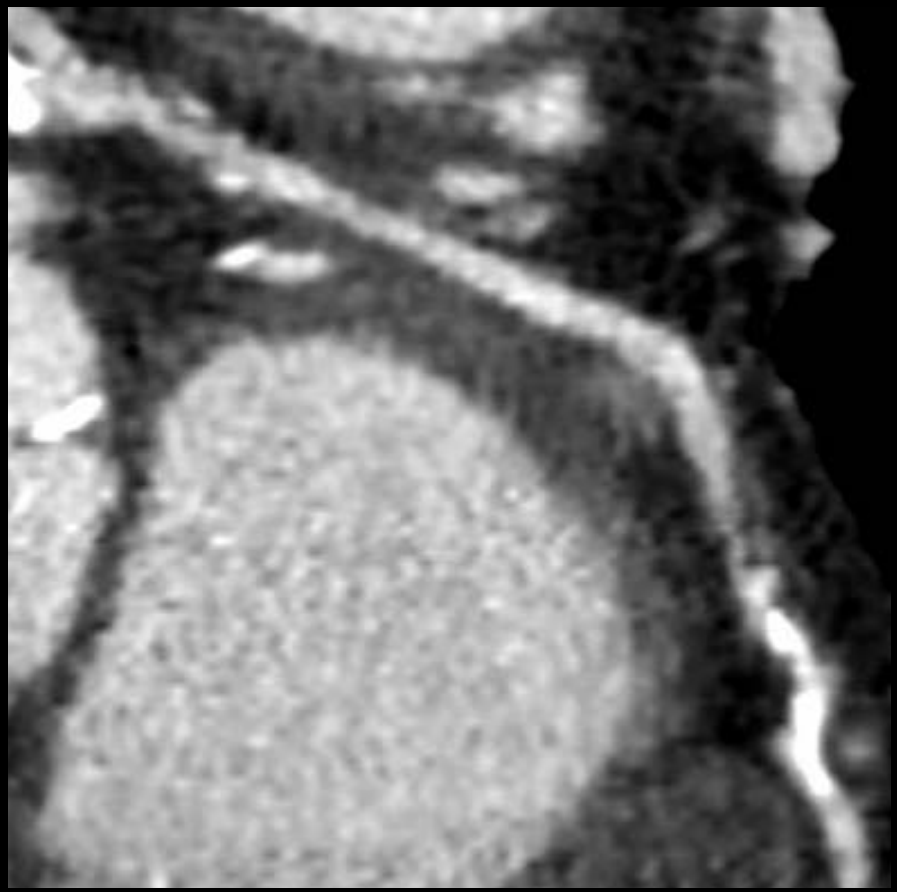
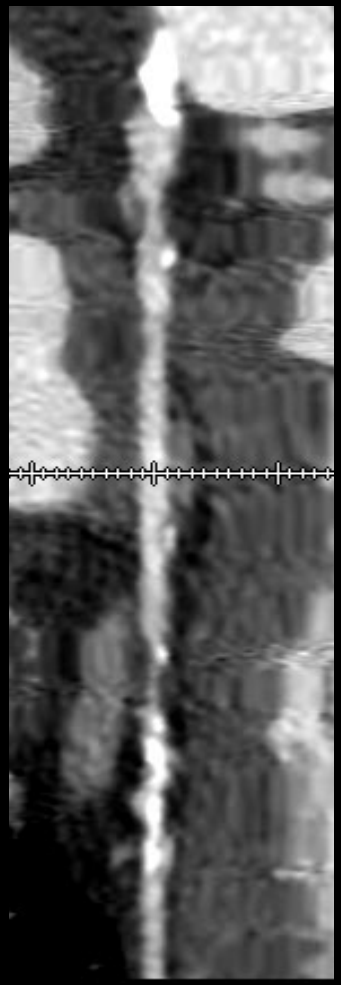
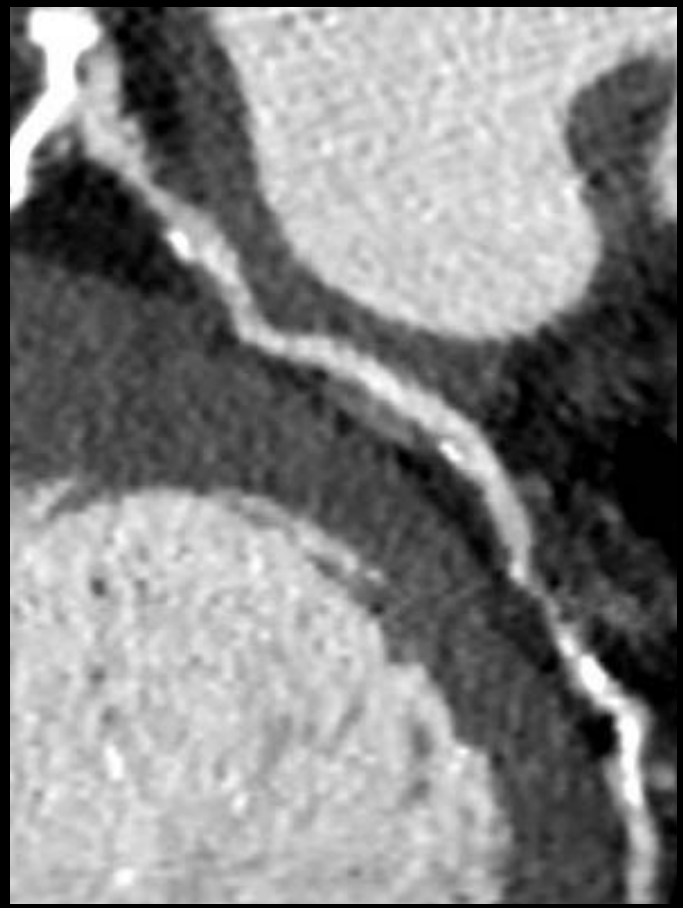
HDCT

LAD

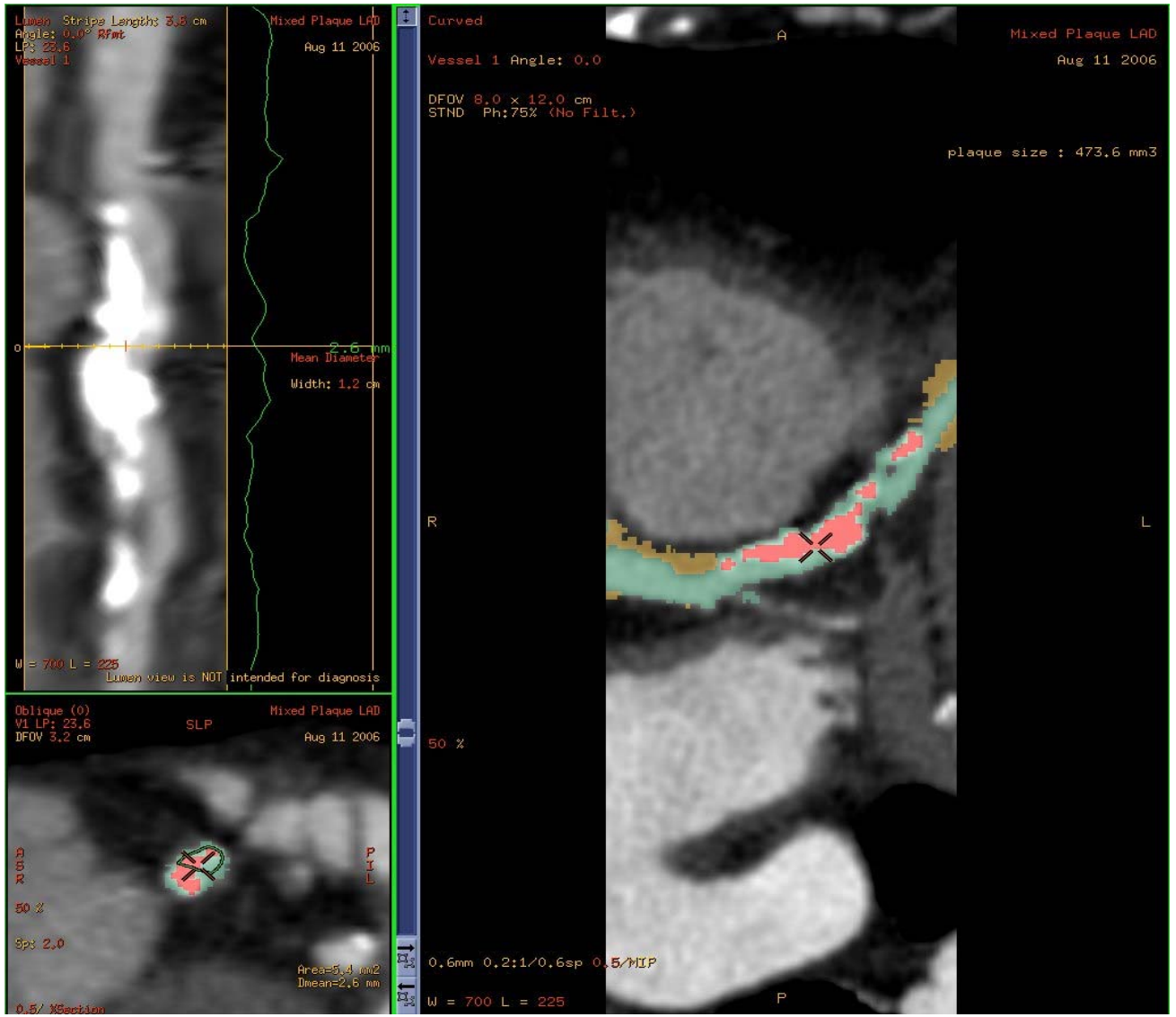
LCX

RCA

0.5 mSv

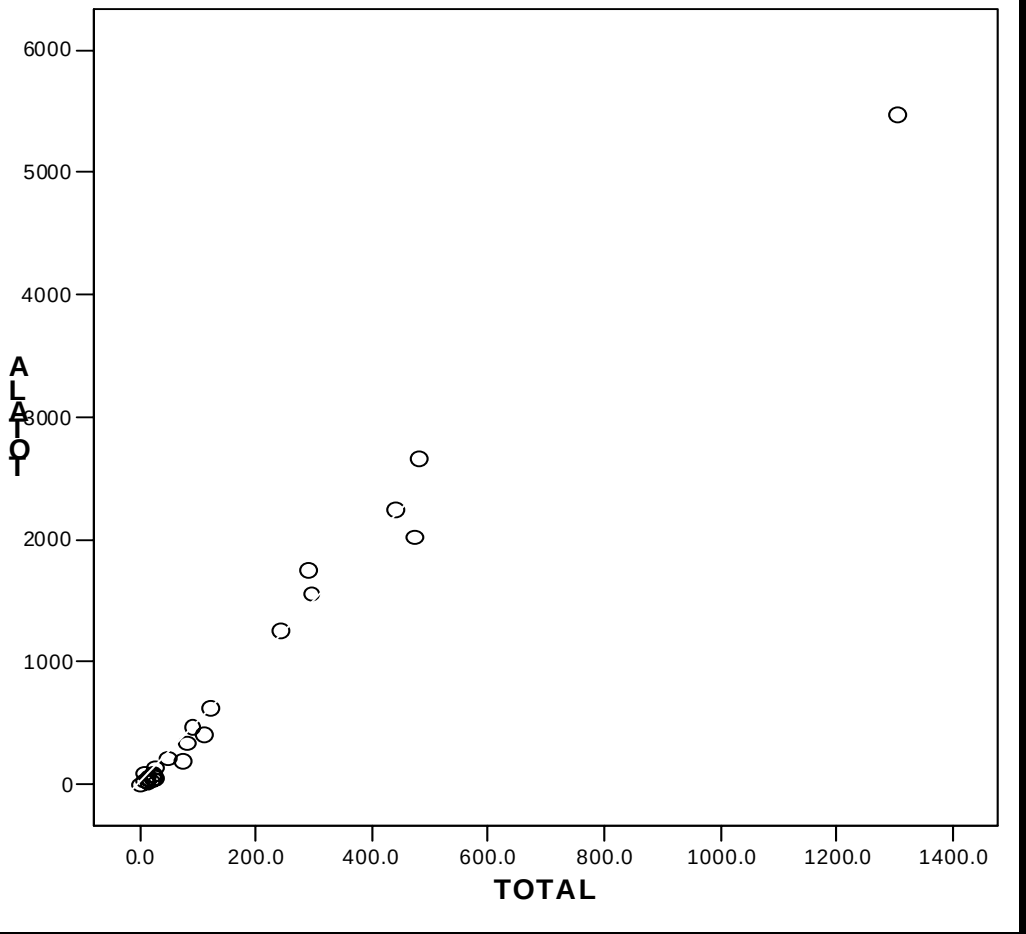




Contrast-enhanced Quantification of Plaque Volumes

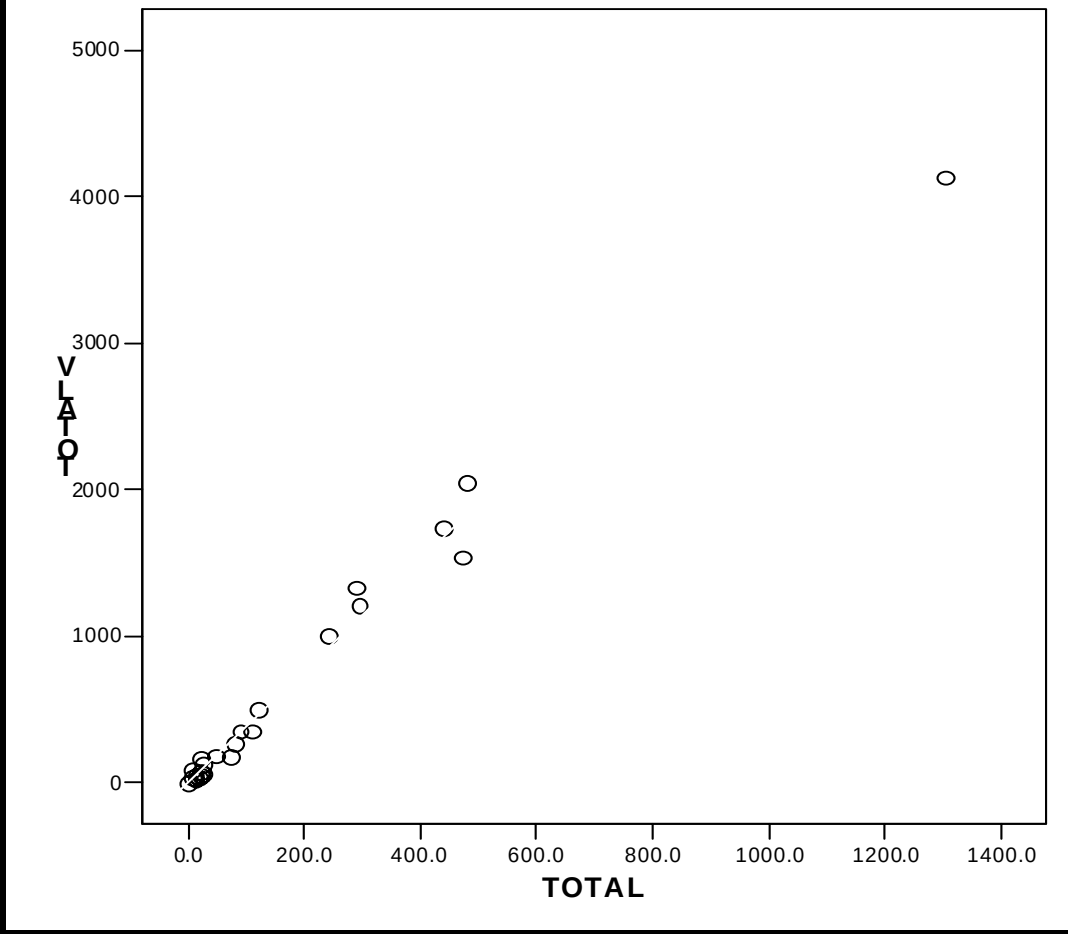


Calcium score vs. Contrast-enhanced calcium measurement

By total calcium score



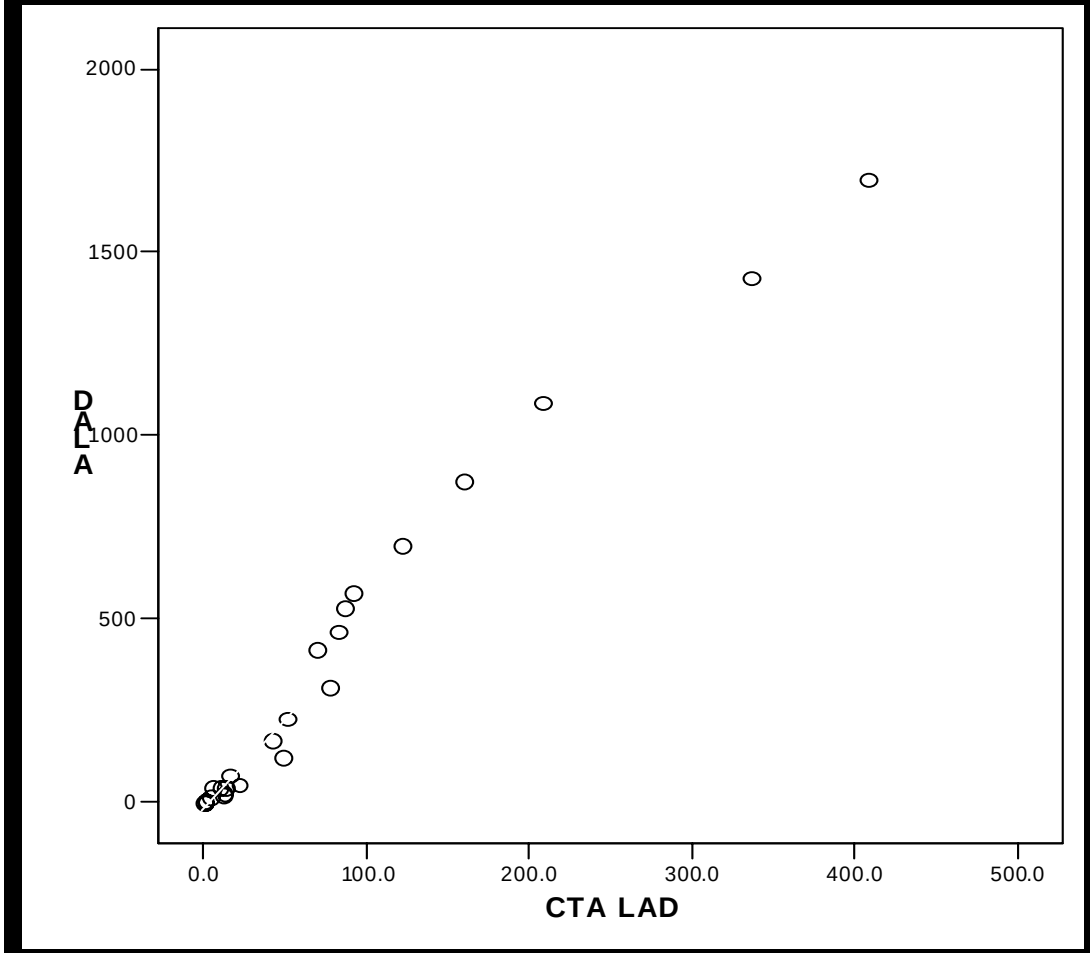
Volumetric vs. Contrast-Enhanced Calcium Score



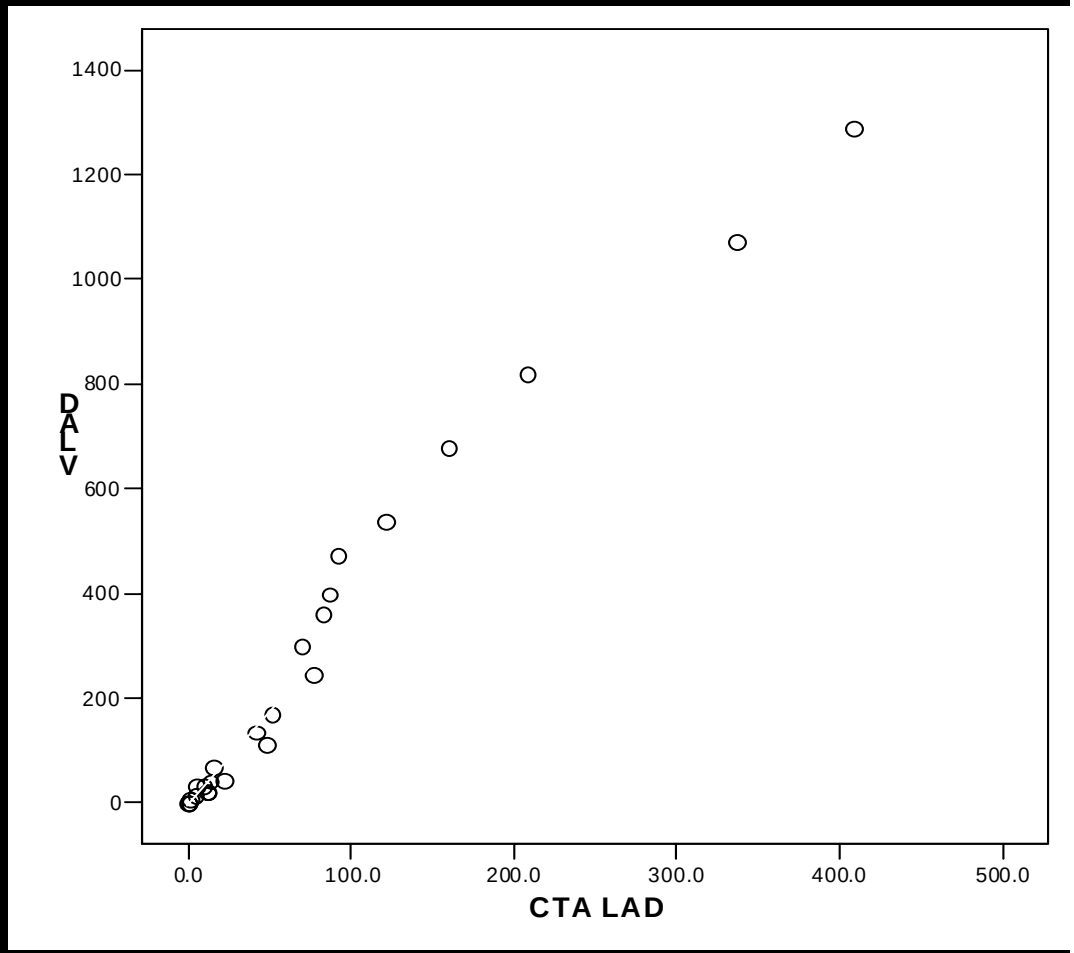
Agatston vs. Contrast-Enhanced Calcium Score

Calcium score vs. Contrast-enhanced calcium measurement

By artery



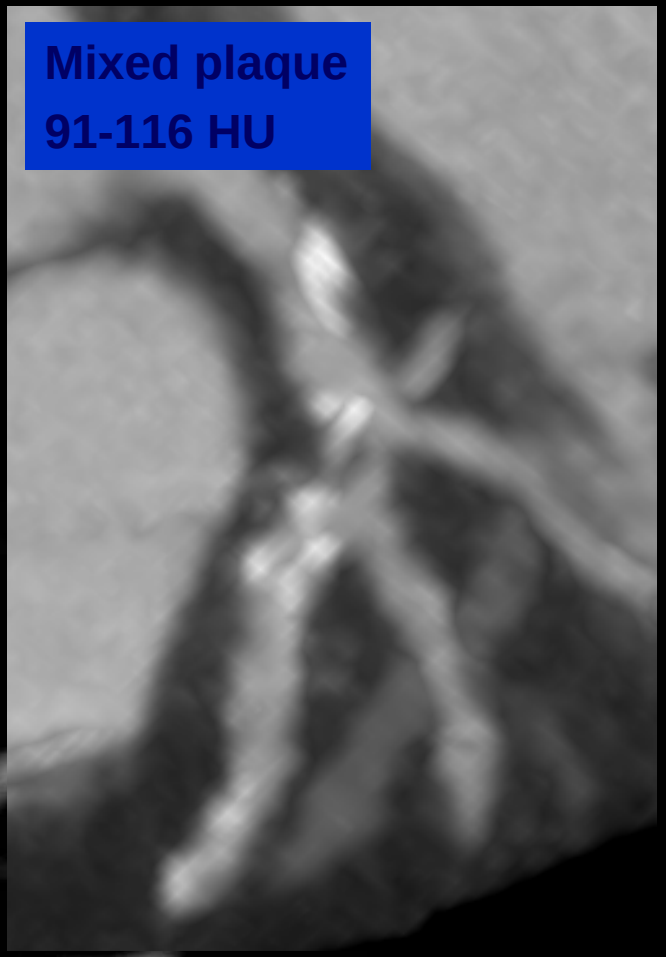
Volumetric vs. Contrast-Enhanced Calcium Score



Agatston vs. Contrast-Enhanced Calcium Score

Plaque composition

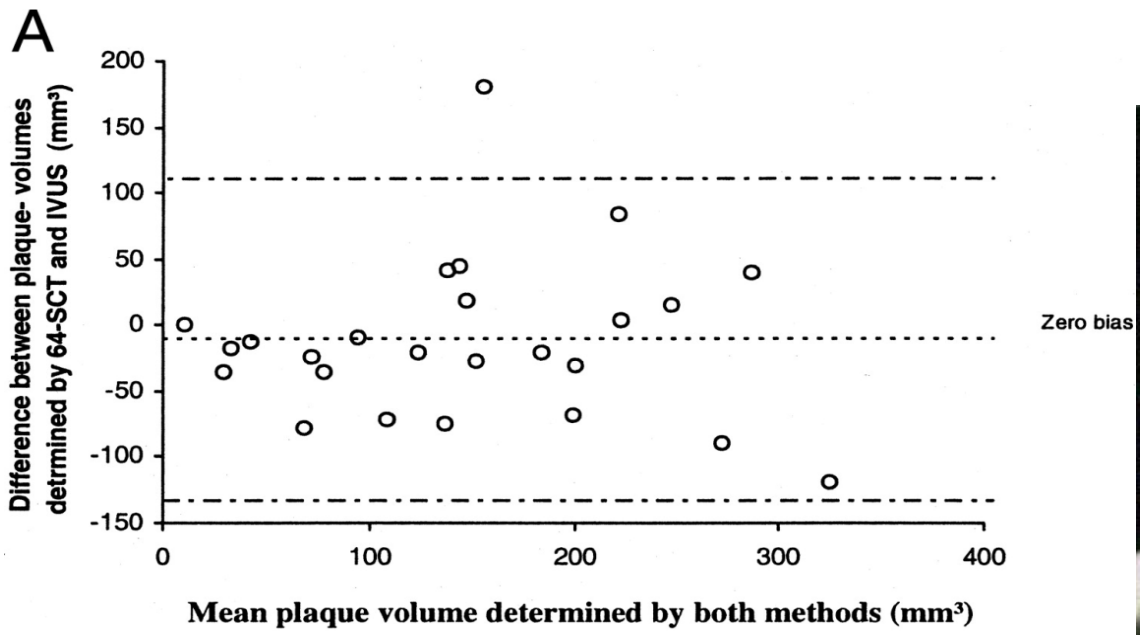
Non-calcified plaque
14-51 HU

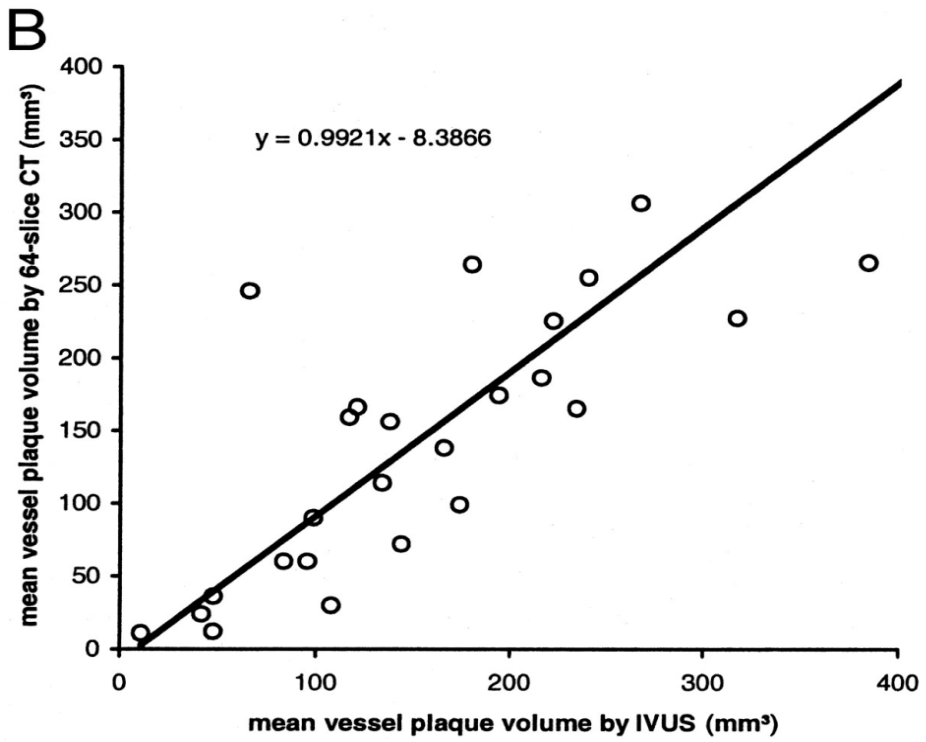


Mixed plaque
91-116 HU

Calcified plaque
391-715 HU

Schroeder et al., Leber et al., Viles-Gonzales et al.

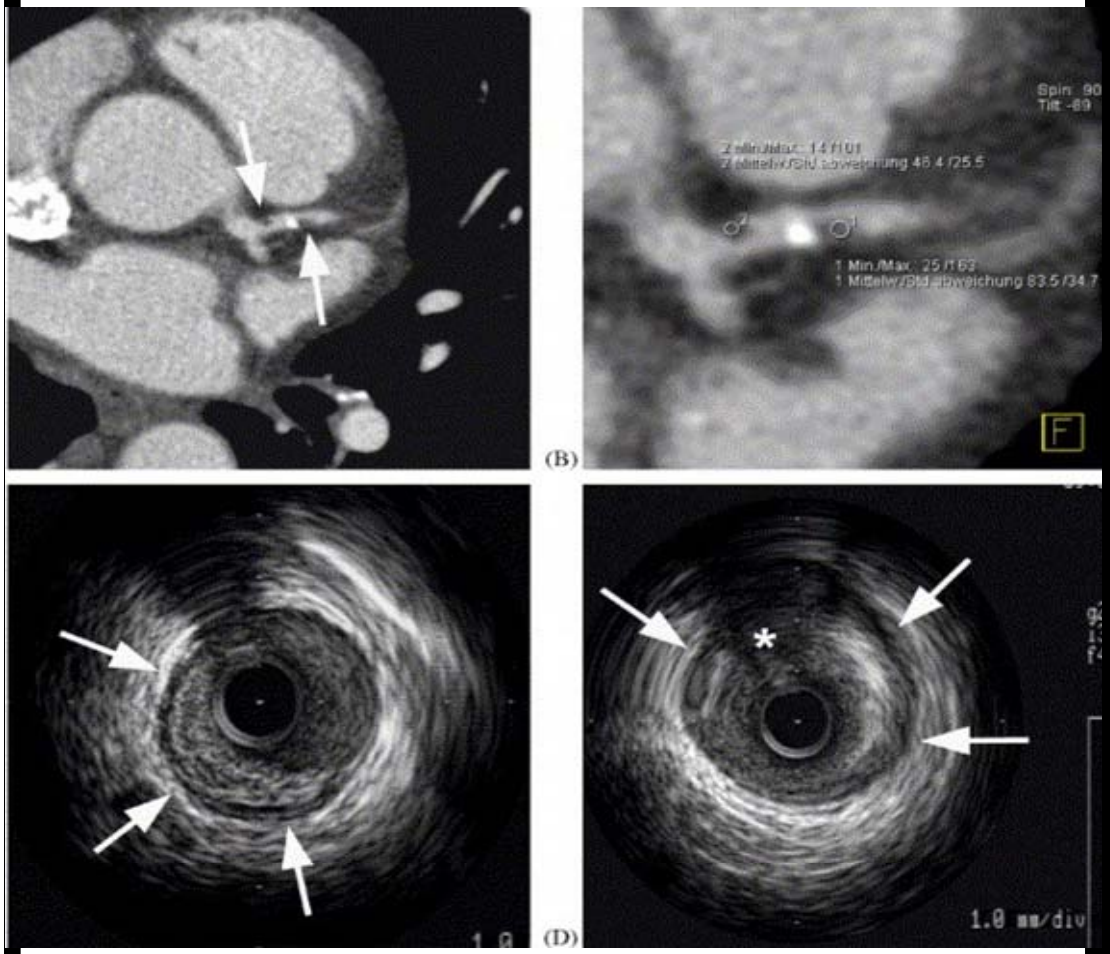




- 20 patients – 64-row CT
- Comparison to IVUS
  - 54/65 (83%) non-calcified
  - 50/53 (94%) mixed
  - 41/43 (95%) calcified
  - 192/204 (94%) accurate identification
- r^2=0.69
  - Underestimate mixed and non-calcified plaque

Leber AW et al. JACC 2006

Plaque Characterization - IVUS



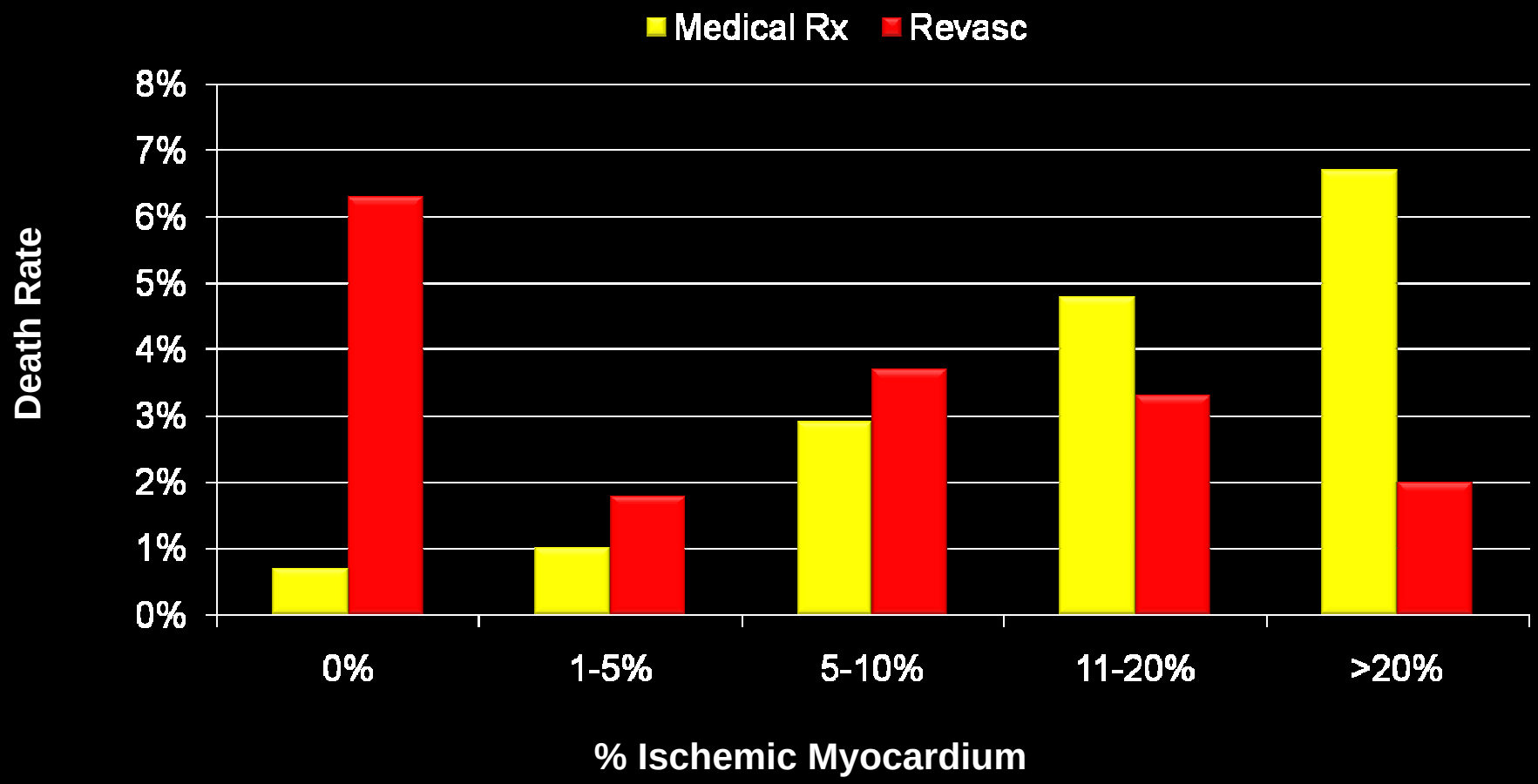
- 32 patients – 16-row CT
- IVUS 252 sites

- Hyper-echogenic IVUS
  - 121±34 HU
- Hypo-echogenic IVUS
  - 43±58 HU

Pohle K et al. Atherosclerosis 2006

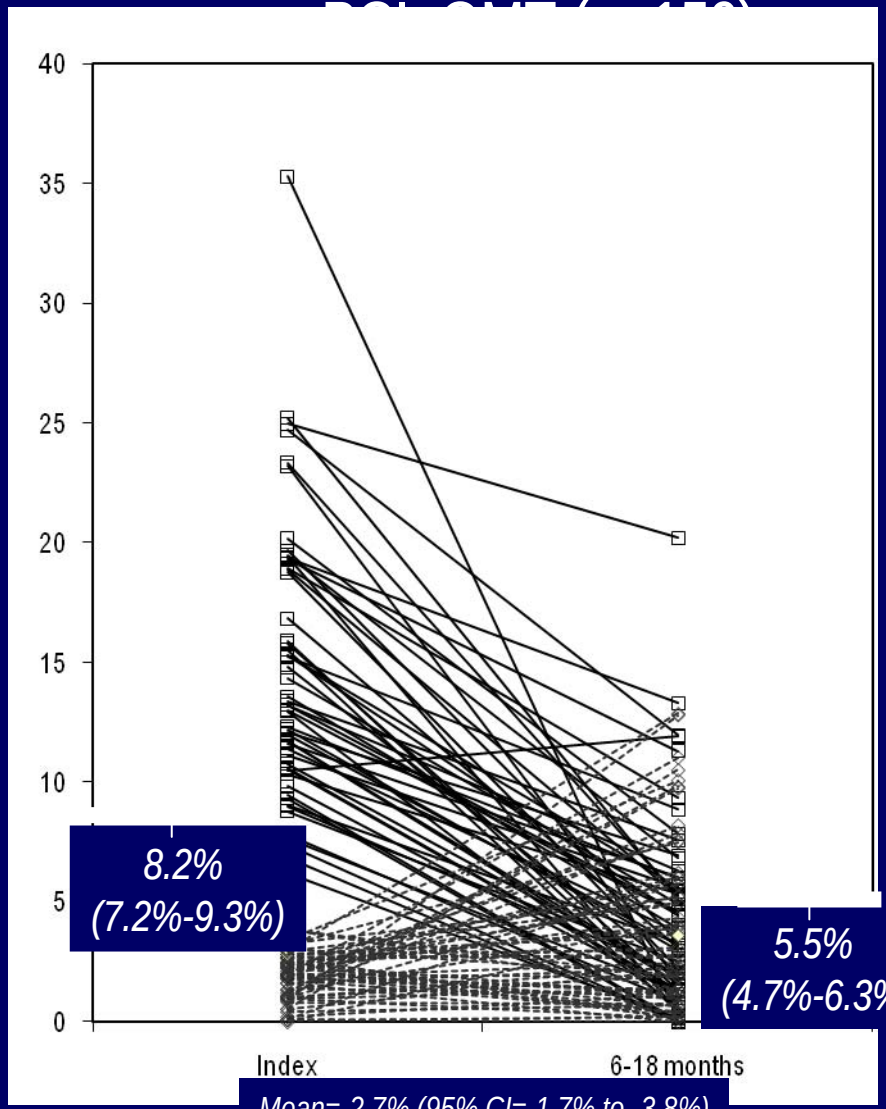
Risk of Death with Medical Therapy vs. Revascularization: Observational Data

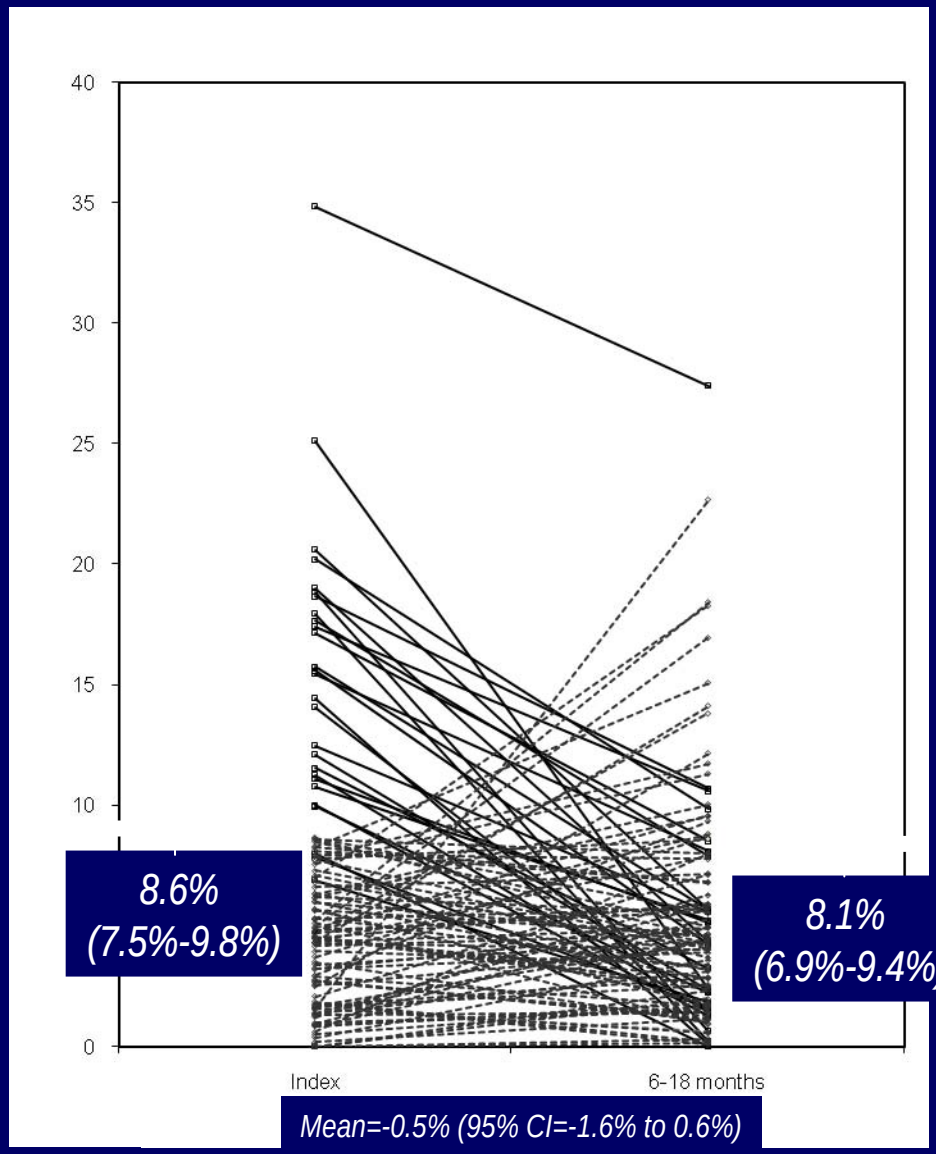
N=13,555; 3,893 deaths; F/U 8.7 yrs



Hachamovitch et al, ACC 2008

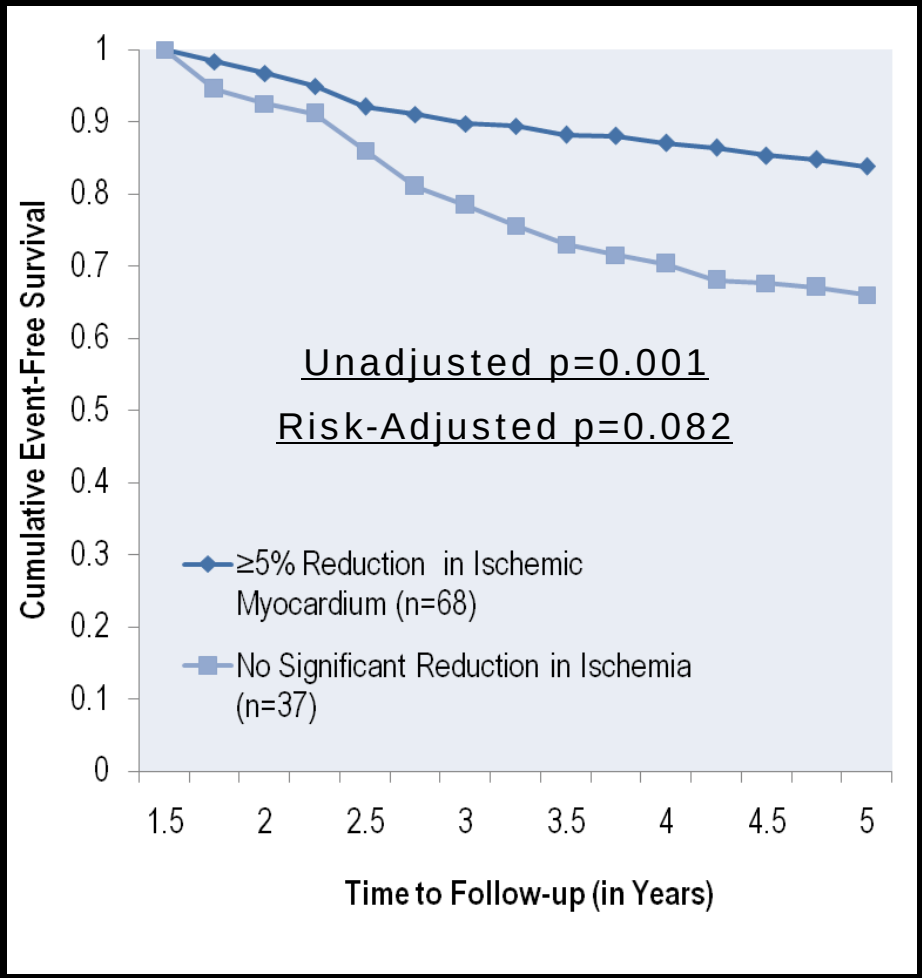
Inducible Ischemia Pre-Treatment and Following 6-18 Months of OMT with or without PCI



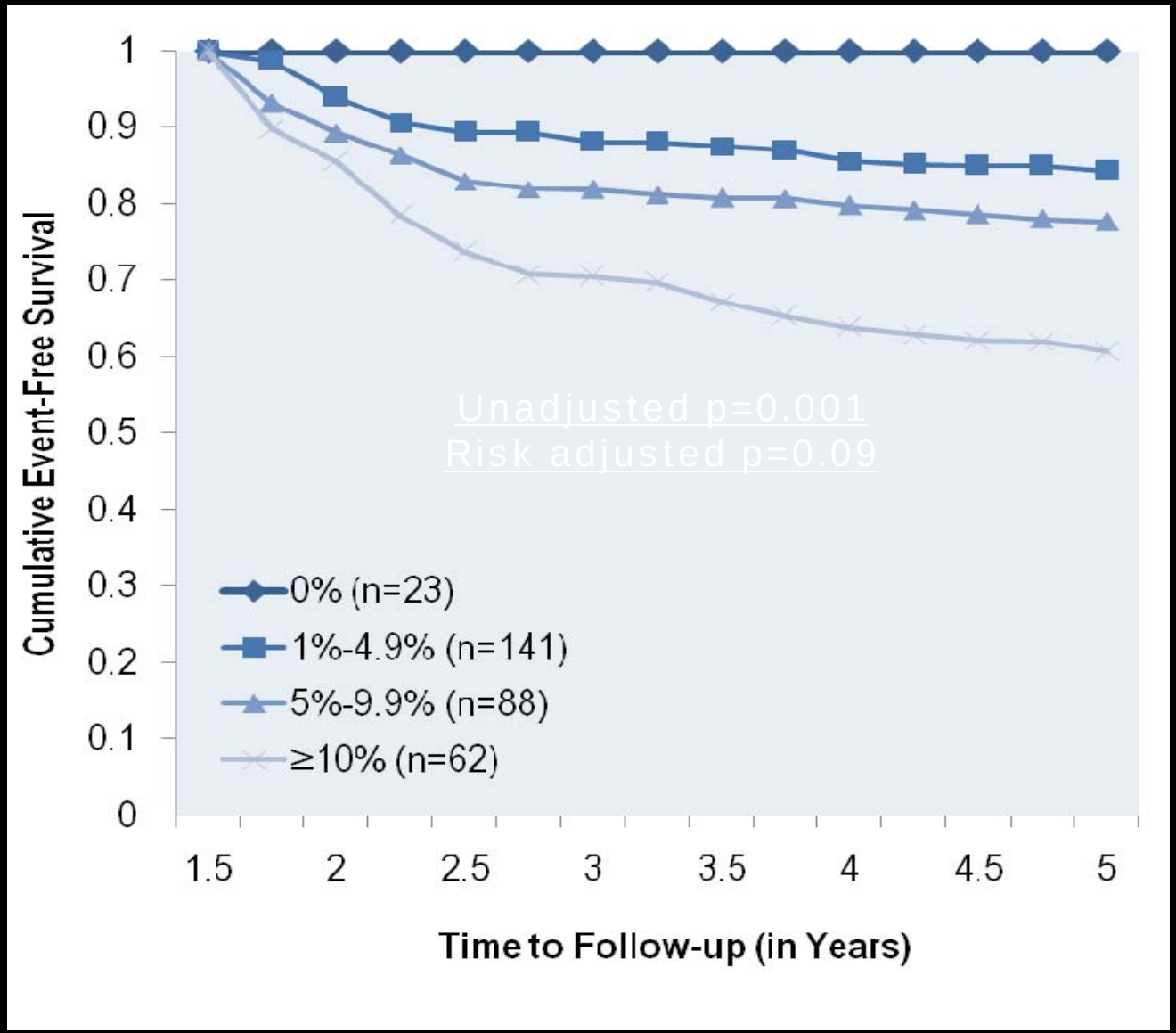


*Changes by treatment were adjusted by index ischemia. Dotted lines indicate no significant reduction in ischemia. Solid lines indicate ≥5% reduction in myocardial ischemia.

Shaw et al. *Circulation*. 2008;117:1283-1291.


Cumulative Event-Free Survival
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
1.5
2
2.5
3
3.5
4
4.5
5
Time to Follow-up (in Years)
Unadjusted p=0.001
Risk-Adjusted p=0.082
≥5% Reduction in Ischemic Myocardium (n=68)
No Significant Reduction in Ischemia (n=37)

Residual Ischemia and Outcome

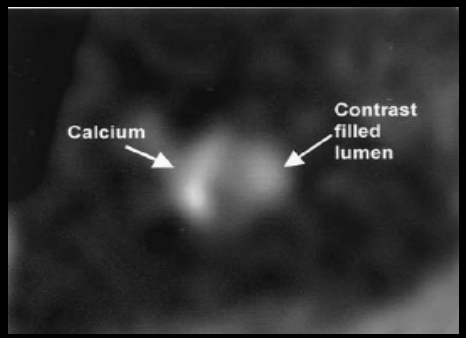


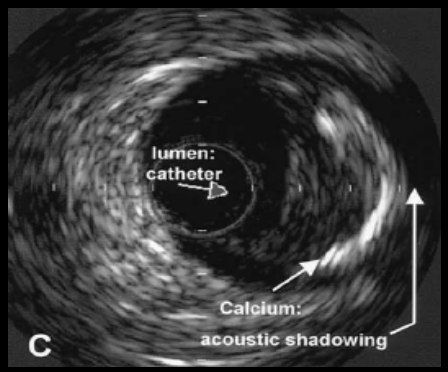
Shaw et al. *Circulation*. 2008;117:1283-1291.

Accuracy of CCTA (16-slice) to Identify and Differentiate Plaque Composition

58 vessels in 37 consecutive patients (33 male, 63±8yrs) patients undergoing CCTA and IVUS, examined for accuracy of CCTA for detection of any plaque and plaque composition.

92% (484/525) atherosclerotic lesions correctly excluded.





	Soft Sensitivity	Fibrous Sensitivity	Calcified Sensitivity	Total Specificity
RCA	(12/16) 75% (48%–92%)	(27/34) 79% (62%–91%)	(49/49) 100% NA	94/102 92% (85%–97%)
LAD	(44/54) 81% (69%–91%)	(47/62) 76% (63%–86%)	(76/83) 92% (83%–97%)	294/315 93% (90%–96%)
RCX	(6/10) 60% (26%–88%)	(13/16) 82% (54%–95%)	(25/26) 96% (80%–99%)	96/108 89% (81%–94%)
Total	(62/80) 78% (67%–86%)	(87/112) 78% (69%–85%)	(150/158) 95% (90%–98%)	484/525 92% (89%–94%)

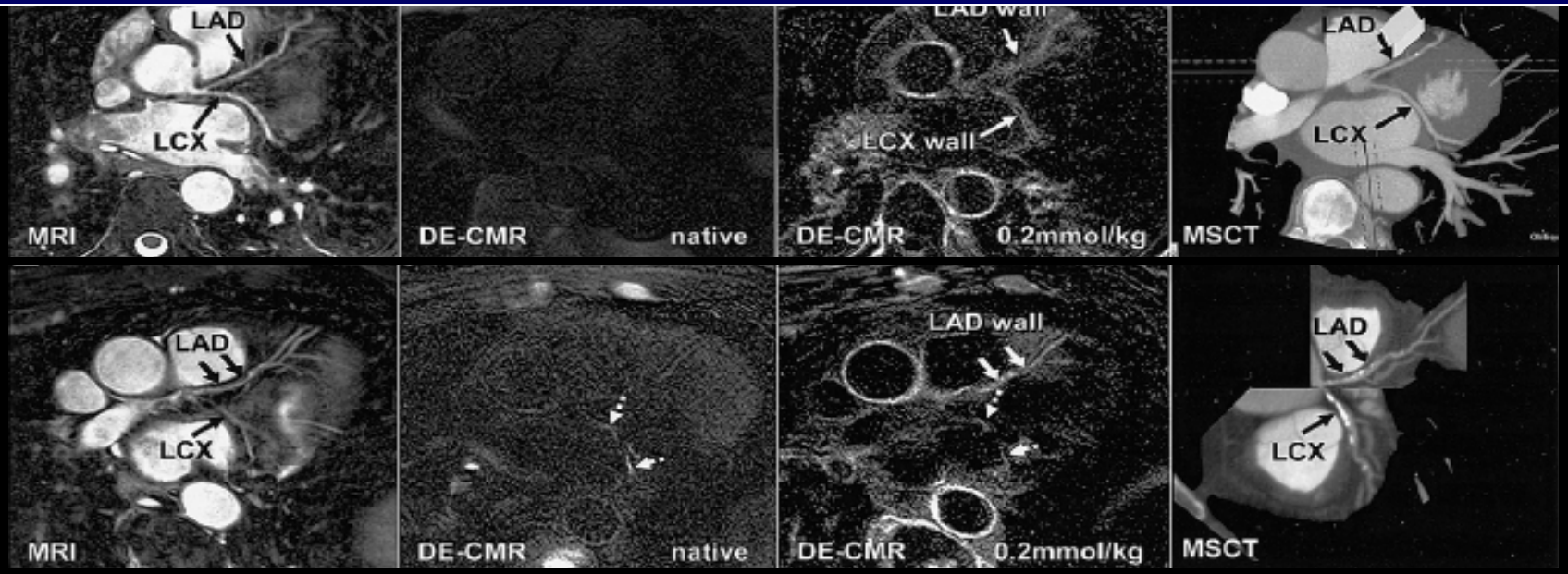
	Detected	Not Detected
Plaque thickness	1.5 ± 0.3 mm	0.9 ± 0.3 mm
Vessel size (EEM CSA)	4.5 ± 1.2 mm	3.6 ± 1.1 mm
% Plaque cross-sectional area	42 ± 16%	22 ± 5%

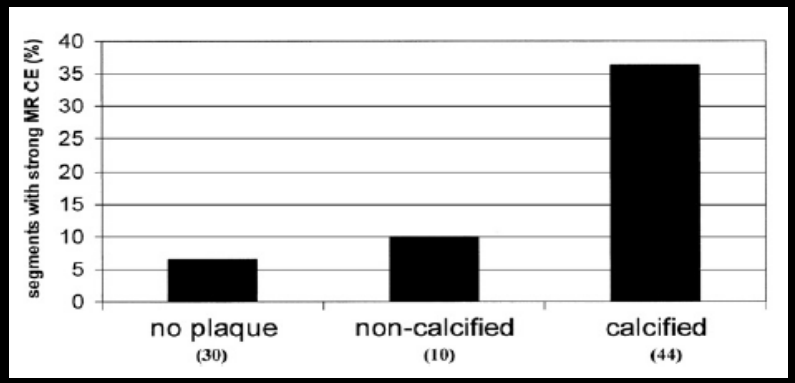
p <0.05 for all categories.

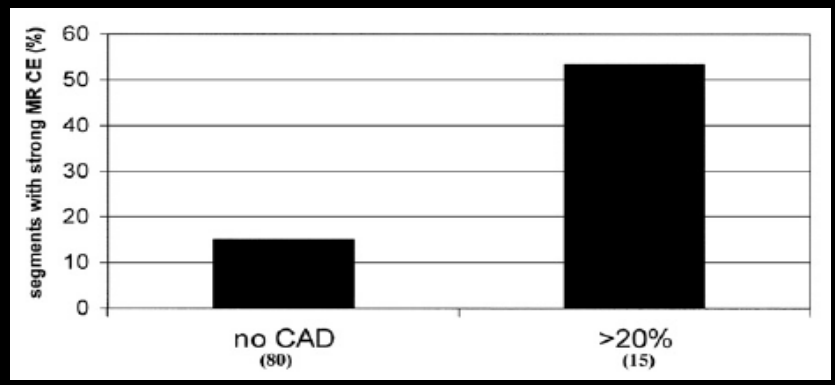
Leber et al. JACC 2004

DE-CMR of the Coronary Arteries and CCTA

20 pts (14 with CV risk factors, 6 healthy subjects without RF). DE-CMR noted in 2/30 (7%) coronary segments with no plaque by CCTA, 1/10 (10%) segments with non-calcified plaque, 16/44 (36%) segments with calcified plaque (p=0.035). DE-CMR noted in 8/15 (53%) segments with >20% coronary artery stenosis by QCA but also in 12/80 (15%) segments w/o stenosis (p=0.01).

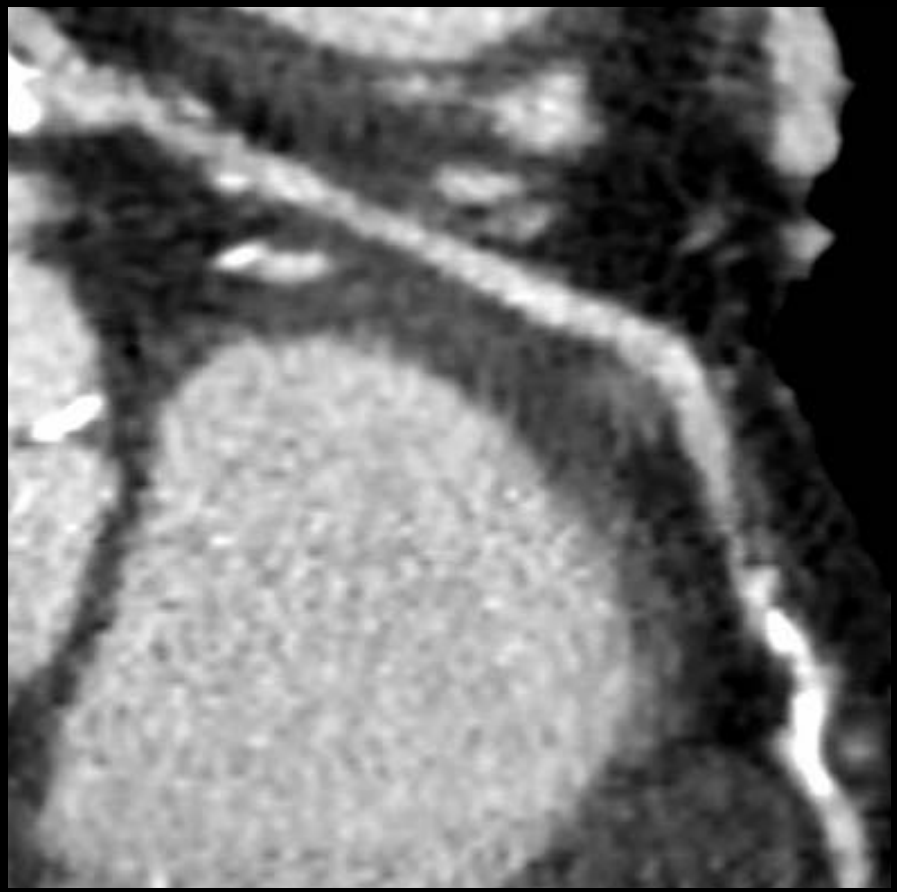


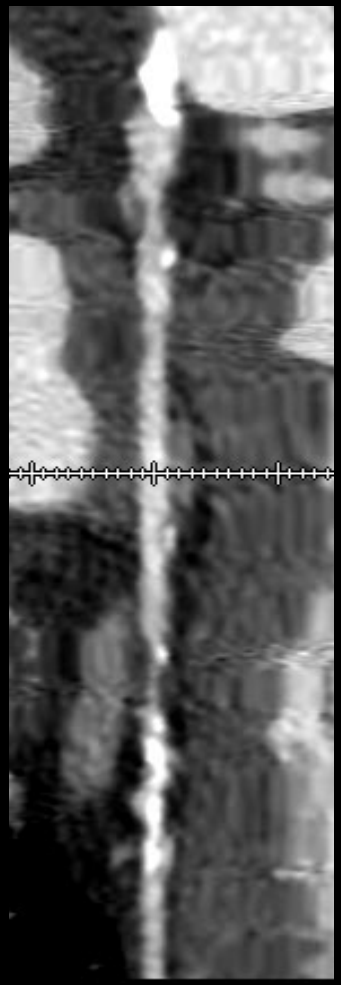


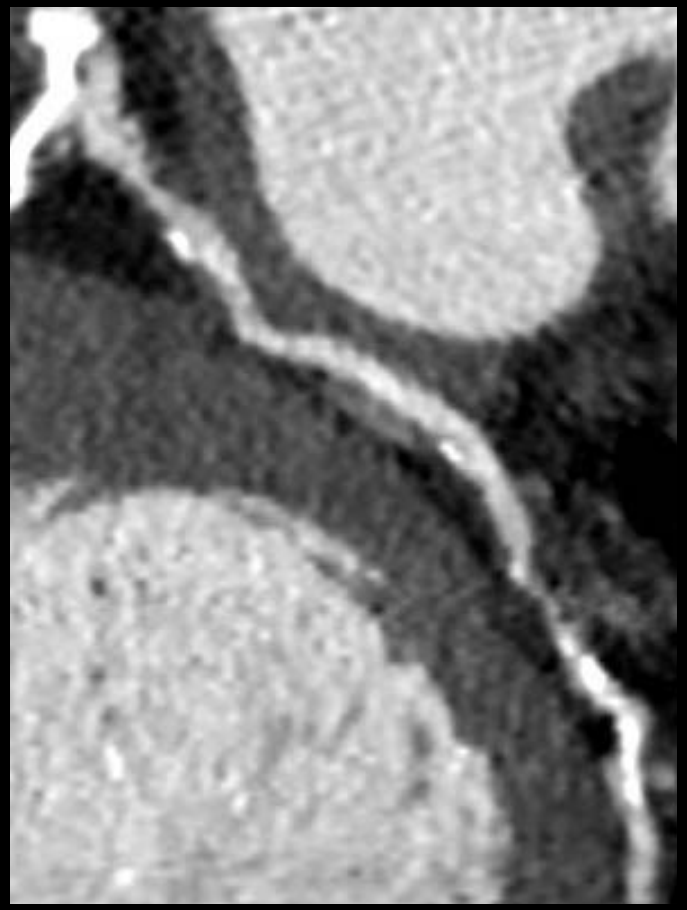


Yeon et al. JACC 2008

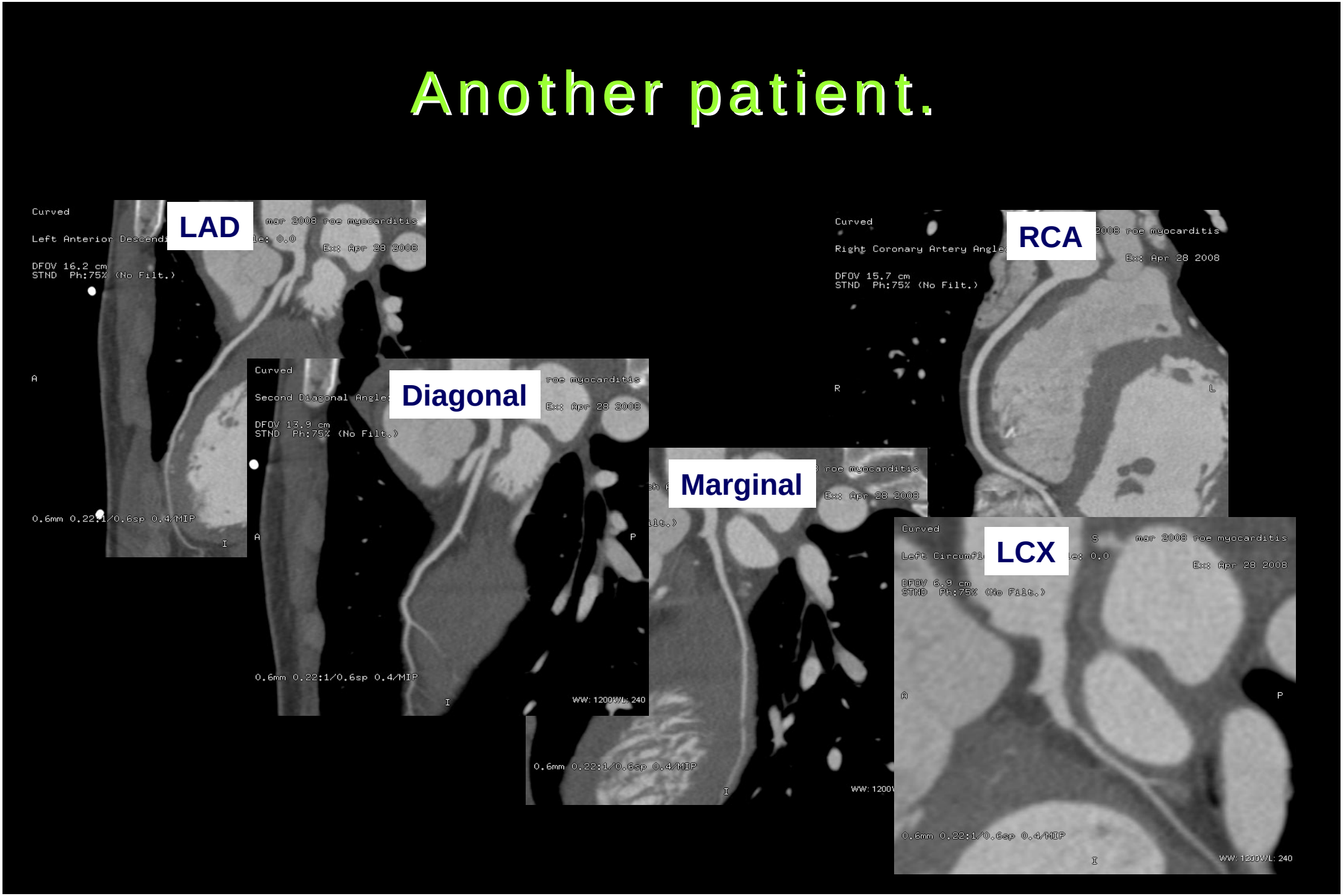
A patient.





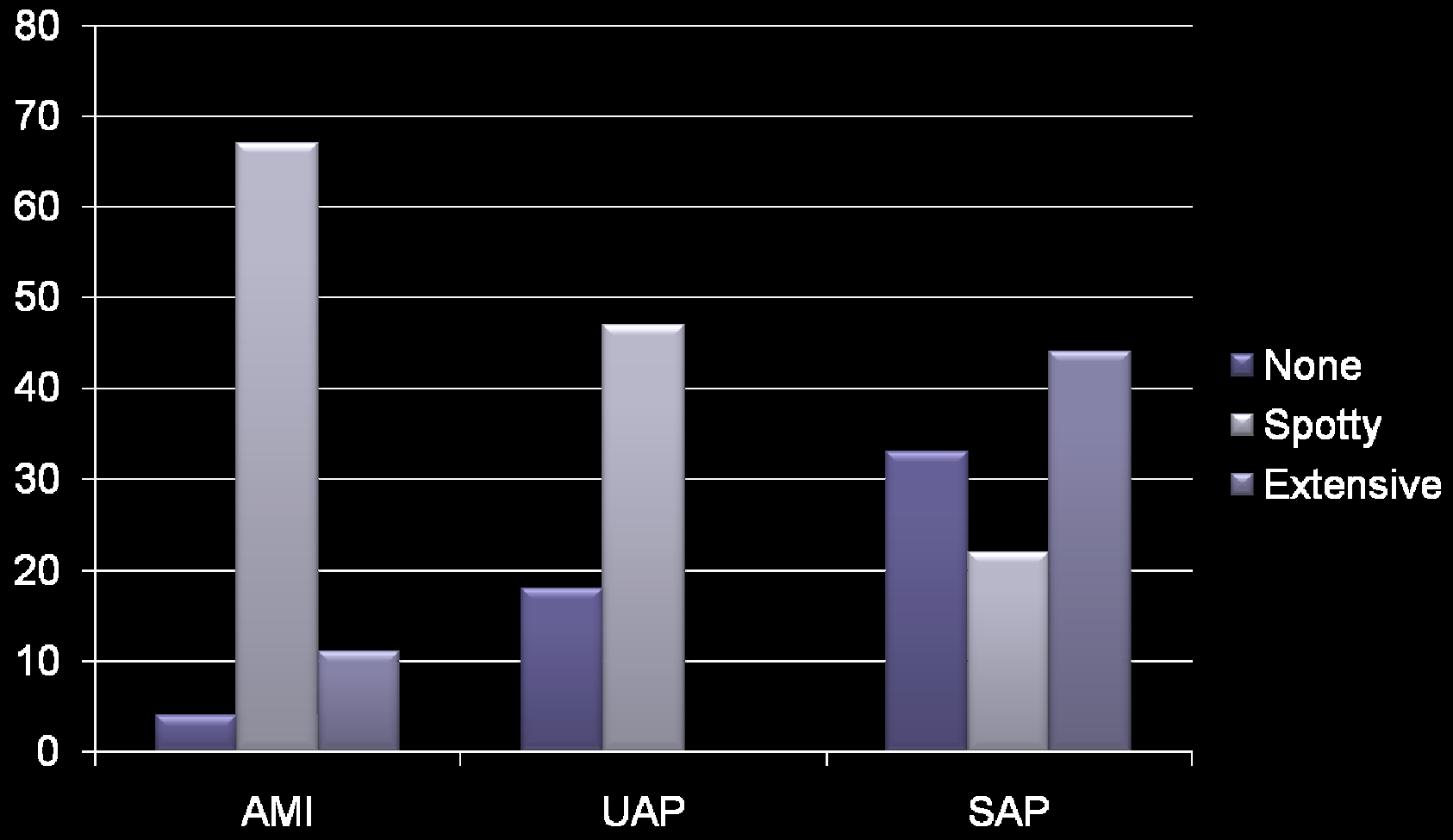


Another patient.



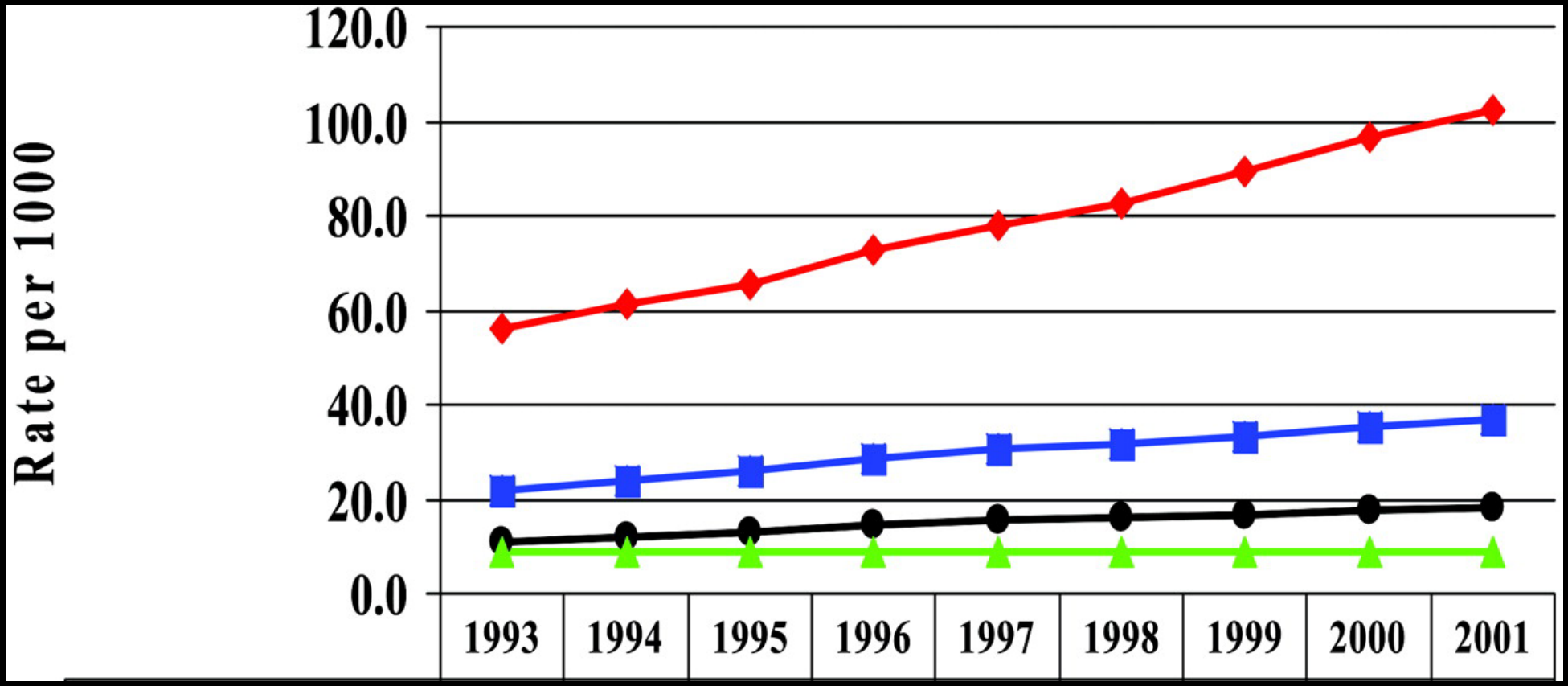
Spotty Calcification Typifies the Culprit Plaque in AMI (IVUS)

% Patients with Positive Remodeling and Calcification Patterns



Haegawa et al. AHJ 2006

Utilization of non-invasive and invasive testing.



- 50% of all imaging relates to CV imaging
- 3 fold increase non-invasive imaging ‘93-’01

Regulla et al. Radiat Prot Dosimetry 2005; Lucas et al. Circulation 2006; Rodgers et al. J Am Coll Cardiol 2000

Non-invasive imaging is more clinically relevant because . . .

- It can identify vulnerable patients ***before*** not after an acute coronary event.
- It is prognostically valuable.
- It provides incremental information about risk beyond plaque.
- It is safer.
- Patients will do it.

Stable Chest Pain

NPV for death

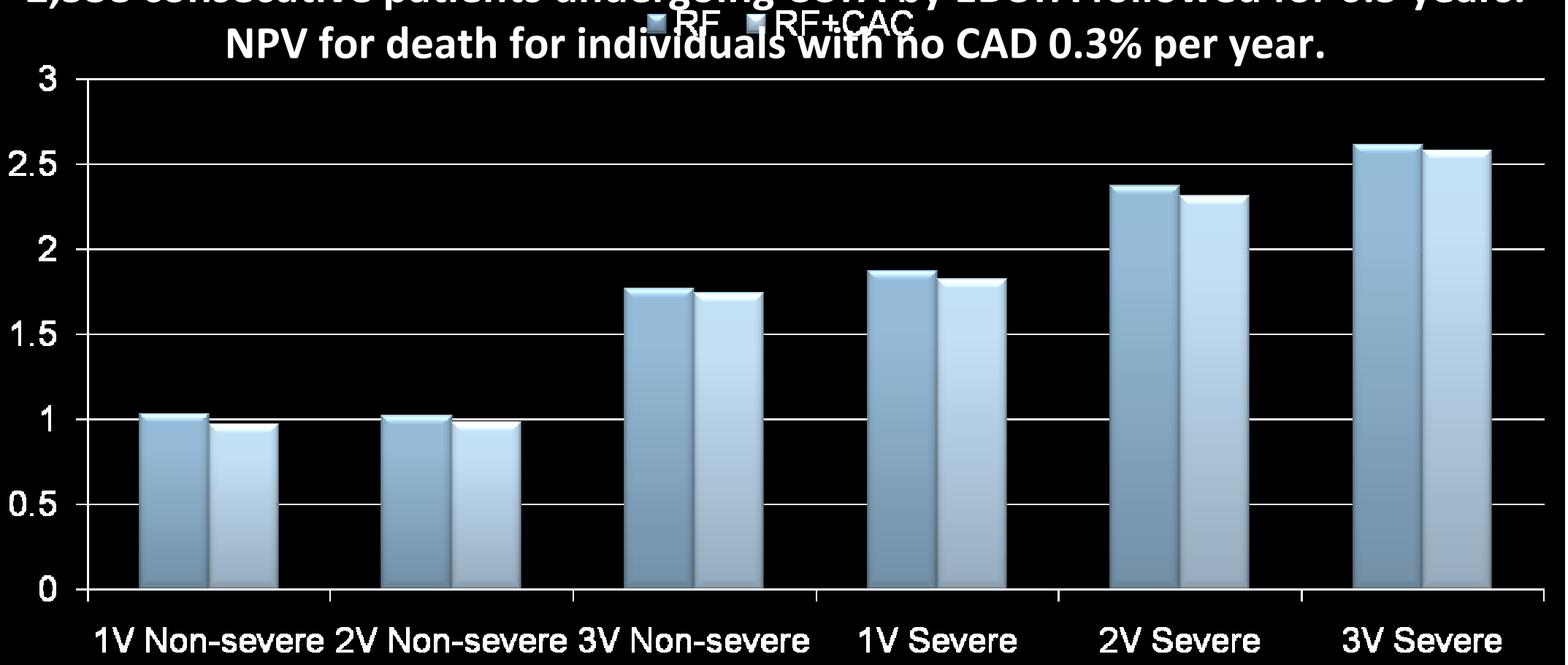
RISK FACTOR	PATIENTS (N)	DEAD (N)	%
Coronary artery plaque score= 0	333	1	0.3%
No left main plaque	951	20	2.1%
No proximal LAD plaque	551	9	1.6%

Negative predictive value 97.9-99.7% for death.

Stable Chest Pain

Long-term Risk Stratification for All-Cause Death

2,538 consecutive patients undergoing CCTA by EBCTA followed for 6.5 years.
NPV for death for individuals with no CAD 0.3% per year.

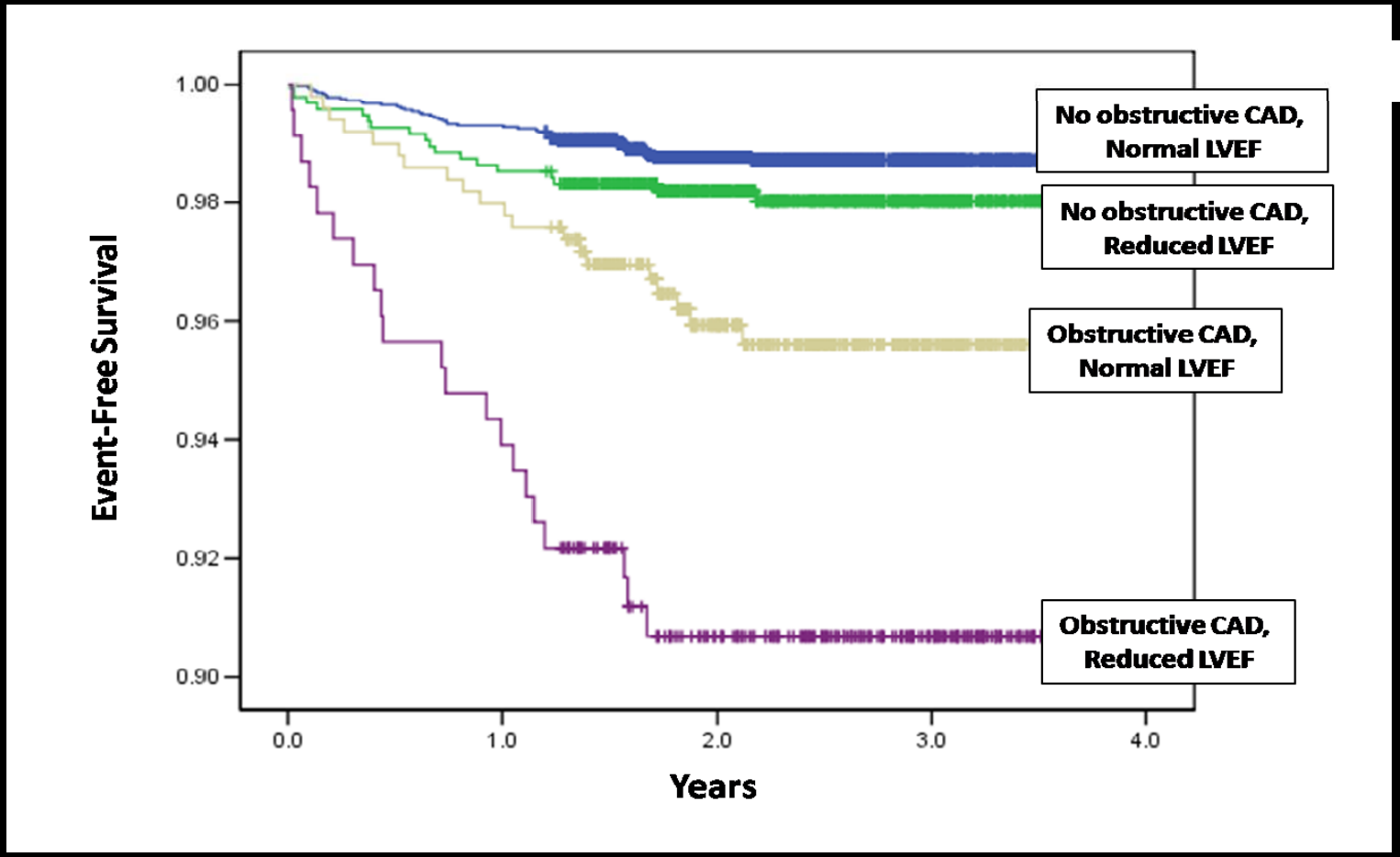


Ostrom JACC 2008

Stable Chest Pain

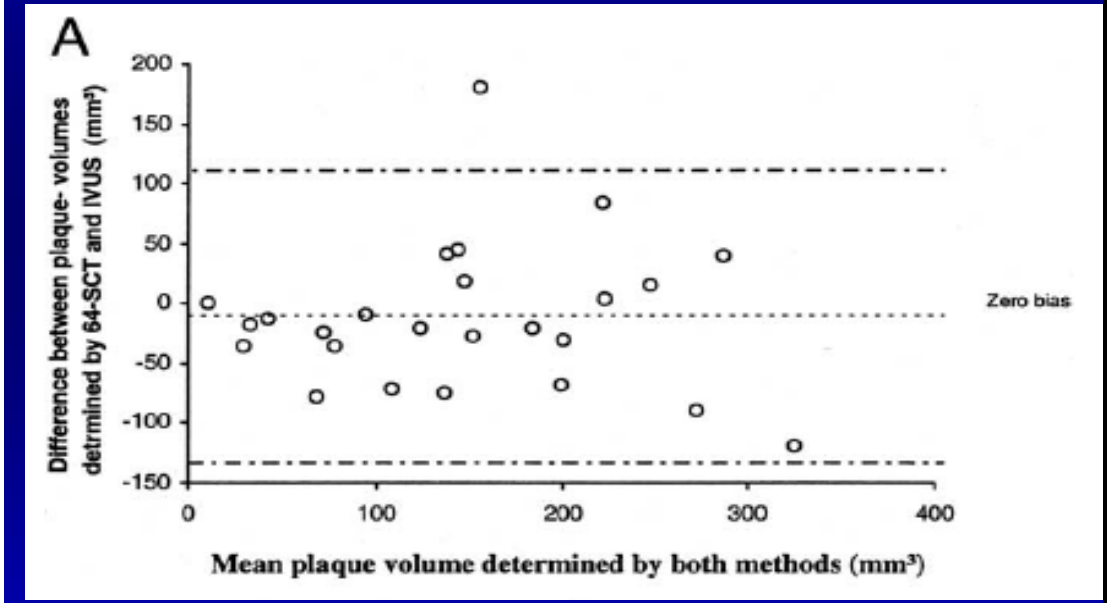
Two Center 64-Detector Row CCTA Risk Stratification for All-Cause Death

5,646 consecutive patients without prior bypass surgery undergoing CCTA followed for 2.3 years.



64-slice CCTA for Classification and Quantification of Plaque Volume in Proximal Coronary System

19 patients underwent 64-slice CCTA and IVUS in 36 vessels. Vessels divided into 3mm sections, evaluated for correct detection of plaque.



Non-calcified plaque:	**54/65 (83%)**
Mixed Plaque:	**41/43 (94%)**
Calcified Plaque:	**41/43 (95%)**

Leber et al. JACC 2006

64-slice CCTA for Classification and Quantification of Plaque Volume in Proximal Coronary System

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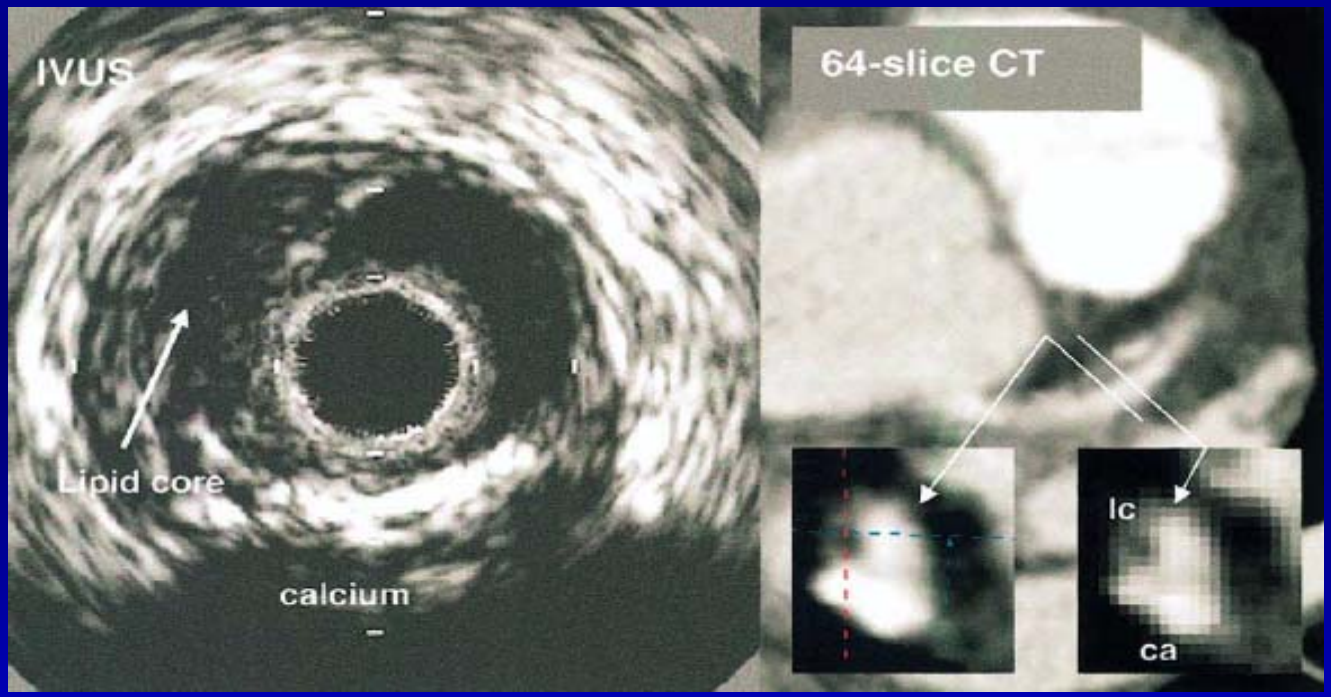


Plaque volume/vessel: r^2=0.69, p<0.001

‡ Underestimates mixed and non-calcified volumes
‡ Overestimates calcified plaque volume

Interobserver variability:

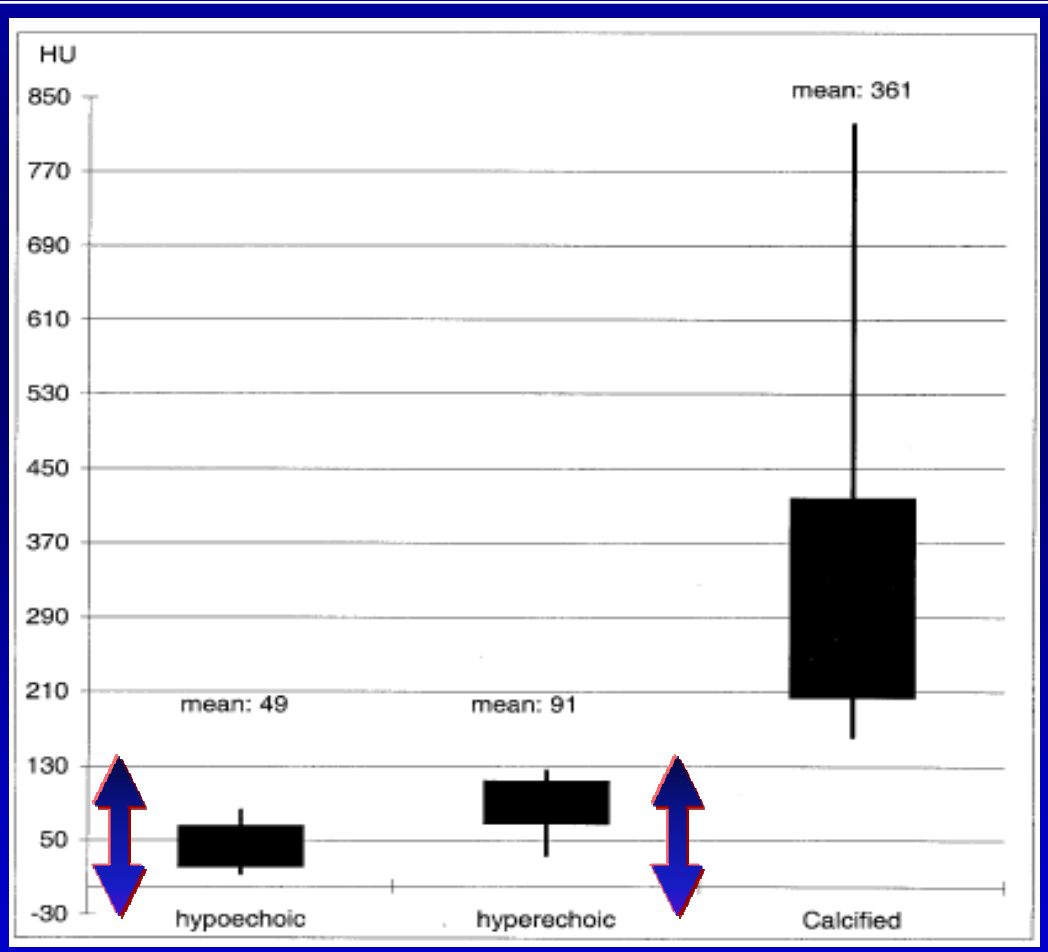
‡ Any plaque (kappa=0.75)
‡ Plaque volume (kappa=0.37)

7/10 (70%) correct for "lipid pool"
27/30 (90%) correct for spotty calcification.

Leber et al. JACC 2006

Accuracy of CCTA to Identify and Differentiate Plaque Composition

Current generation CCTA can NOT differentiate effectively between lipoid, fibrolipoid or fibrous plaque because HU densities overlap.



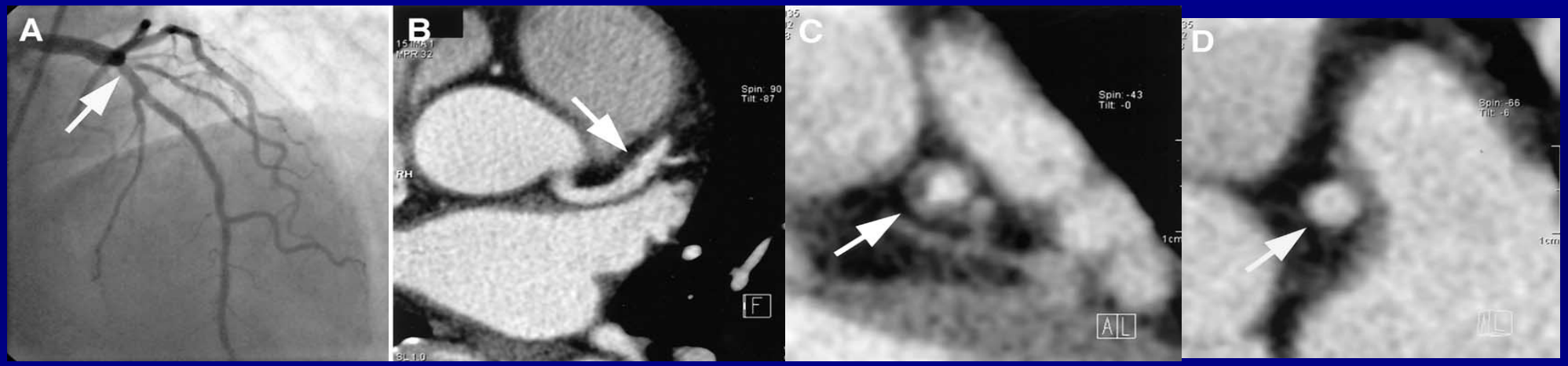
Leber et al. JACC 2004

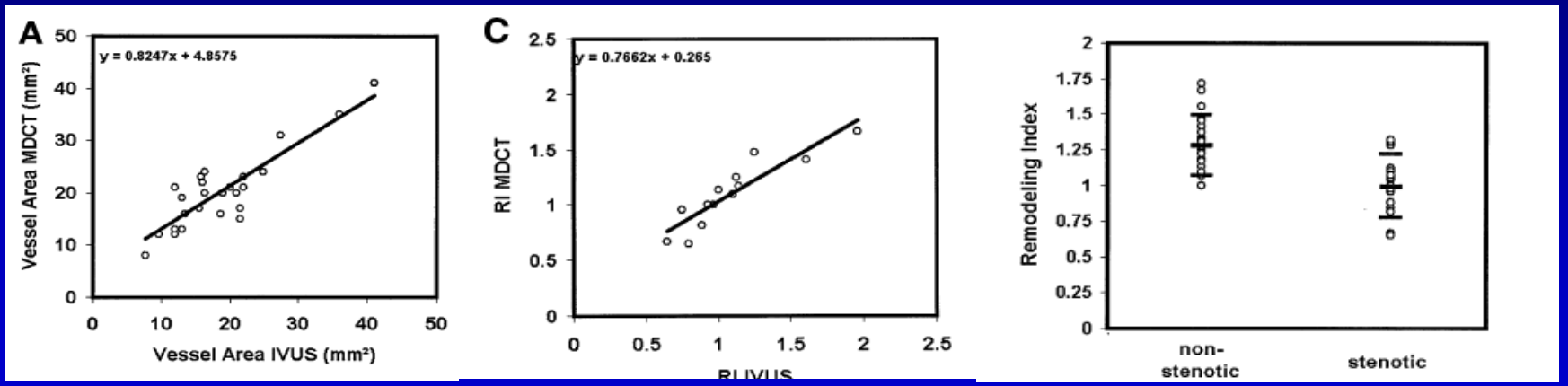
Assessment of Coronary Remodeling by CCTA

44 patients undergoing CCTA and ICA. CSA measured for respective lesion and for reference segment proximal to the lesion.

'Remodeling Index" = vessel area/ reference segment.

Results correlated to IVUS and ICA stenosis measurements >50%.



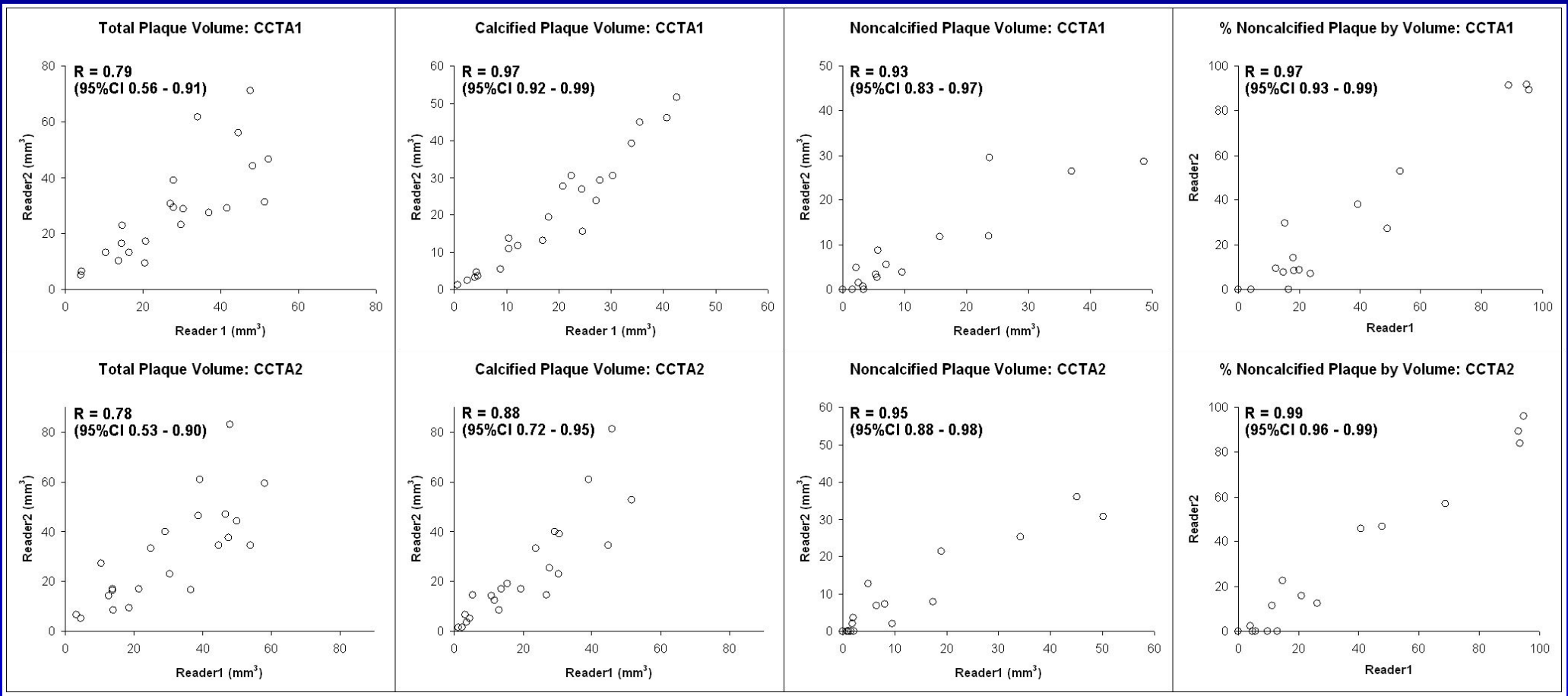


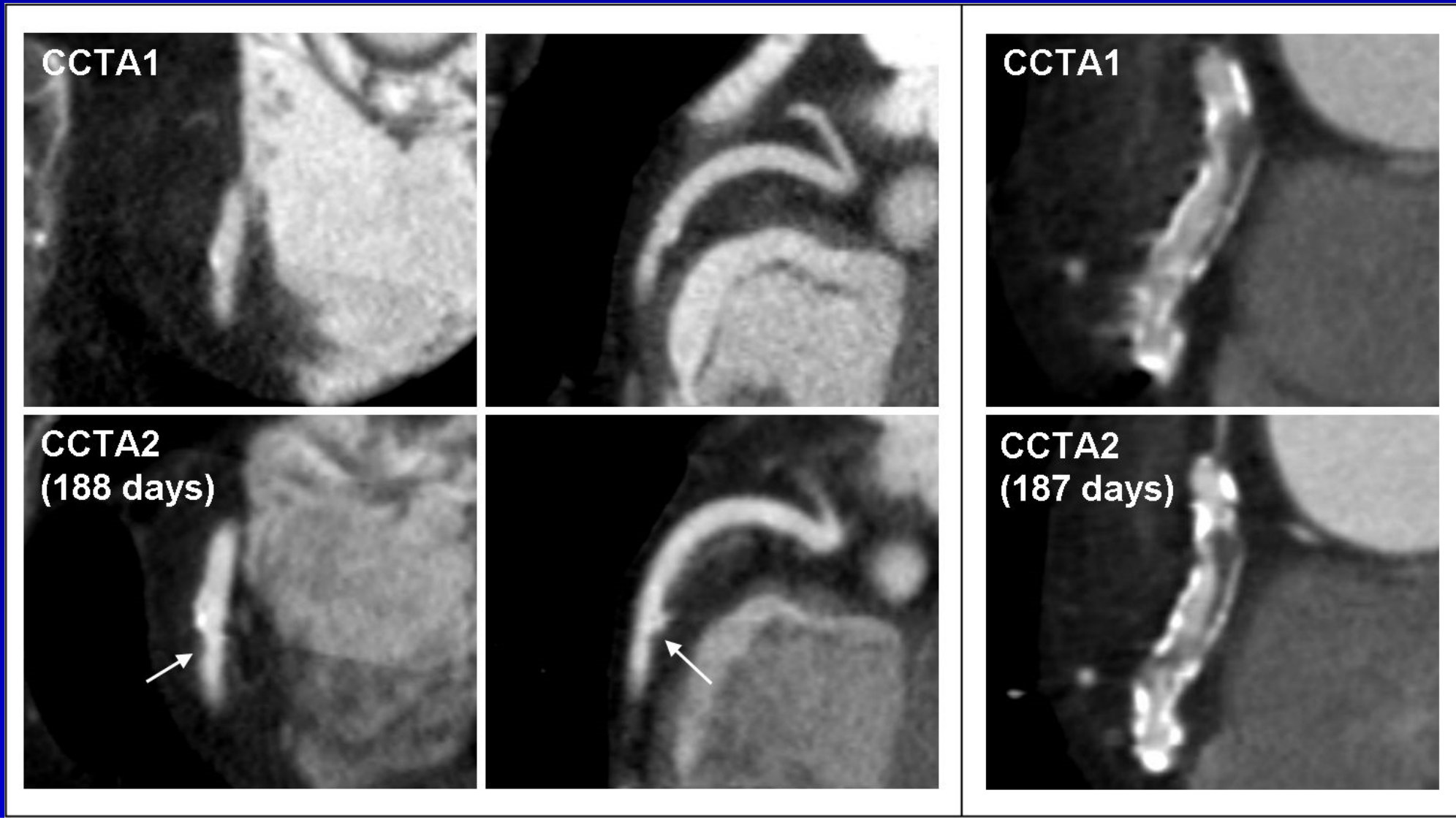
Hoffman et al. JACC 2006

Vulnerable Plaque

- A **vulnerable plaque** is an atheromatous plaque, an unstable collection of white blood cells (primarily macropahges) and lipids (including cholesterol) in the wall of an artery which is particularly prone to produce sudden major problems, such as heart attack

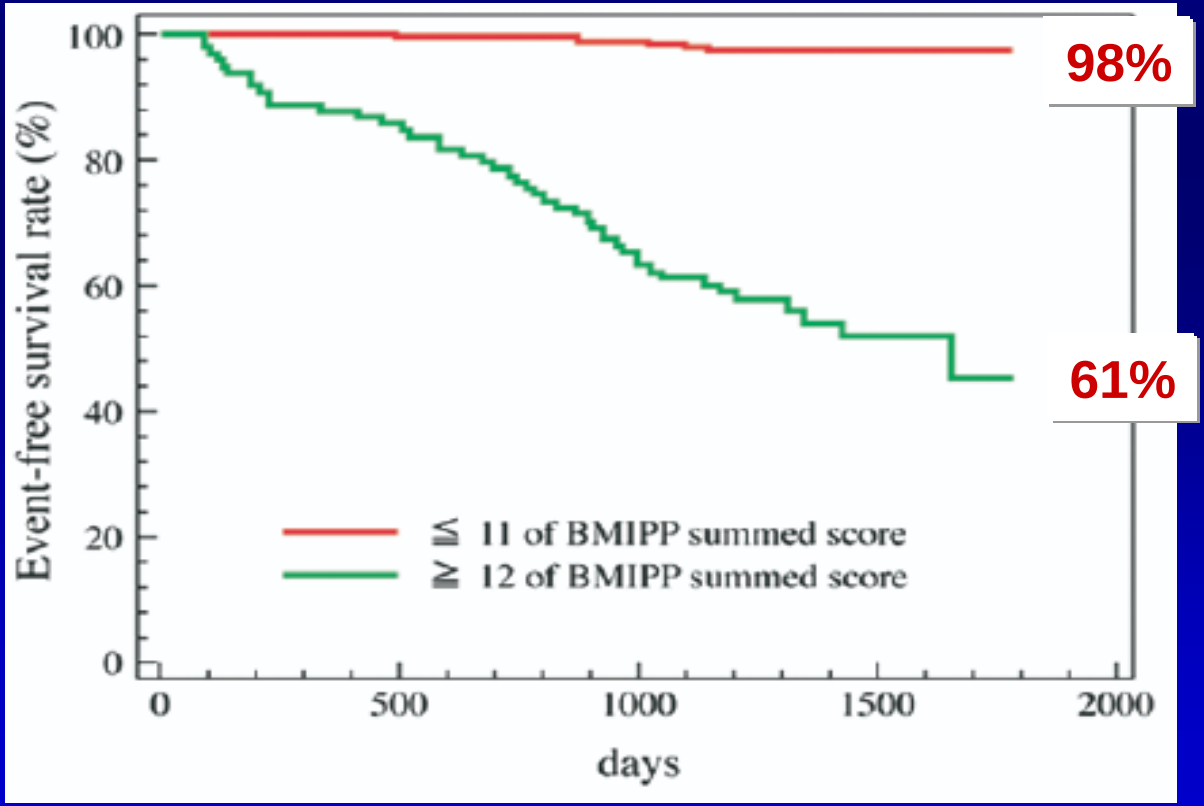
- Susceptible to physical injury.
  - Implies a state which has not yet occurred, i.e., before the event occurs


Total Plaque Volume: CCTA1
R = 0.79
(95%CI 0.56 - 0.91)
Reader2 (mm3)
Reader 1 (mm3)
Calcified Plaque Volume: CCTA1
R = 0.97
(95%CI 0.92 - 0.99)
Reader2 (mm3)
Reader 1 (mm3)
Noncalcified Plaque Volume: CCTA1
R = 0.93
(95%CI 0.83 - 0.97)
Reader2 (mm3)
Reader1 (mm3)
% Noncalcified Plaque by Volume: CCTA1
R = 0.97
(95%CI 0.93 - 0.99)
Reader2
Reader1
Total Plaque Volume: CCTA2
R = 0.78
(95%CI 0.53 - 0.90)
Reader2 (mm3)
Reader1 (mm3)
Calcified Plaque Volume: CCTA2
R = 0.88
(95%CI 0.72 - 0.95)
Reader2 (mm3)
Reader1 (mm3)
Noncalcified Plaque Volume: CCTA2
R = 0.95
(95%CI 0.88 - 0.98)
Reader2 (mm3)
Reader1 (mm3)
% Noncalcified Plaque by Volume: CCTA2
R = 0.99
(95%CI 0.96 - 0.99)
Reader2
Reader1


CCTA1
CCTA2
(188 days)
CCTA1
CCTA2
(187 days)

Prediction of Cardiac Death in Hemodialysis Patients by Myocardial Fatty Acid Imaging

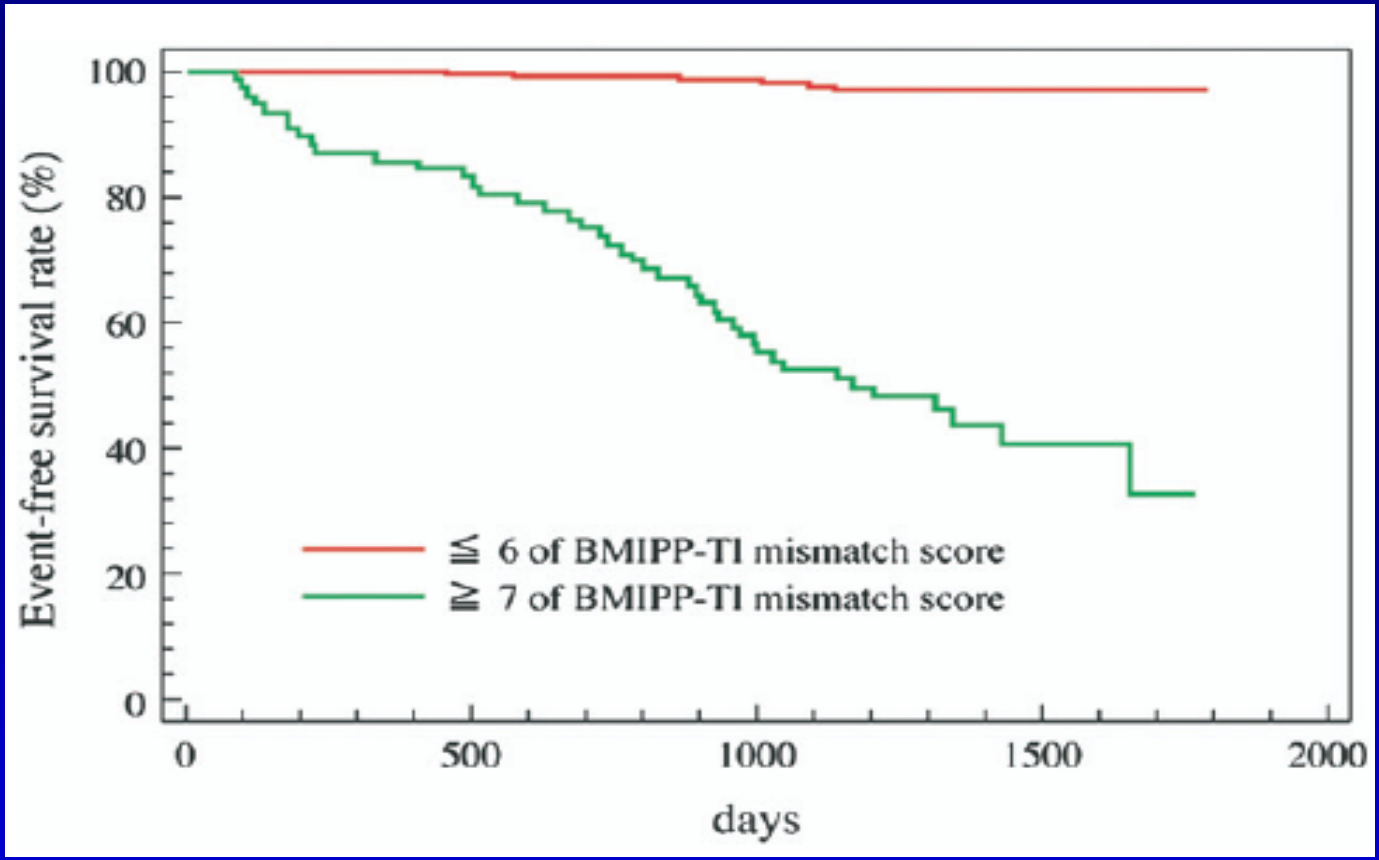
Prospective enrollment of 318 asymptomatic HD patients (male/female: 170/148; 64 yrs), without known CAD who underwent dual SPECT using 123I–BMIPP and 201-thallium. 3.6+/-1.0 yr f/u. 50 died of cardiac events (MI=22, CHF=17, SCD=11). Cox hazard analysis associated cardiac death with age (70 years) and with abnormal BMIPP SPECT images (BMIPP SSS>12: HR 21.9; p 0.0001).



Nishimura et al. JACC 2008

Prediction of Cardiac Death by Myocardial Fatty Acid Imaging

Mean BMIPP–Tl mismatch score higher in pts with cardiac death than in those w/o (14.0 +/-8.1 [n =50] vs. 2.9+/-4.6 [n =268]; p<0.001).

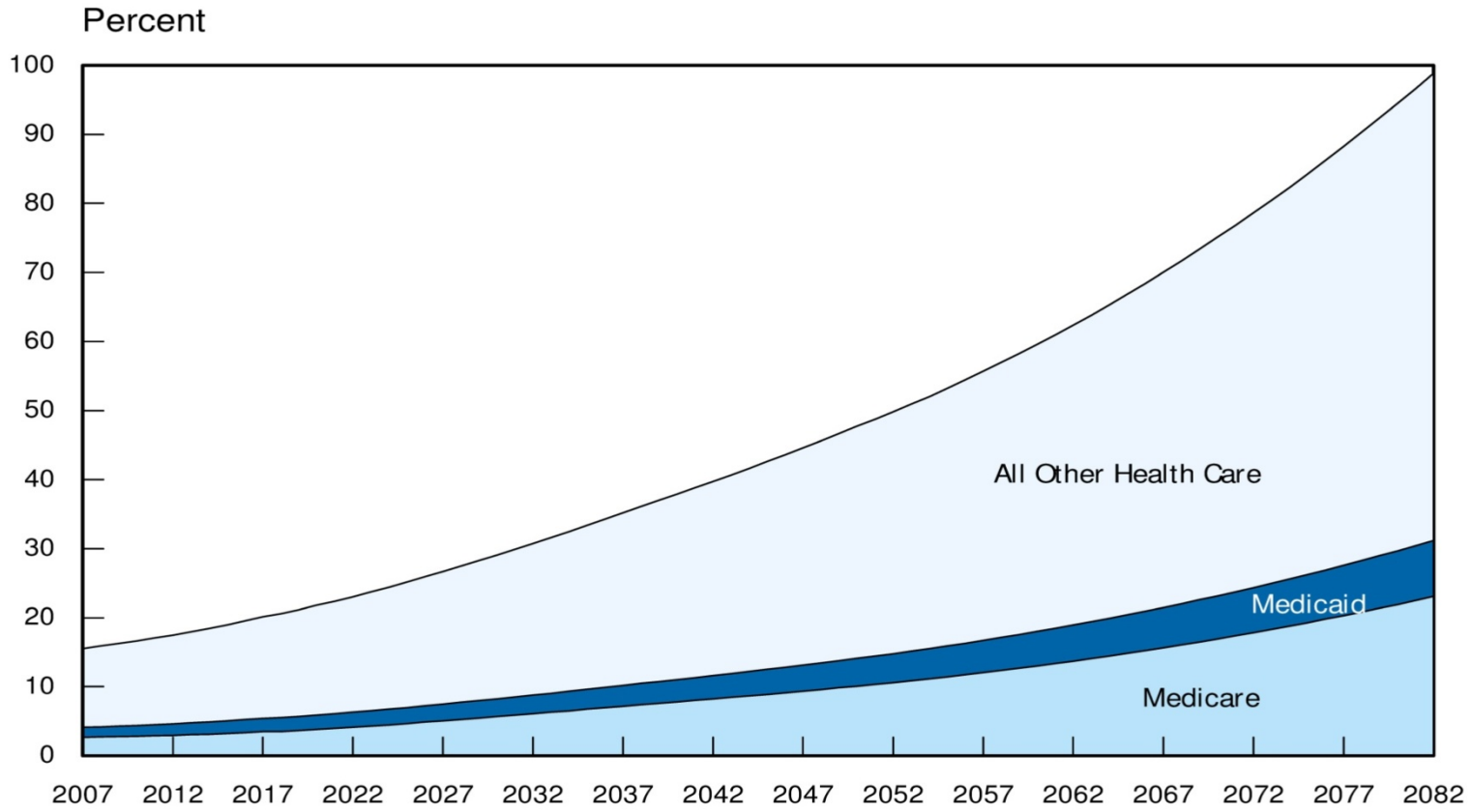


Nishimura et al. JACC 2008

REASON #8:

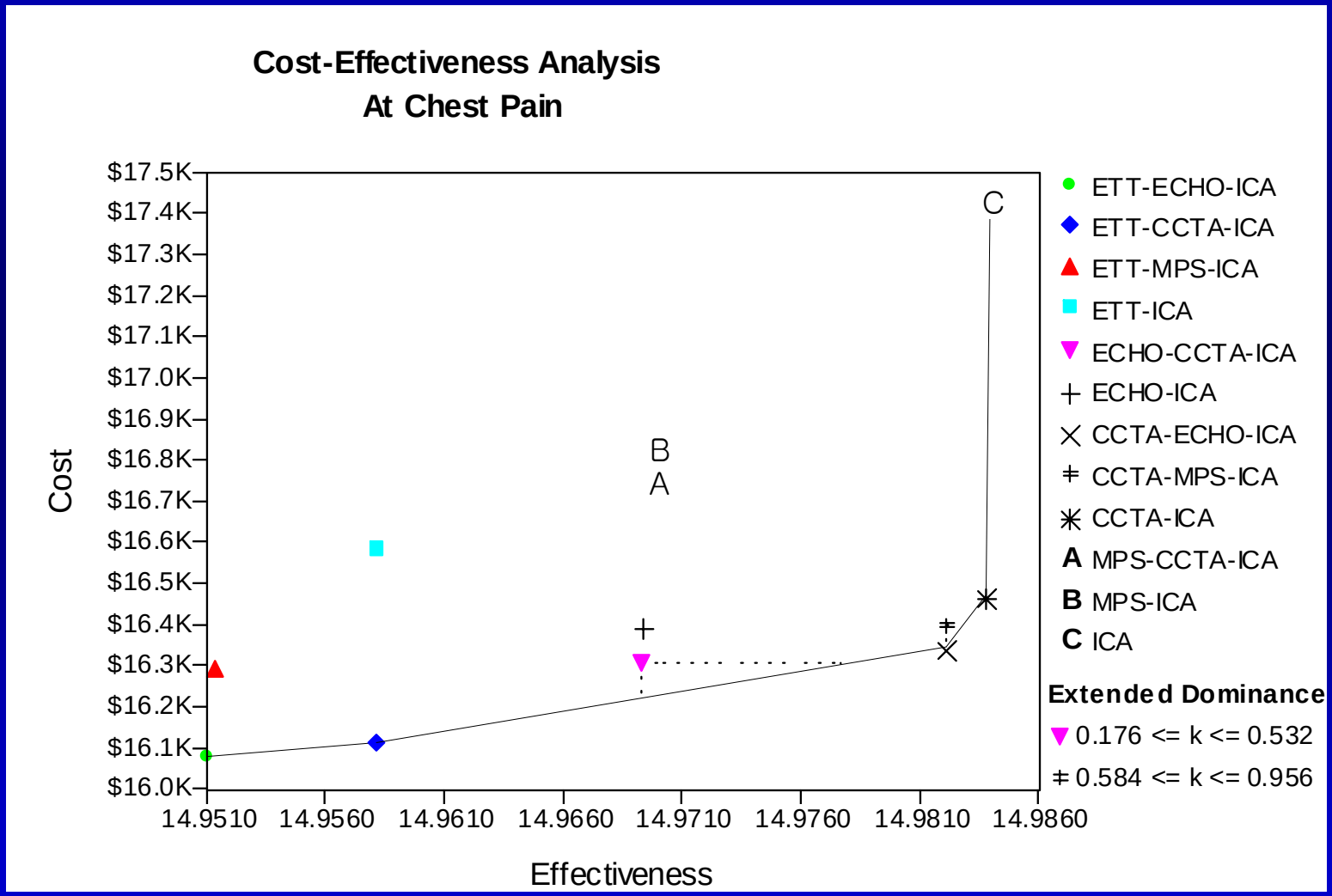
Non-invasive imaging is less costly.

Spending on Health Care as a Percentage of Gross Domestic Product Under an Assumption That Excess Cost Growth Continues at Historical Averages



Ezekiel J. Emanuel, MD, PhD: NIH

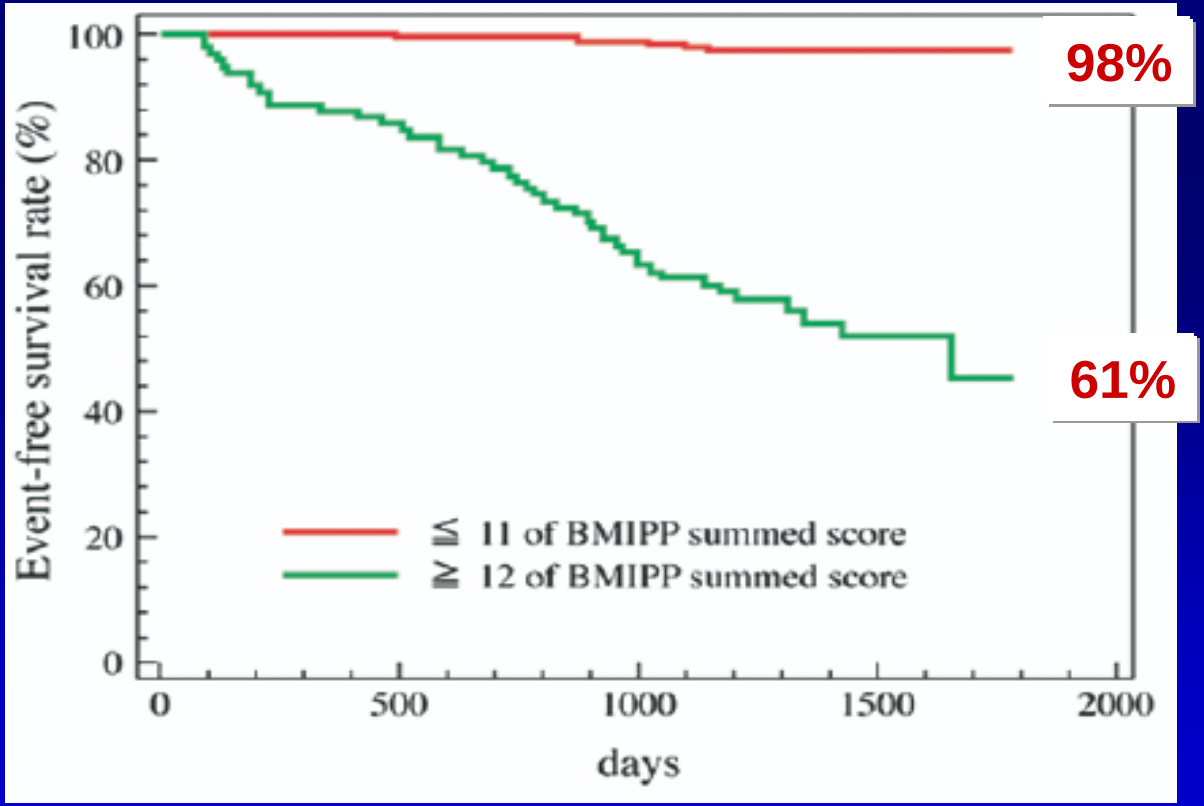
Noninvasive imaging is cost effective.



Min, preliminary data

Prediction of Cardiac Death in Hemodialysis Patients by Myocardial Fatty Acid Imaging

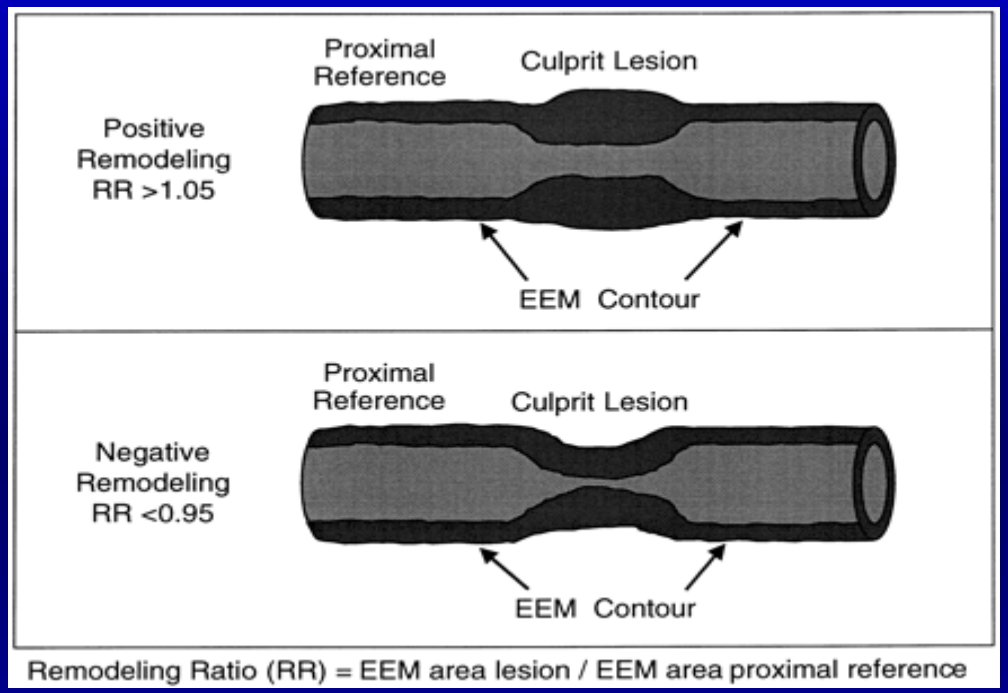
Prospective enrollment of 318 asymptomatic HD patients (male/female: 170/148; 64 yrs), without known CAD who underwent dual SPECT using 123I–BMIPP and 201-thallium. 3.6+/-1.0 yr f/u. 50 died of cardiac events (MI=22, CHF=17, SCD=11). Cox hazard analysis associated cardiac death with age (70 years) and with abnormal BMIPP SPECT images (BMIPP SSS>12: HR 21.9; p 0.0001).

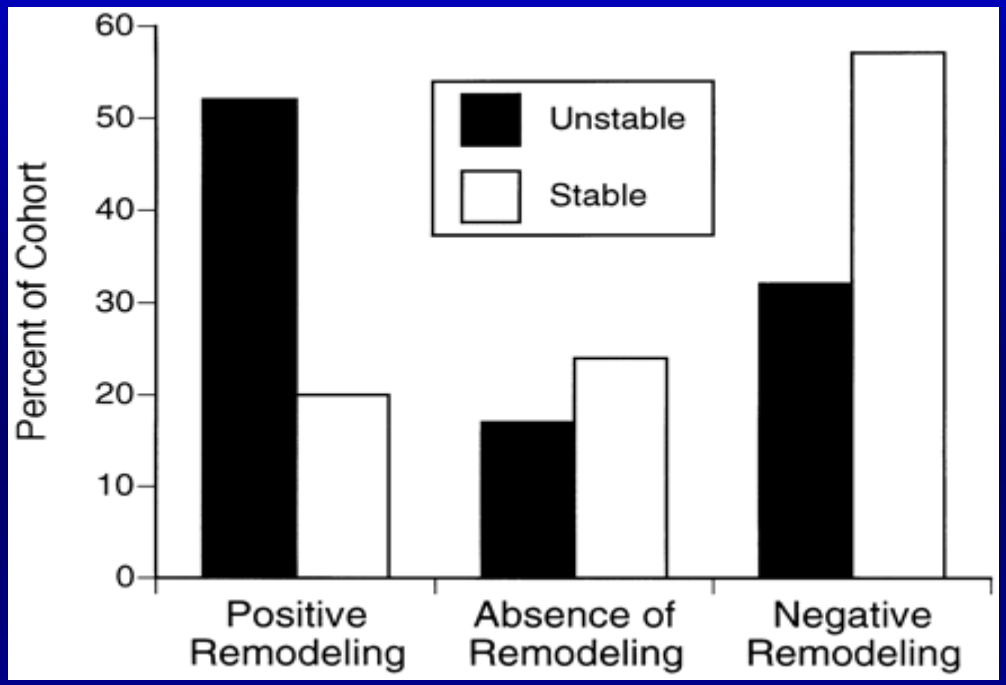


Nishimura et al. JACC 2008

Extent and Direction of Arterial Remodeling in Stable Versus Unstable Coronary Syndromes: An IVUS Study

85 pts with ACS and 46 pts with stable coronary syndromes studied by IVUS prior to PCI.





Remodeling ratio (RR) = (EEM_{lesion})/(EEM_{prox}).
Positive remodeling: RR >1.05;
Negative remodeling: RR <0.95.

ACS vs. Stable Angina:

1. Plaque area

(13.9±5.5 vs 11.1±4.8 mm2; *P*=0.005)

2. EEM area

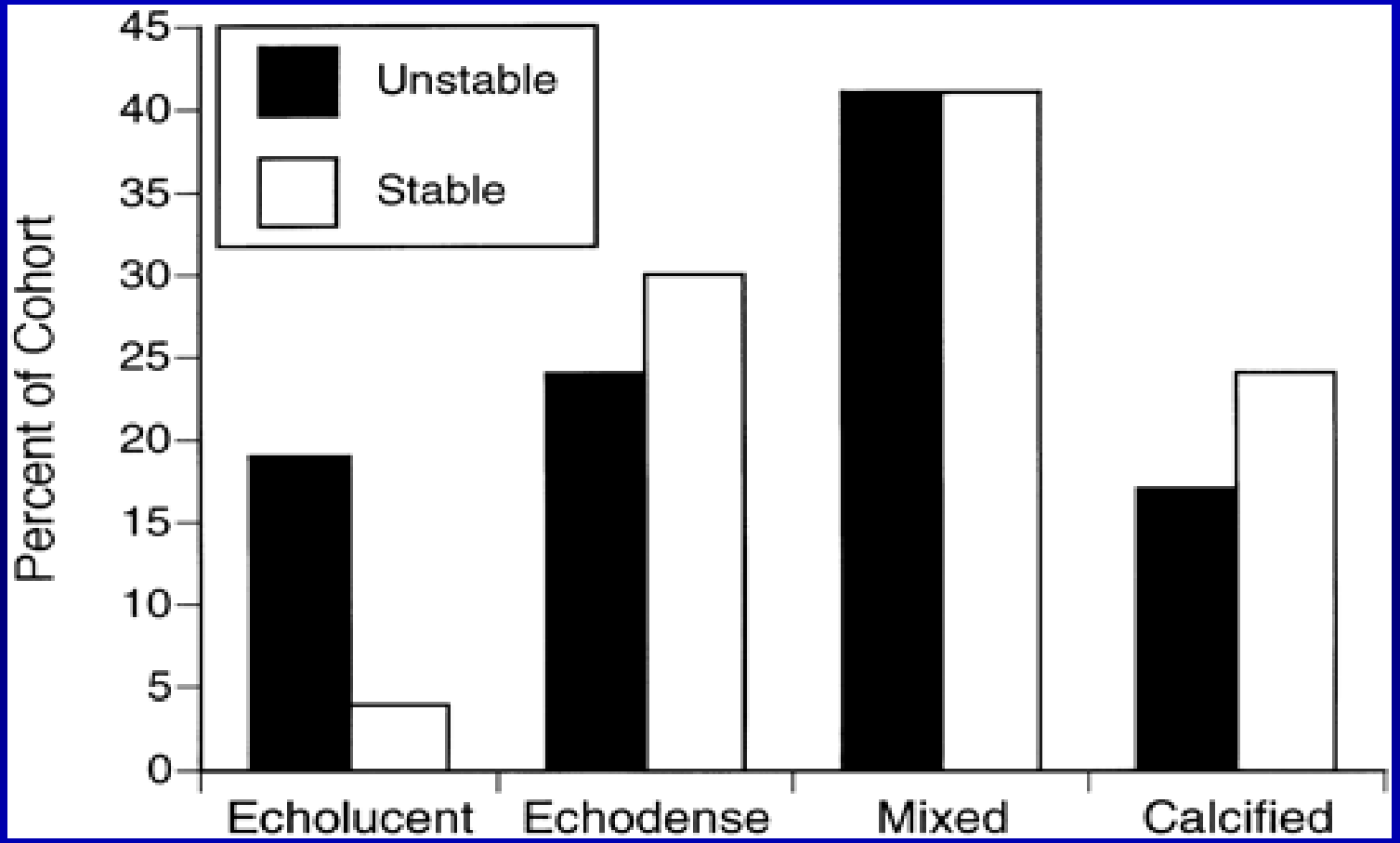
(16.1±6.2 vs 13.0±4.8 mm2; *P*=0.004)

3. Relative Remodeling

(1.06±0.2 vs 0.94±0.2; *P*=0.008)

Schoenhagen et al. Circulation 2000

Plaque Composition in Stable Versus Unstable Coronary Syndromes

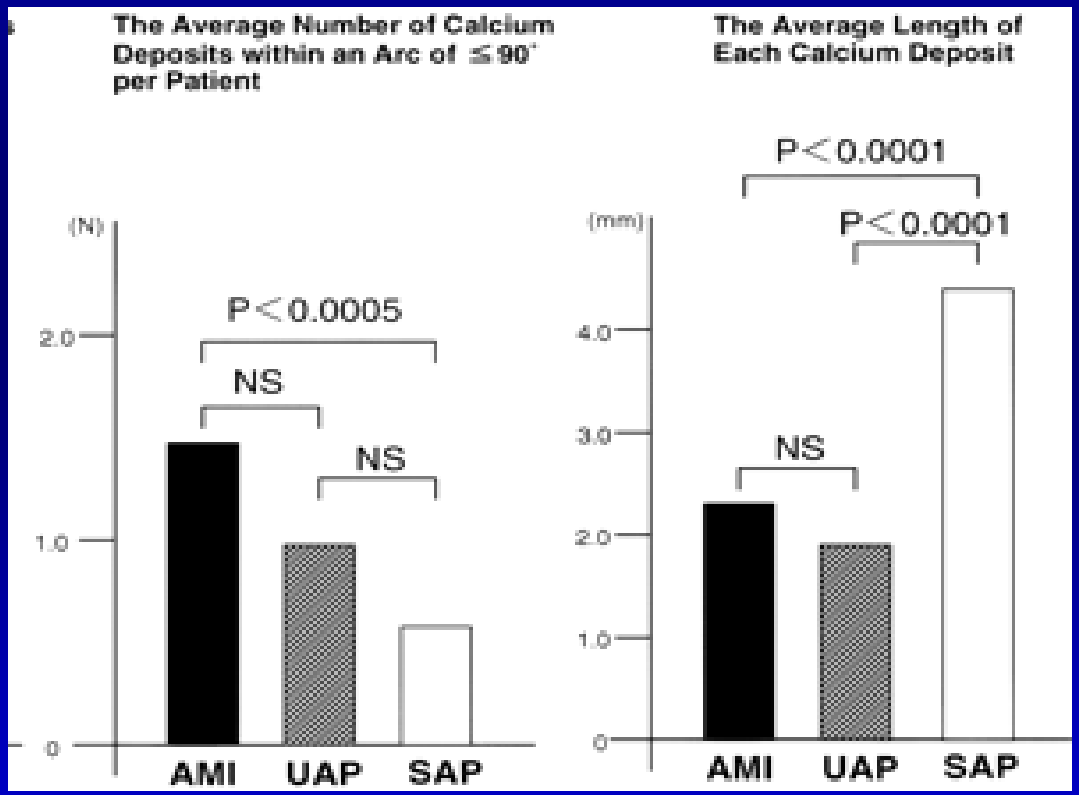


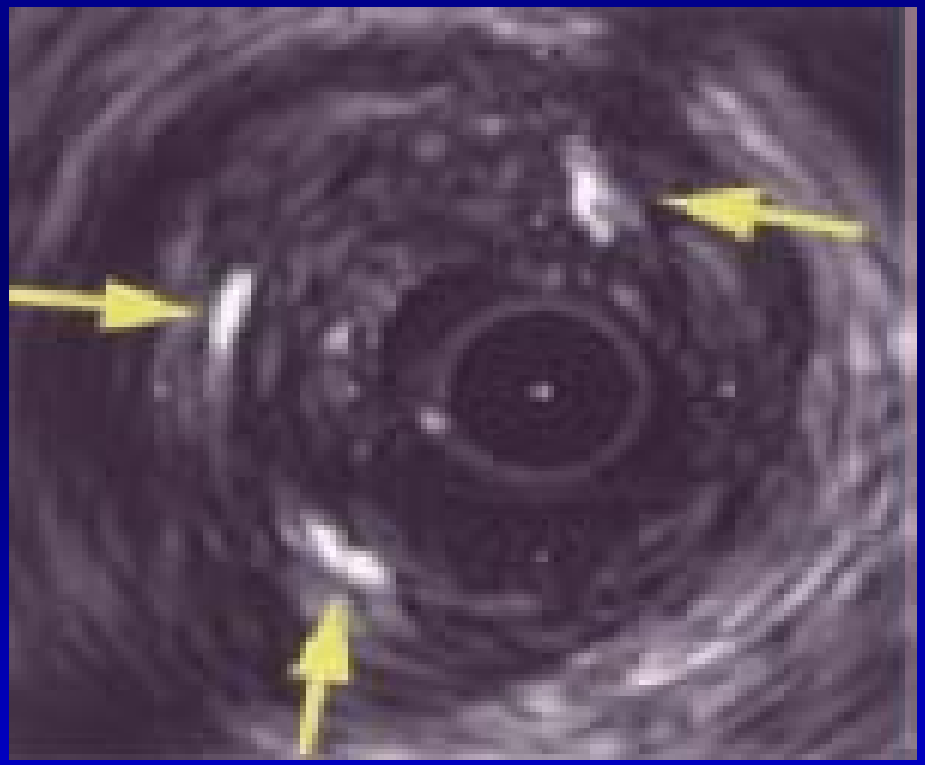
Compared with the 3 other morphology groups, echolucent plaques were more frequent in the unstable than in the stable angina group (19% versus 4%; P=0.02).

Schoenhagen et al. Circulation 2000

Spotty Calcification in Culprit Plaques in AMI: An IVUS Study

171 pts—61 AMI, 70 UAP, 47 SAP. Frequency and # of calcium deposits within arc <90º for all calcium deposits measured.



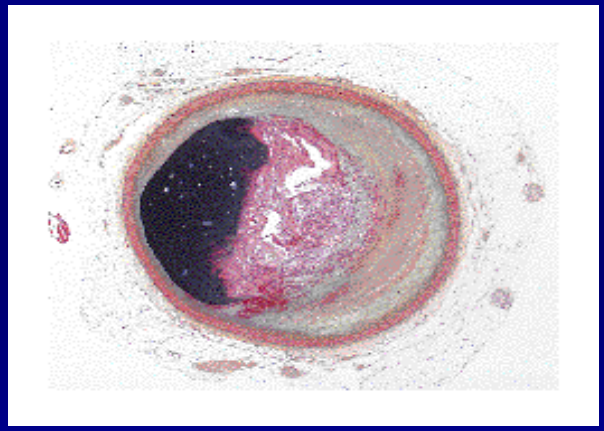


Ehara et al. Circulation 2003

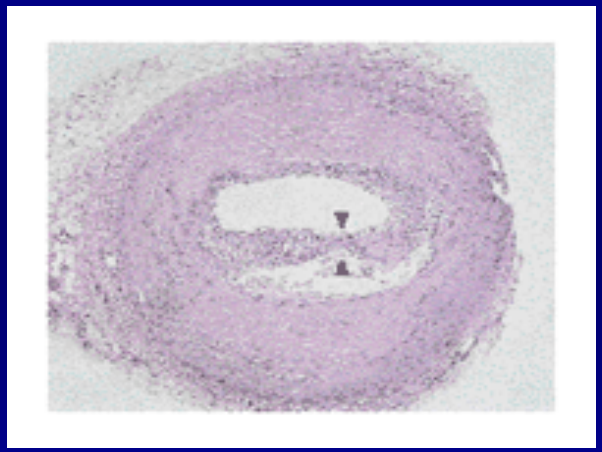
Plaque Morphology in Men with CAD Who Died Suddenly

113 men: 59 acute thrombus; 54 severe narrowing by plaque without thrombosis (stable plaque). Thrombosis divided into 2 groups: 41 from rupture of a vulnerable plaque (a thin fibrous cap overlying a lipid-rich core); 18 resulting from the erosion of a fibrous plaque rich in smooth-muscle cells and proteoglycans.

PLAQUE COMPOSITION



PLAQUE VOLUME



PLAQUE REMODELING

MULTIFACTORIAL ASSESSMENT OF PLAQUE IDENTIFIES PATIENTS WITH UNHERALDED SUDDEN CARDIAC DEATH

Vermani NEJM