London, Friday, 29 October

Imaging 2: Screening for Coronary Artery Disease with CT and MR

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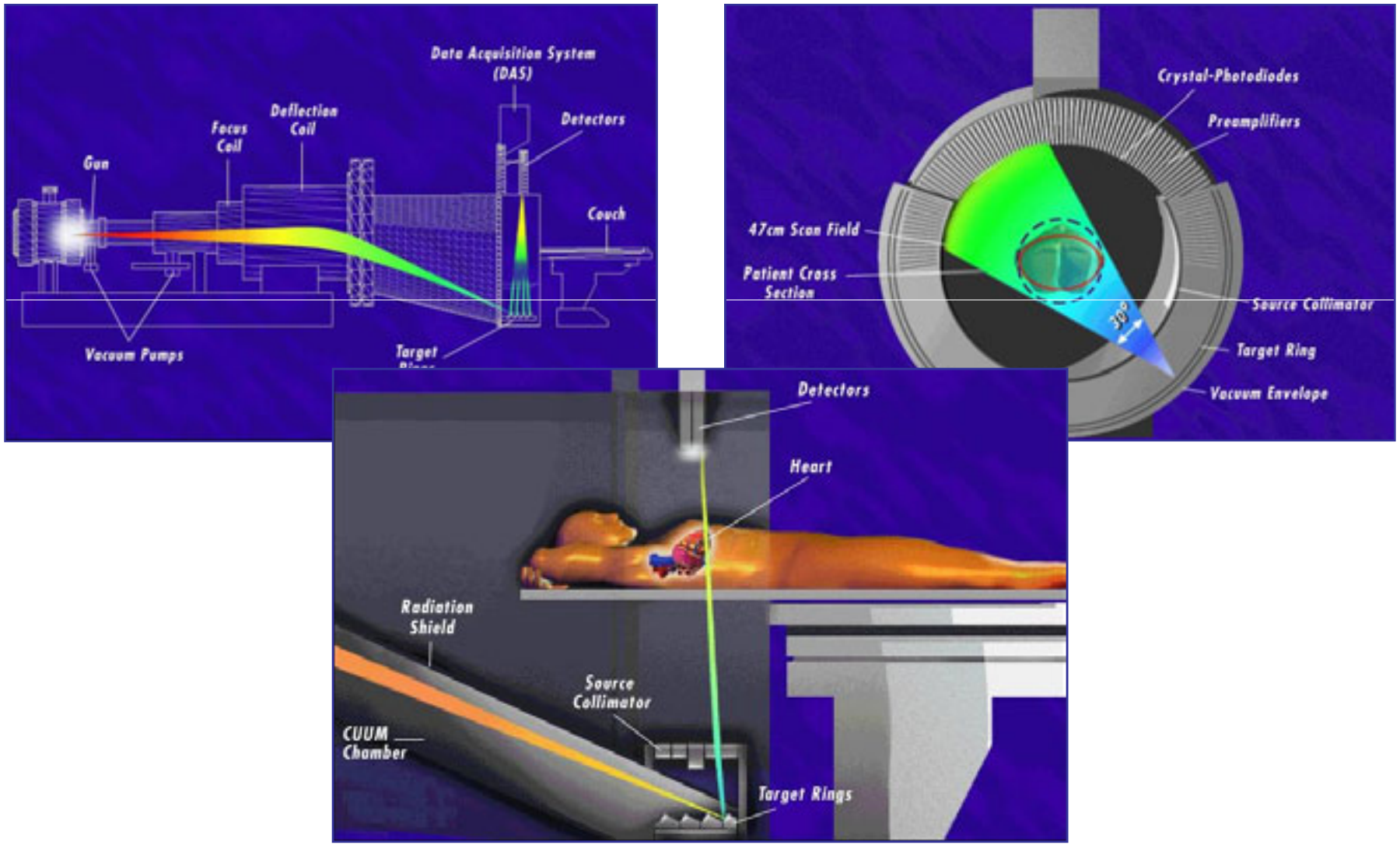
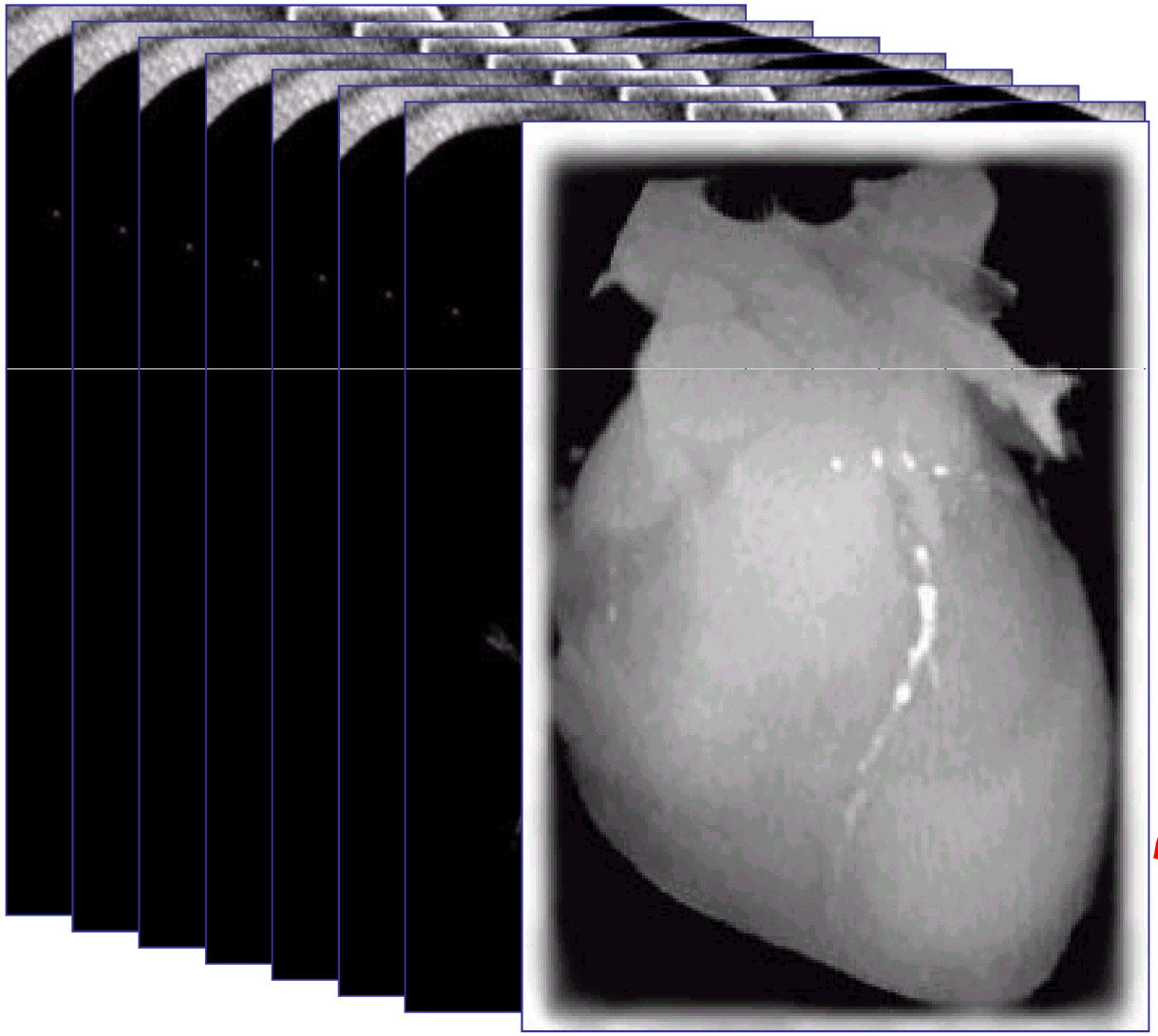
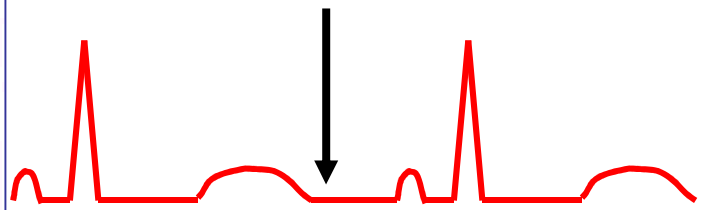
EBT Scan Configuration



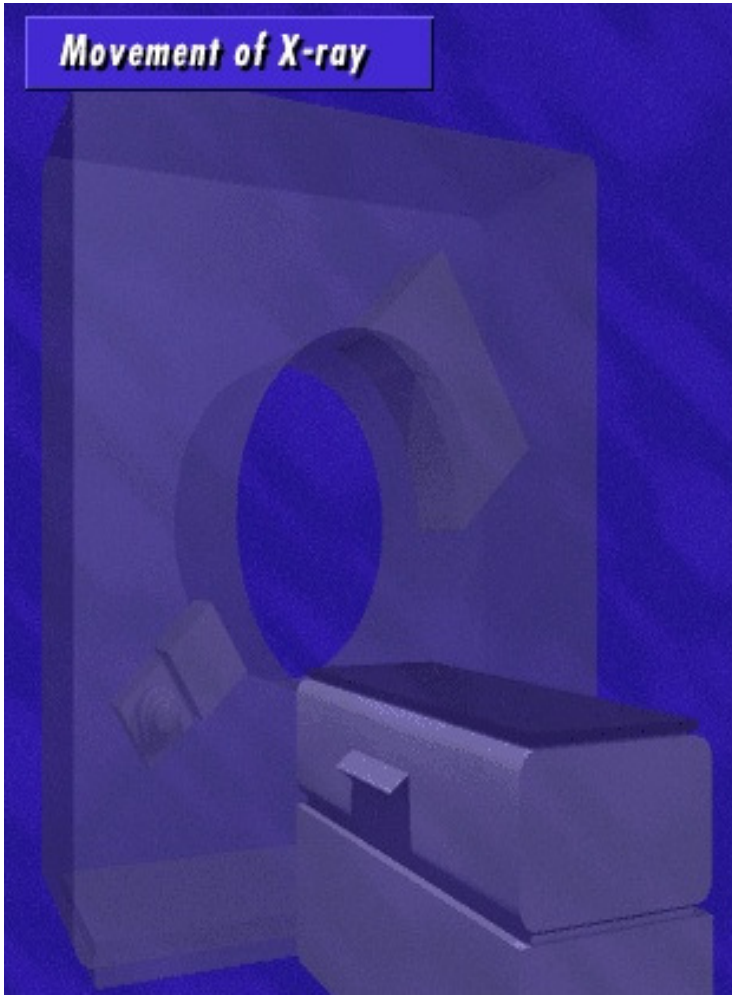
Step and shoot modality

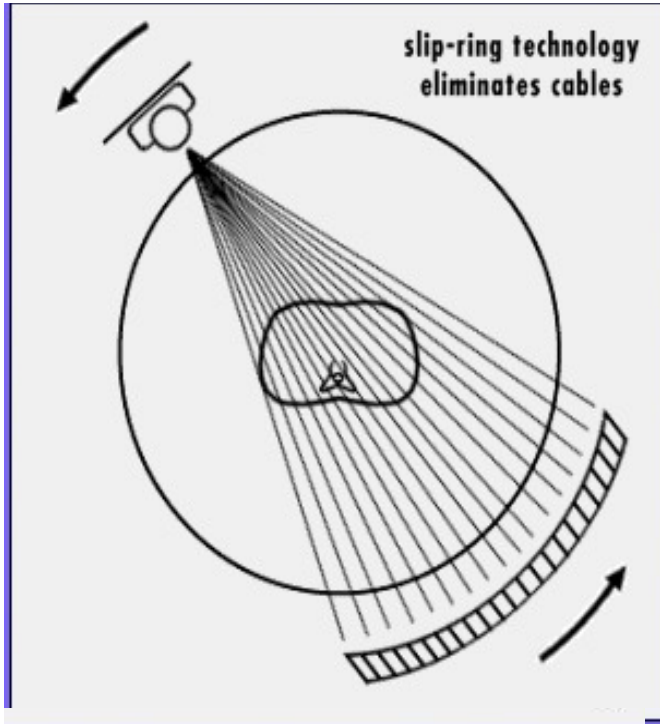




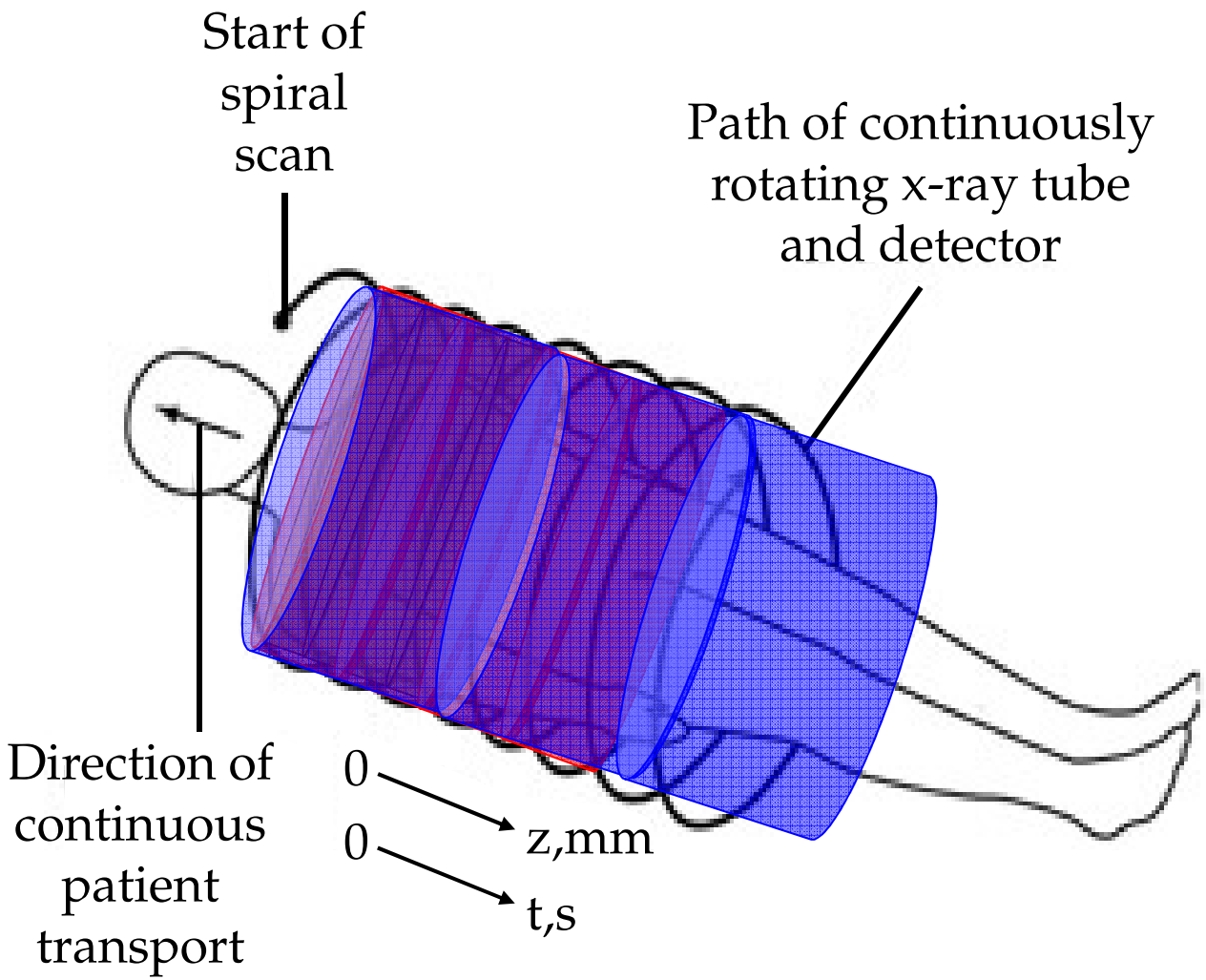
50%–70% RR interval

Helical/ Spiral/ Multidetector CT





Helical/ Spiral/ Multidetector CT



2–4 slices

8–16 slices

16–32 slices

32–64 slices

64 x 2 slices

256 slices

320 slices

CT techniques: technical aspects

Test	Radiation dose	
1 Stress MIBI	6 mSv	
1 LC spine	1.3 mSv	
1 Barium Enema	7 mSV	
1		
1 A		
1 I		
1 C		
1 C		
		CT
Ca		
CT angiography	8-13 mSv	1-1.5 mSv
CTA dose modulation	5-8 mSv	-
Lung CT	8 mSv	1.5 mSv
Abdomen/Pelvis	10 mSv	2 mSv
Body scan	12 mSv	2.6 mSv
Virtual colon	8-14 mSv	2-3 mSv

- An effective dose of 10 mSv maybe associated with an increase in fatal cancer 1/2000
- 50% of a person radiation exposure is due to medical testing

Adapted from Cardiac CT Imaging-Diagnosis of Cardiovascular Disease Springer2006

Clinical Applications of Cardiovascular CT

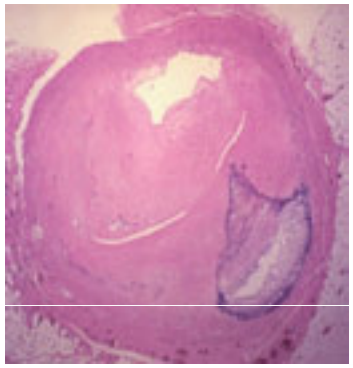
Cardiac CT has several diagnostic capabilities applicable of many facets of CAD worth the radiation exposures:

1. Non contrast enhanced can identify and quantify **coronary calcification** (marker of total burden)
2. Contrast enhanced studies can **define ventricular volumes, ejection fraction, wall motion defects and wall thickening, coronary lesions**

Types of Vascular Calcification in CKD

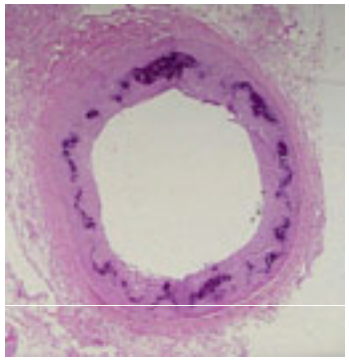
Atherosclerosis

Patchy lesions
- related to lipids
- older persons
- elastic and muscular arteries



Atherosclerosis
↓
Atherosclerotic atherosclerotic plaque
↓
arterial stenotic lesion
↓
ischaemia

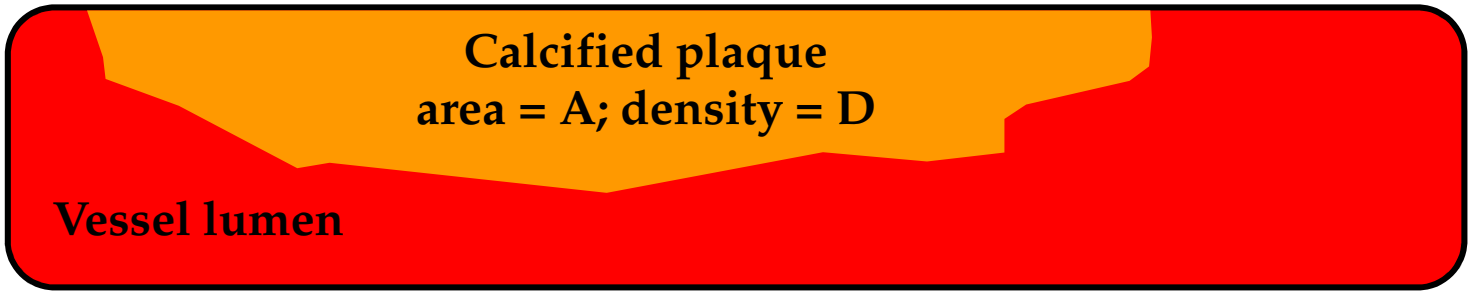
Uremic arteriolopathy:



linear lesions
- disturbances in mineral metabolism
- young and old persons
- CKD, DM
- muscular arteries

Atheriolosclerosis
↓
Modification of arterial wall properties
↓
↑ arterial stiffness (↑ PWV; ↑PP)
↓
↑Afterload • LVH
Coronary perfusion • Angor

The Agatston Score

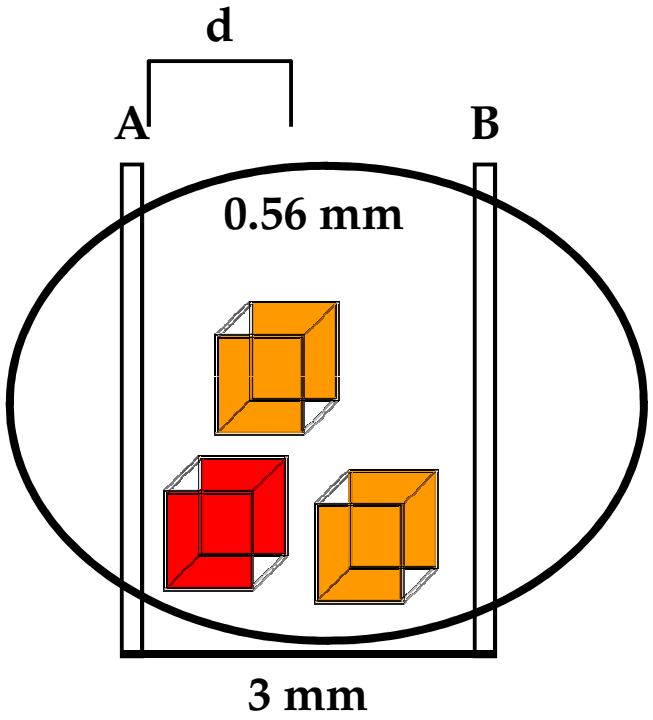


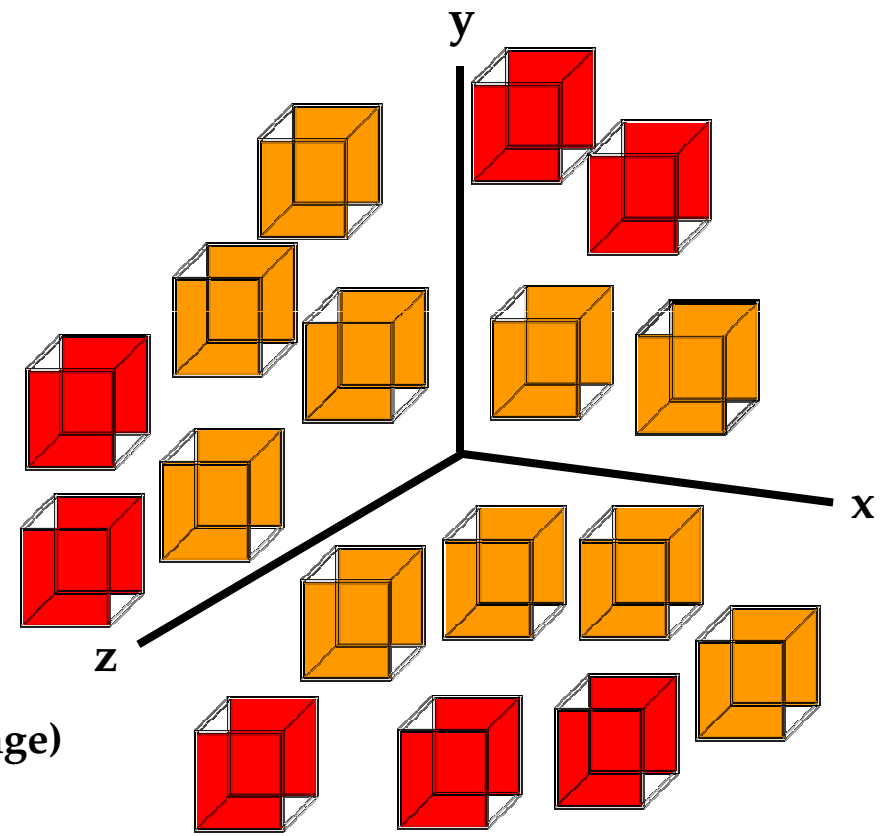
- Density = 130–200; coefficient 1
- Density = 201–300; coefficient 2
- Density = 301–400; coefficient 3
- Density >401; coefficient 4

Agatston score = A x Dcoef

Reported variability: 10–40%

Calcium Volume Score





DA x (1–d) + (DB x d)

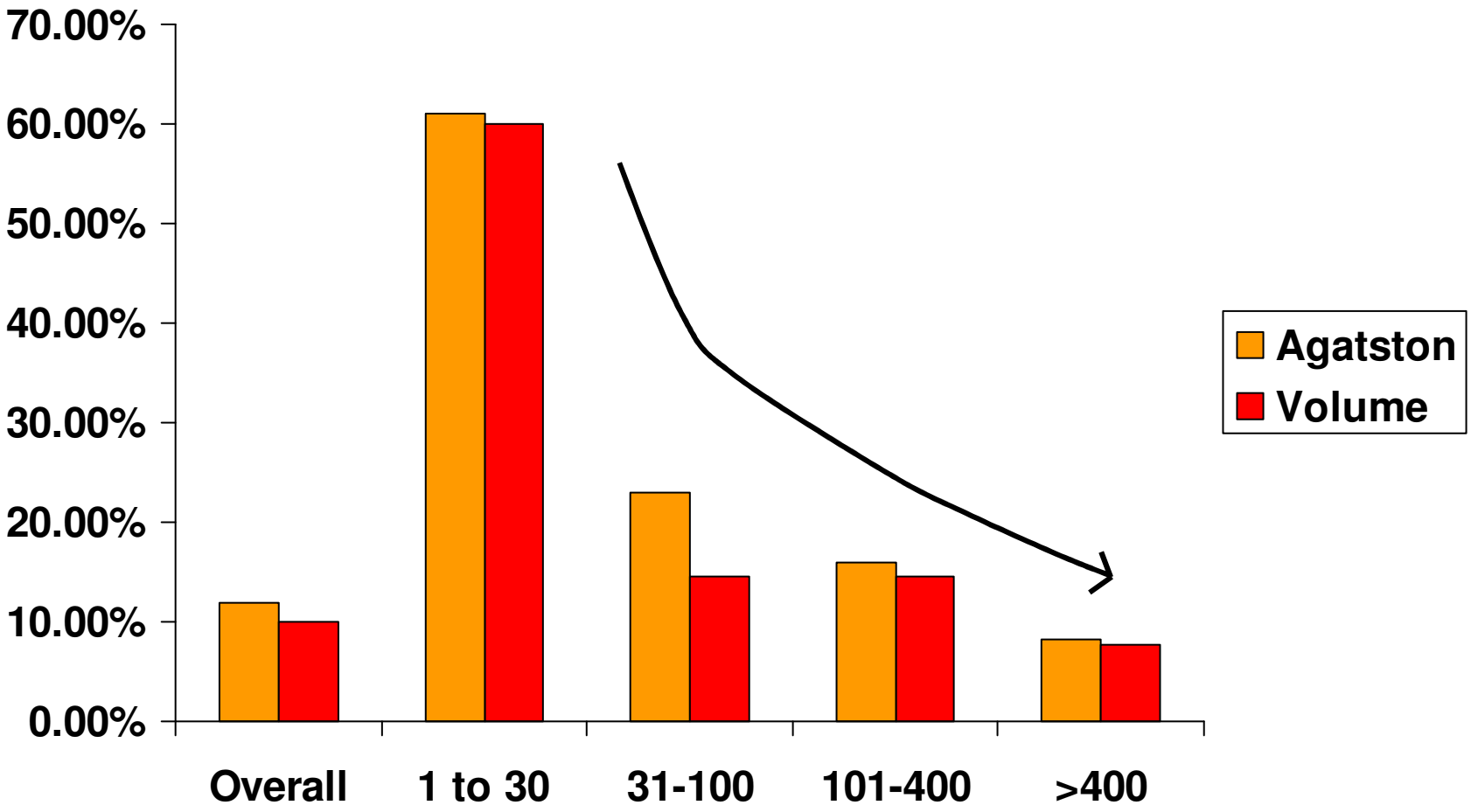
DA, density in A
DB, density in B

- **130 HU included (orange)**
- **130 HU excluded (red)**

Reported variability: 8–10%

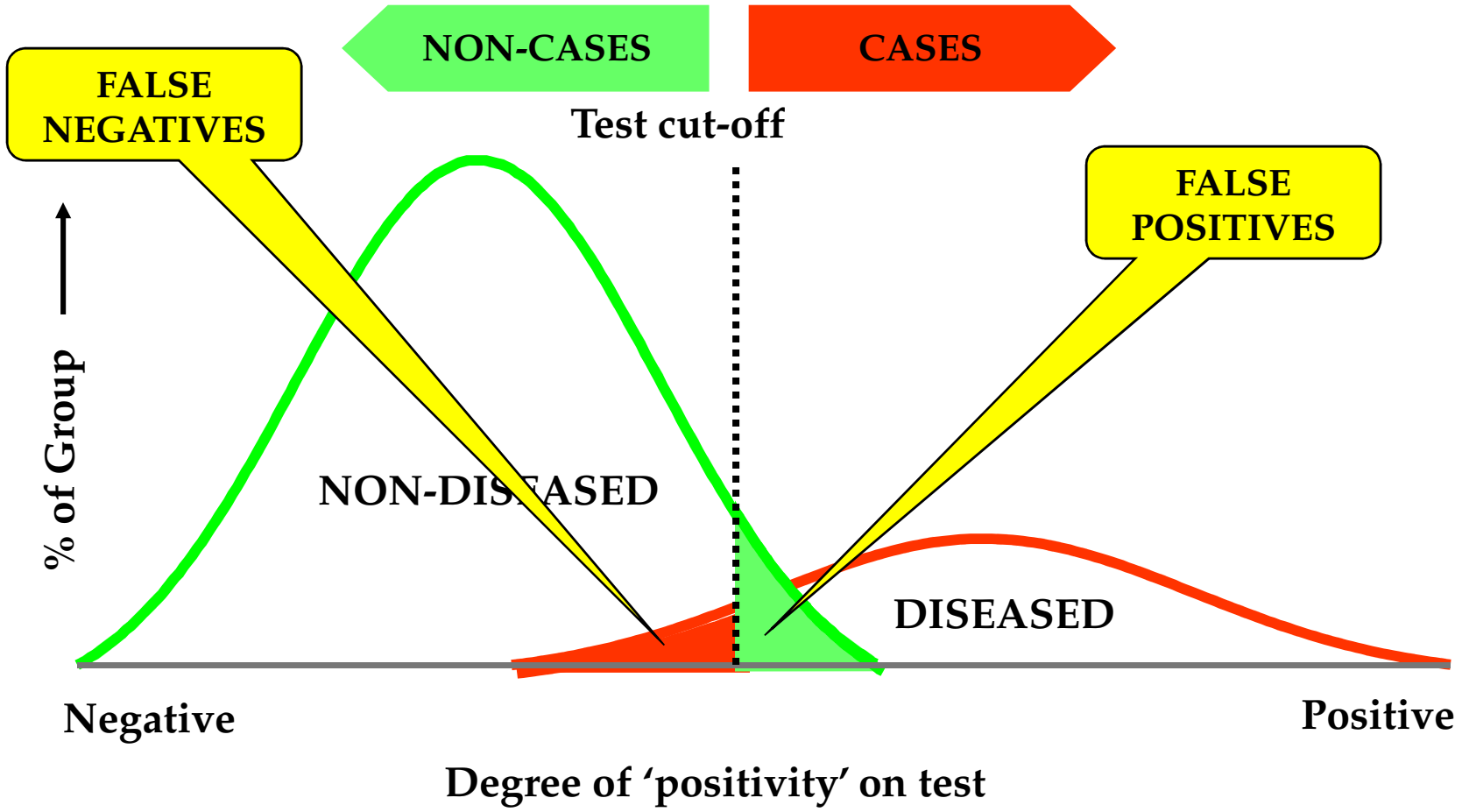
Callister TQ *et al*. *Radiology* 1998;208:807–14

Variability of Agatston and Volume Score on Electron Beam Tomography in CARE-2 Trial

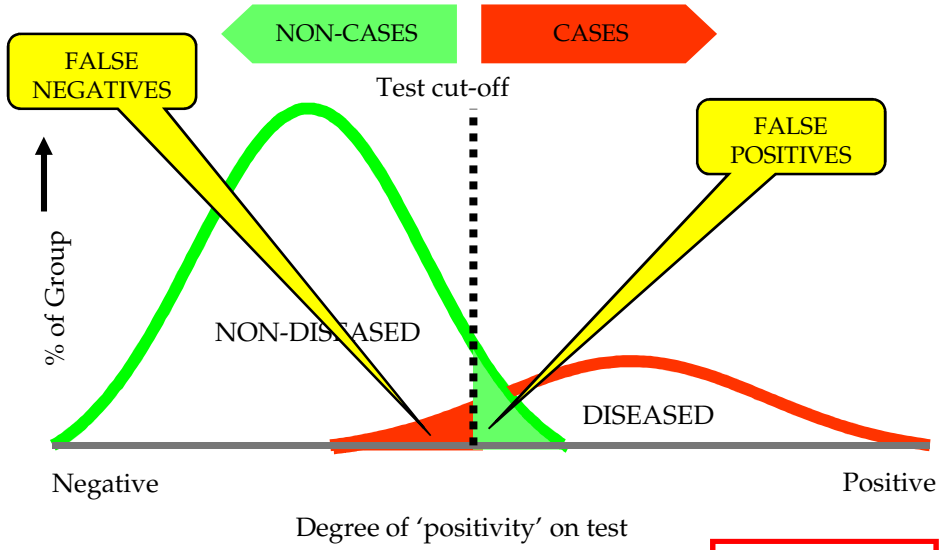


Budoff M et al. Acad Radiol. 2008;15:58-61

Performance of a diagnostic test



Performance of a diagnostic test



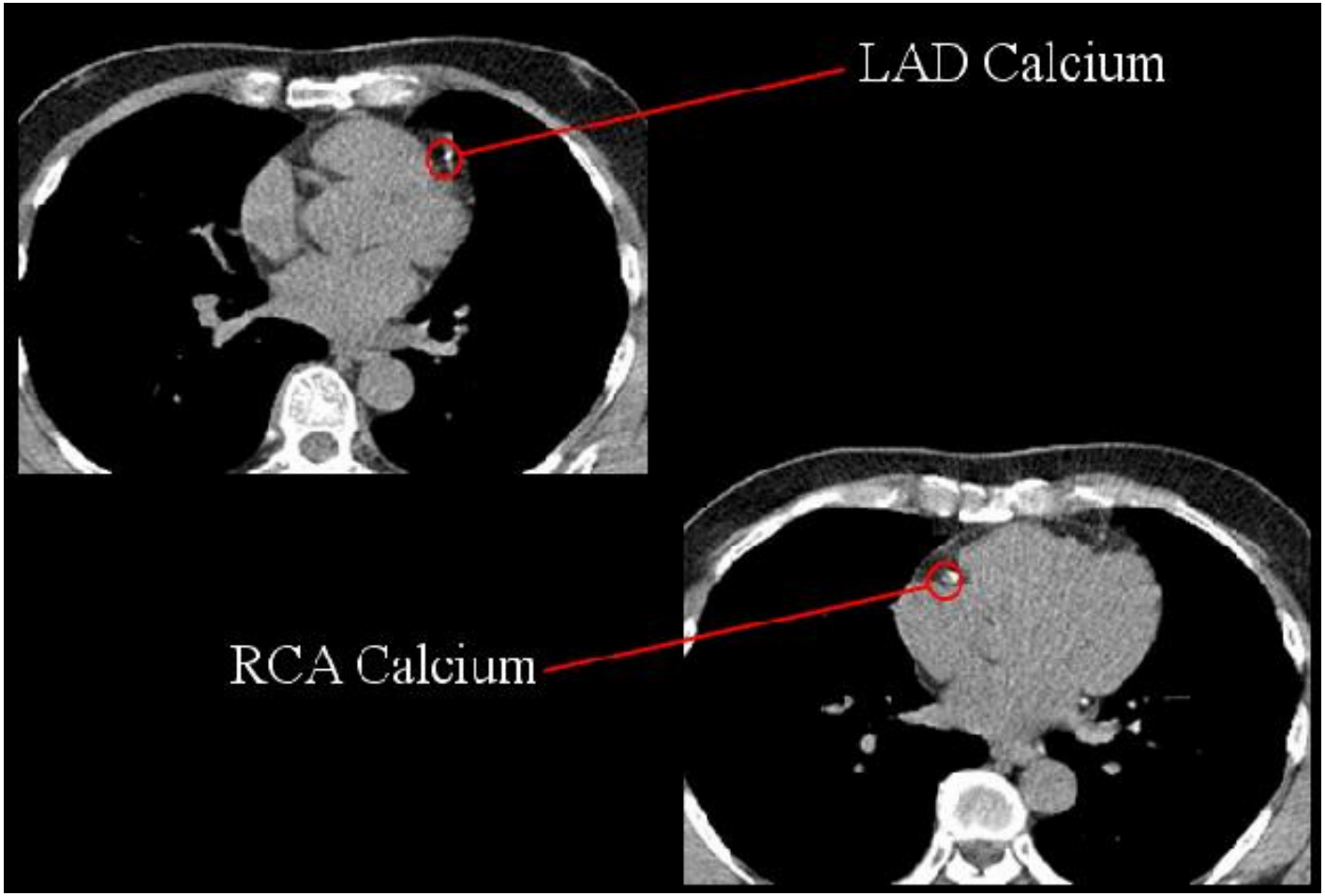
		Disease	
		Present	Absent
Test	Positive	A (true positive)	B (false positive)
	Negative	C (false negative)	D (true negative)

Healthy artery
Risk factors
assessment

disease
c lesion
ification
ent

disease
osis
graphy

Cardiac CT
Coronary Artery Calcium Scoring



Adapted from Cardiac CT Imaging-Diagnosis of Cardiovascular Disease Springer2006

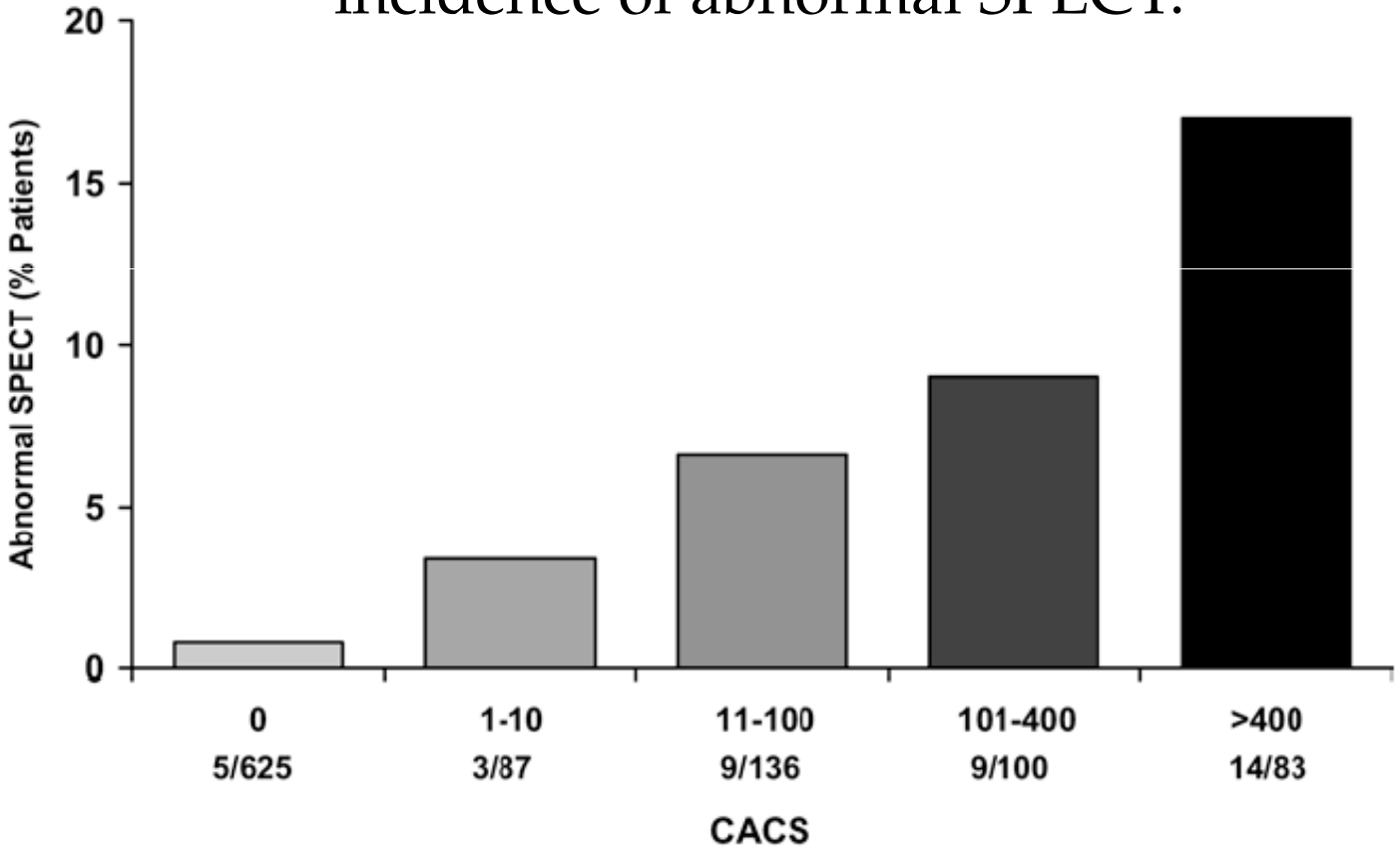
Studies examining the relationship between CACS and acute coronary syndrome in the ED setting

Study	Year	N	CAC=0 (%)	Sn (%)	Sp (%)	PPV (%)	NPV (%)
Laudon et al.	1999	105	59 (59)	100	63	30	100
McLaughlin et al	1999	134	48 (36)	100	38	8	100
Georgiu et al	2001	192	76 (40)	97	55	48	97
Hoffman et al	2009	368	197 (54)	97	59	18	99.5
Nabi et al	2010	1031	625 (61)	93.8	62.4	7.4	99.7

Coronary Artery Calcium Scoring in the Emergency Department: Identifying Which Patients With Chest Pain Can Be Safely Discharged Home

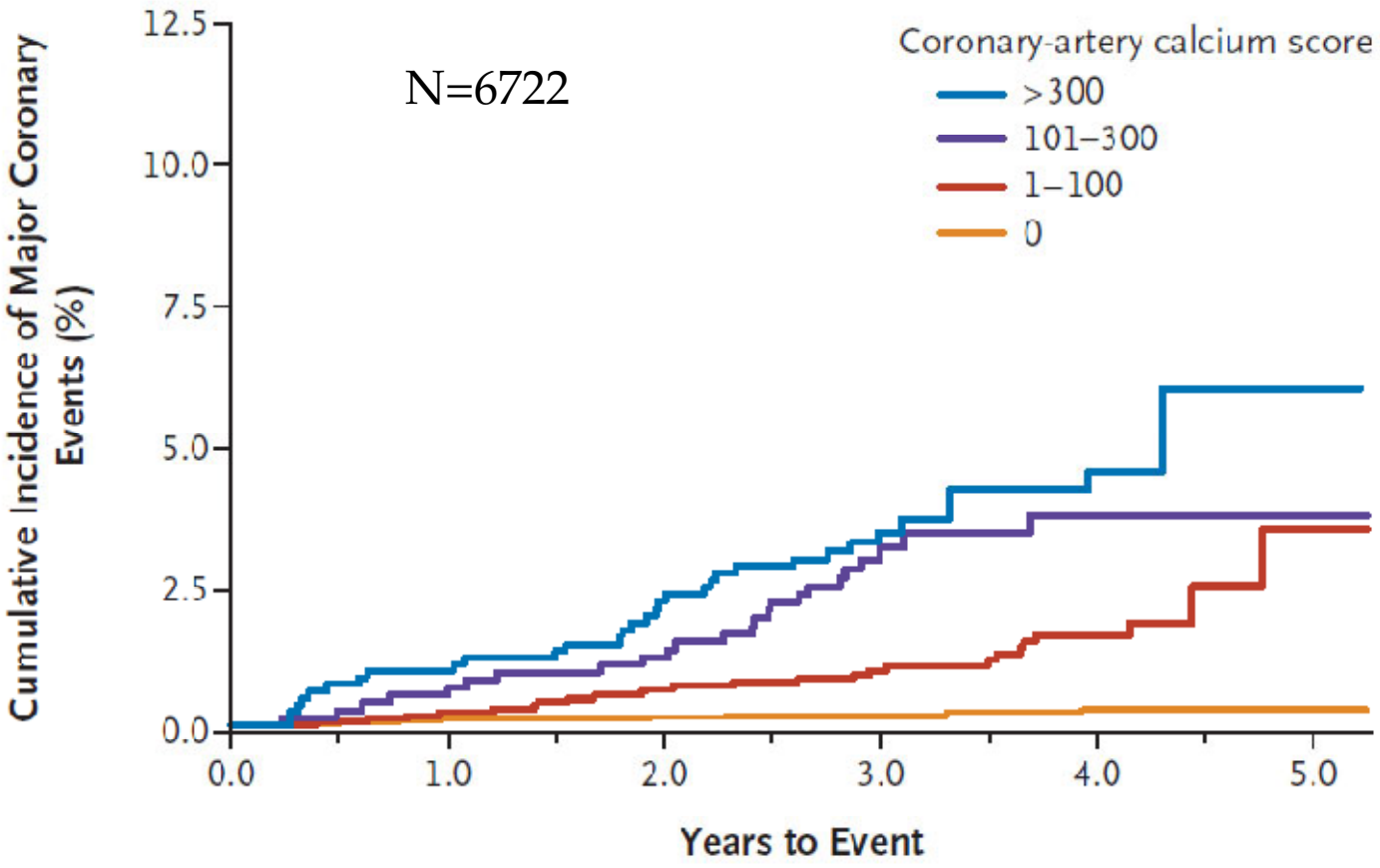
Nabi et al Ann Emerg Med 2010

Relationship between CACS results and the incidence of abnormal SPECT.



Coronary Calcium as a Predictor of Coronary Events in Four Racial or Ethnic Groups

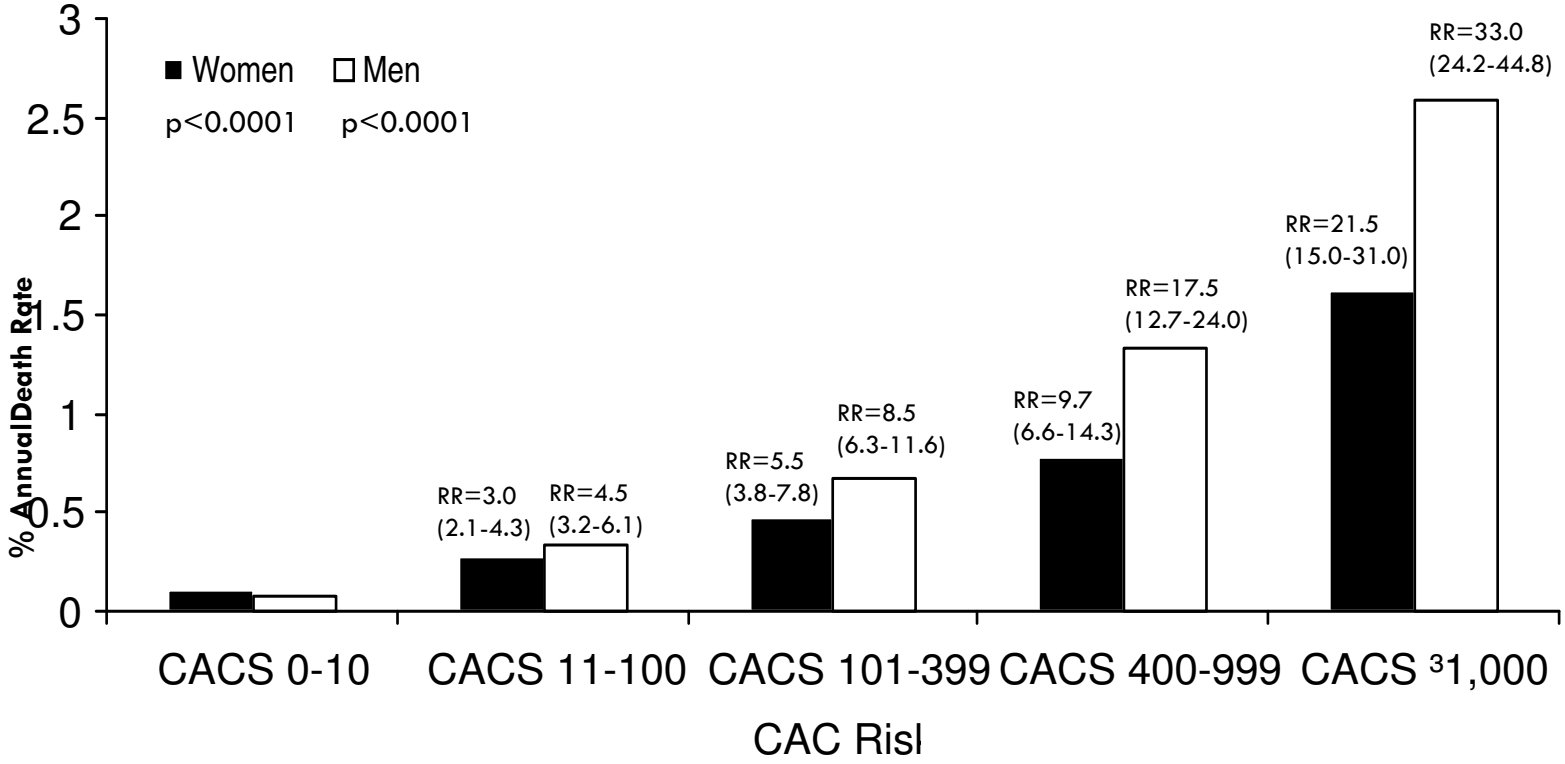
Detrano et al *N Engl J Med 2008; 358:1336-45*



Major coronary events (myocardial infarction and death from coronary heart disease). The differences among all curves are statistically significant (P<0.001)

The American Journal of Cardiology

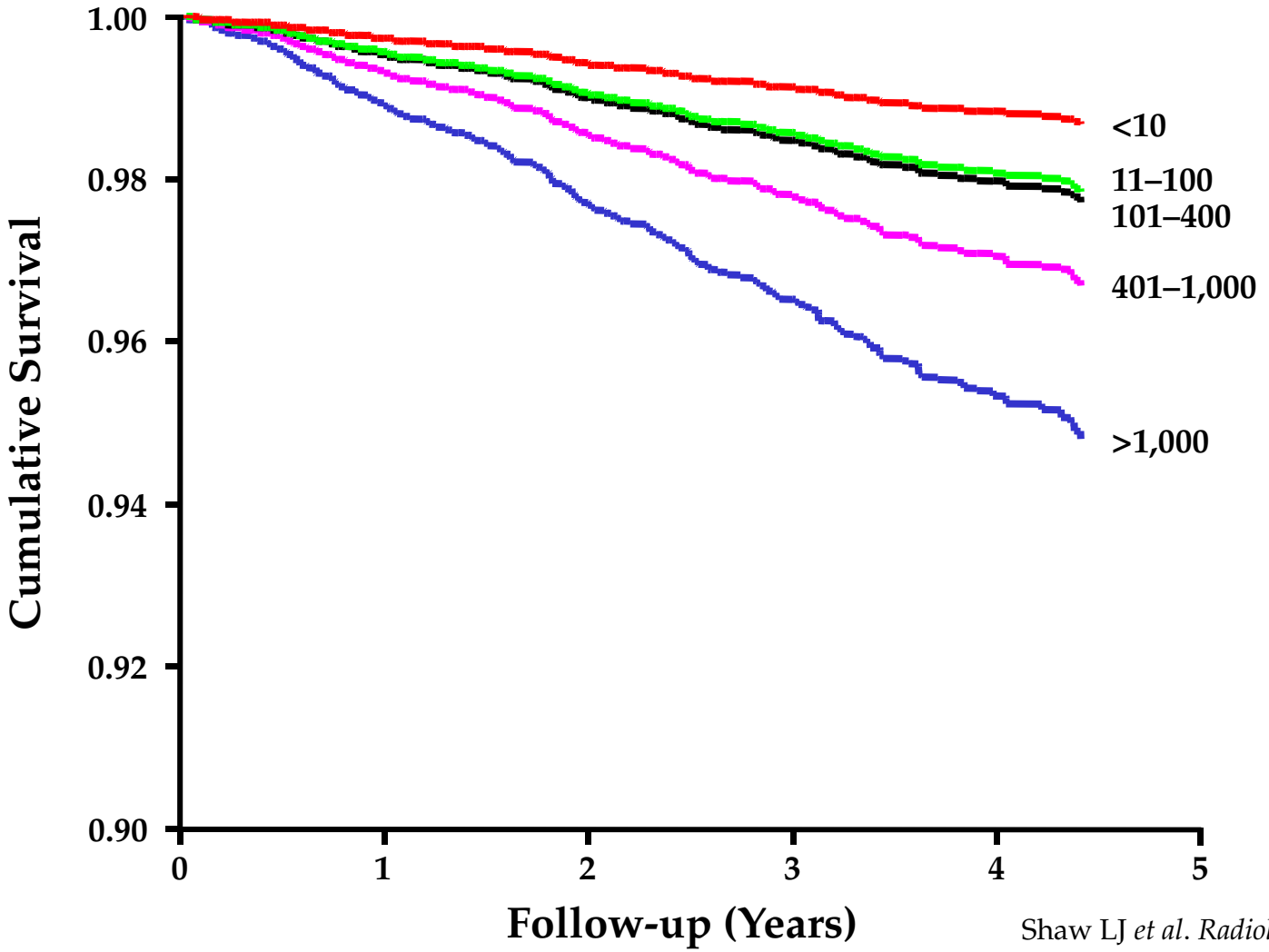
Comparison of Prognostic Usefulness of Coronary Arterial Calcium in Men versis Women (Results from a Meta- and Pooled Analysis Estimating All-Cause Mortality and Coronary Heart Disease Death or Myocardial Infarction)



Women	(n=9,969)	(n=3,681)	(n=2,384)	(n=1,075)	(n=669)
Men	(n=10,59)	(n=3,395)	(n=2,225)	(n=1,011)	(n=629)

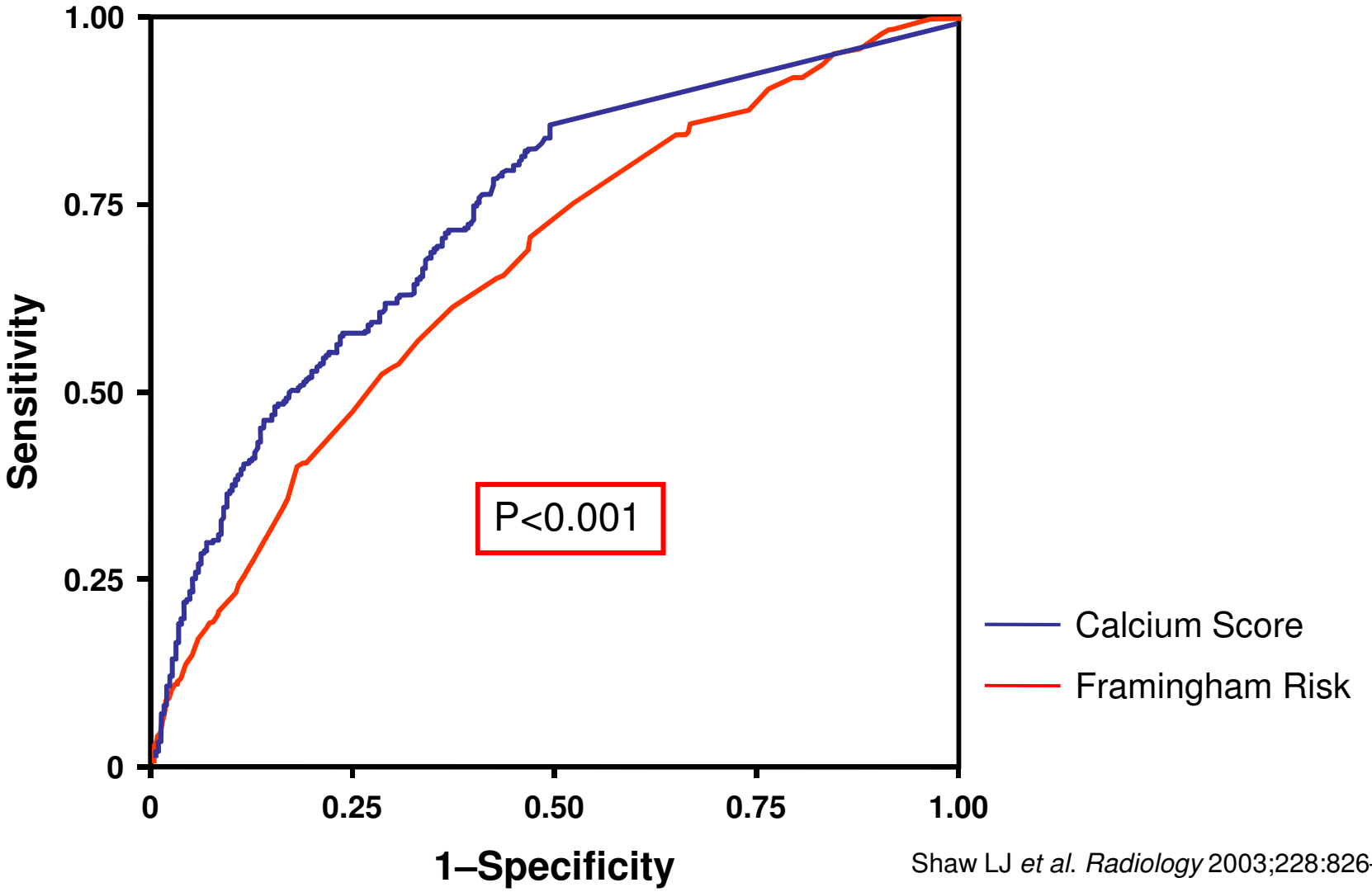
Bellasi et al, Am J Cardiol 2007

Risk-Adjusted Survival (All-Cause Mortality) by Calcium Score Subsets



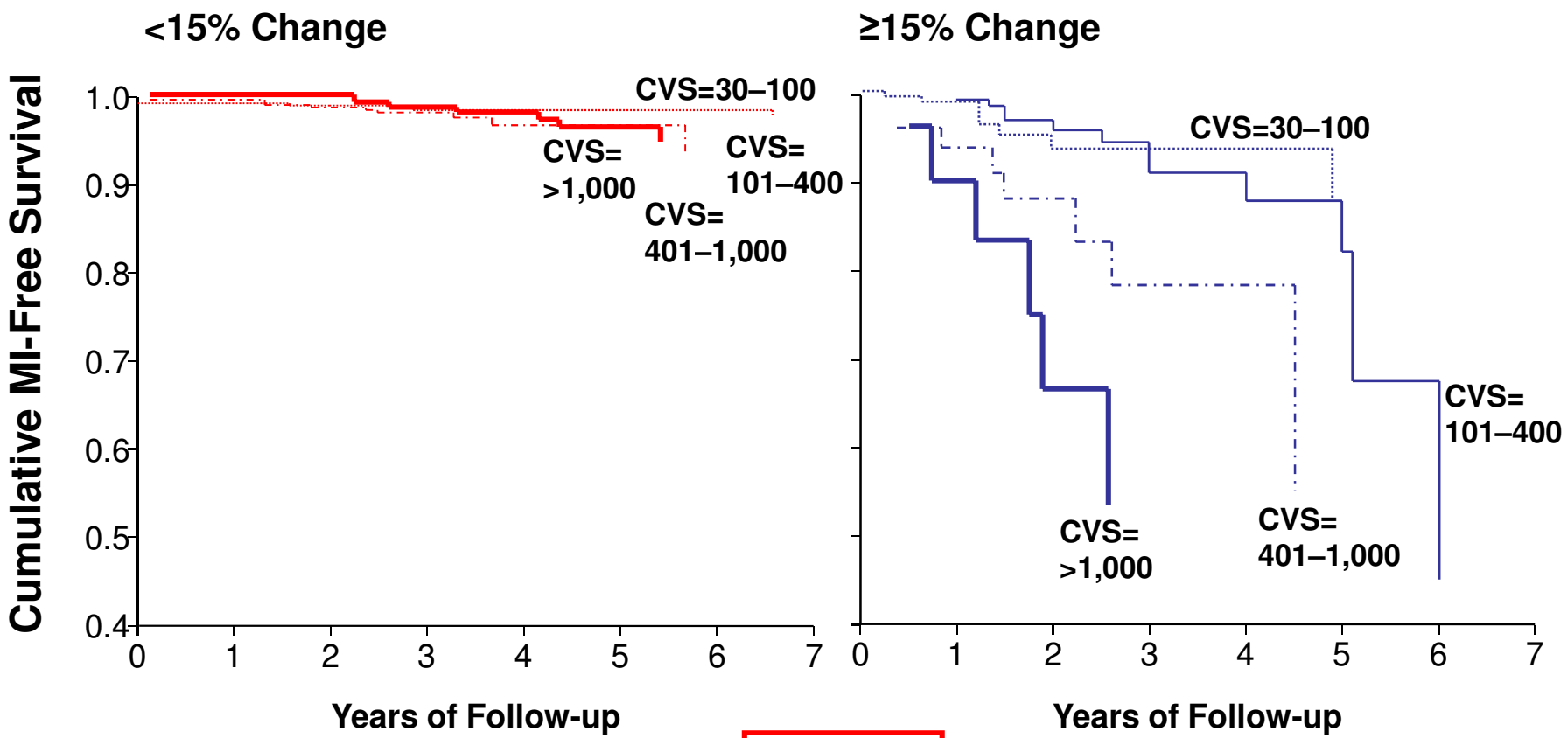
Shaw LJ *et al*. *Radiology* 2003;228:826–33

Incremental Value of CAC Over Traditional Risk Factors for ALL-Cause Mortality



Shaw LJ *et al. Radiology* 2003;228:826–33

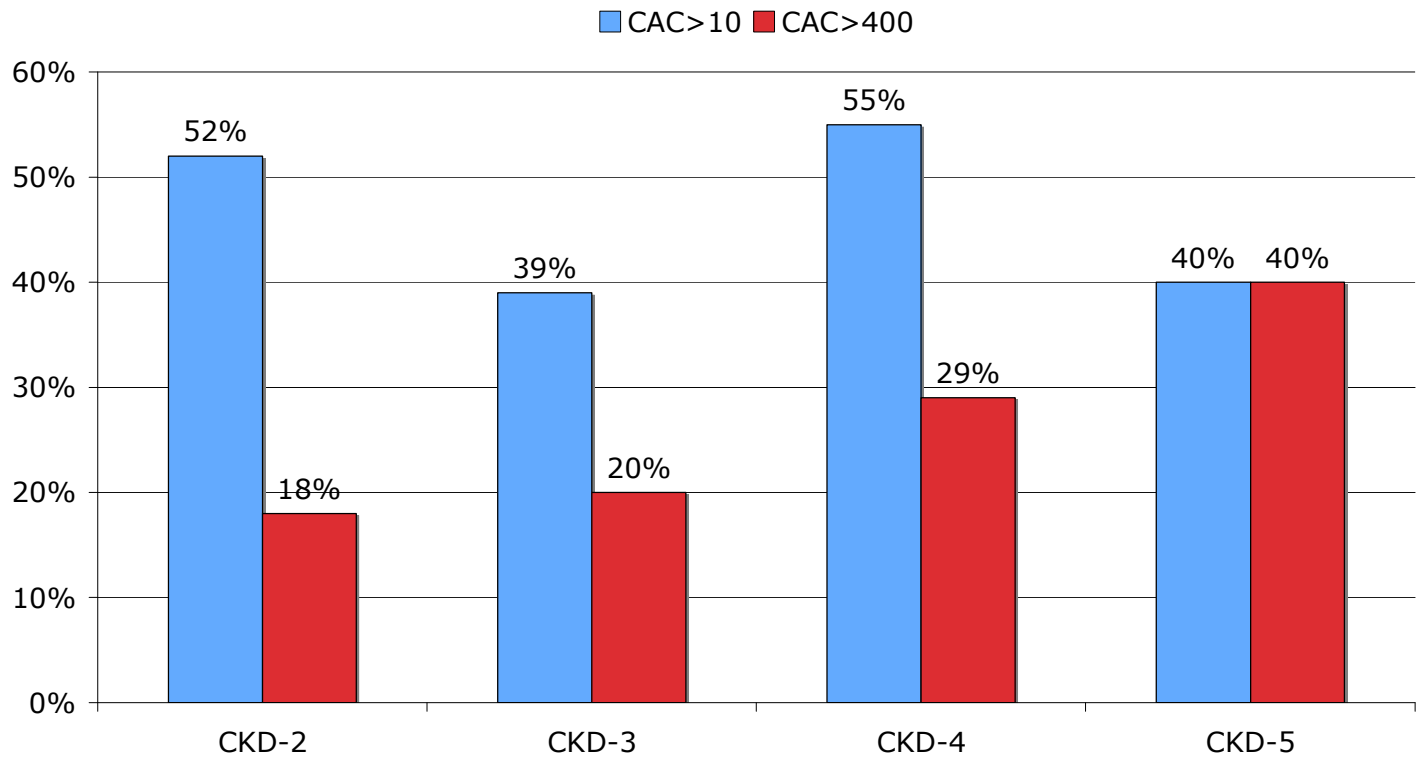
Cox Survival Analysis of Time to Acute MI for Patients with >15% Δ from Baseline Calcium Volume Score



p<0.0001

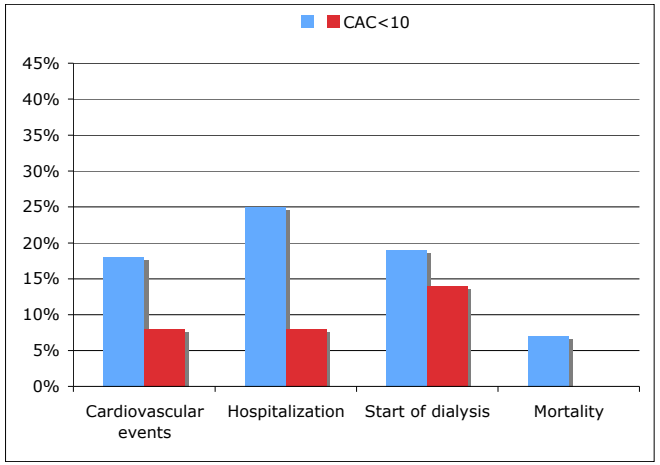
Raggi P *et al. Arterioscler Thromb Vasc Biol* 2004;24:1272–7

CAC Score prevalence in CKD Patients



Adapted from Watanabe et al Clin J Am Soc Nephrol. 2010 Feb;5(2):189-94. Epub 2009 Dec 3

Baseline CAC Score is a Predictor of Morbidity and Mortality in CKD Patients



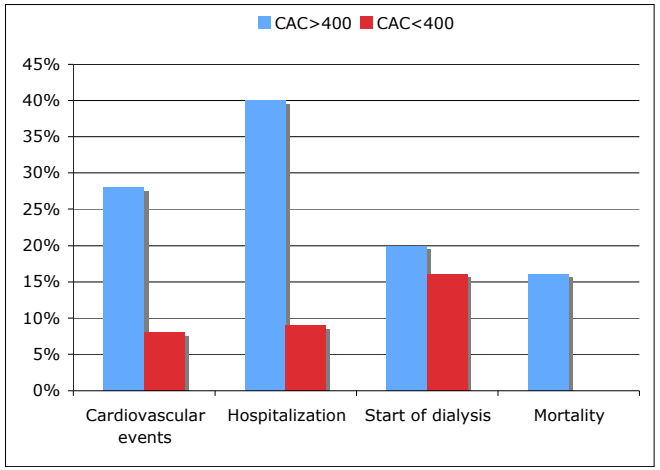
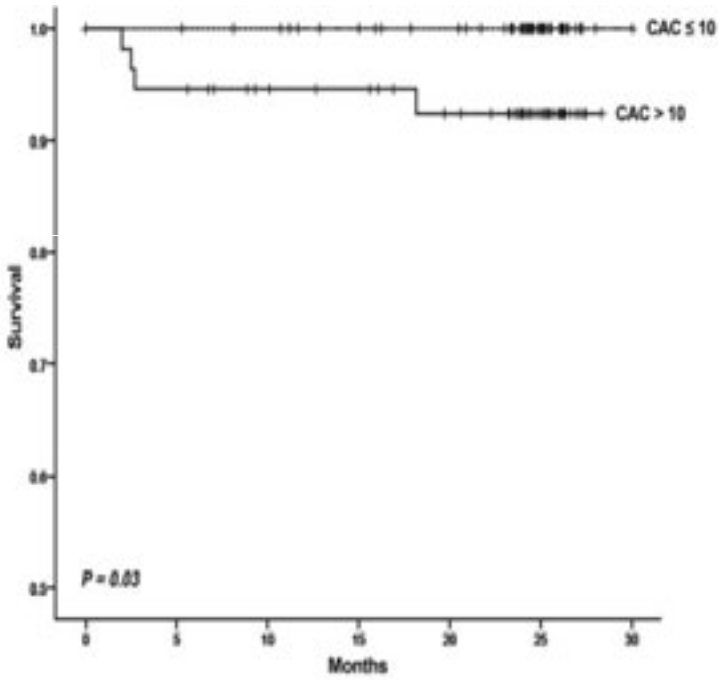


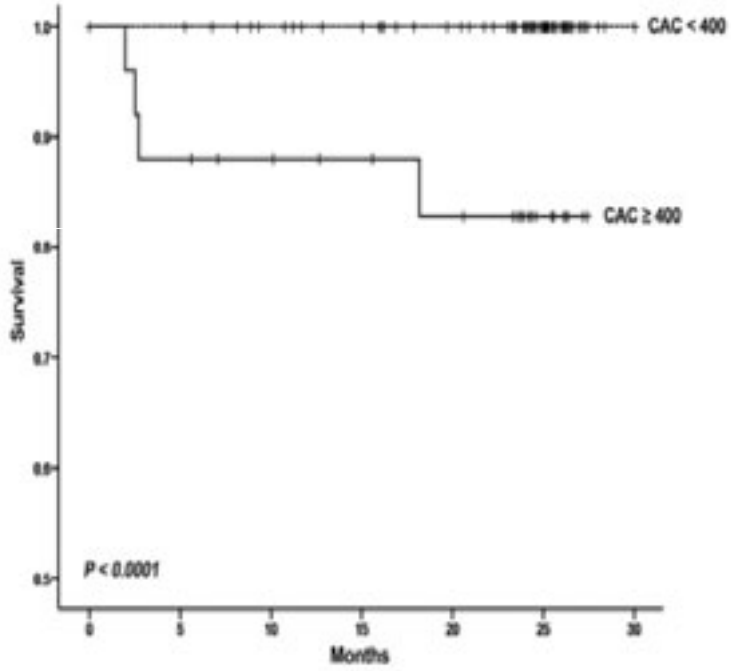
Table 2. Occurrence of cardiovascular events, hospitalization, start of dialysis, and mortality during the 2-year follow-up according to the baseline CAC scores

	CAC > 10 (n = 56)	CAC ≤ 10 (n = 61)	P	CAC ≥ 400 (n = 25)	CAC < 400 (n = 92)	P
Cardiovascular events [n (%)]	10 (18%)	5 (8%)	0.16	7 (28%)	8 (8%)	0.017
Hospitalization [n (%)]	14 (25%)	5 (8%)	0.02	10 (40%)	9 (9%)	0.001
Start of dialysis [n (%)]	11 (19%)	9 (14%)	0.62	5 (20%)	15 (16%)	0.76
Mortality [n (%)]	4 (7%)	0	0.05	4 (16%)	0	0.002

Watanabe et al Clin J Am Soc Nephrol. 2010 Feb;5(2):189-94. Epub 2009 Dec 3

Baseline CAC Score is a Predictor of All-cause Mortality in CKD Patients





Watanabe et al Clin J Am Soc Nephrol. 2010 Feb;5(2):189-94. Epub 2009 Dec 3

Baseline CAC Score is a Predictor of All-cause Mortality in CKD Patients

Watanabe et al Clin J Am Soc Nephrol. 2010:189-94			
Baseline CAC	Alive	dead	Event rate
<400	92	0	-
>400	21	4	16%

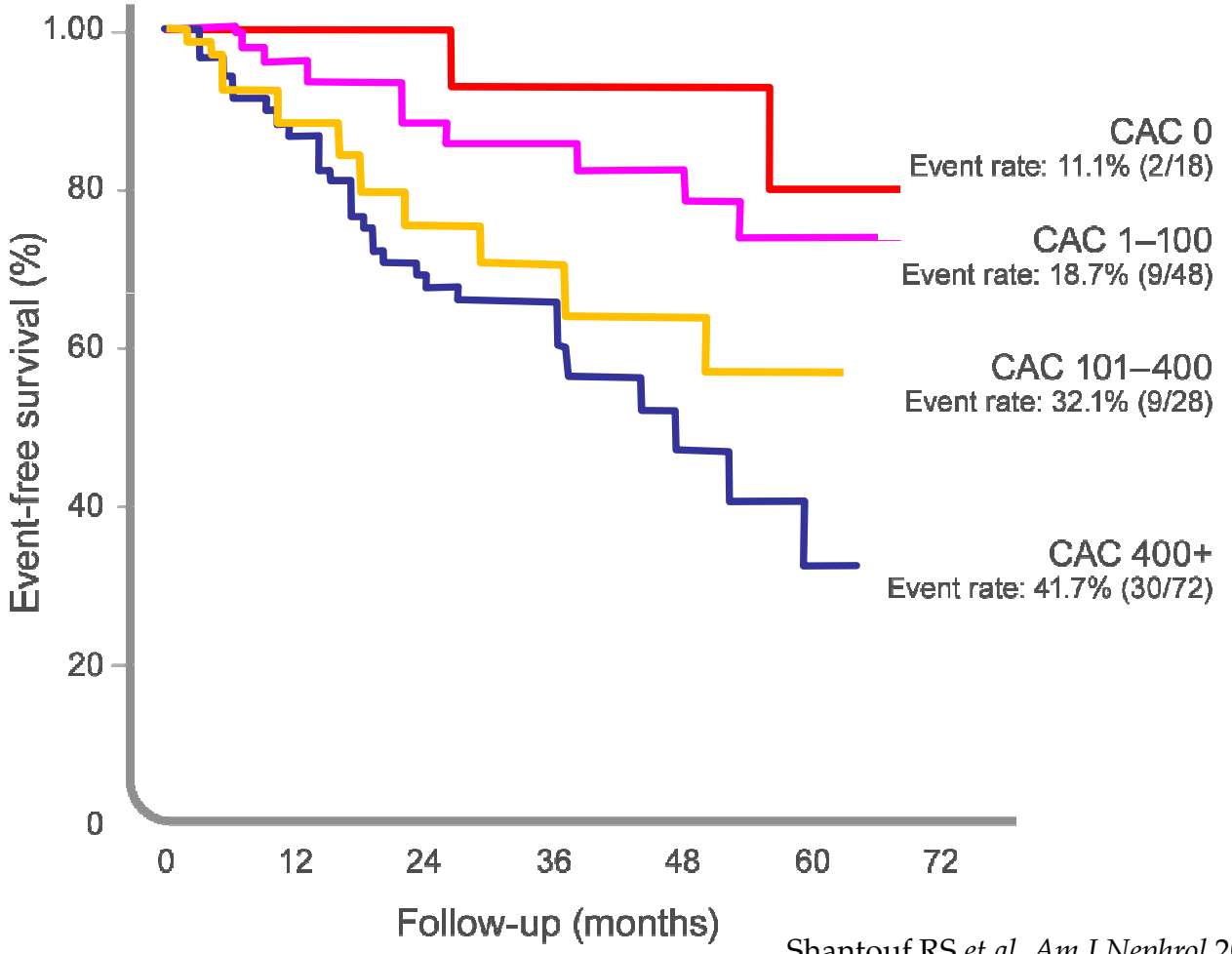
Sensitivity= 100% (95%CI 51-100)

Specificity=81.4%(95%CI 73-87)

PPV=16.0% (95%CI 6-34)

NPV= 100% (95%CI: 96-100)

Baseline CAC Score is a Predictor of All-Cause Mortality in Dialysis Patients



Shantouf RS *et al*. *Am J Nephrol* 2010;31:419–25

Is CAC Score a Useful Predictor of Survival Mortality in Dialysis Patients

Shantouf RS *et al*. *Am J Nephrol* 2010;31:419–25			
Baseline CAC	Alive	dead	Event rate
0	2	16	11.1%
1-100	9	39	18.7%
101-400	9	19	32.1 %
>400	30	42	41.7%

Sensitivity=96.0%(95%CI 86.5-98.9)

Specificity=13.8% (95%CI 8.7-21.2)

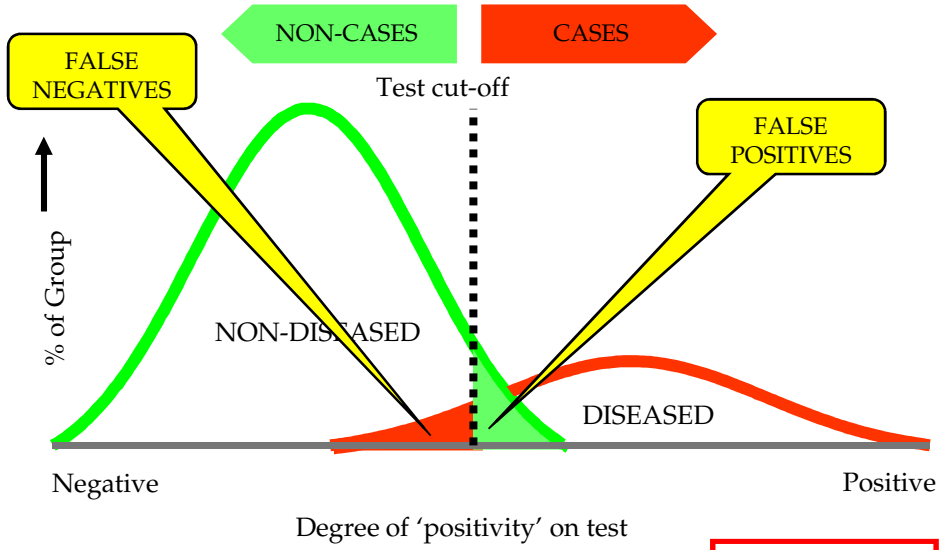
PPV=32.4% (95%CI 25.4-40.3)

NPV=88.9% (95%CI 67.2-96.9)

CAC Score: take home messages

- The amount of CAC correlates to the extent of atherosclerosis plaque burden
- CAC is an interesting tool for risk stratification purposes
- Calcification is neither a sign of stability nor a sign of instability of an individual plaque and its presence is not associated with the likelihood of an individual lesion to rupture
- There is a weak correlation between the the amount of CAC and the angiographic severity of luminal stenosis
- The absence of CAC makes the presence of luminal stenosis unlikely however it does not rule out coronary stenosis especially in symptomatic, young individuals

Performance of a diagnostic test



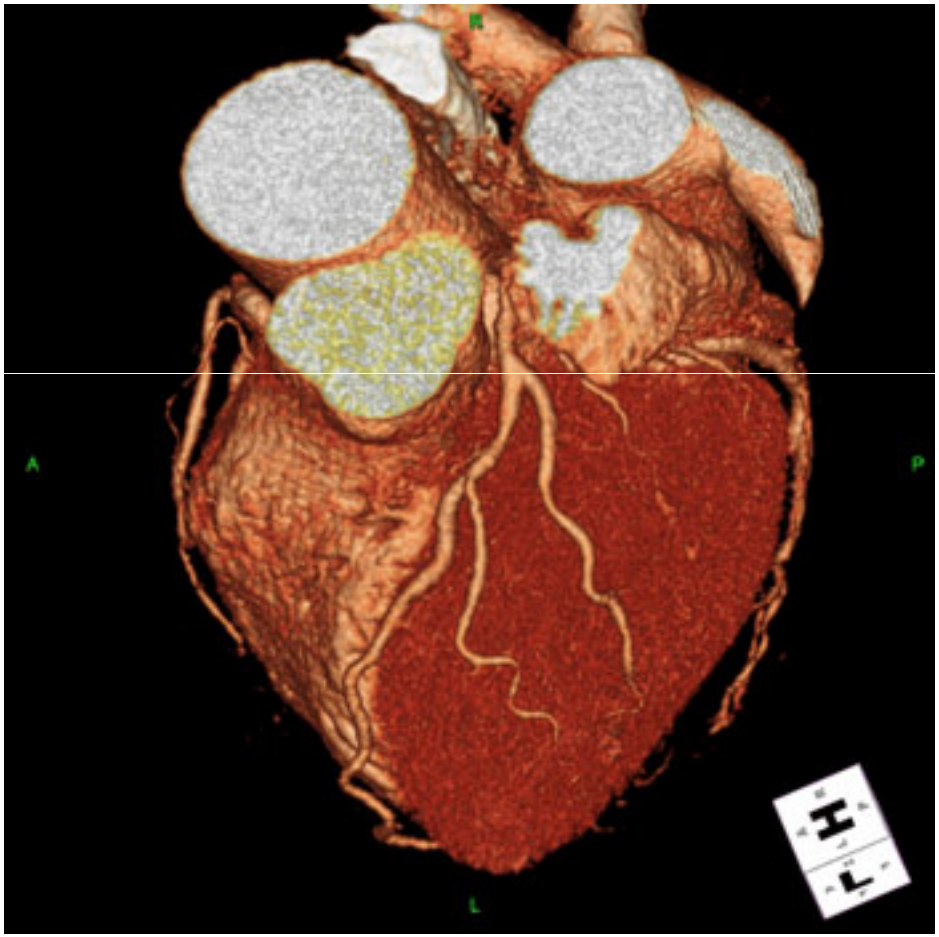
		Disease	
		Present	Absent
Test	Positive	A (true positive)	B (false positive)
	Negative	C (false negative)	D (true negative)

Healthy artery
Risk factors
assessment

disease
c lesion
ification
ent

disease
osis
graphy

CT Angiography (CTA)



Cardiac CT Imaging-Diagnosis of Cardiovascular Disease Springer 2006

CT Angiography (CTA)

- Permits the visualization of the coronary artery lumen and detection of coronary artery stenoses
- In contrast to "calcium screening" it allows visualization and, to some extent, quantification and characterization of non-calcified plaque deposits
- It requires excellent image quality without artifacts (high spatial and temporal resolution)
- Image quality is strongly dependent on HR (it is usualy required to to lower HR <65 bpm)
- Image acquisition is substantially more elaborate than coronary calcium imaging

CT Angiography (CTA)

- IV injection of contrast is required (60-100 mL)
- Patients selection:
  - sinus rhythm
  - ability to breath holding
  - low HR
  - severe obesity

CT Angiography (CTA)

In individuals with **low to intermediate** risk for coronary artery disease:

- Sensitivity: 95-99%
- Specificity: 64-83%
- Negative predictive value: 97-99%
- Positive predictive value: 64-86%(overestimation of stenoses and image artifacts often results in false positive interpretations)

Budoff et al J Am Coll Cardiol 2008: 52: 1724-1732
Meijboom et al J Am Coll Cardiol 2008:52:2135-2144-1475

CT Angiography (CTA)

CTA performs best in **patient group who are not at high likelihood of CAD**. In a study of 291 patients with 56%prevalence of coronary artery stenoses as well as 20% of patients with previous MI and 10% with prior revascularization:

- Sensitivity: 95-99% --> 85%
- Specificity: 64-83%--> 90%

However, a very low event rate has been demonstrated in the absence of stenoses by CTA in patients with stable angina or acute chest pain

Rubbinshtein et al Cirtculation 2007;115:1762-1768
Hollander et al Acad Emerg Med 2009;16:693-698
Meijboom et al J Am Coll Cardiol 2007:50:1469-1475

CT angiography (CTA)? What is its role in CKD?

Aim: evaluate whether the presence of CKD can provide additional prognostic information for CV events in patients undergoing CTA

- 885 patients with suspected CAD underwent CTA. Patients were stratified according to GFR as moderate
- CKD (<60 ml//min) or no CKD (>60 ml//min).
- Obstructive stenosis if greater/equal than 50%
- Median follow-up: 896+353 days
- Outcome of interest: non-fatal MI, cerebrovascular accident and all-cause of mortality

Submitted to the Nuclear Cardiology Meeting, Spring 2011

CT angiography (CTA)? What is its role in CKD?

Results:

- Obstructive CAD is more common in moderate CKD (47% vs 32%; $p<0.01$)
- Higher annualized CV event rate is two fold higher in CKD patients (1.2% vs 2.5%)
- Multivariate models demonstrated that both moderate CKD (HR 2.39, 95%CI 1.08-5.26, $p=0.03$) and obstructive CAD (HR 2.75, 95%CI 1.38-5.49, $p<0.001$) were independent predictors of CV events after adjustment for age, gender, CV risk factors

CT angiography (CTA)? What is its role in CKD?

Conclusion:

- Higher incidence of obstructive CAD by CTA in CKD patients
- Moderate CKD is associated with CV events and provided additional prognostic information over age, gender, CV risk factors and the presence of obstructive CAD on CTA

CT Angiography (CTA): Assessment of Coronary Atherosclerotic Plaque

Non-calcified plaques can be identified with CTA:

- Compared to IVUS sensitivity and specificity between 80-90%

- Limited agreement between techniques

- Inter-observer variability 30% for plaque quantification
  - Left descending coronary artery 17±10%
  - Circumflex 29±13%
  - Right coronary artery 32±10%

Pflederer et al Rafa 2007; 179:953-957

CT Angiography (CTA): Assessment of Coronary Atherosclerotic Plaque

Prognostic implication of Non-Obstructive Plaque :

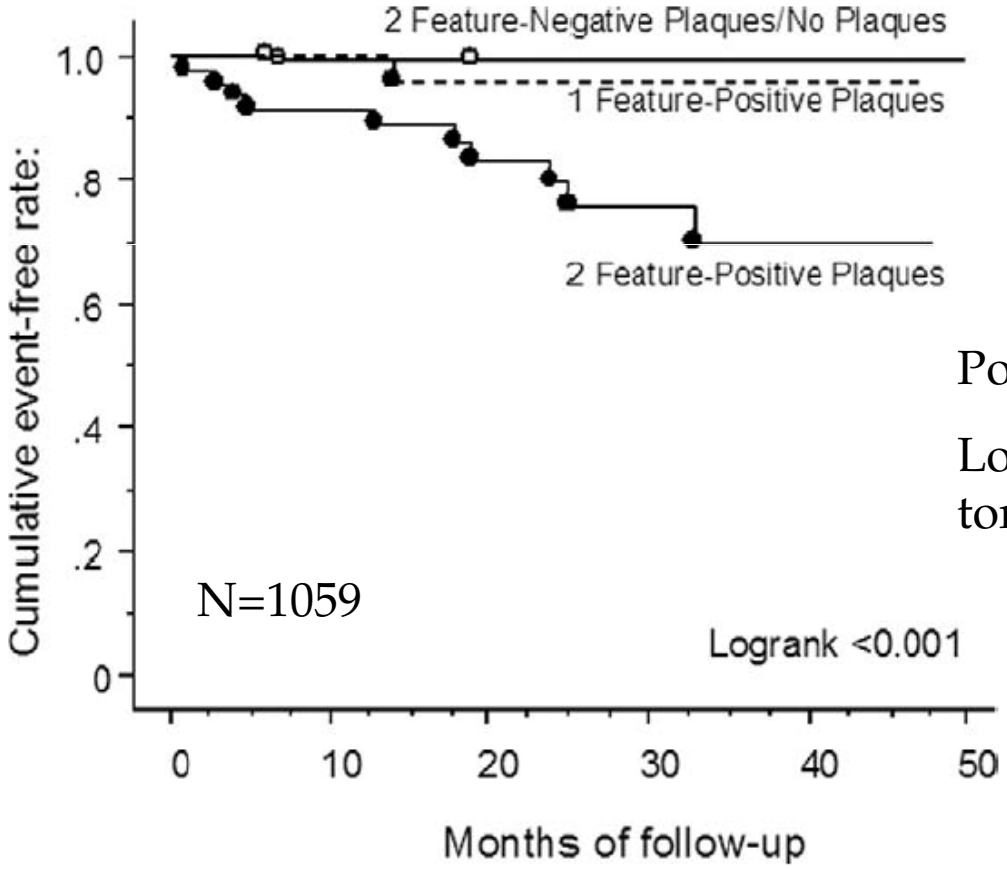
- Ostrom et al. Reported the presence of non-obstructice plaque in all 3 coronaries was associated with increased risk of death (Relative Risk 1.77)

- Min et al. Demonstrated that the presence of coronary atherosclerotic plaque in at least 5 coronary artery segments was associated with increased mortality

Ostrom et al J Am Coll Cardiol 2008; 52:1335-1343
Min et al J Am Coll Cardiol 2007; 50:1161-11170

CT Angiography (CTA): Assessment of Coronary Atherosclerotic Plaque

Prognostic implication of specific plaque parameters



Positive remodelling

Low computed tomography attenuation

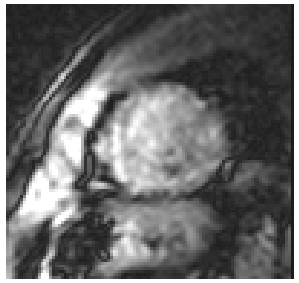
Motoyama et al J Am Coll Cardiol 2009; 54:49-57

CT Angiography (CTA): Take Home Messages

- Substantial inter-observer variability
- Requires high quality images
- Substantially higher radiation dose compared to calcium screening (12 mSv)
- Requires injection of contrast
- Prognostic implication of specific plaque parameters(?)

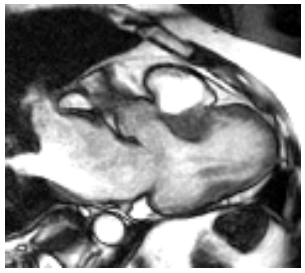
Clinical use of coronary CTA to detect plaque in asymptomatic individuals should be discouraged

Cardiovascular Magnetic Resonance Imaging



Wall motion

Gadolinium enhanced scan.
Perfusion deficit



Cardiomyopathy

Cardiac CT Imaging-Diagnosis of Cardiovascular Disease Springer 2006

Cardiovascular Magnetic Resonance Imaging

- Useful for proximal coronary artery disease
- Useful for assessing the patency and stenoses of coronary artery bypass grafts
- It allows for plaque characterization

Issues:

- Cardiac, coronary and respiratory motion
- Assessment of small caliber vessels

- Lack of data in CKD patients

Thanks for your attention