Imaging in CAD

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4 major imaging techniques:

- Echocardiography
- Magnetic resonance imaging
- Multi-slice CT
- Nuclear imaging (PET and SPECT)
- Can provide all anatomical and functional information, but use should be clinically driven

Diagnosis is important

But the imaging results need to have impact on choice of therapy

From atherosclerosis to heart failure: Where may imaging help?

✂☞**Asymptomatic patients**
at elevated risk for atherosclerosis/CVD: screening / early detection

- **Symptomatic patients: detection of coronary artery disease**

- **Ischemic heart failure: extensive evaluation**

Patient example

Woman 48 years old

Outpatient clinics:

No symptoms

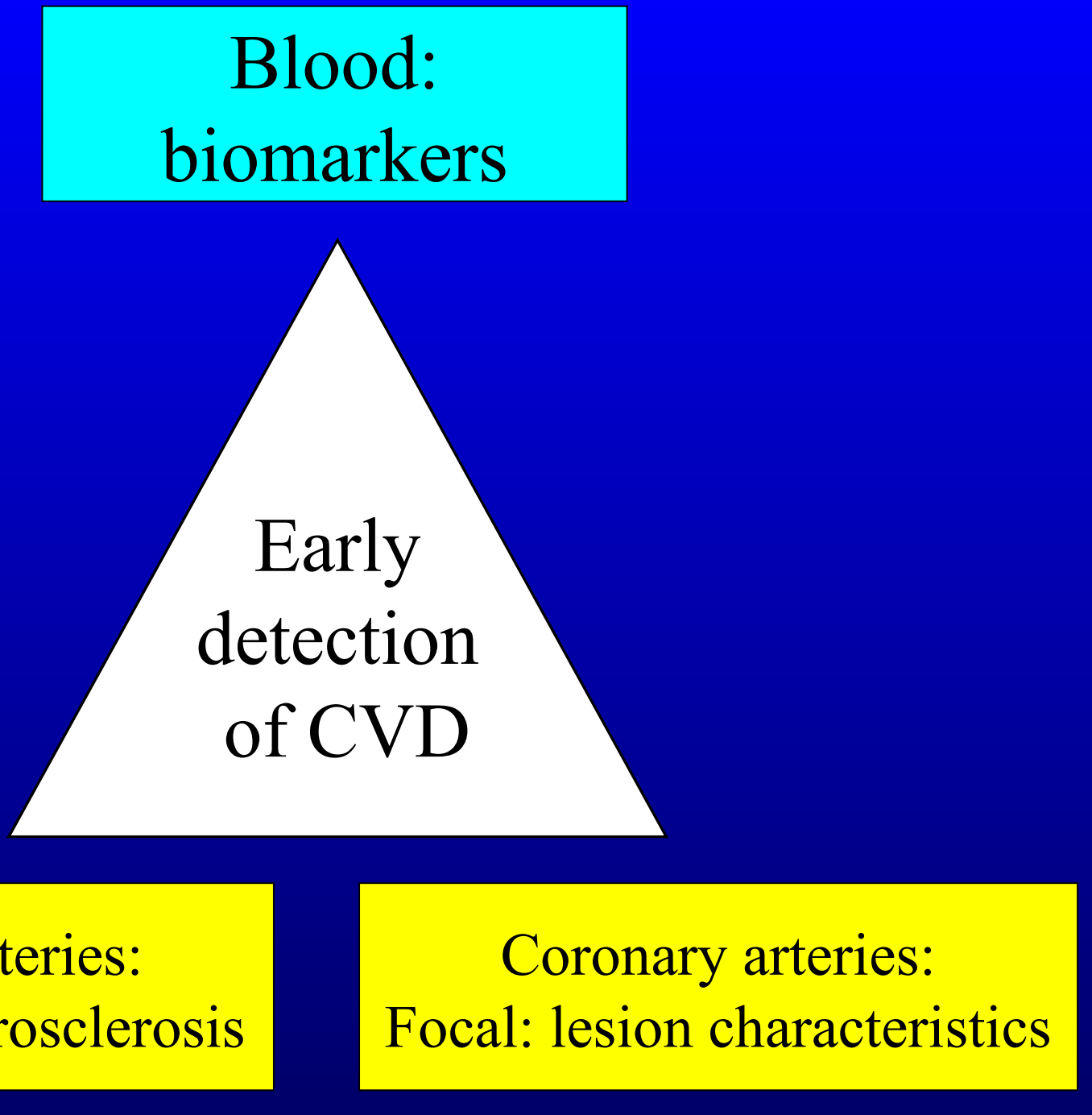
Risk factors for CAD:

*Family history of CAD

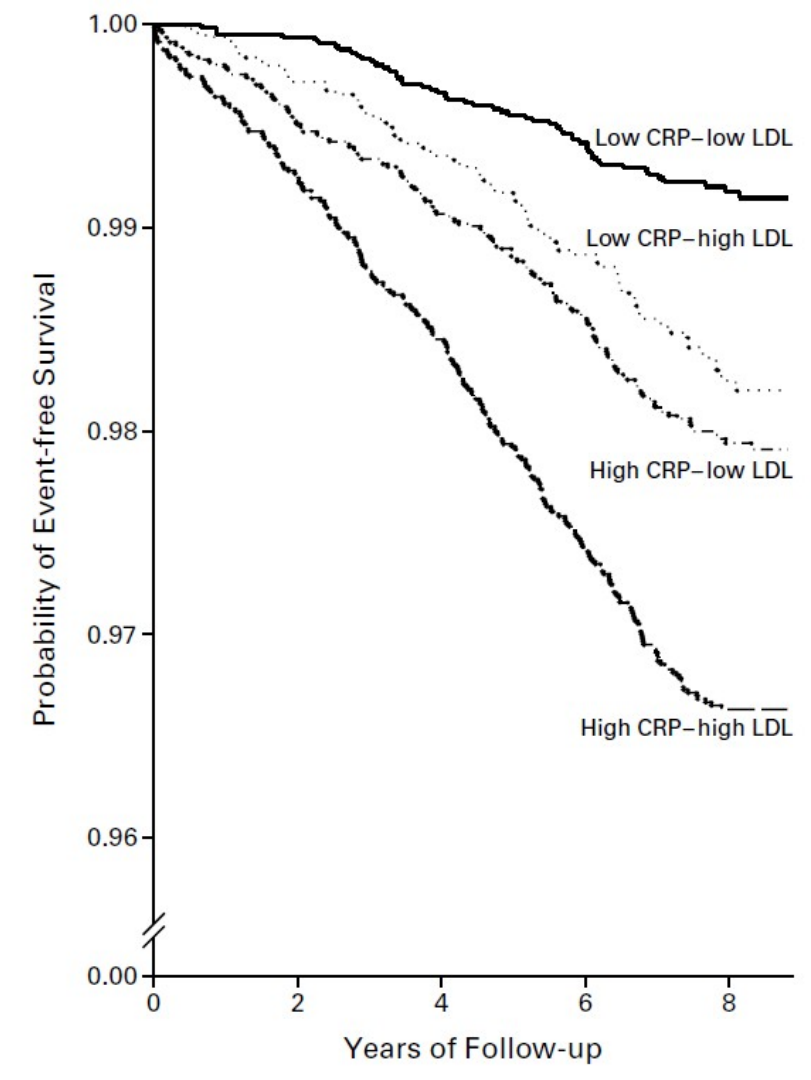
Asymptomatic individual, low risk

The question is:

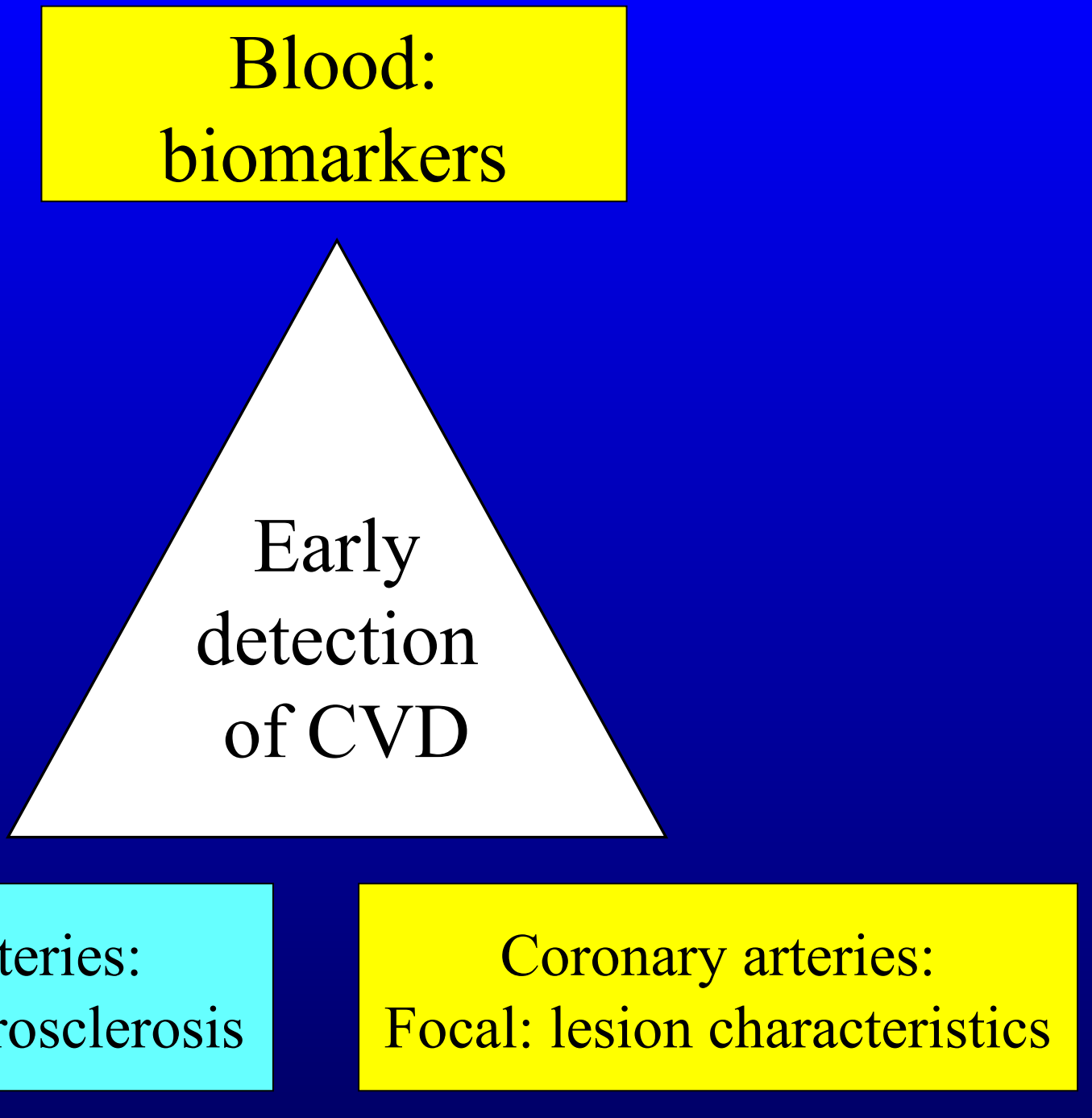
Risk stratification


Blood:
biomarkers
Early
detection
of CVD
Large arteries:
Global: atherosclerosis
Coronary arteries:
Focal: lesion characteristics

Cardiovascular event-free survival, according to CRP and LDL



Ridker et al. NEJM 2002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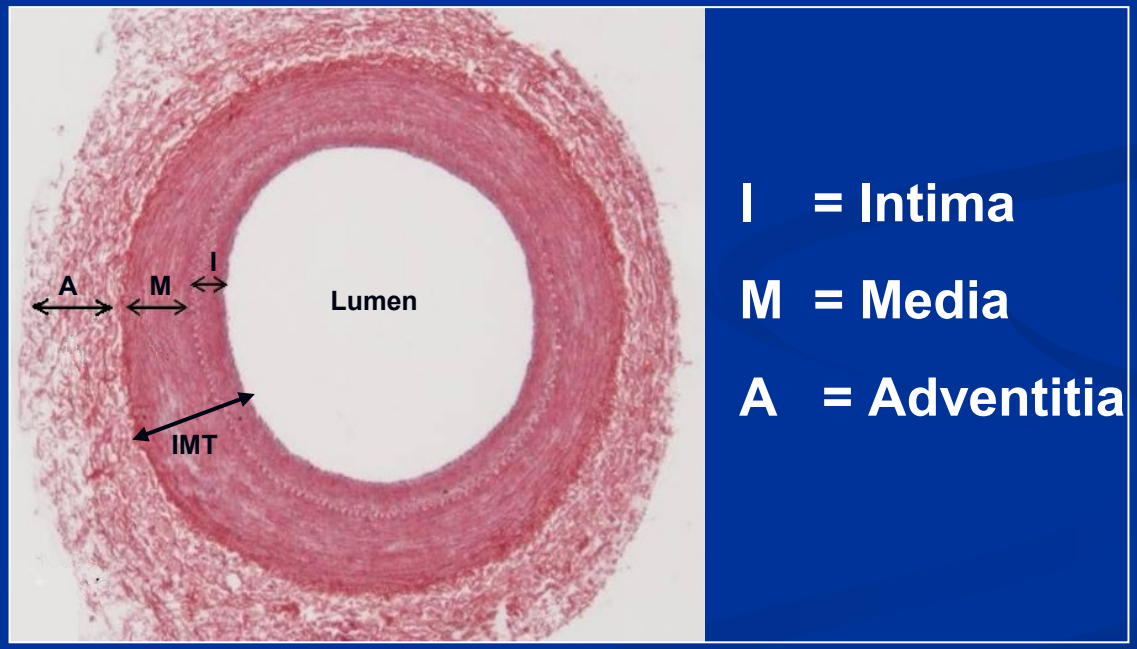
Carotid Intima Media Thickness (CIMT)

Tissue between luminal edge of the artery and the boundary between media and adventitia



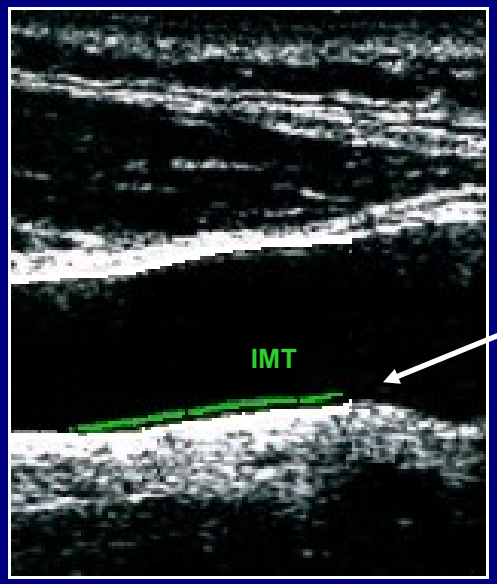
Assessment of CIMT

Semi-automatic B-mode ultrasound measurements

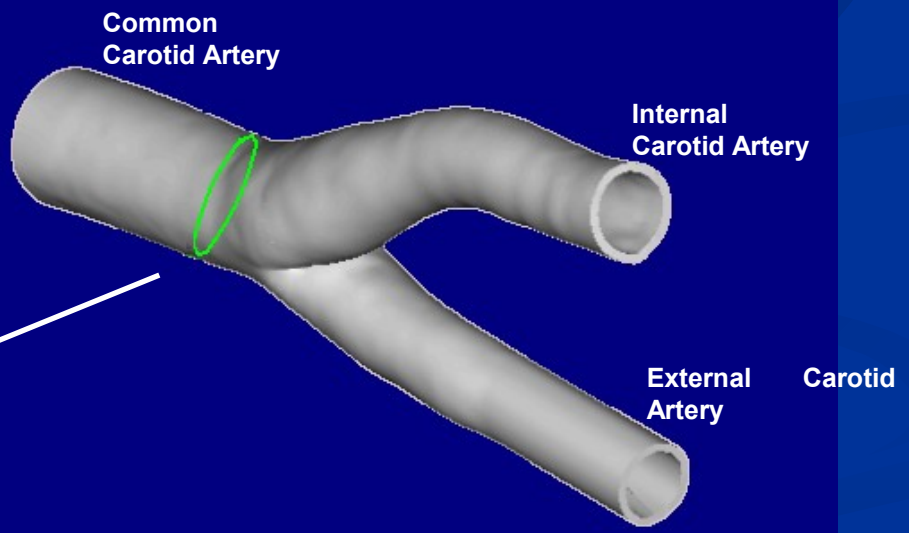
Left and right common carotid artery, directly proximal to the bifurcation

Mean CIMT measurements at four angles

Calculation of the average of 8 mean CIMT per patient



Ultrasound measurement of CIMT

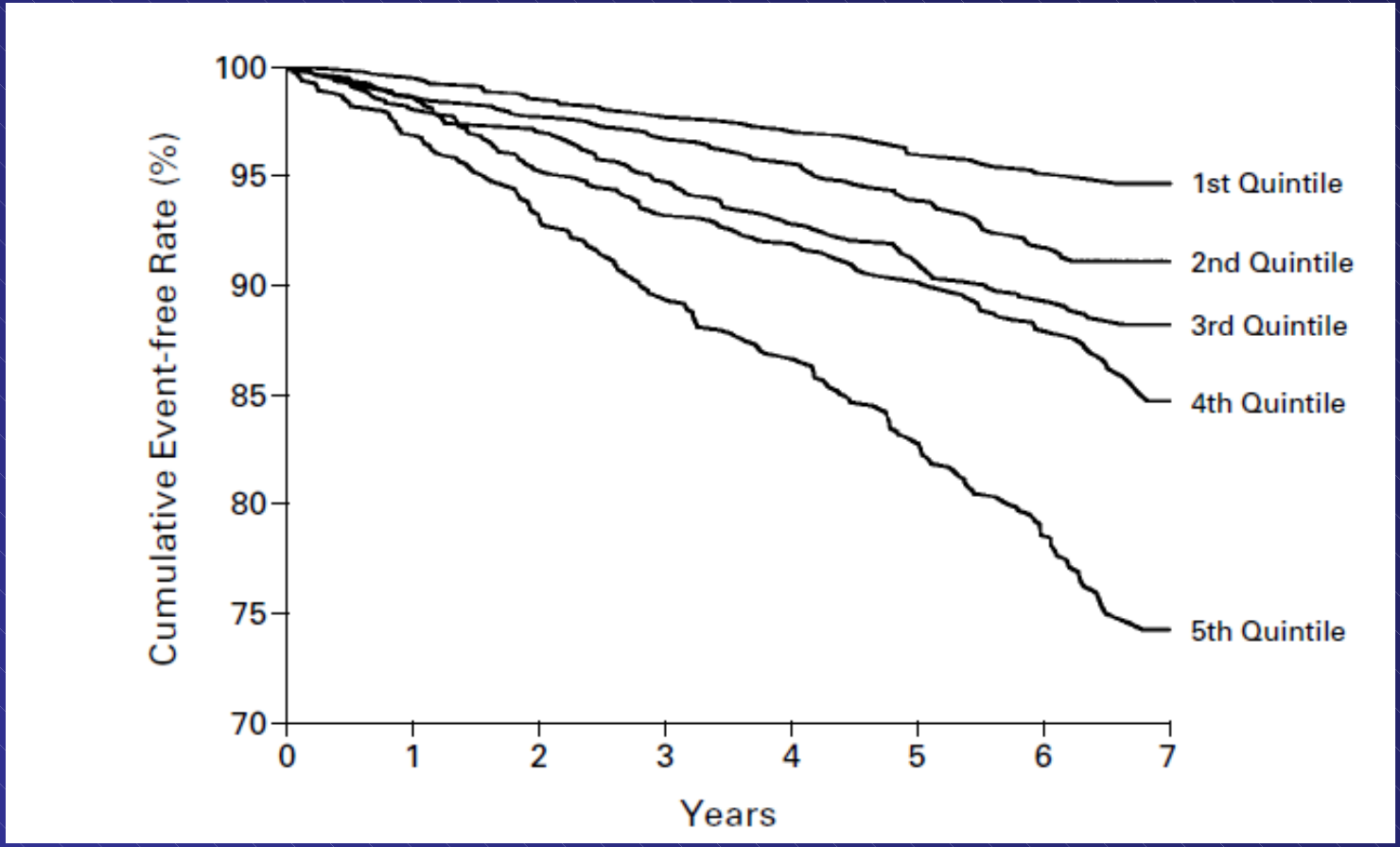


CIMT in the general population

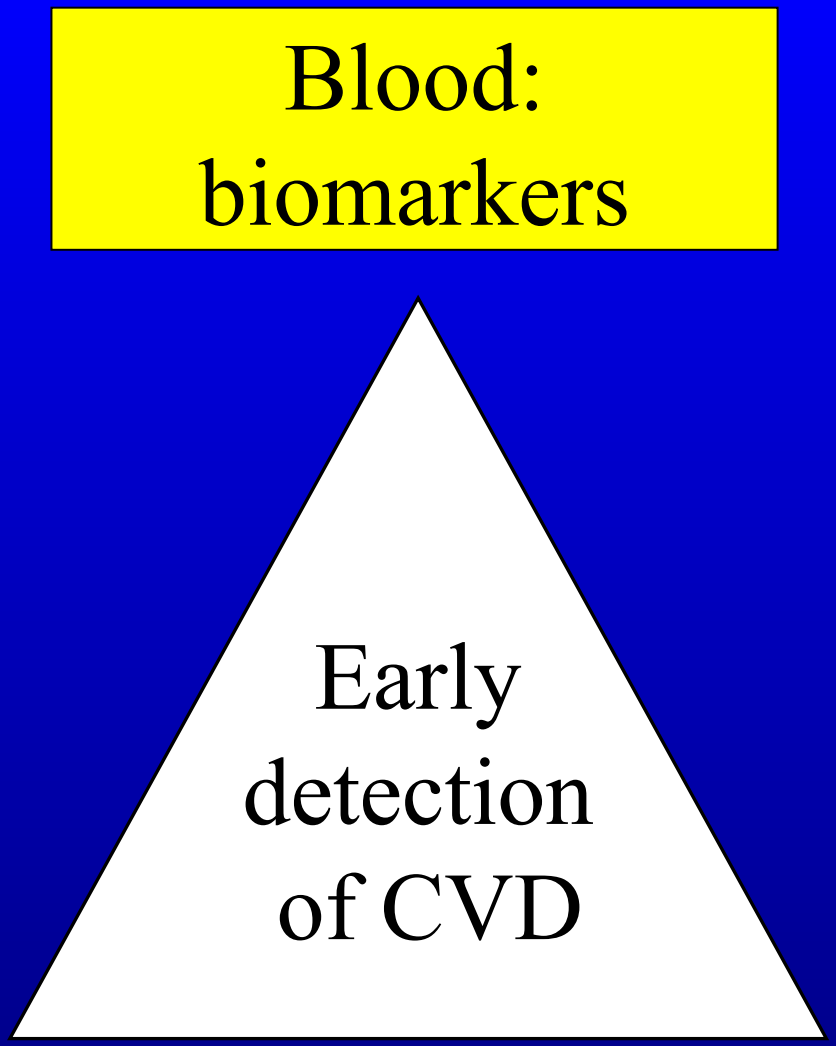
- Increases with age and cardiovascular risk factors
- Correlates with presence of cardiovascular disease
- Independent predictor of cardiovascular events

O'Leary et al. NEJM 1999

Cumulative event free rate (stroke or MI) according to IMT quintiles



O'Leary et al. N Eng J Med 1999


Blood:
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Global: atherosclerosis
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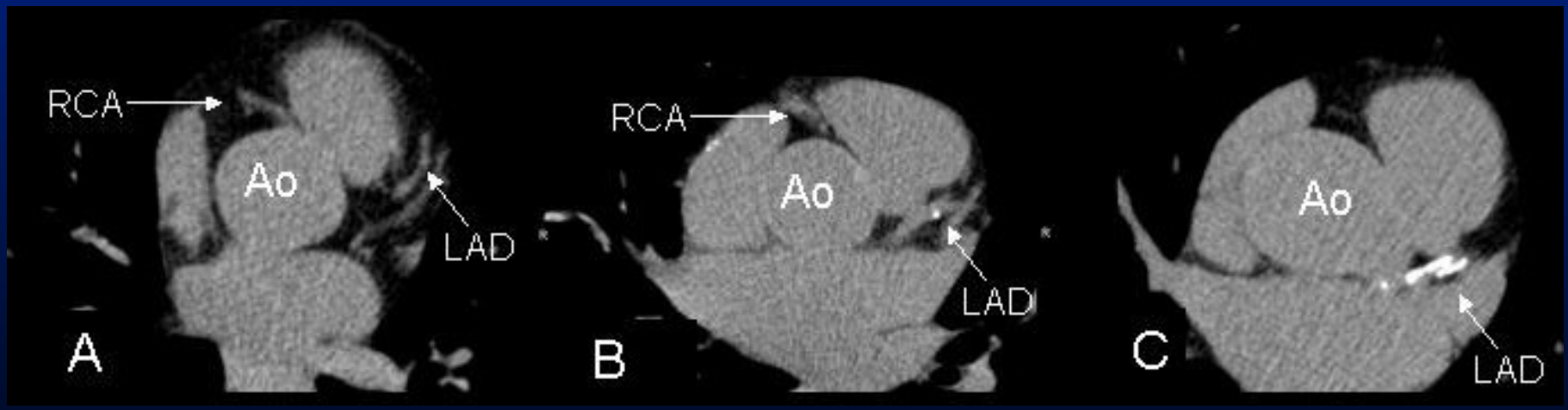
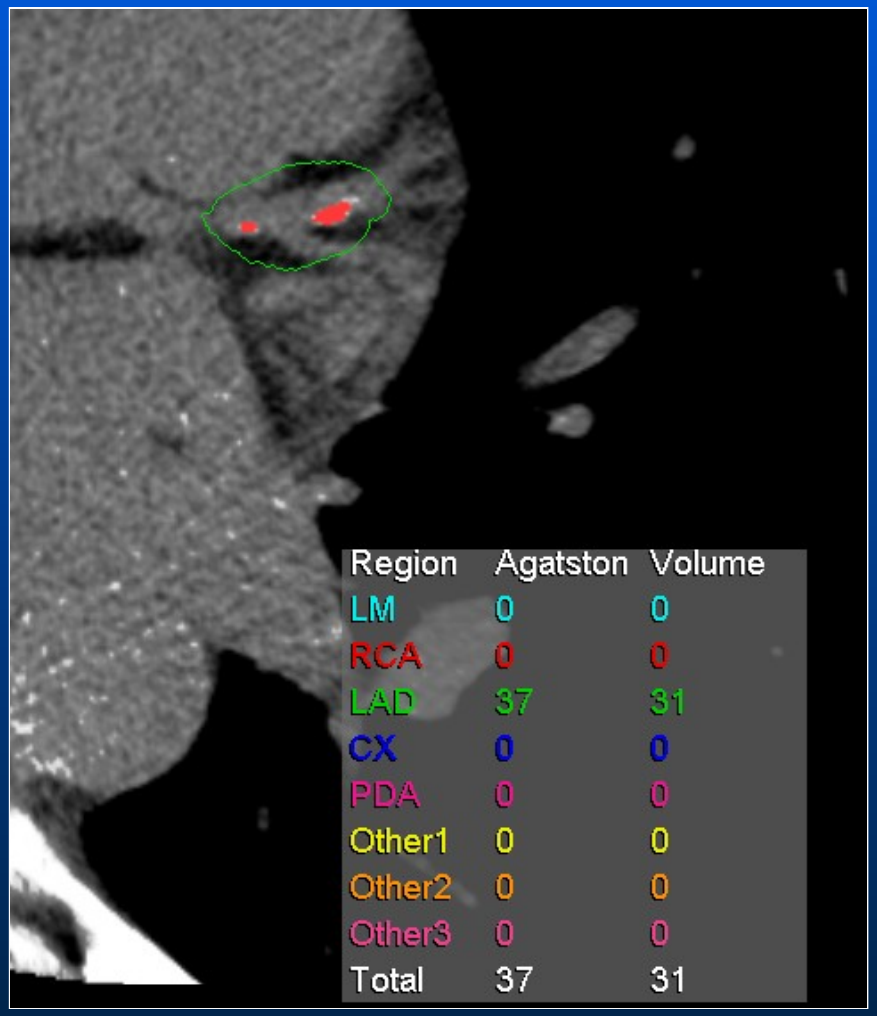
Calcium Scoring (EBCT/MSCT)

No calcification | Moderate calcification | Extensive calcification



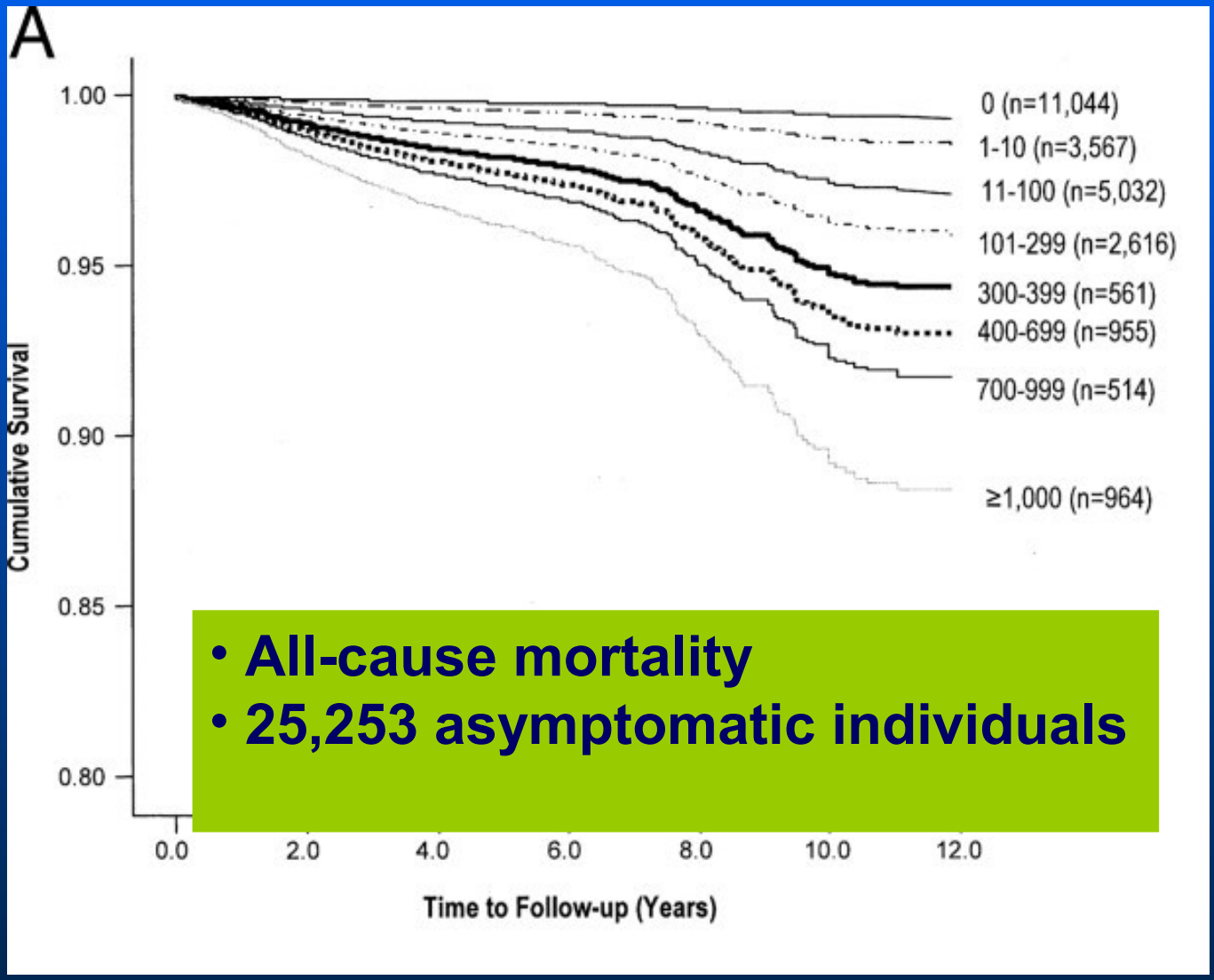
Coronary calcifications provide a marker for atherosclerotic disease burden

Calcium scoring (EBCT/MSCT)



CAC Score	Calcified Plaque Burden
0	No identifiable atherosclerotic plaque
1-10	Minimal plaque burden
11-100	Mild plaque burden
101-400	Moderate plaque burden
401-1,000	Extensive plaque burden
>1,000	Very extensive plaque burden

Calcium score vs risk stratification



- All-cause mortality
- 25,253 asymptomatic individuals

Budoff et al. JACC 2007

Calcium Scoring (EBCT/MSCT)

- Presence of coronary calcifications associated with increased risk of coronary events
- Marker for CAD in general, rather than marker for specific site
- Unable to identify localized vulnerable plaque
- Population risk marker rather than individual specific

Screening for CVD

- What (blood, large vessels, coronary arteries) do we screen?
- Will it improve outcome?
- When do we screen?
- Do we need to screen periodically?
- What are the therapeutic consequences?

From atherosclerosis to heart failure: Where may imaging help?

- **Asymptomatic patients**
  at elevated risk for atherosclerosis/CVD: screening / early detection

✂☞ **Symptomatic patients: detection of coronary artery disease**

- **Ischemic Heart failure: extensive evaluation**

Patient example

Man 47 years old

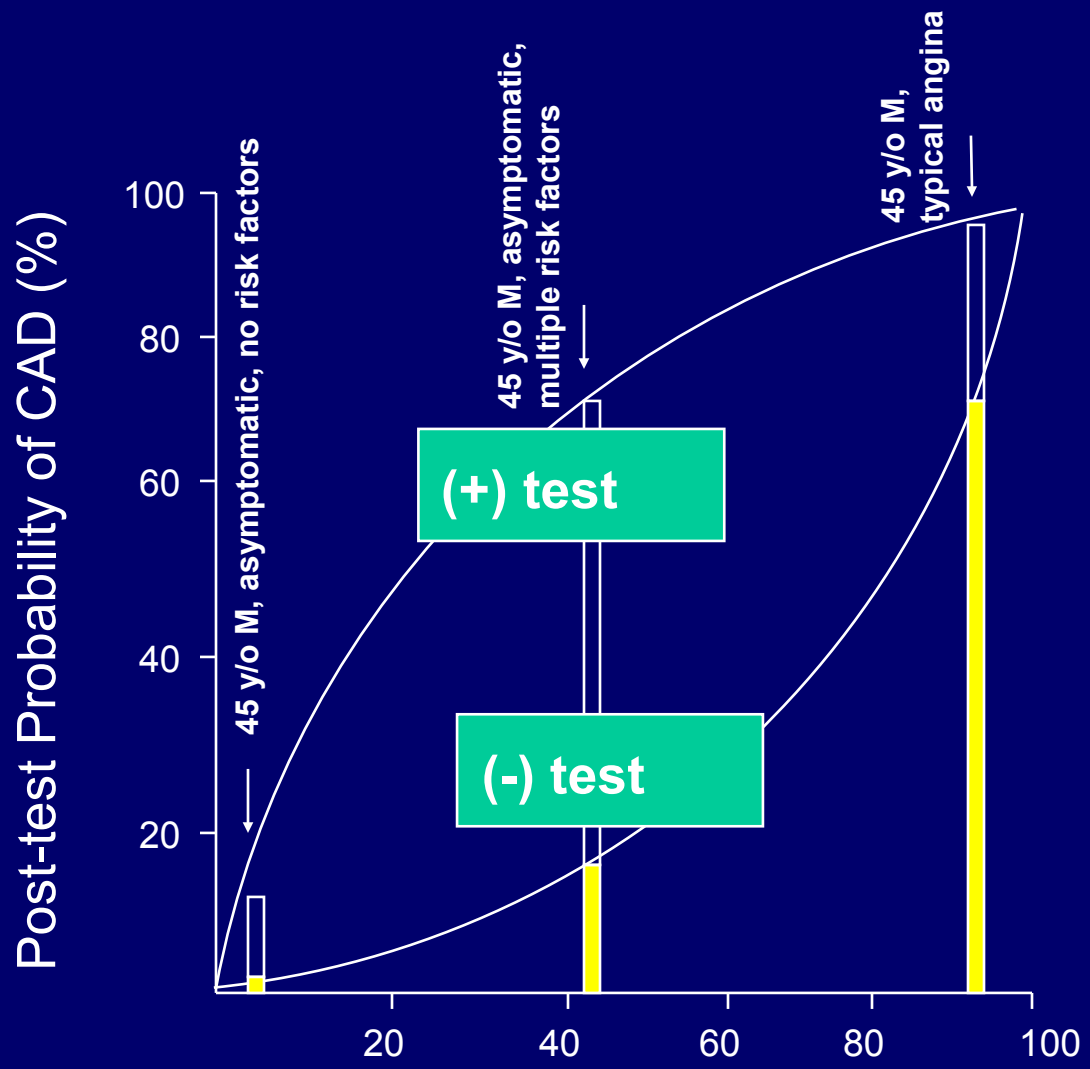
Outpatient clinics:

Dyspnea or atypical chest pain at exercise

Risk factors for CAD:

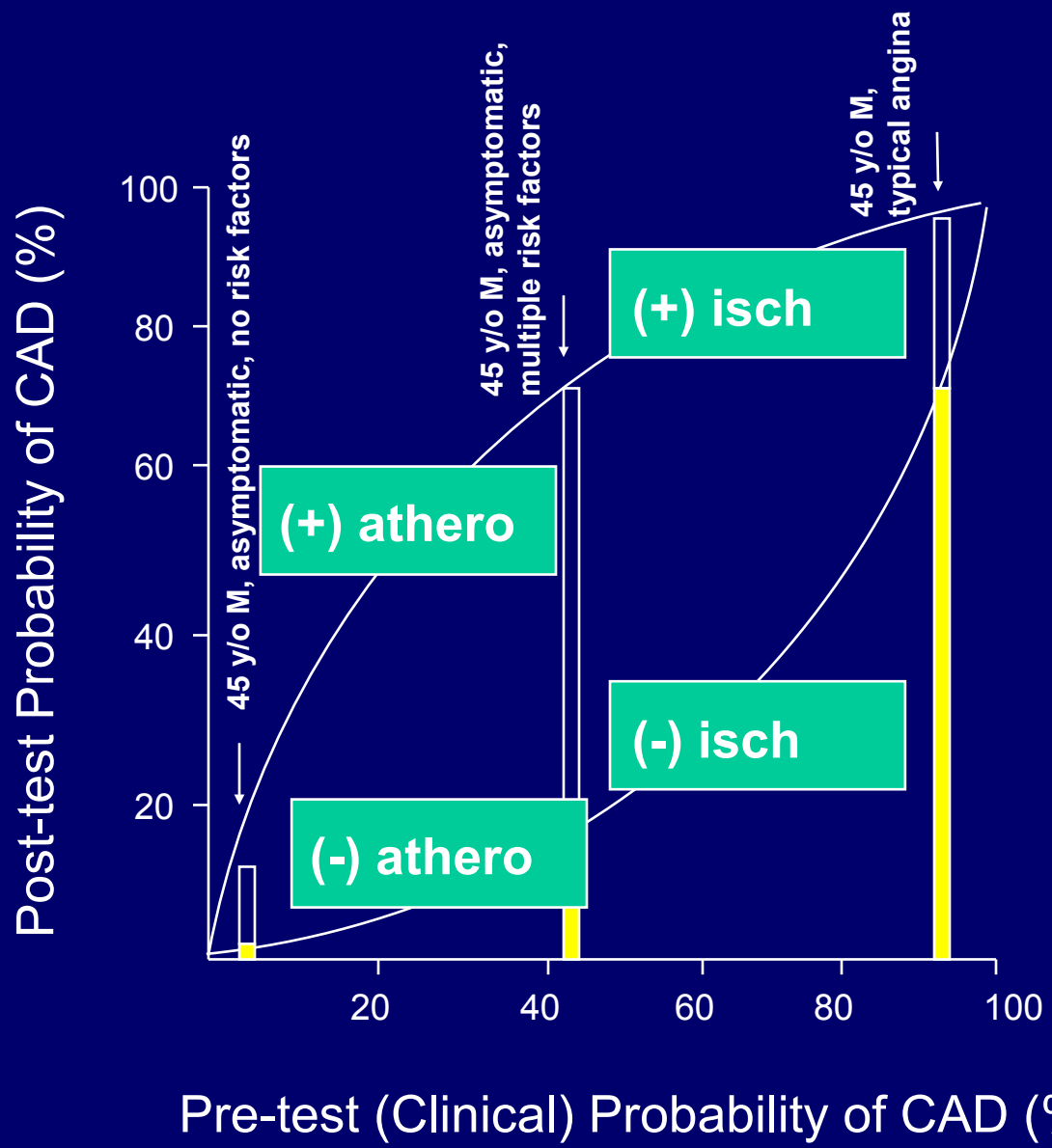
*Dyslipidemia

Non-invasive assessment of CAD: Which Patients?



Patterson et al. JACC 1989

Non-invasive assessment of CAD: Which Patients?



Patterson et al. JACC 1989

Symptomatic patient, low-intermed risk

The question is:

Atherosclerosis? (medical therapy needed and follow-up or discharge?)

☞ We order a non-invasive anatomical test to detect /exclude atherosclerosis

MRI – angiography (1.5T)

Leiden, NL

Aarhus, DK

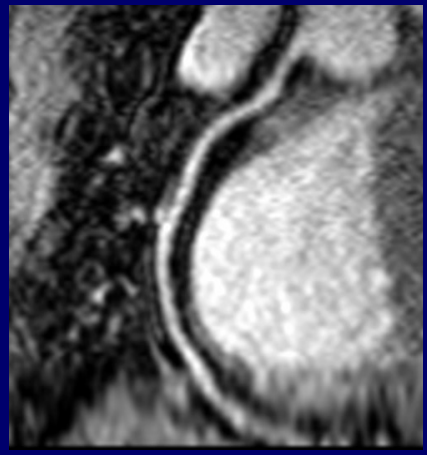
Munich, GER

Boston, USA

Berlin, GER

Leeds, UK

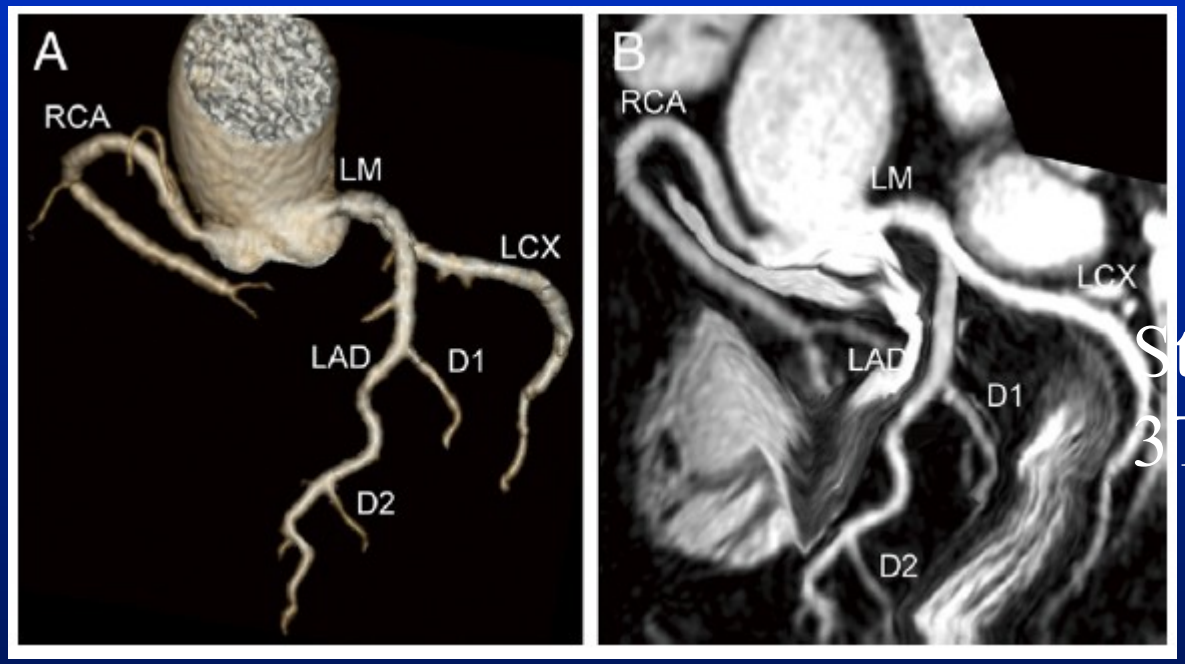
Kurashiki, JP



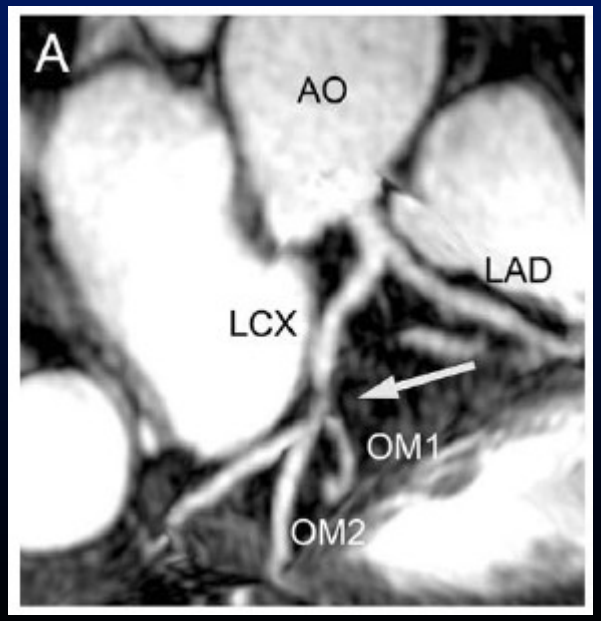
St. Louis, USA

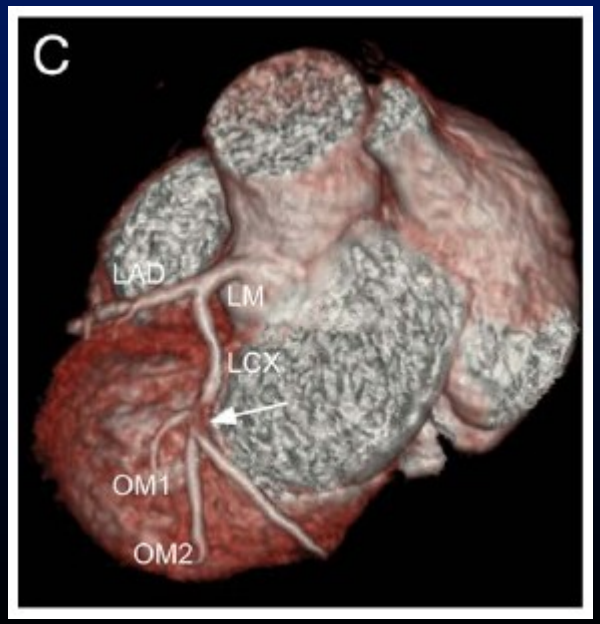
NEJM 2002

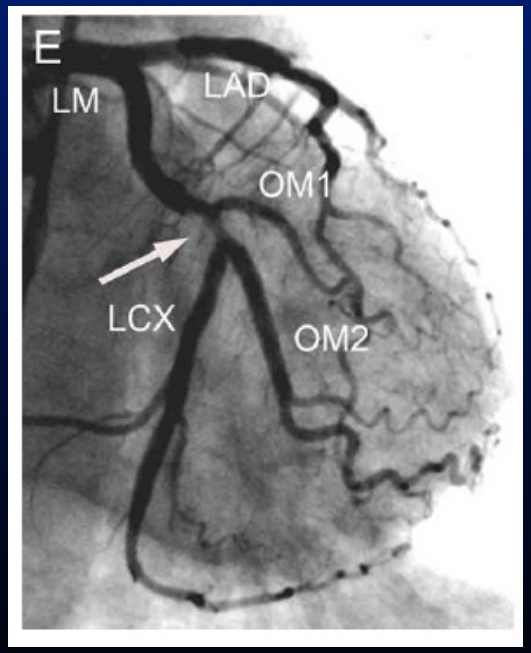
MRI - angiography



Stronger magnets:
3T coronary imaging



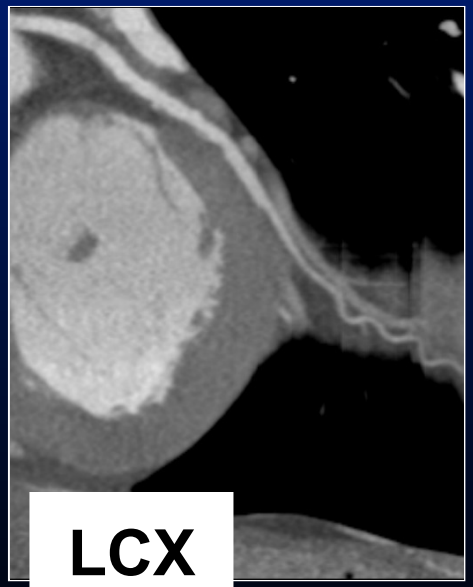




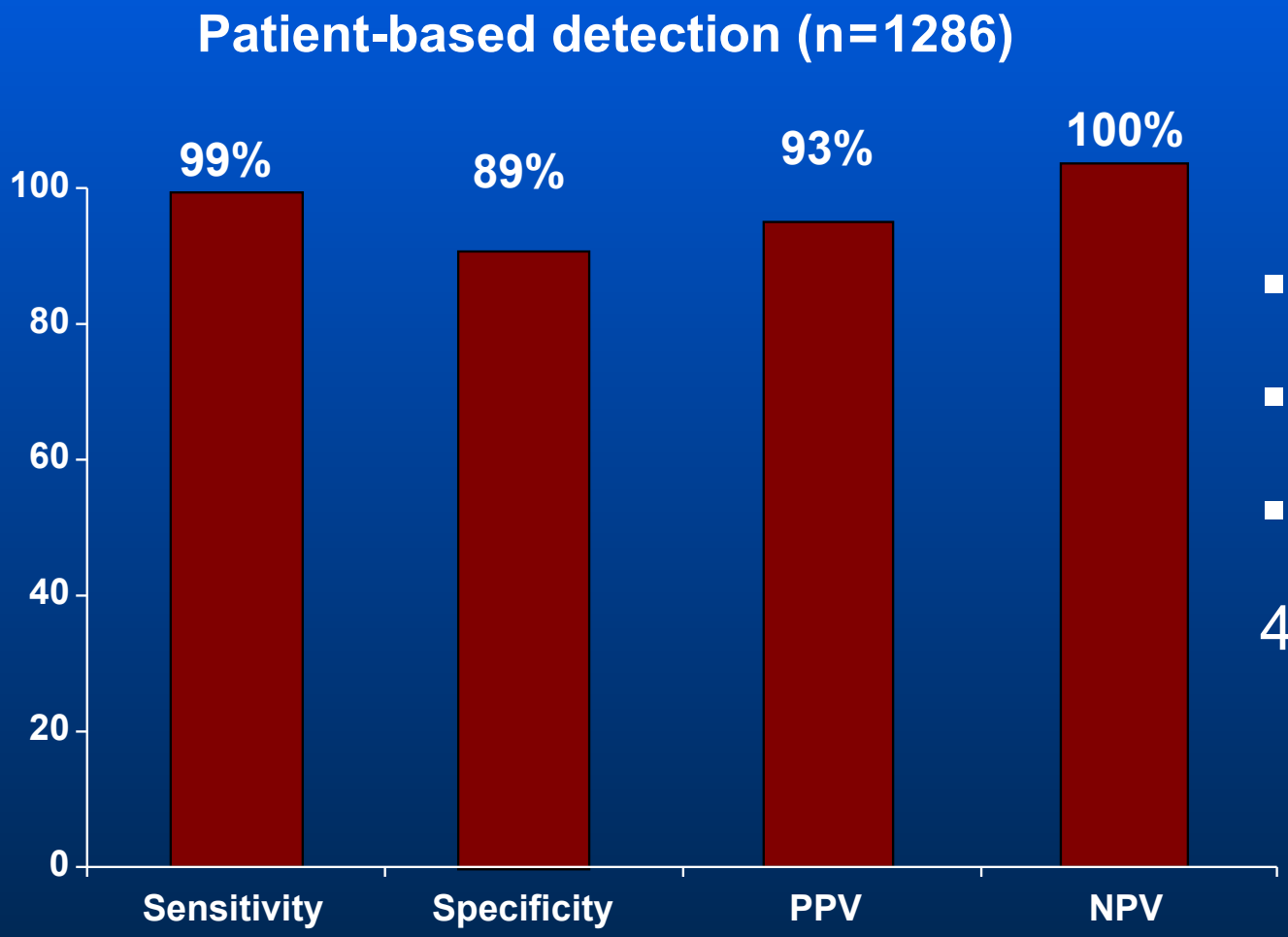
Yang et al. JACC 2009

CT angiography - raw data

curved MPR



Meta-analysis 64-slice CT

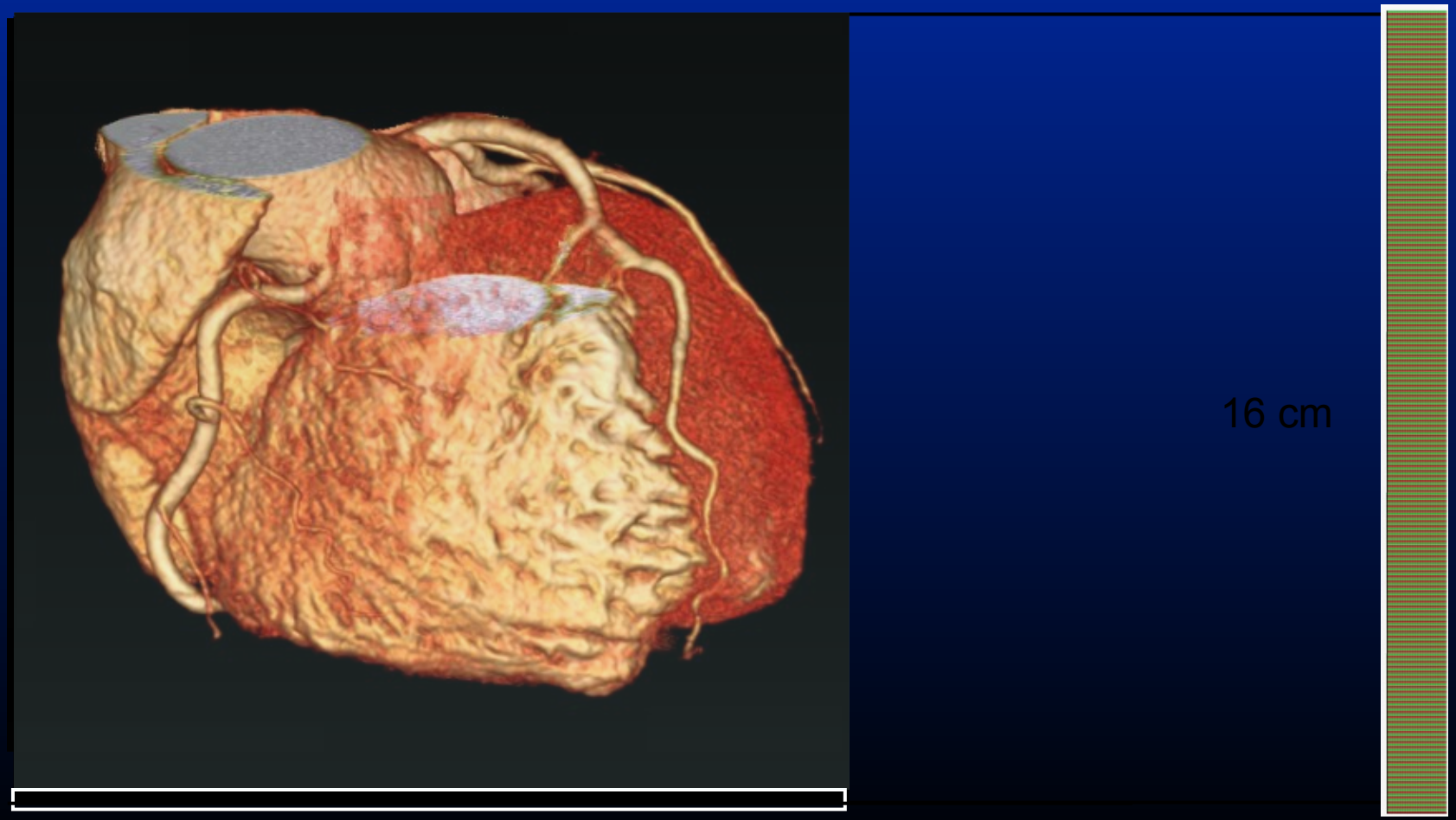


- ≥ 50% stenosis
- versus CAG
- Not assessable: 4% (0-14%)

Mowatt et al *Heart* 2008

320-CT

Coverage of the heart in 1 rotation



Patient example

Man 47 years old

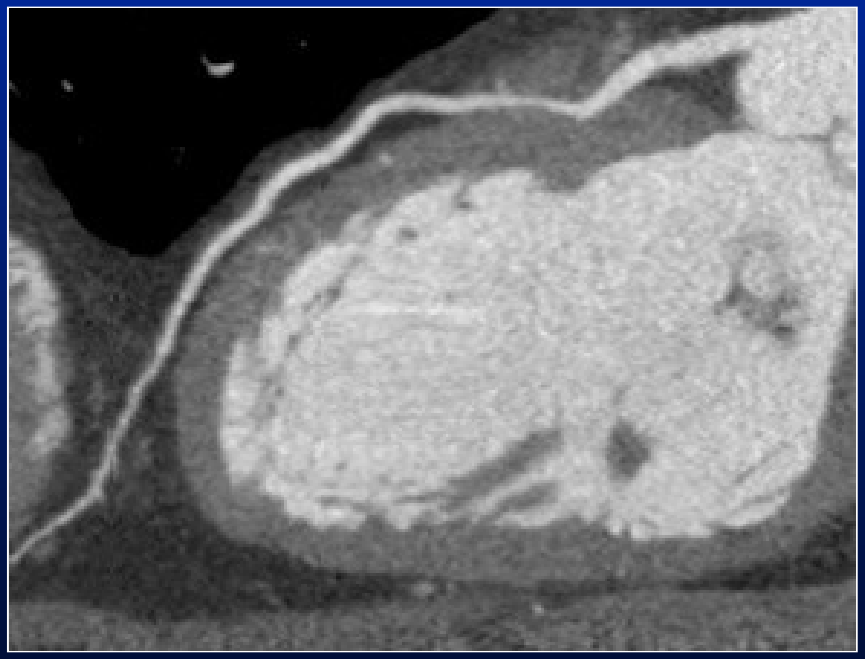
Outpatient clinics:

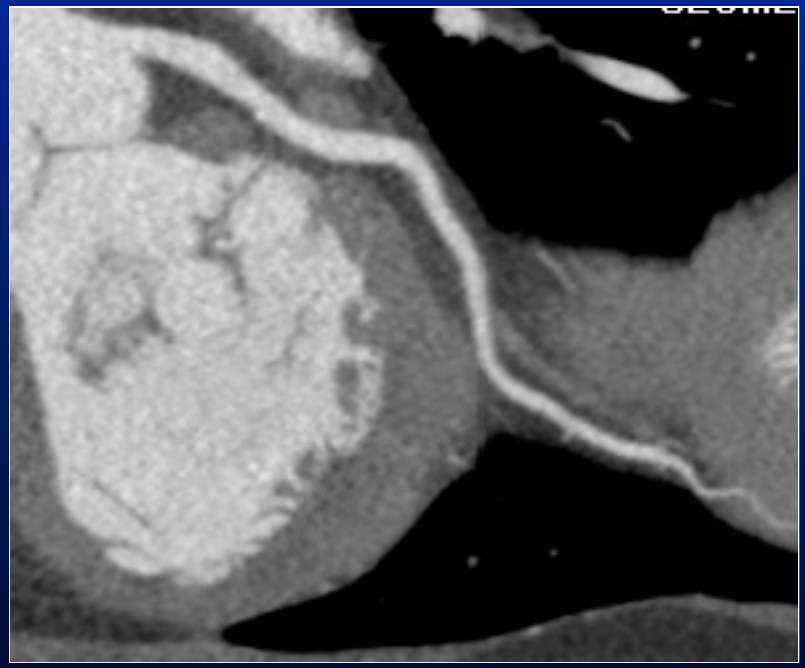
Dyspnea or atypical chest pain at exercise

Risk factors for CAD:

*Dyslipidemia

Non-invasive angiography - MSCT





LAD: normal,

intramural course mid

LCx: normal

320-CT – rule out CAD

57 yr old woman, 2x TIA
Analysis cardiac source of embolism

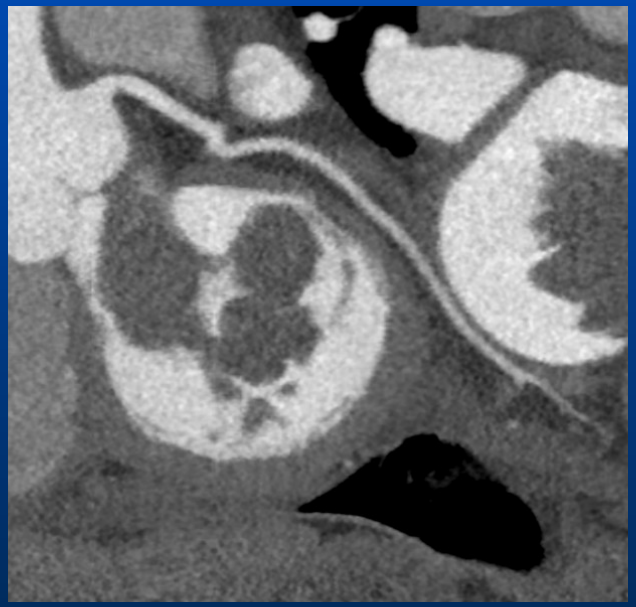
320-CT – rule out CAD

Smoking 39 pack years

Severe dyslipidemia (chol 7.8 mmol/L)

MSCT angiography to exclude (?) CAD

LAD

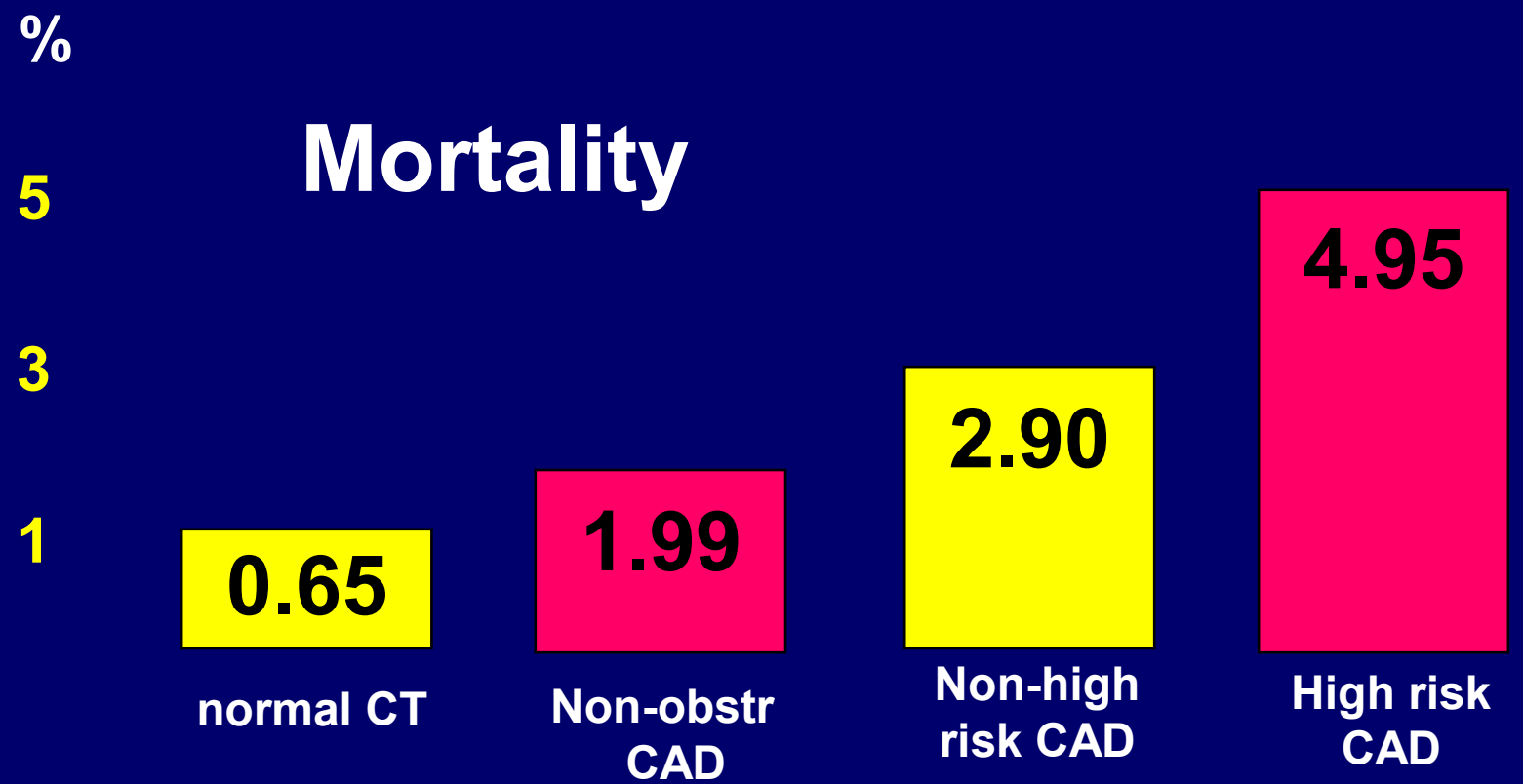


LCx

RCA

No significant stenosis

Prognosis MSCT
13,966 pts, mean F-up 22.5 months



Chow et al. Circ 2011

Patient example

Man 58 years old

Outpatient clinics:

chest pain at rest, sometimes stress

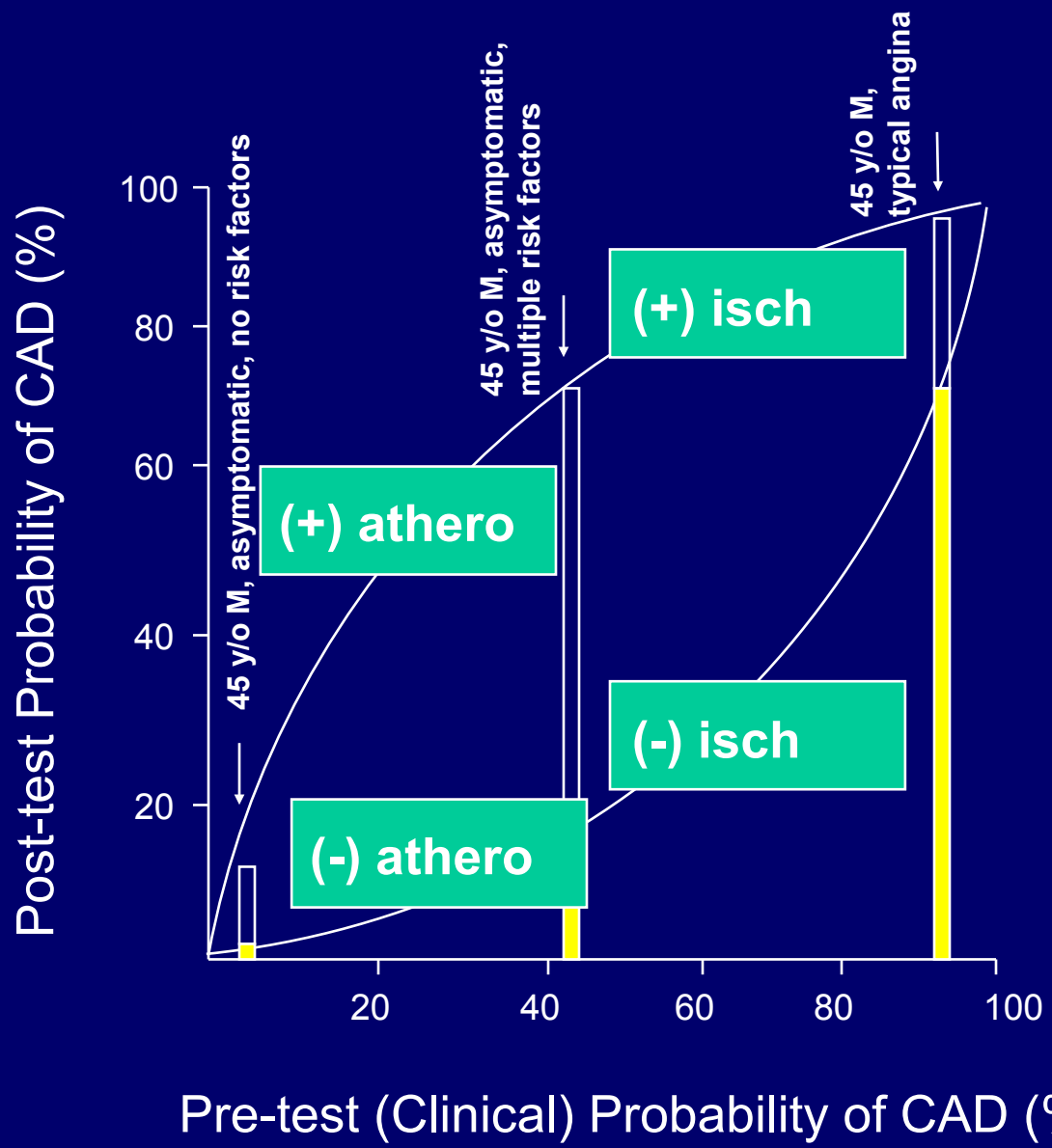
Risk factors for CAD:

*Hypercholesterolemia

*Hypertension

*Smoking

Non-invasive assessment of CAD: Which Patients?



Patterson et al. JACC 1989

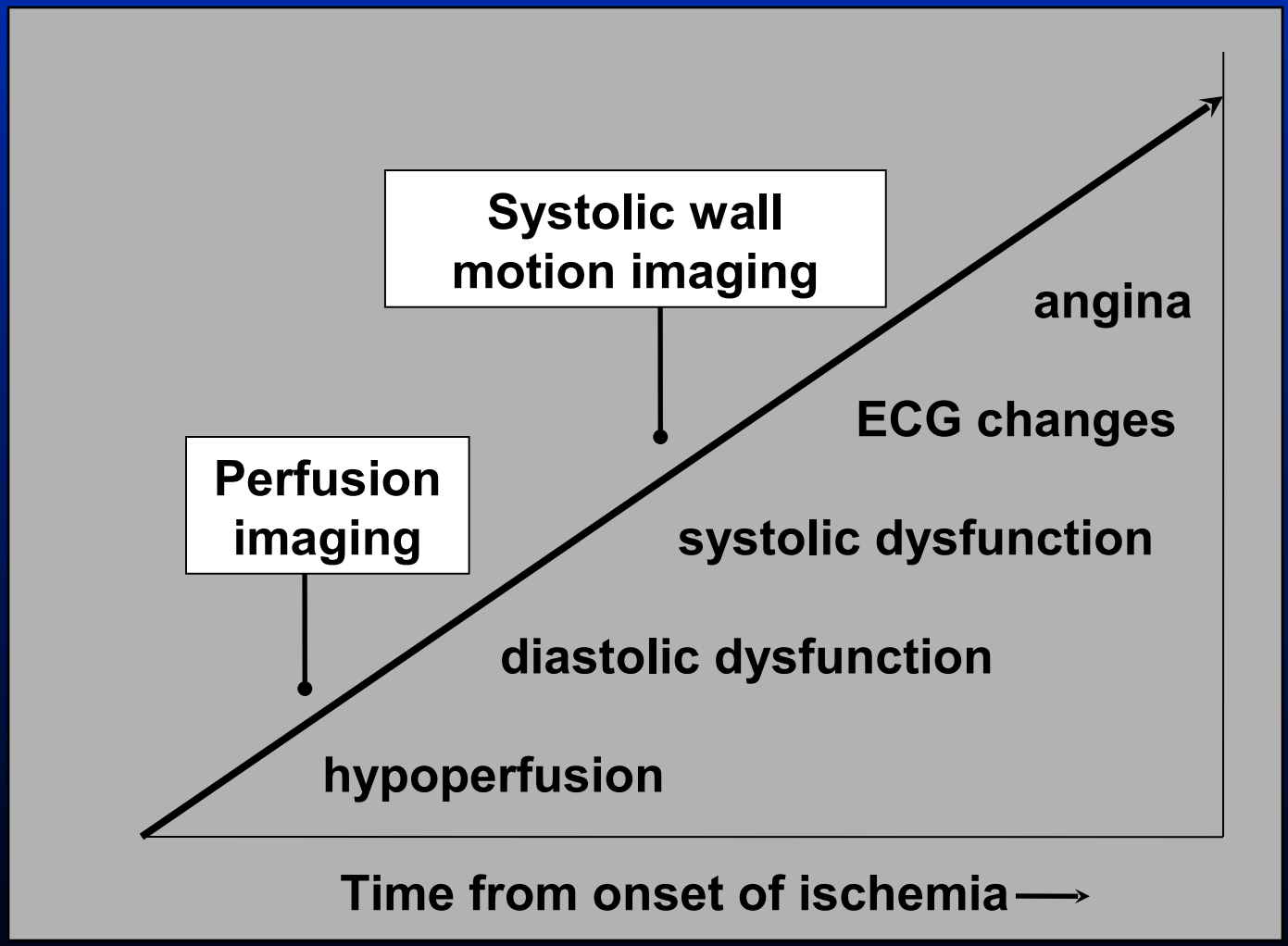
Symptomatic patient, intermed – high pre-test likelihood

The patient has high likelihood to have atherosclerosis

The question is: does he have ischemia? (is intervention needed?)

☞ We order a non-invasive ischemia test

The ischemic cascade

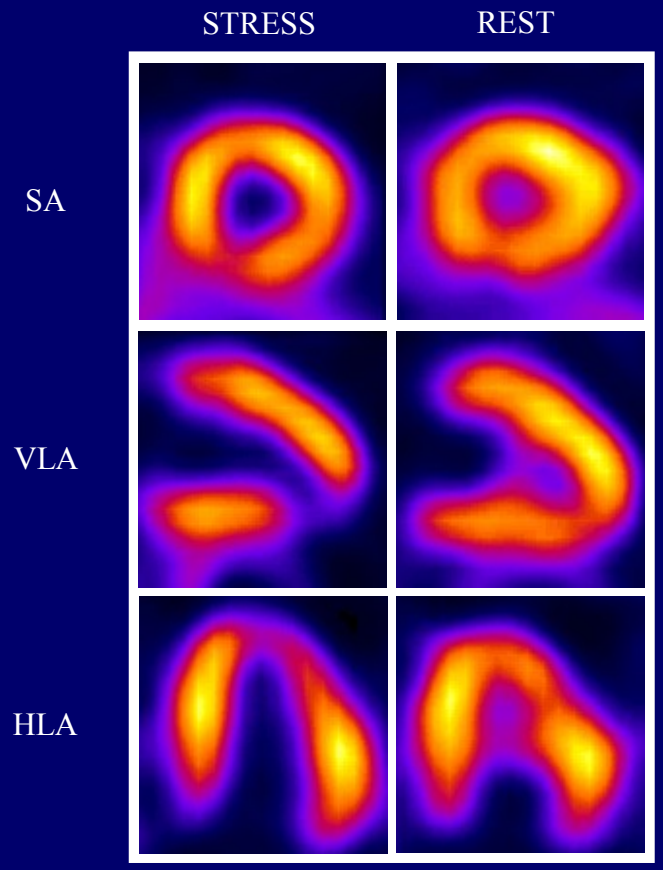


Schinkel et al. EHJ 2003

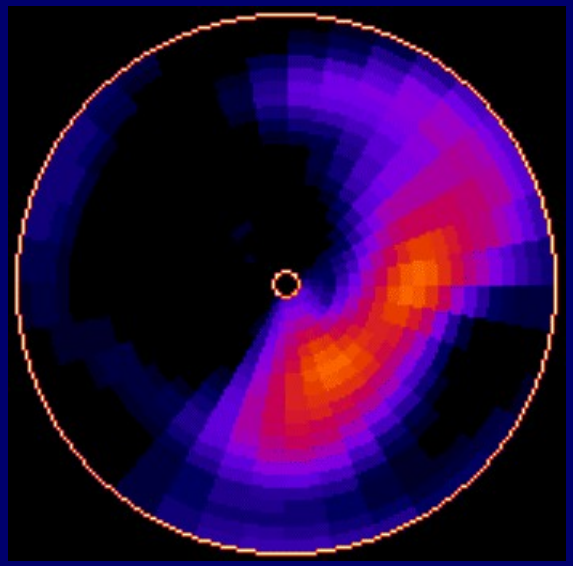
Ischemia as an expression of a flow-limiting stenosis

- Assessment of
  - perfusion abnormalities (stress-inducible)
- Assessment of
  - systolic wall motion abnormalities (stress-inducible)

Nuclear perfusion imaging, SPECT



POLAR MAP TO QUANTIFY
EXTENT AND SEVERITY OF ISCHEMIA



Nuclear perfusion imaging with ECG gating

- Permits assessment of LVEF, LV volumes and regional function
- At rest and stress

Stress echo to assess flow-limiting stenosis: wall motion

rest

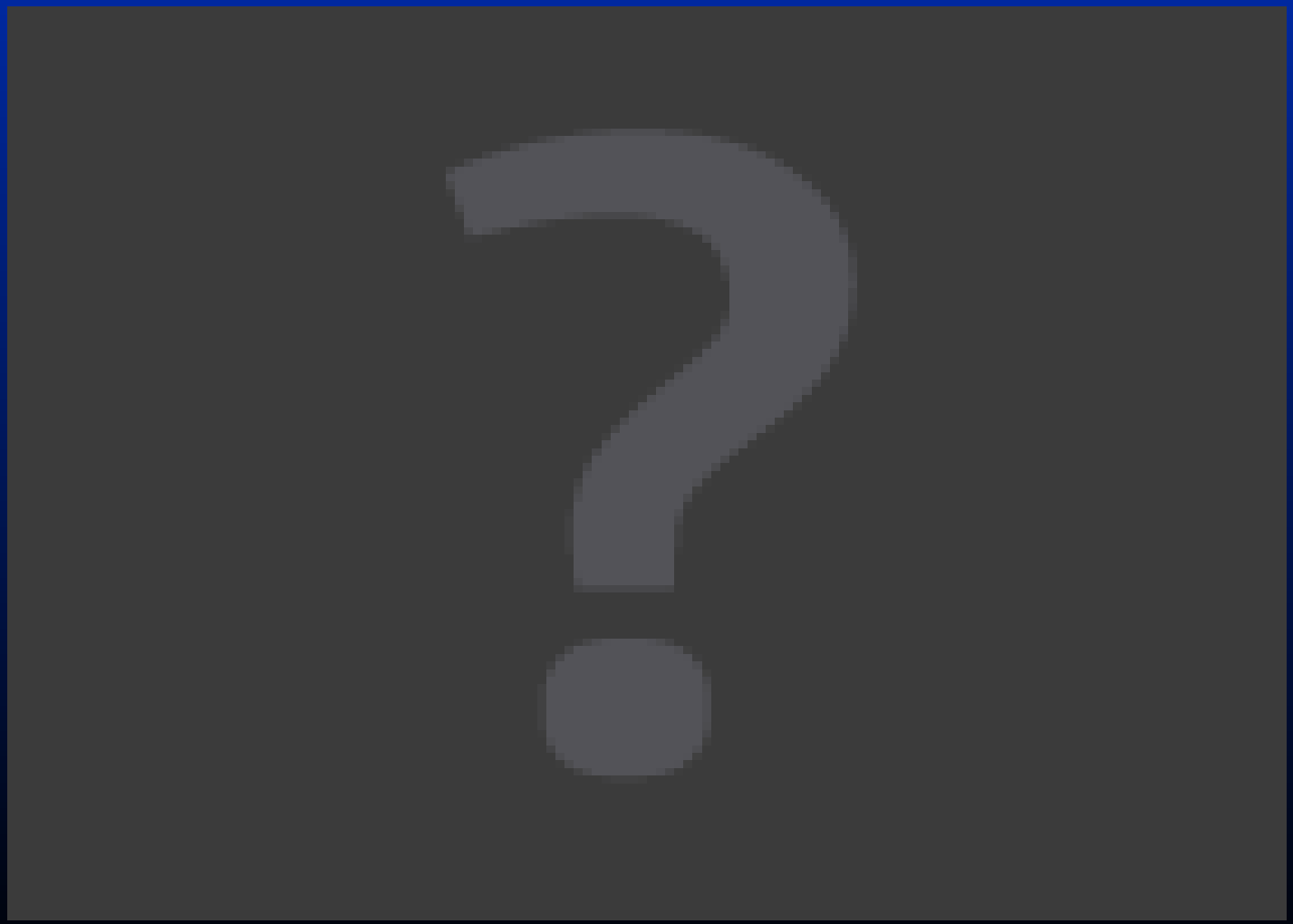
10 mcg

40

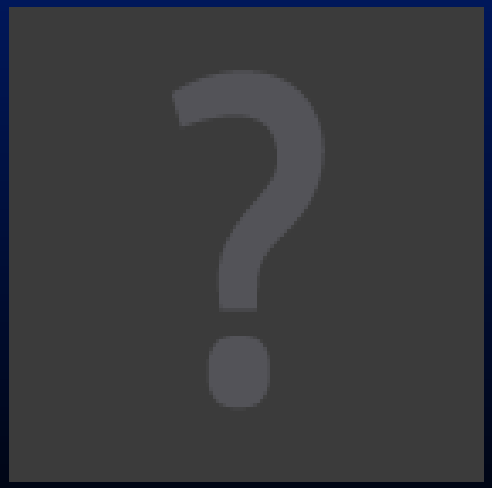
rest

Addition on intravenous contrast to improve border opacification

Stress MRI to assess flow-limiting stenosis: wall motion



MRI – perfusion imaging



Comparison of imaging techniques for diagnosis of CAD

- **In low-intermediate likelihood:**
- atherosclerosis imaging (non-invasive angiography)
- MSCT preferred over MRI

- **In intermediate-high likelihood:**
- ischemia imaging
- all modern techniques can assess perfusion and systolic function

From atherosclerosis to heart failure: Where may imaging help?

- **Asymptomatic patients**
  at elevated risk for atherosclerosis/CVD: screening / early detection

✂☞ **Symptomatic patients: detection of coronary artery disease**

✂☞ **Ischemic heart failure: extensive evaluation**

Patient example

Male, 62 yrs

- 1987: Infero-postero-lateral infarct
- 1988: Repeat inferior infarct
- 1994: Antero-septal infarct
- 1996: CABG: LIMA-graft LAD,
  venous graft MO-LCX and RDP/RCA
- 2000: Non-sustained ventricular tachycardia

Co-morbidities

- Diabetes II
- COPD
- chronic renal failure (creatinine 300 micromol/l)

Patient example

Male, 62 yrs

- Reduced exercise capacity
- NYHA III
- Dizziness / Hypotension

- Weight 53 kg, length 1.64 m
- RR 90/65 mmHg
- Holosystolic murmur 3/6 apex

Severe heart failure patient

To determine therapy, the information below is needed

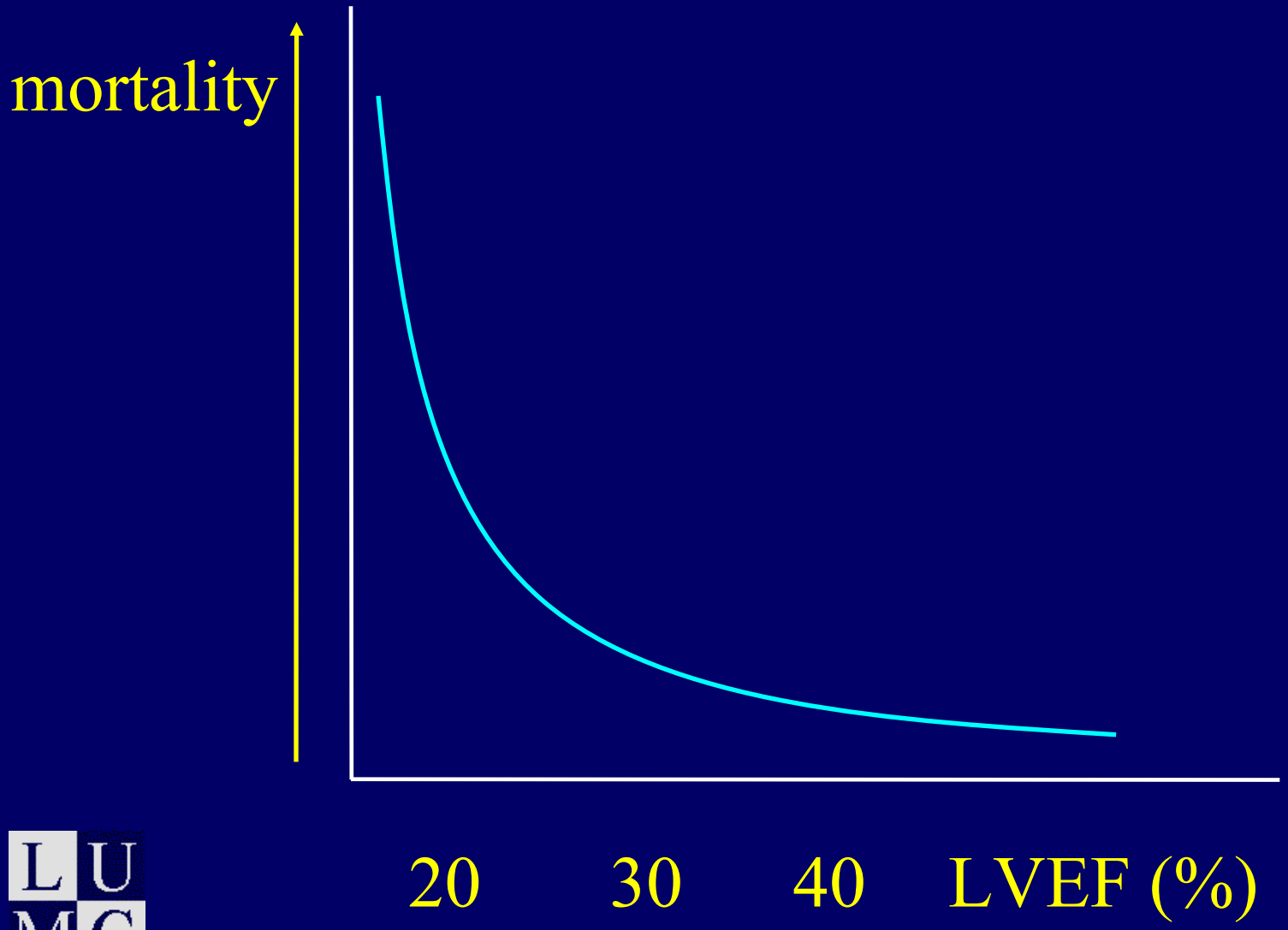
LV function and LV size?

CAD: ischemia/viability?

Severe MR?

ICD needed?

LV function and size?



Adapted from White et al. NEJM 1986

LV function and size?

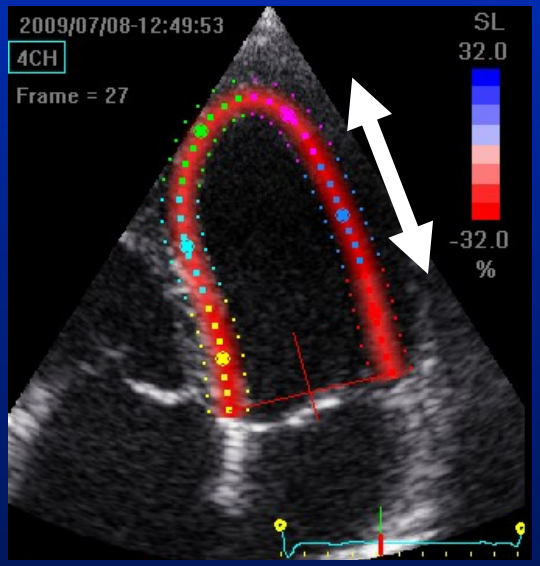
LV function and size?
Towards 3D imaging?

LV function and size?

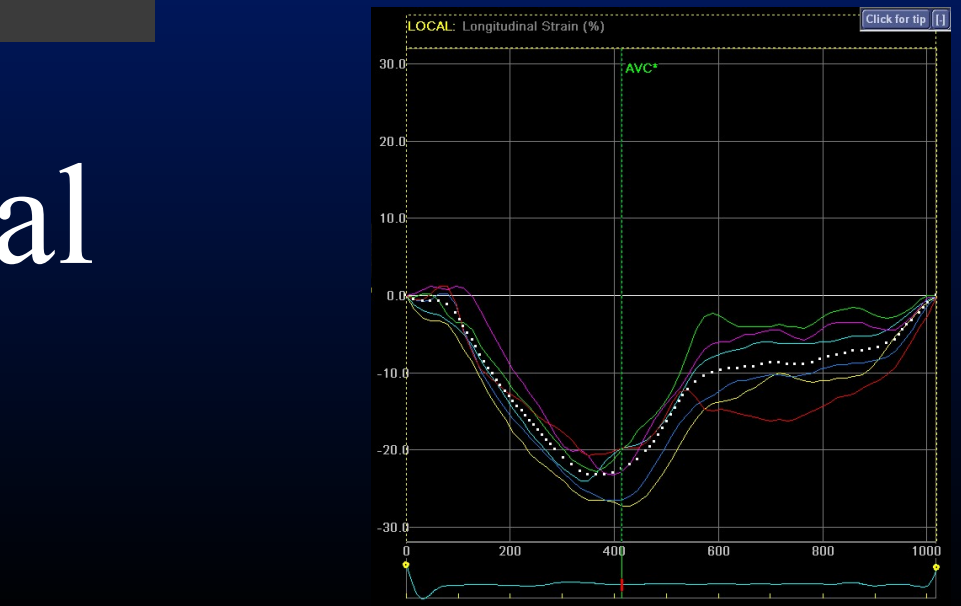
- We need:
- Highest resolution images in every patient
- Assessment of LVEF but also
  - LV dimensions : LVESD, LVEDD
  - LV volumes: LVESV, LVEDV

- Exact quantification – prognosis but also for justification of ICD therapy

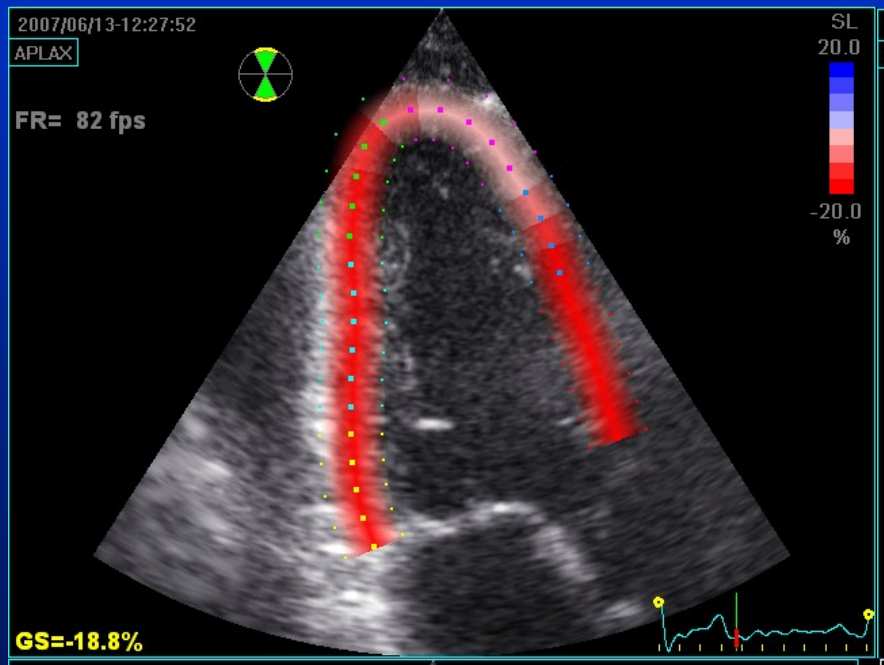
Advanced LV function assessment

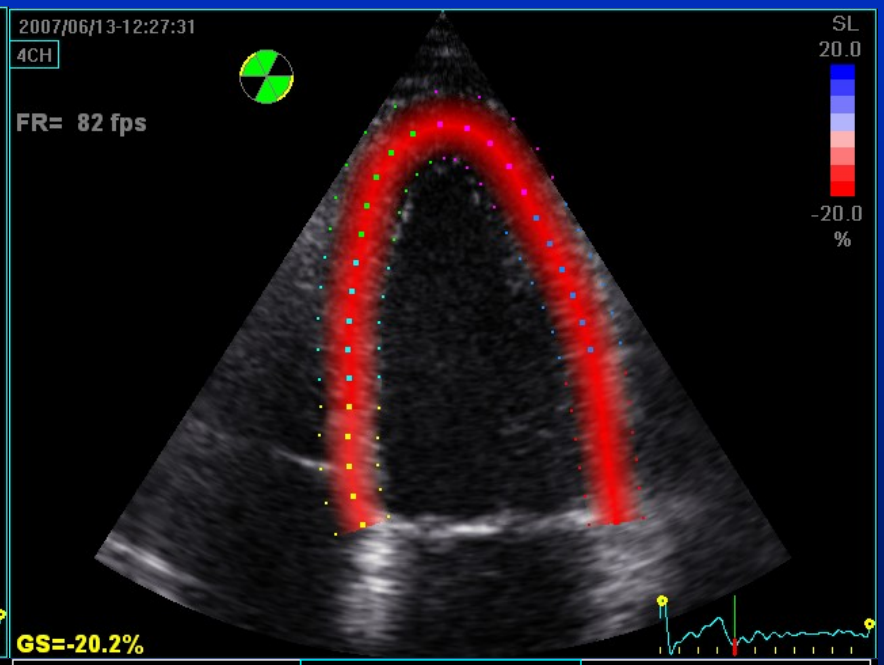


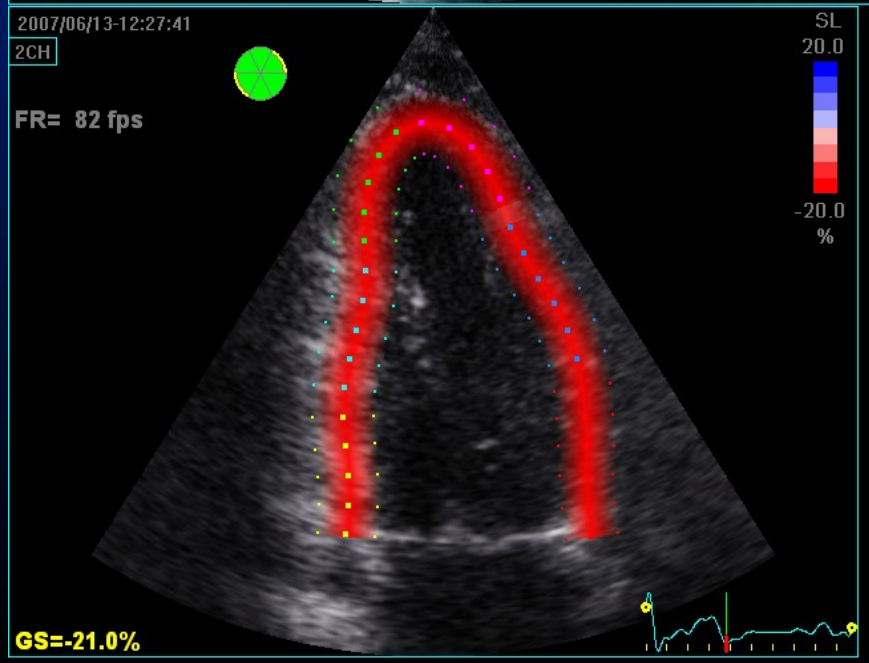
Longitudinal strain

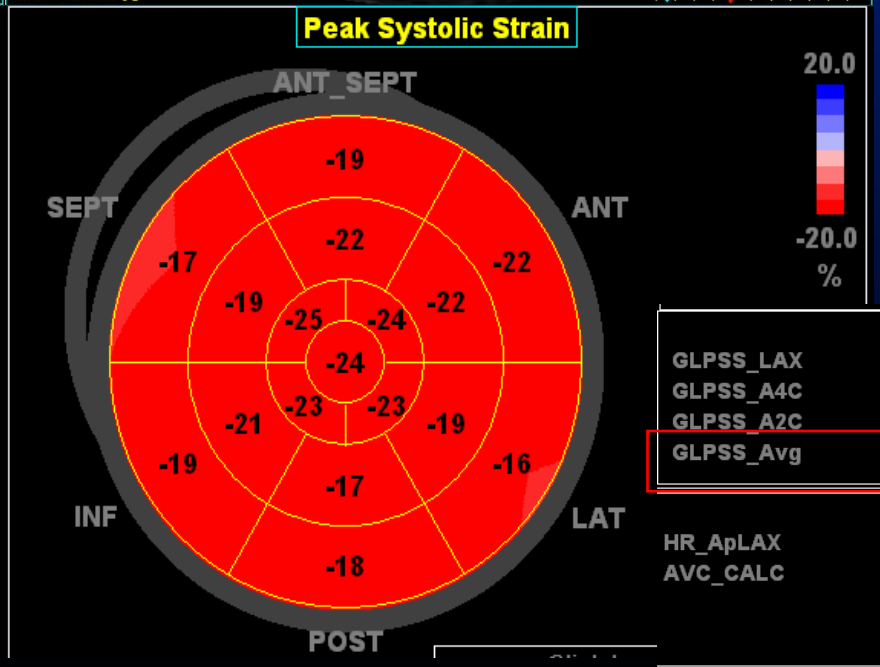


From regional to global LV strain

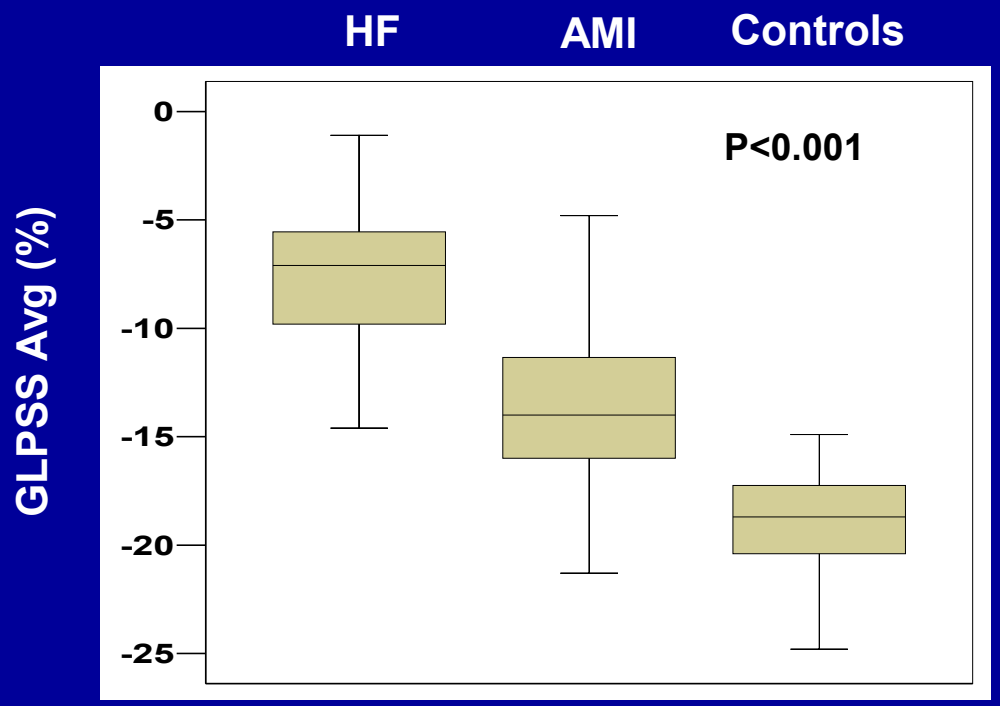




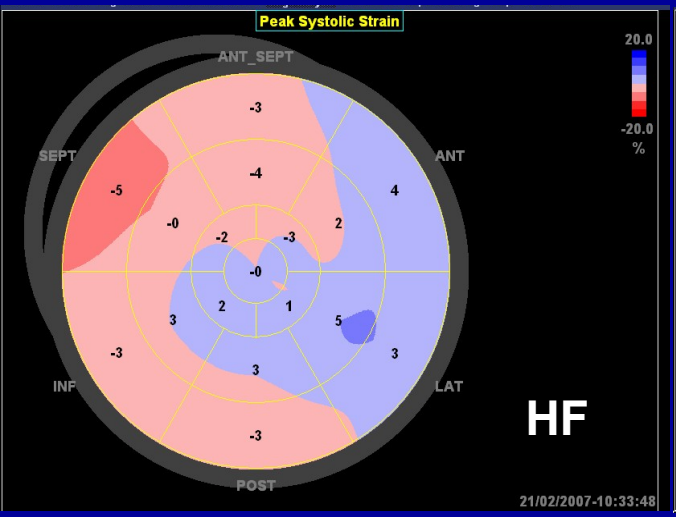




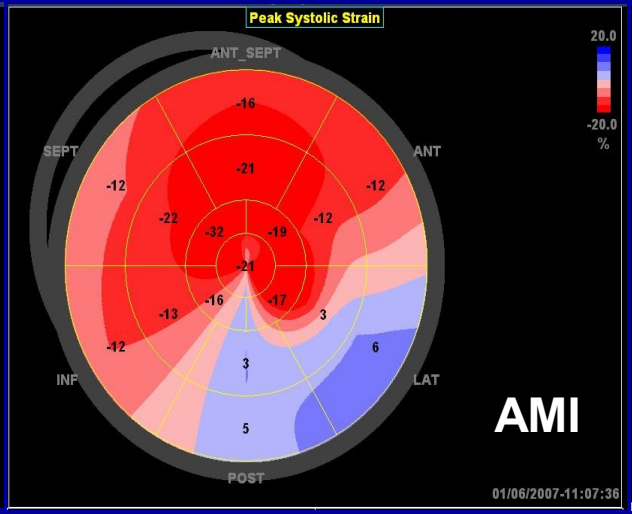
Global strain maps: HF, infarction, and normal



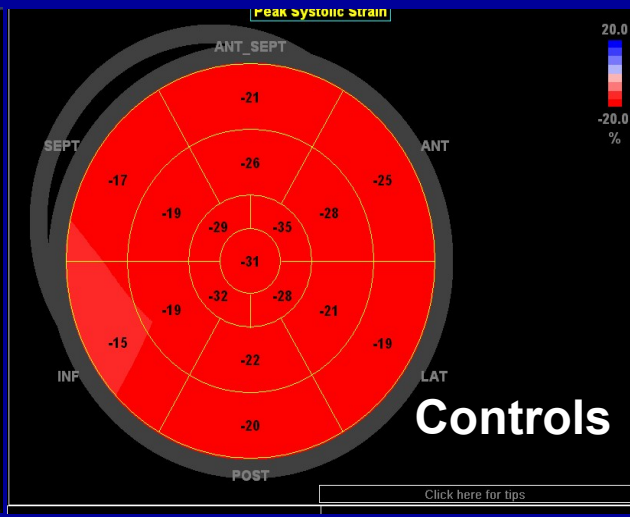
GLPSS Avg: -7.3 ± 3%



GLPSS Avg: -13.8 ± 3.3%

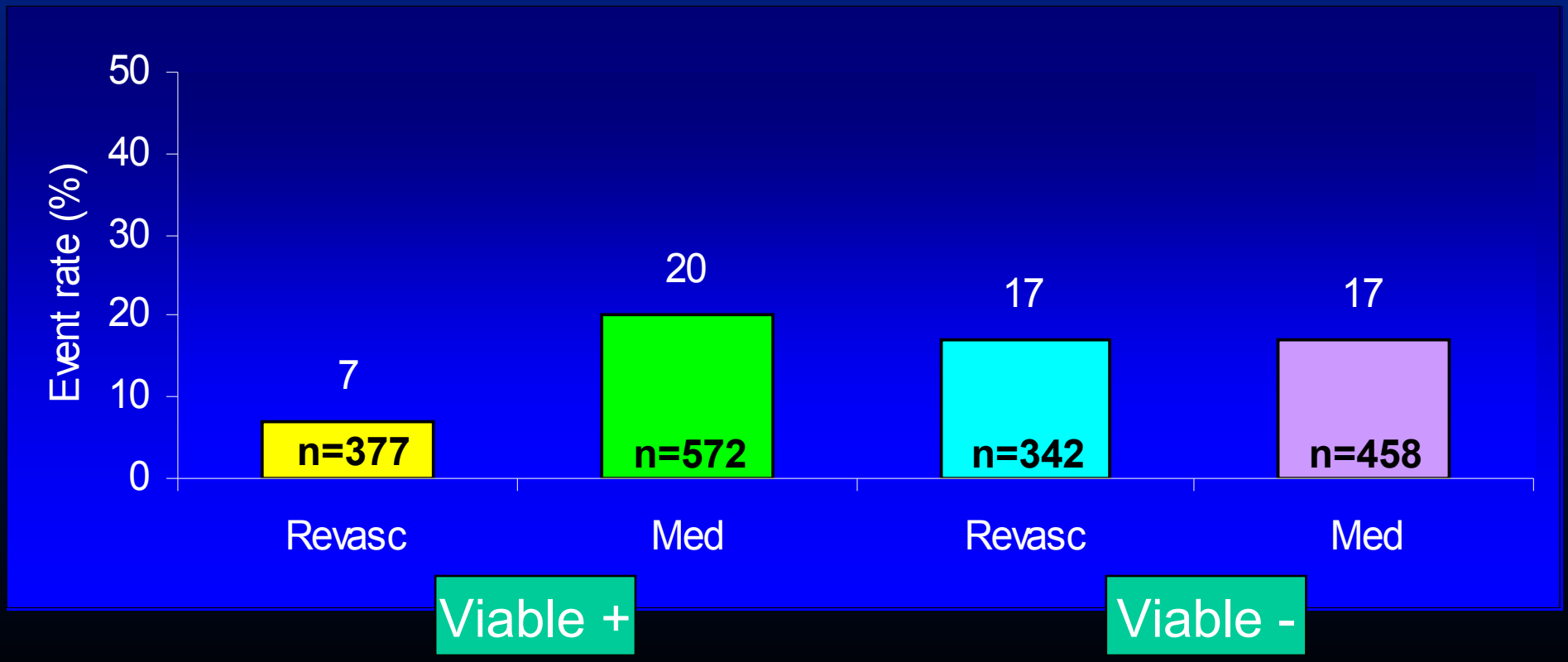


GLPSS Avg: -19.1 ± 3.1%



Is there viability?

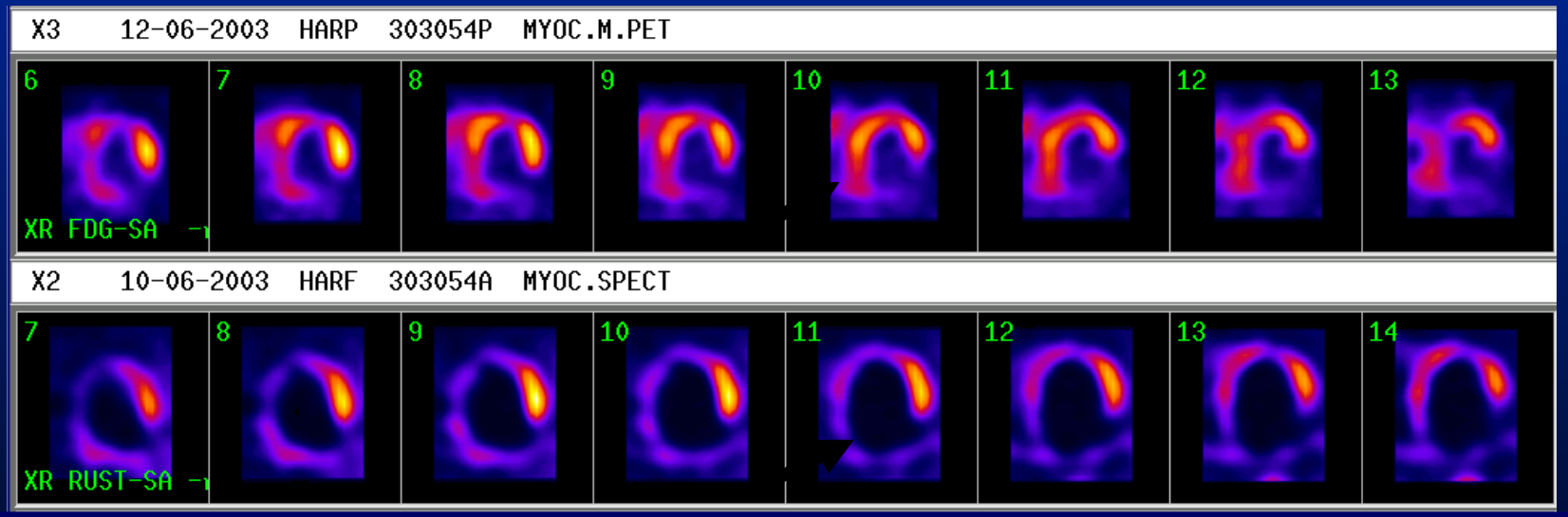
to predict prognosis post-surgery
N= 20 studies, 2362 pts
All retrospective analyses



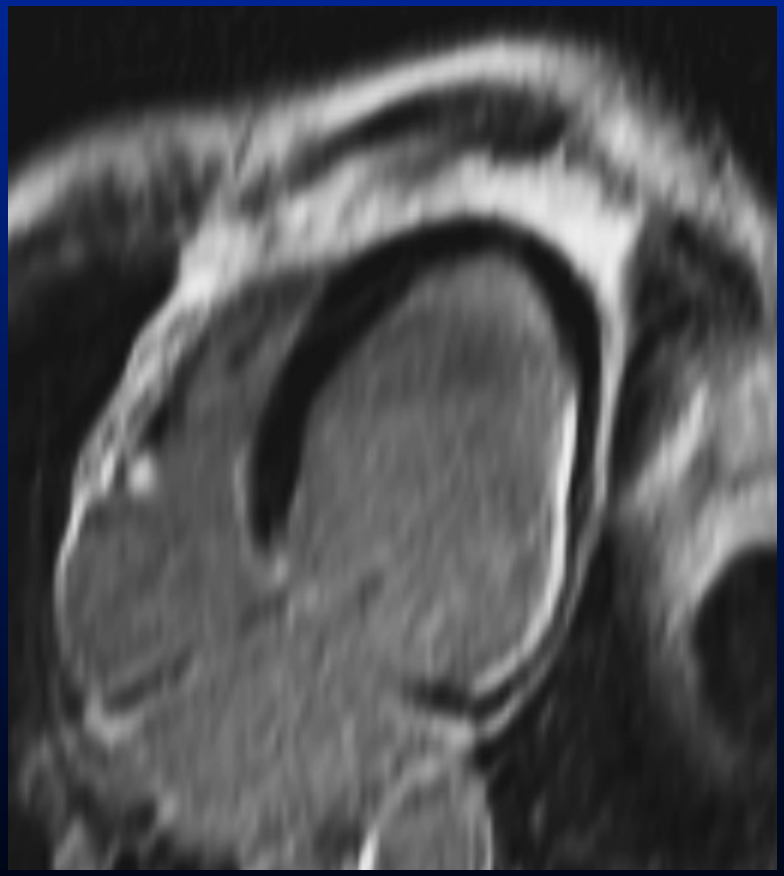
Is there viability?

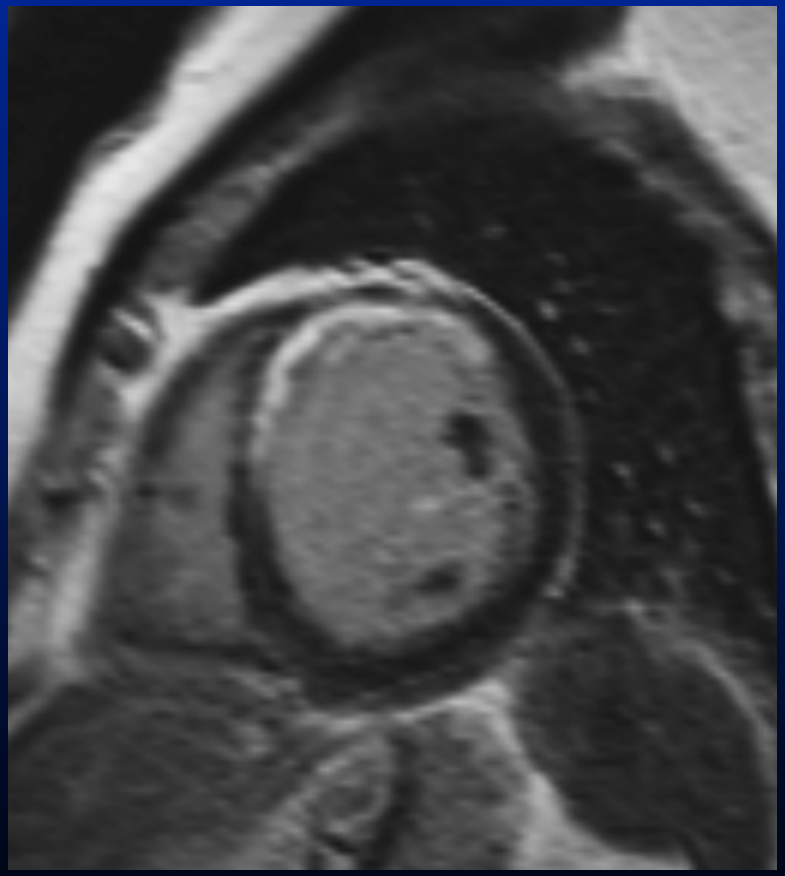
FDG

Perf



Infarct imaging with delayed enhancement MRI

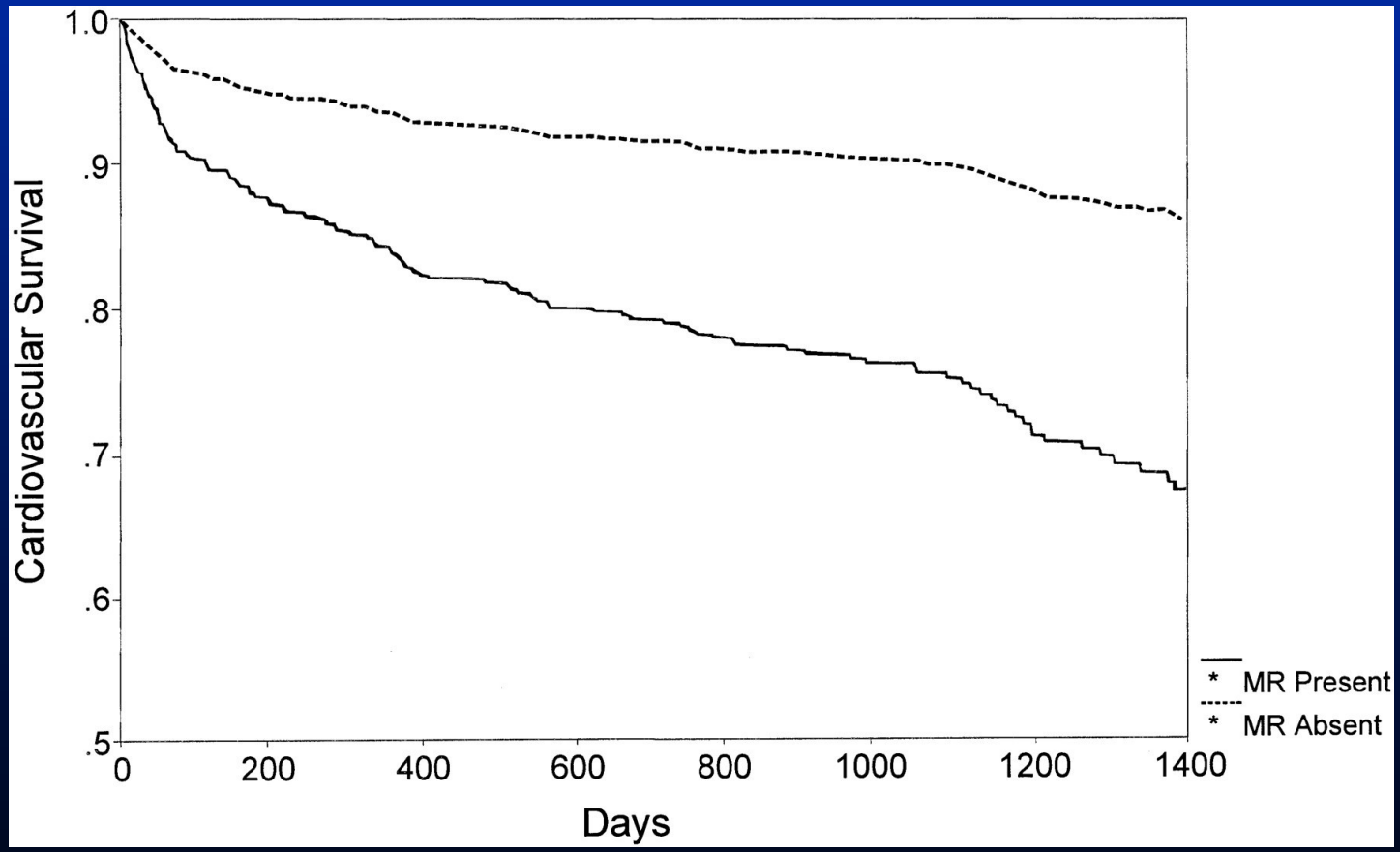




Viability assessment - Future?

Courtesy Schwaiger M.

Severe MR affects prognosis



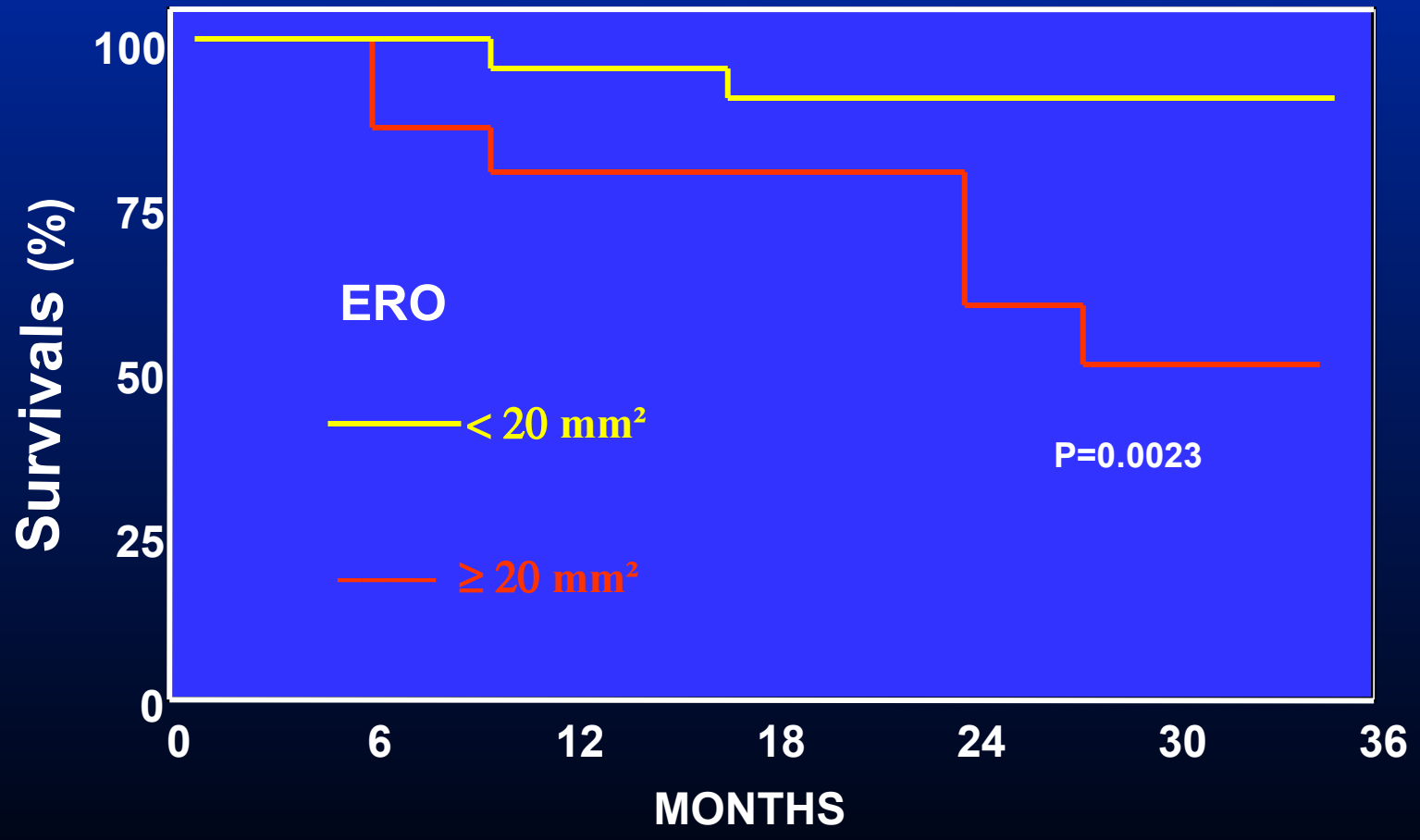
Lamas et al. Circ 1997

Severe MR?

TTE

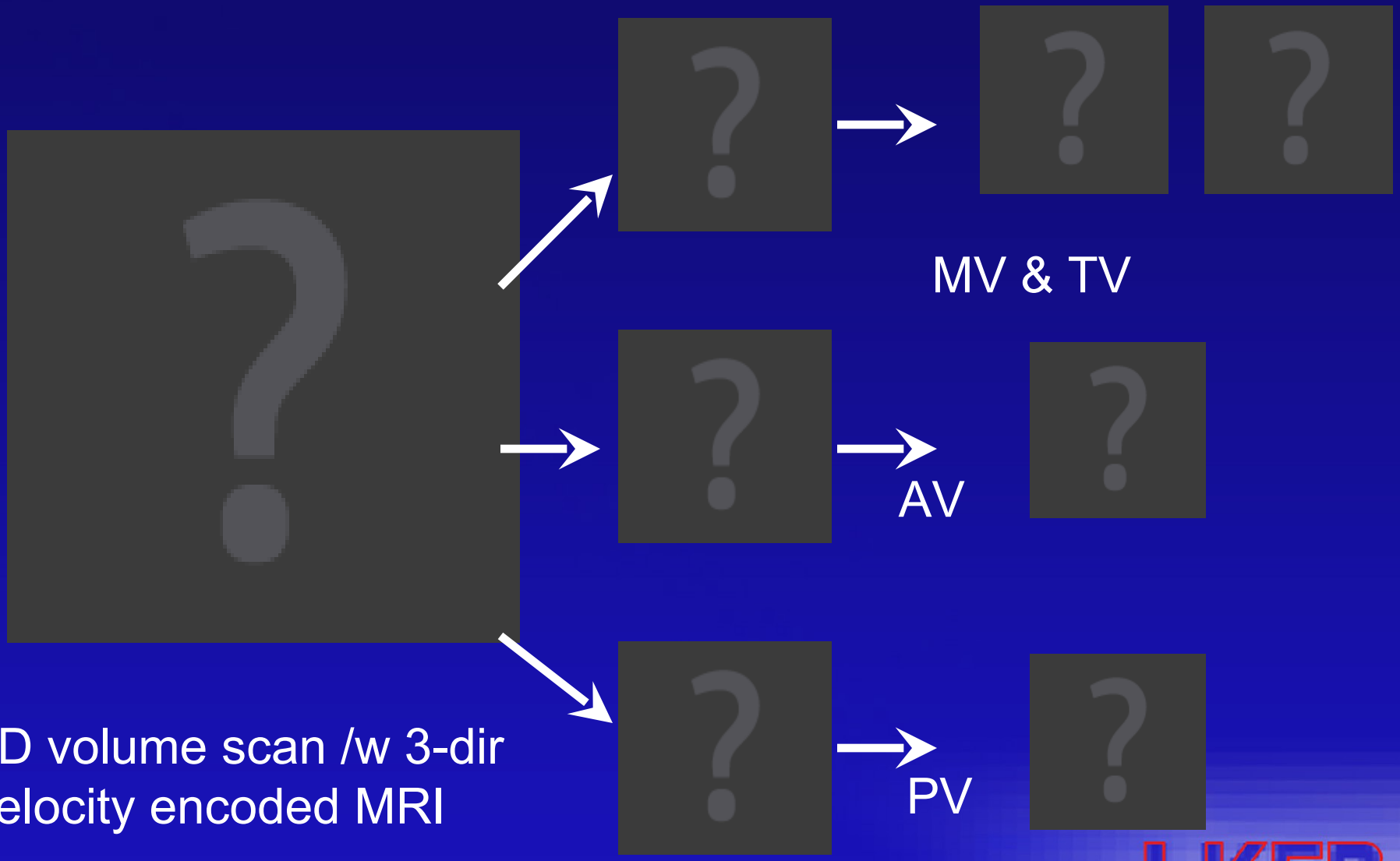
TEE

Is quantification of MR severity needed?



Lancellotti et al. Circ 2003

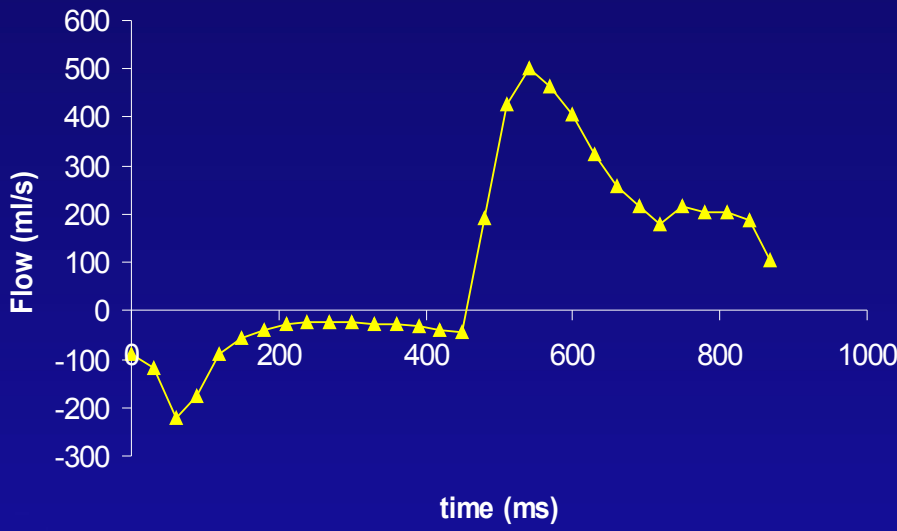
MRI: 3D Flow Quantification in All Valves



3D volume scan /w 3-dir velocity encoded MRI

MRI: 3D Flow Quantification mitral valve

MV flow



$V_{forward}$ = 116 ml

V_{back} = 32 ml

V_{eff} = 84 ml

Regurg. Fraction = 27%

Severe MR – other techniques?

3D TTE

Importance of MV anatomy
Is surgical repair feasible?

3D TEE

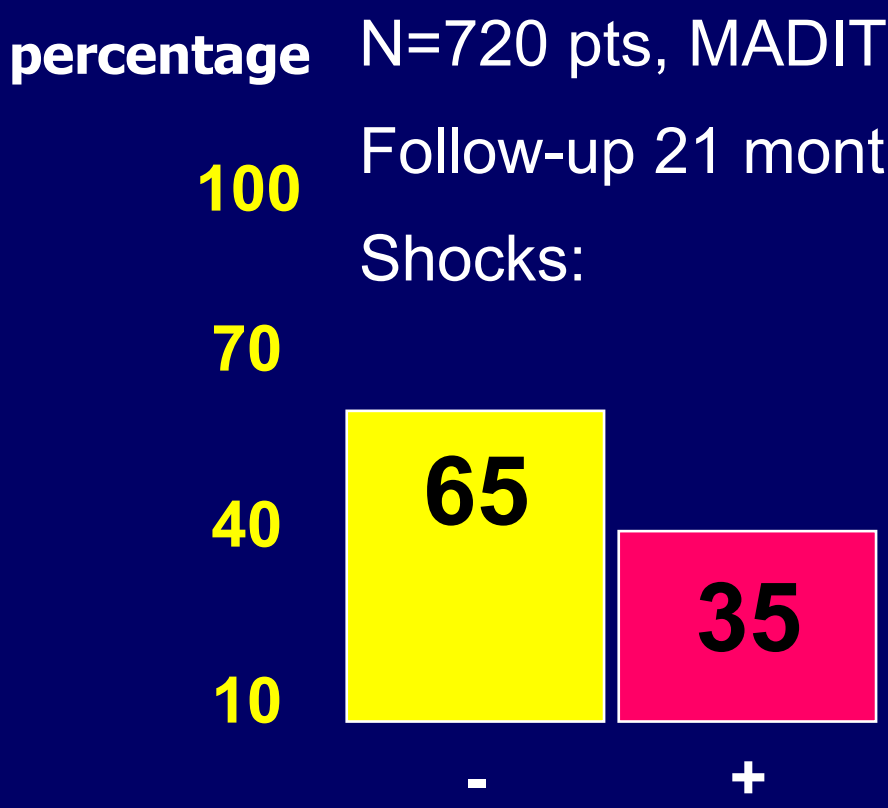
ICD needed?

- Patients with:
  previous infarction
  LVEF <30%

- Benefit from ICD:
- MADIT II: improved survival

ICD needed?

ICD shocks in primary prevention



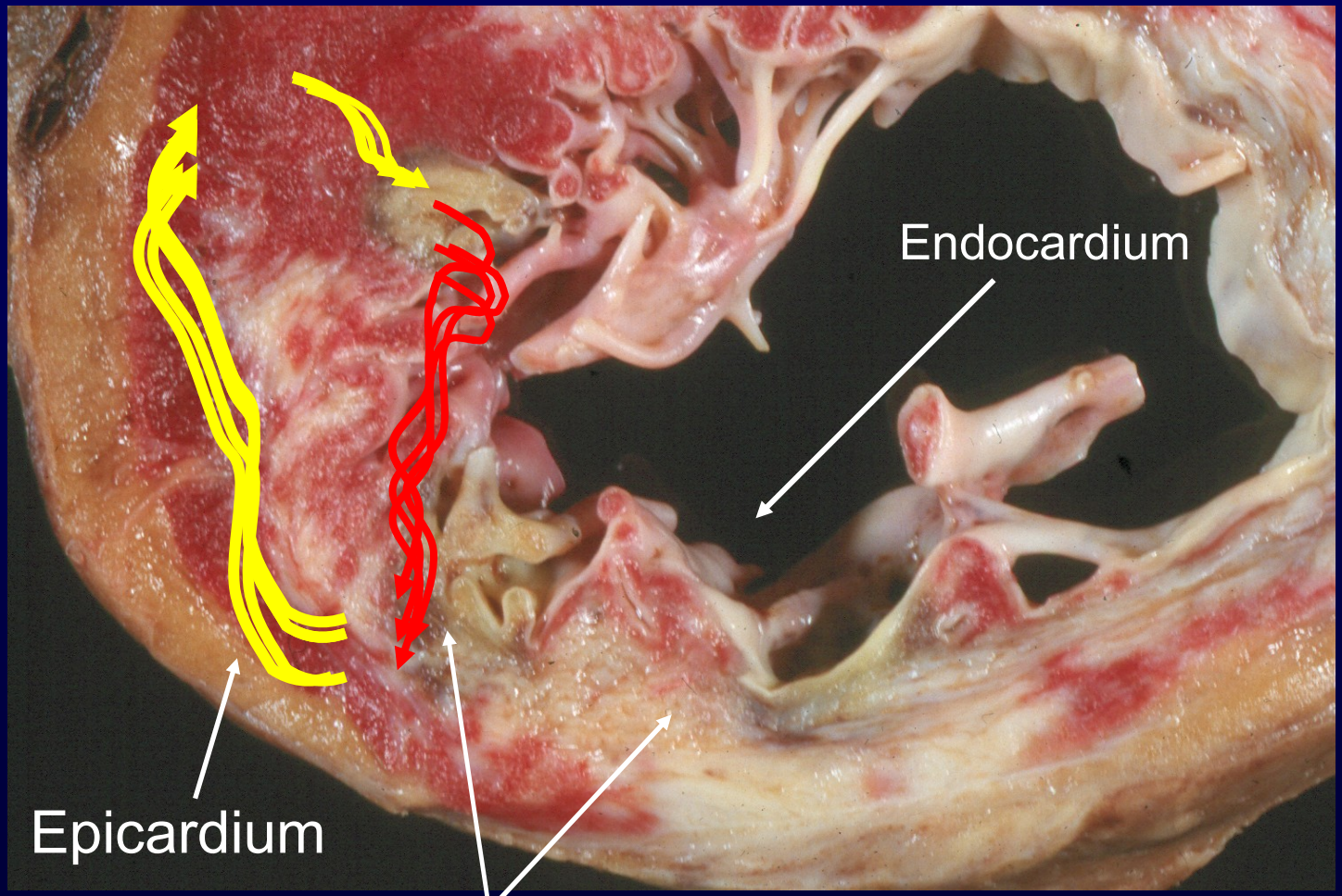
N=720 pts, MADIT II

Follow-up 21 months

Shocks:

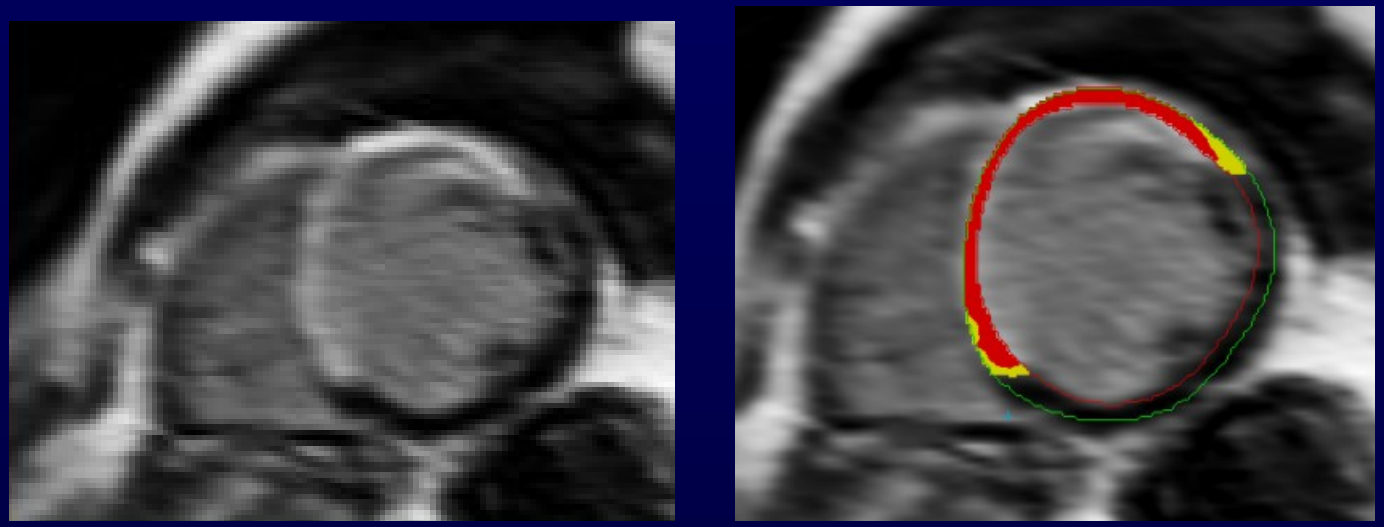
Moss et al. Circ 2004

What is the pathophysiological substrate for SCD in CAD?



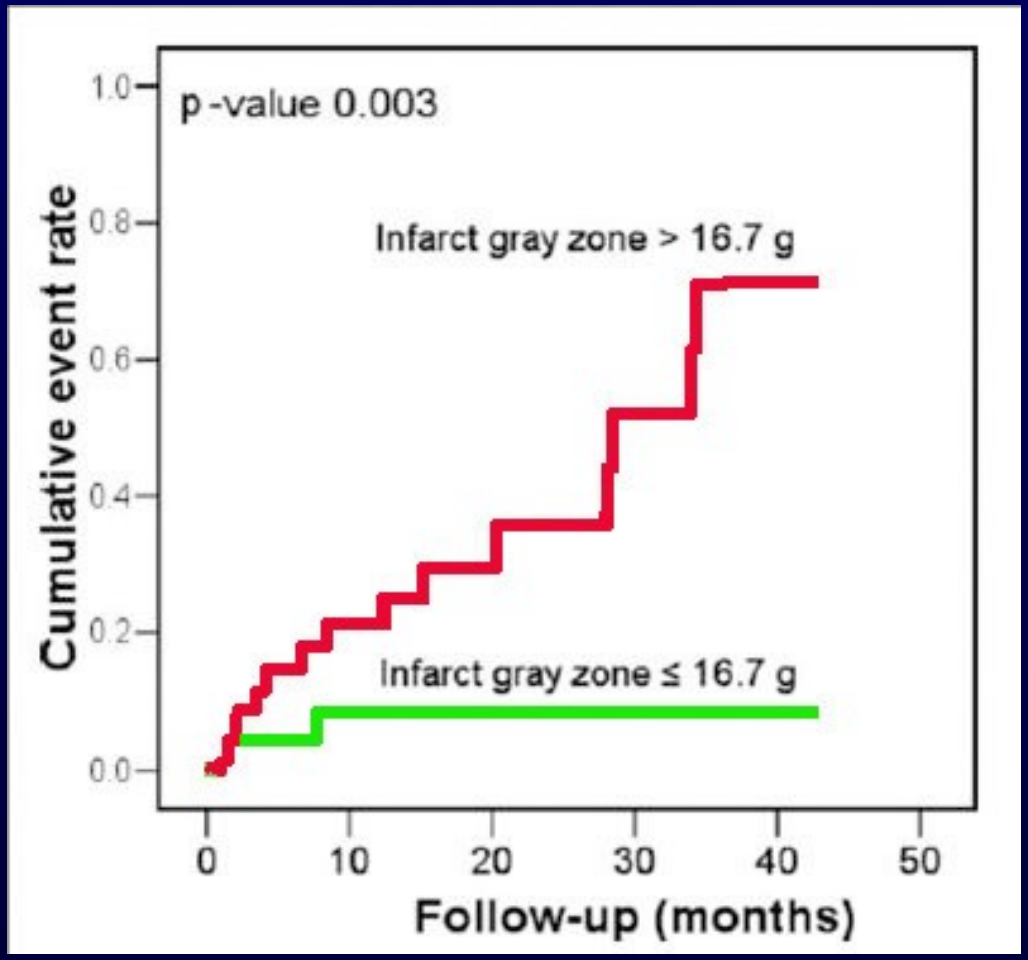
Courtesy W Stevenson

MRI to assess arrhythmogenic substrate:



- Late-gadolinium enhancement: scar area and peri-infarct zone

Value of border zone to predict VTs



HR (95%CI): 1.47 (1.04 to 2.08)
P = 0.003

Roes et al. Circ Cardiovasc Imaging 2009

Severe heart failure patient

Complex information is needed to determine therapy

Can be provided by multi-modality imaging

Conclusions

- Virtually all anatomical and functional information can be obtained by (a combination) of the available imaging techniques

- The choice of techniques should be guided by the information needed

- Implementation of pre-defined care tracks may promote systematic use of the different techniques