

Interventional physiology

Cardiac PET to guide PCI

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Disclosure Statement of Financial Interest

Within the past 12+ months, Nils Johnson has had a financial interest/arrangement or affiliation with the organization(s) listed below.

Affiliation/Financial Relationship

- Grant/research support
(to *institution*)
- Licensing and associated consulting
(to *institution*)
- Support for educational meetings/training
(honoraria/fees donated to *institution*)
- PET software 510(k) from FDA
(application by Lance Gould, to *institution*)
- Patent pending
(USPTO serial number 62/597,134)

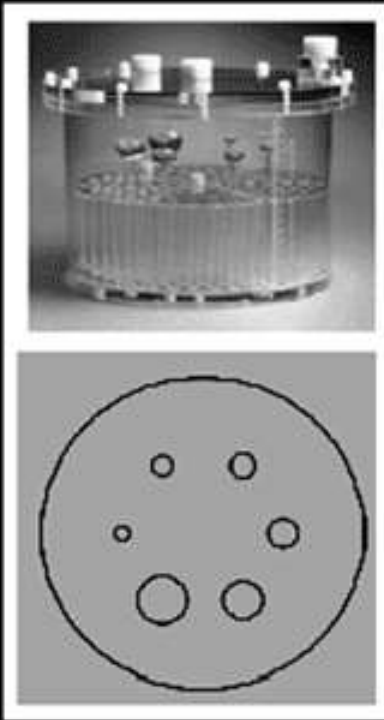
Organizations (alphabetical)

- St Jude Medical (for CONTRAST study)
- Volcano/Philips (for DEFINE-FLOW study)
- Boston Scientific
(for smart-minimum FFR algorithm)
- Various, including academic and industry
- K113754 (cfrQuant, 2011)
- K143664 (HeartSee, 2014)
- K171303 (HeartSee update, 2017)
- SAVI and $\Delta P/Q$ methods

Clinical history

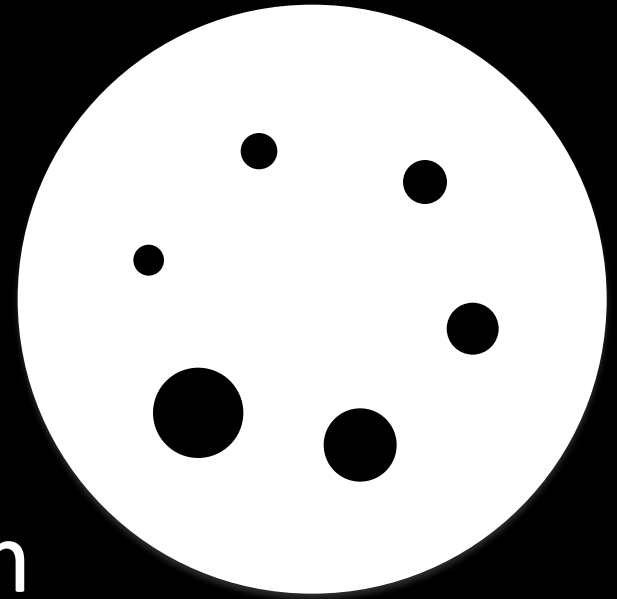
- 79 year-old man with new-onset but mild angina
- Risk factors were well treated
 - hypertension (calcium blocker)
 - dyslipidemia (statin)
 - prior tobacco (<10 pack-years)
- Pacemaker 6 years previously for bradycardia
- Subclinical carotid atherosclerosis by ultrasound
- Subclinical coronary calcium by CT (taking aspirin)
- *Referred for PET scan*

Cold Spot Imaging - spheres 9.5, 12.7, 15.9, 19.1, 25.4, 31.8 mm Jaszczak Phantom



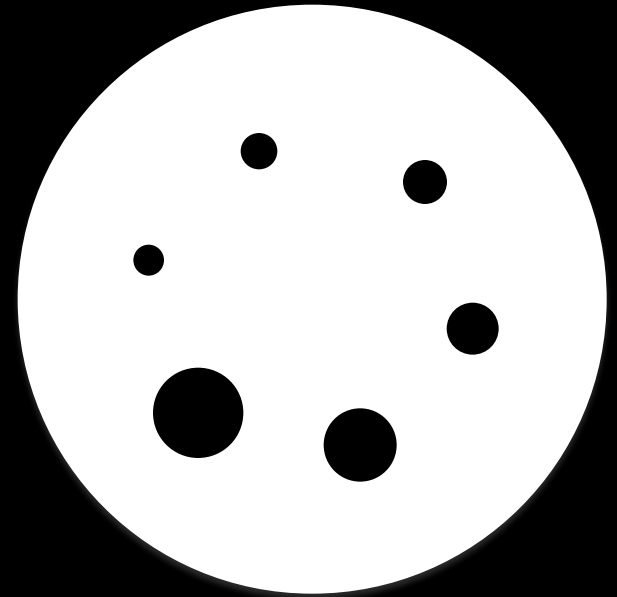
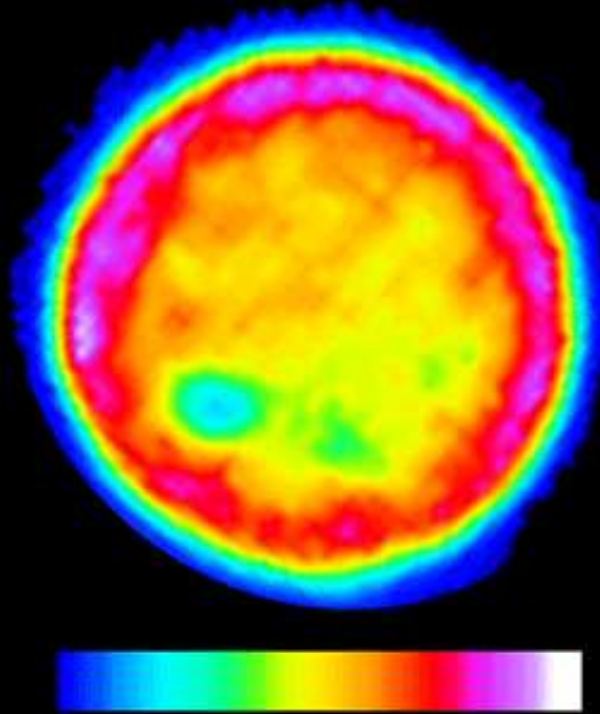
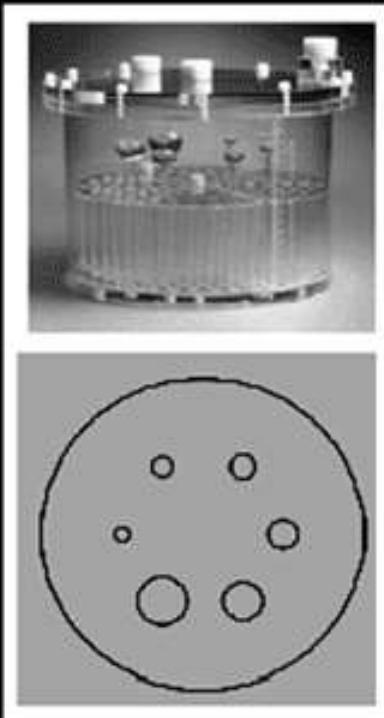
Ideal image:

- Uniform tracer
- Sharp holes
- Smallest defect
0.95mm \approx 1 cm

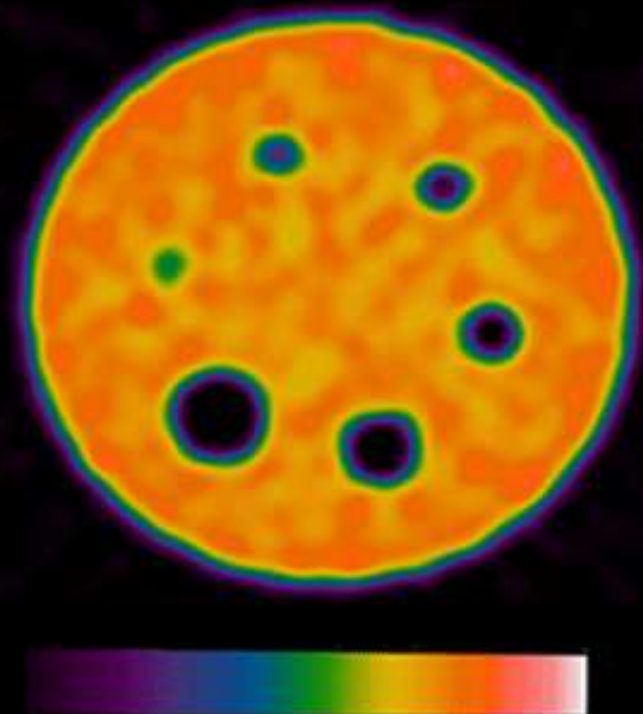
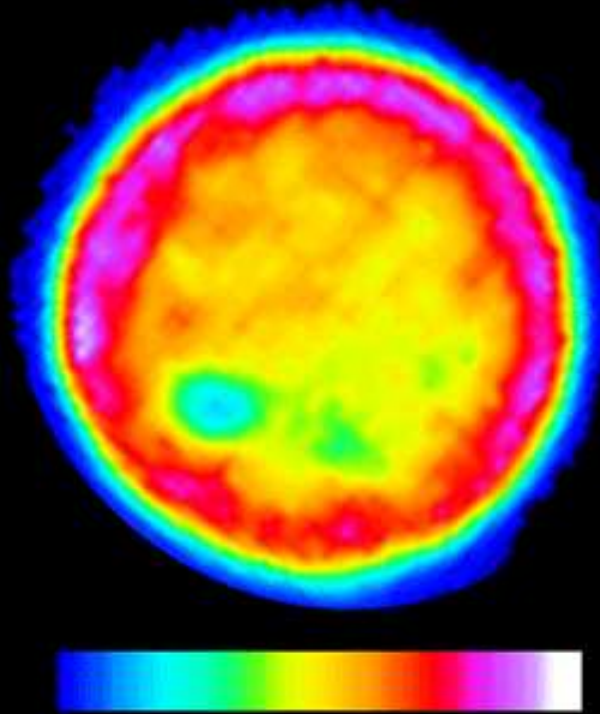
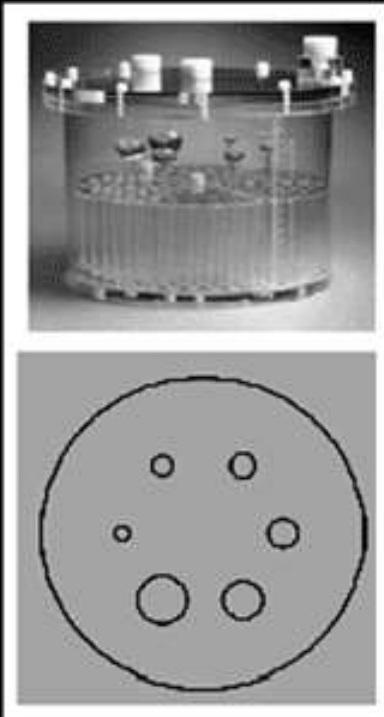


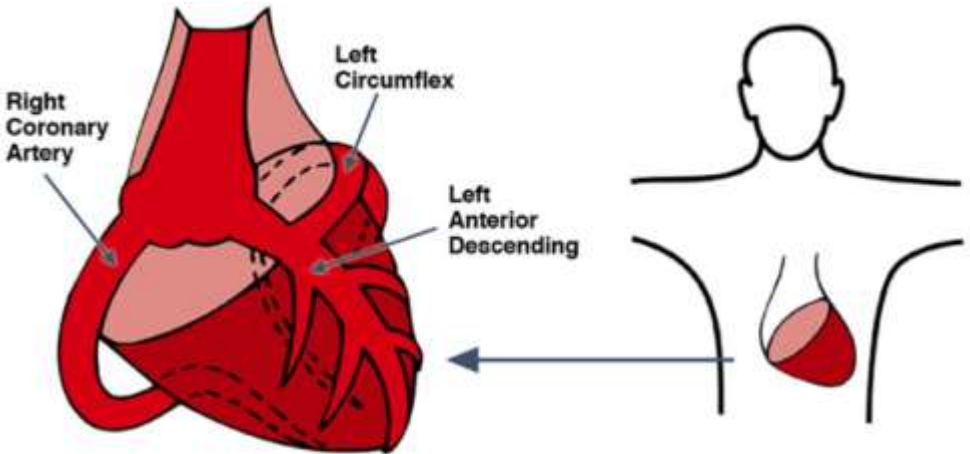
Cold Spot Imaging - spheres 9.5, 12.7, 15.9, 19.1, 25.4, 31.8 mm

Jaszczak Phantom SPECT



Cold Spot Imaging - spheres 9.5, 12.7, 15.9, 19.1, 25.4, 31.8 mm
Jaszczak Phantom SPECT PET





“topographic”

PET map
(3D into 2D)

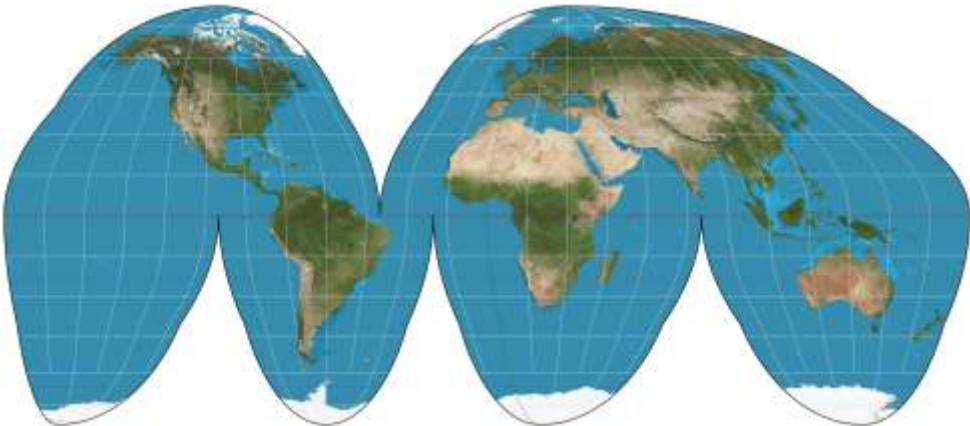


Johnson NP, *JACC CV Img* 2011 Sep;4(9):990-8. (Figure 1)

3D

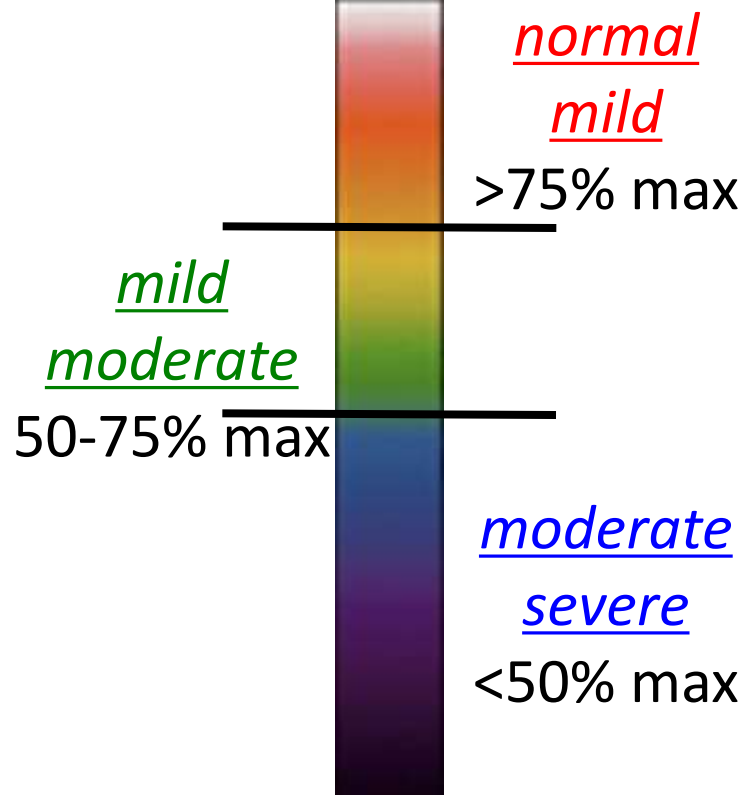
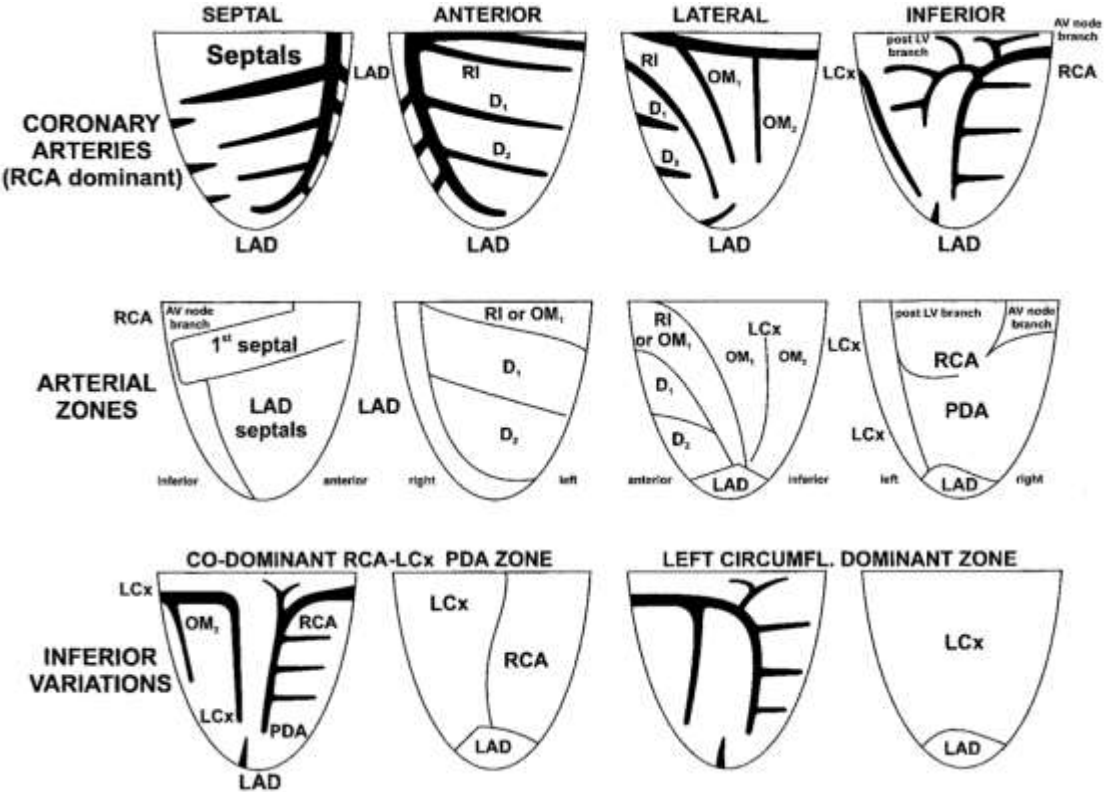


← make 2D
minimal distortion



Wikipedia “Goode homolosine projection”

http://www.sos.noaa.gov/Education/earth_system.html



Nakagawa Y, *J Nucl Cardiol* 2001 Sep-Oct;8(5):580-90. (Figure 1)

“atlas”

high resolution

“color scheme”

relative uptake

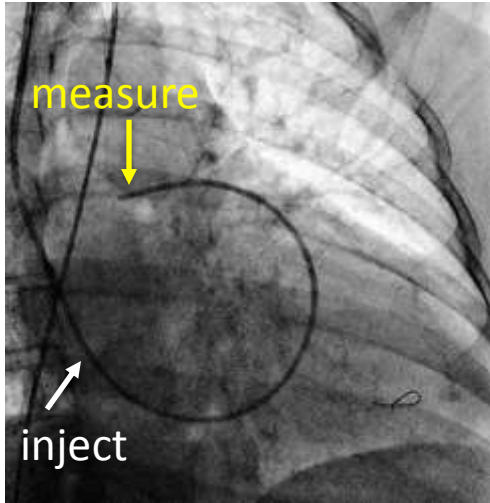
bolus

+

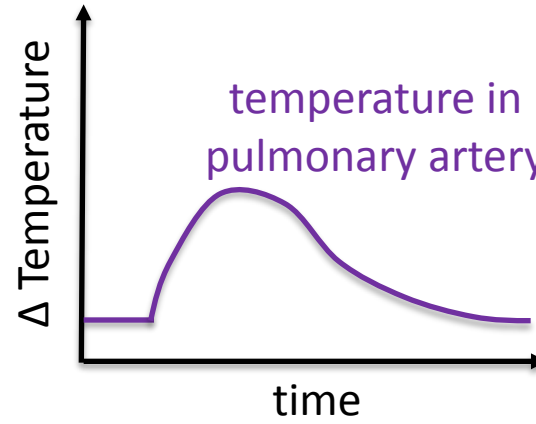
tracking

= *flow*

cath
lab



cold saline



time-temperature curve

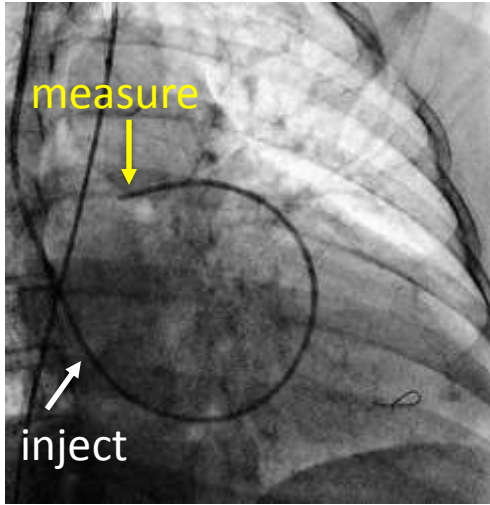
L/min
(cardiac
output)

bolus

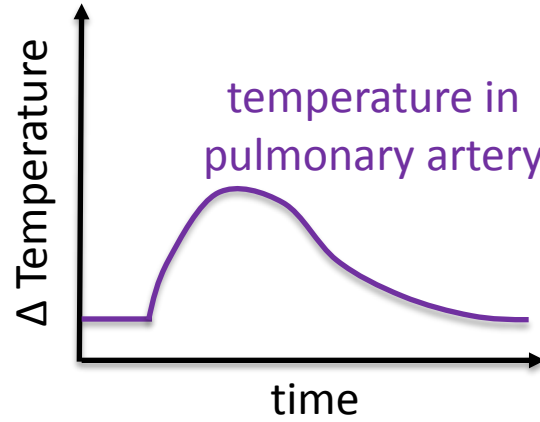
+ *tracking*

= *flow*

cath
lab



cold saline



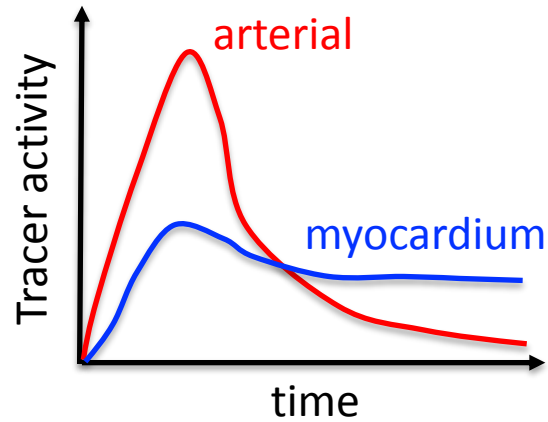
time-temperature curve

L/min
(cardiac
output)

PET
lab



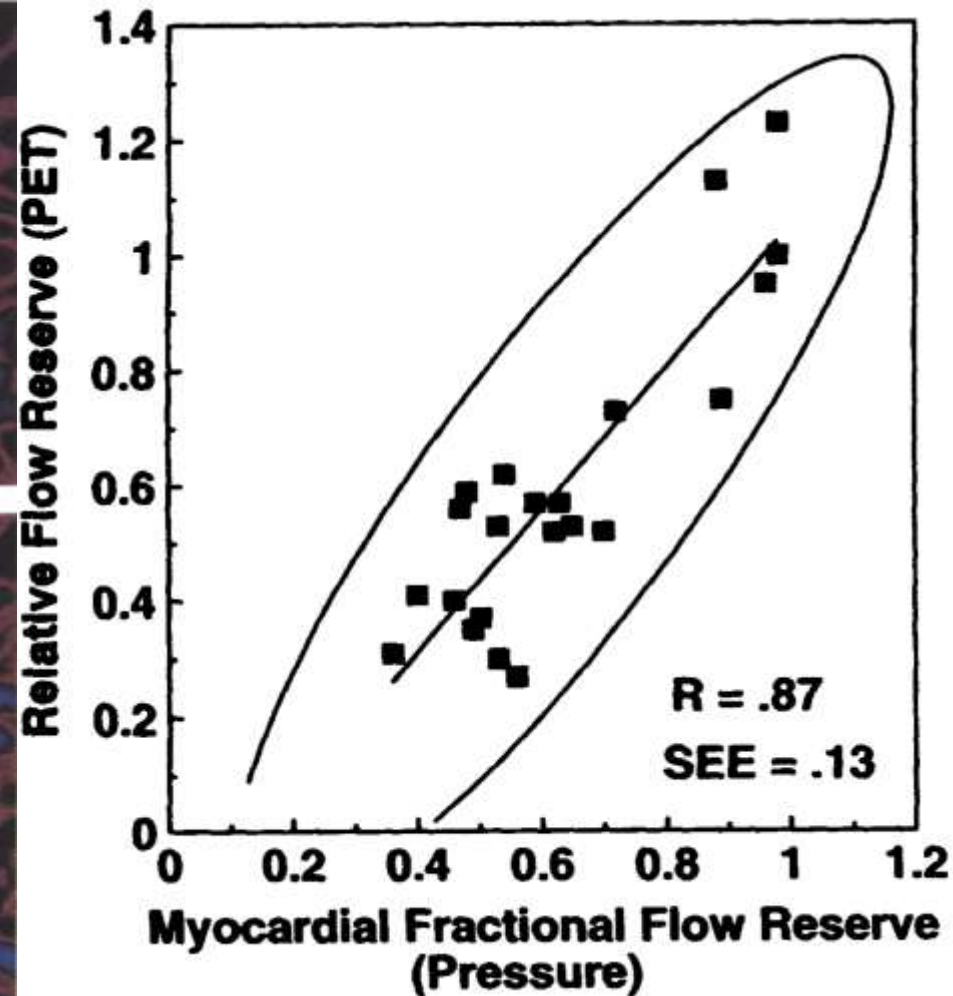
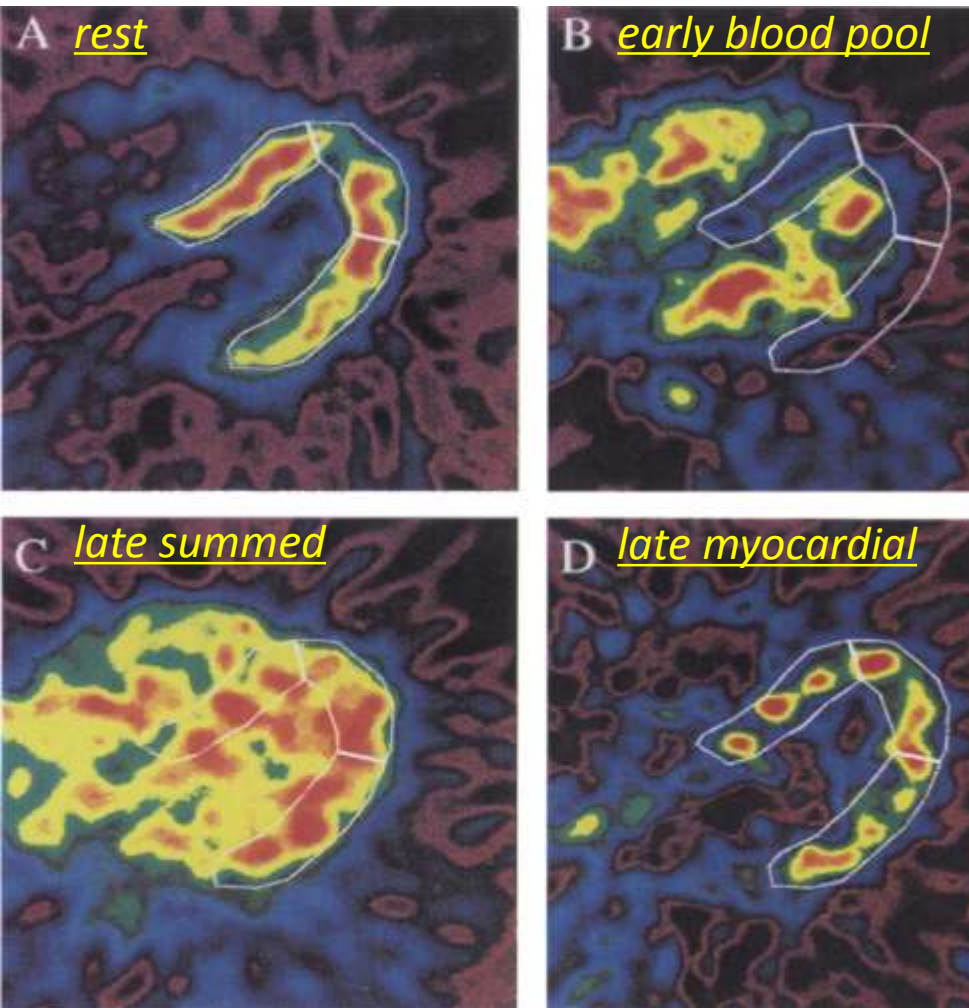
"hot" radiotracer



time-activity curve

cc/min/gm
(myocardial
perfusion)

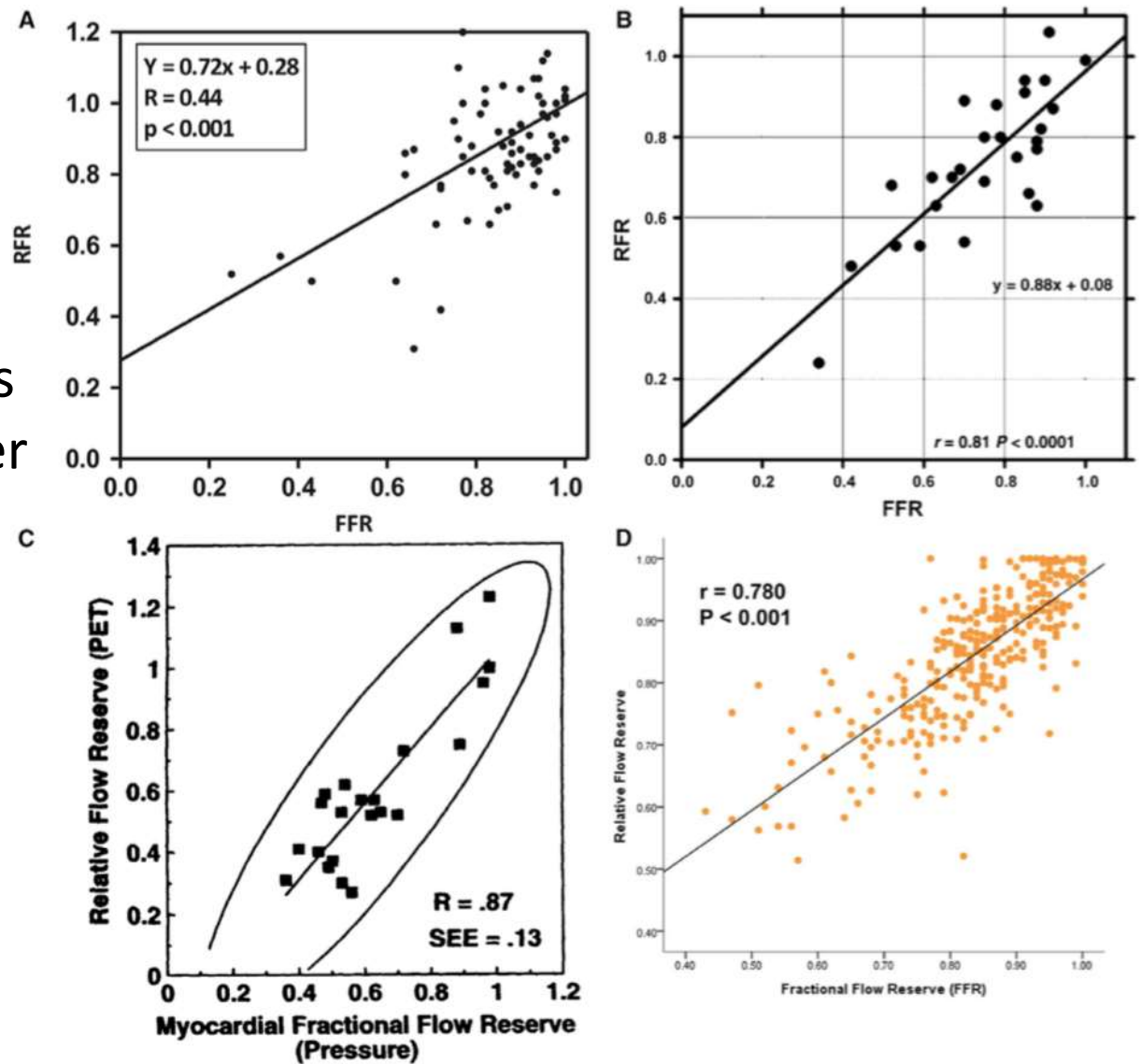
Conceptual link between PET and FFR



CFR by PET vs invasive FFR

FFR \approx relative stress flow by PET

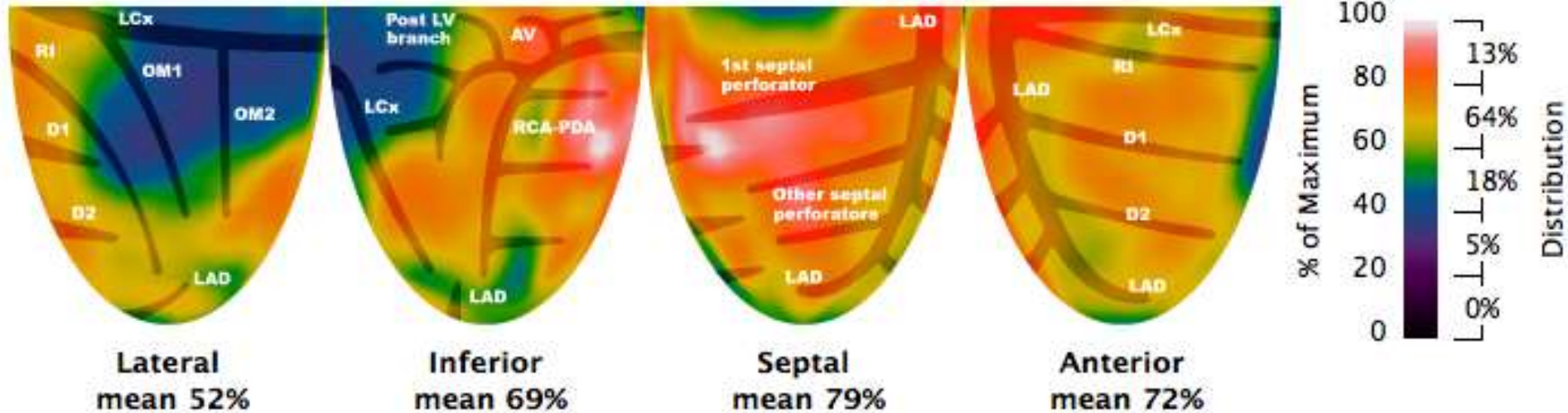
448 lesions
271 subjects
4 papers over
22 years



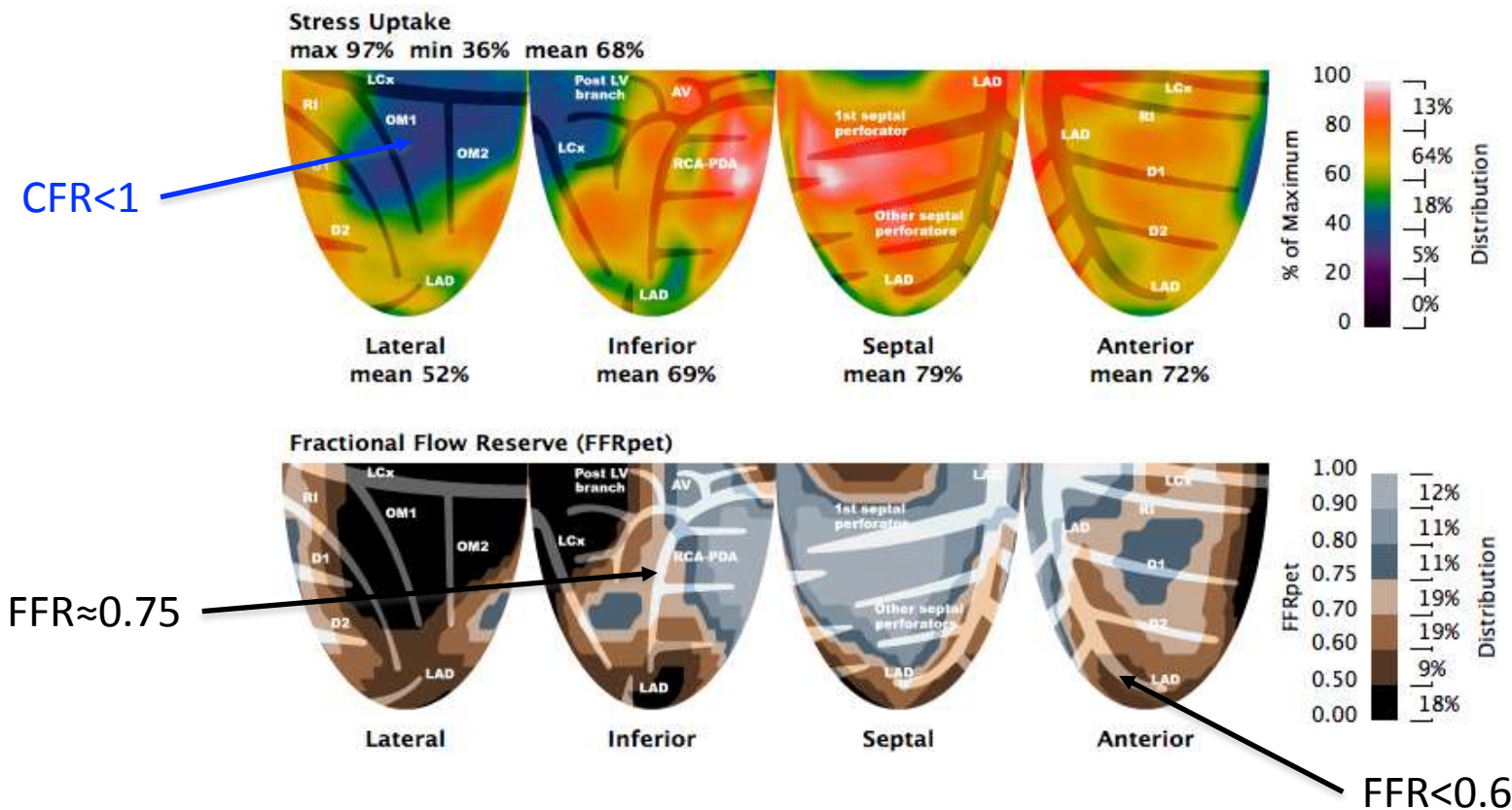
Basic PET with relative uptake

Stress Uptake

max 97% min 36% mean 68%

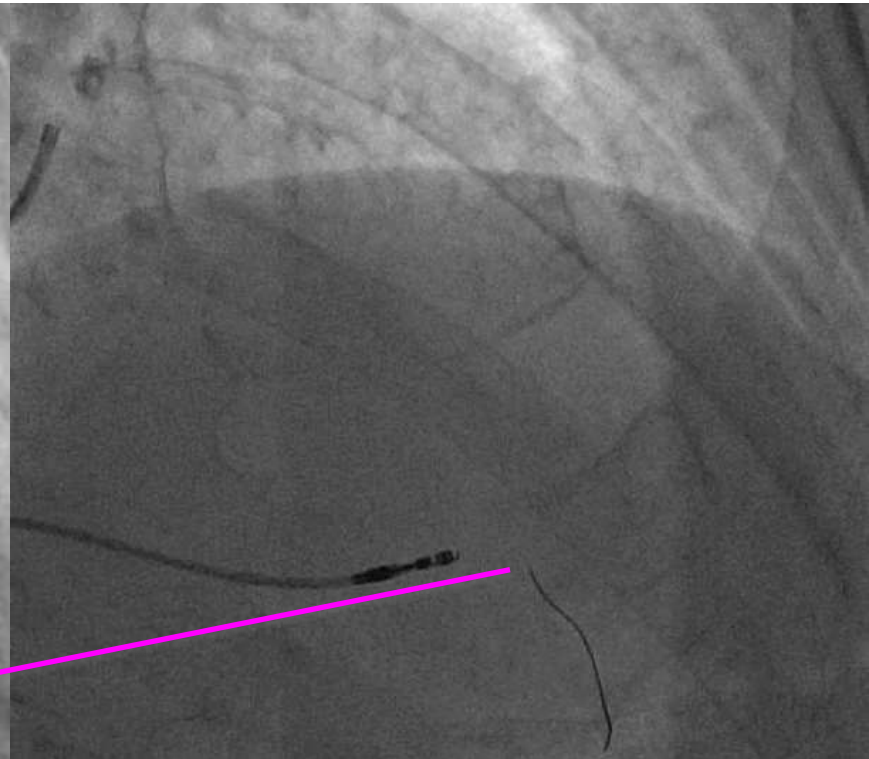
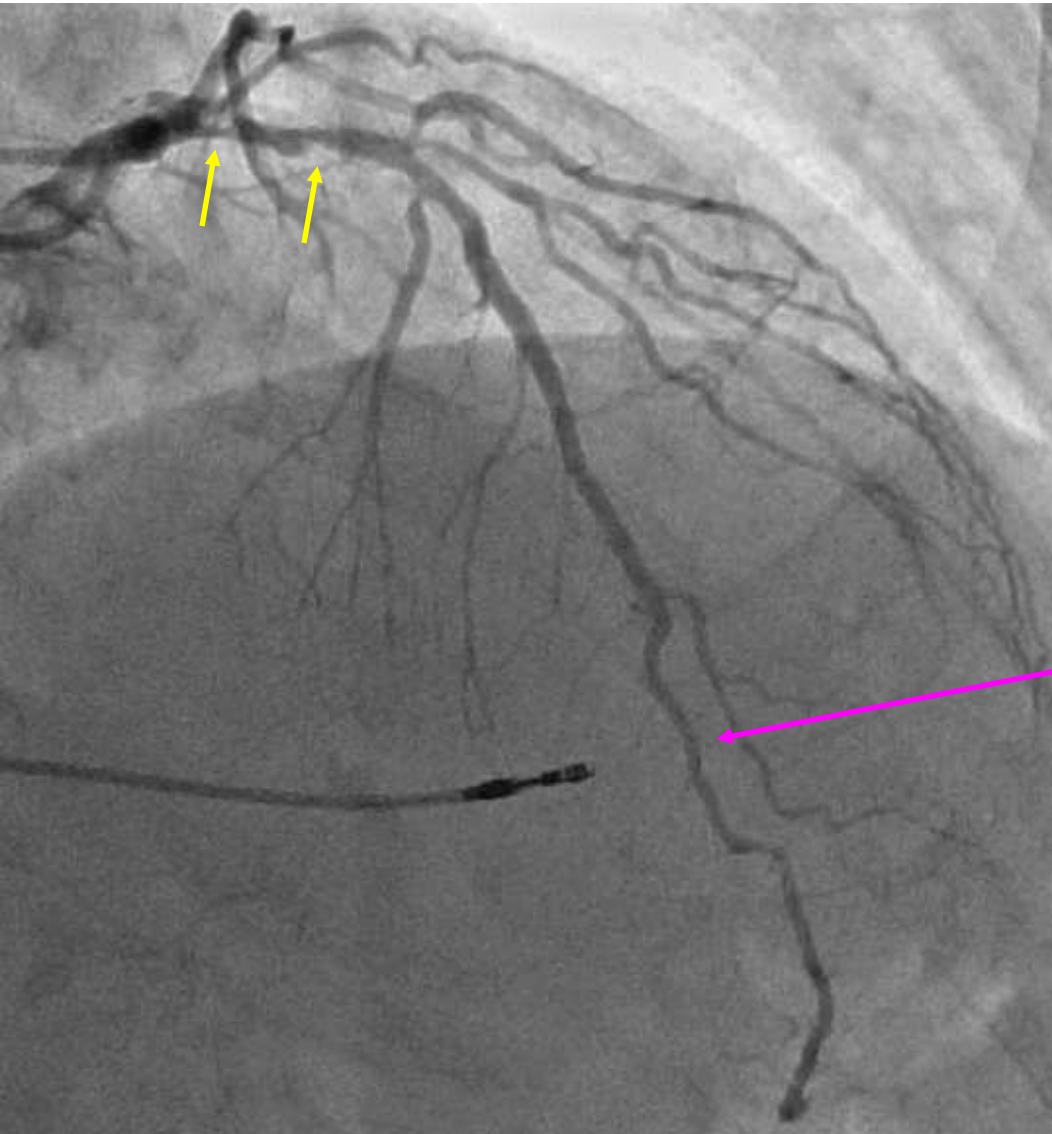


PET flow ≈ “physiologic angiogram”



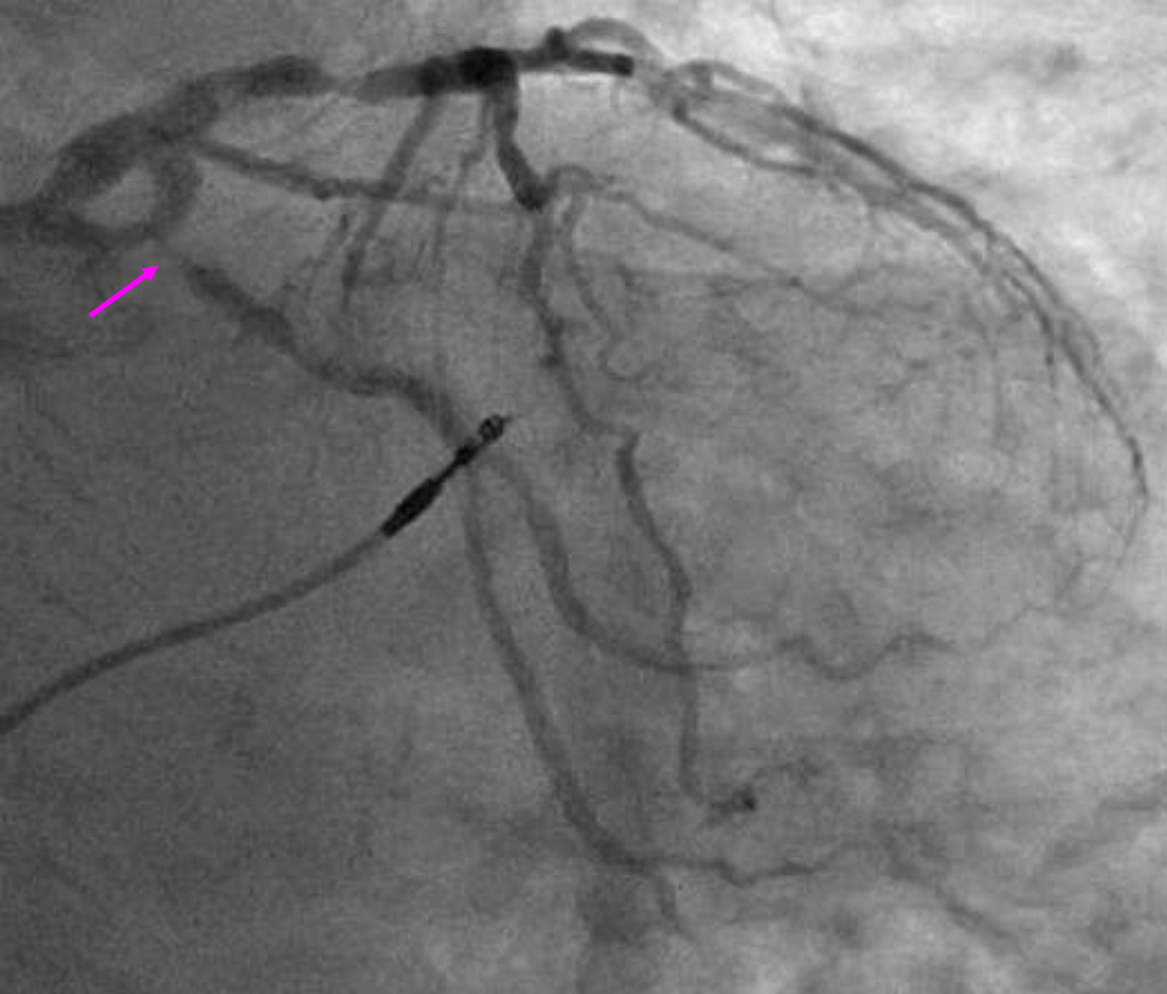
- Functional total occlusion of the proximal LCx
- Diffuse RCA disease, mid FFR ≈ 0.75
- Moderate proximal LAD, distal FFR < 0.6

LAD angiogram and physiology

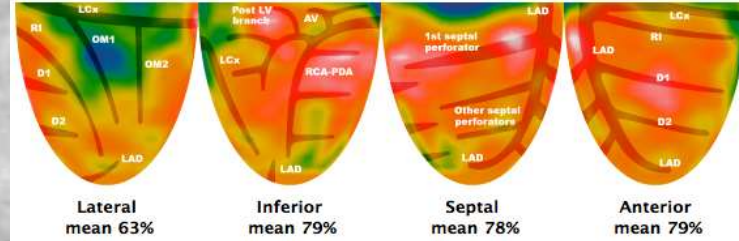


LAD *FFR 0.54* with jump over proximal lesion during pullback with IV adenosine

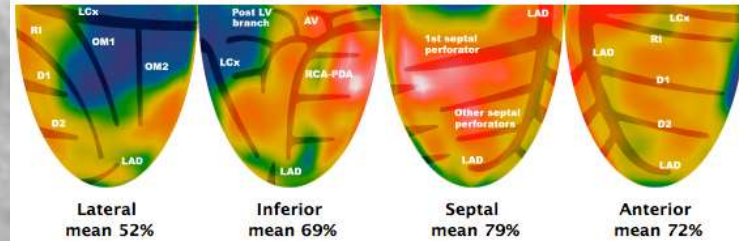
LCx angiogram



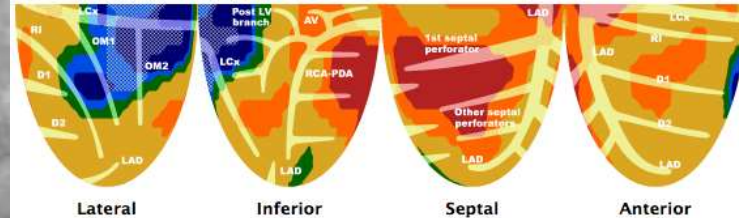
Rest Uptake
max 97% min 42% mean 75%



Stress Uptake
max 97% min 36% mean 68%

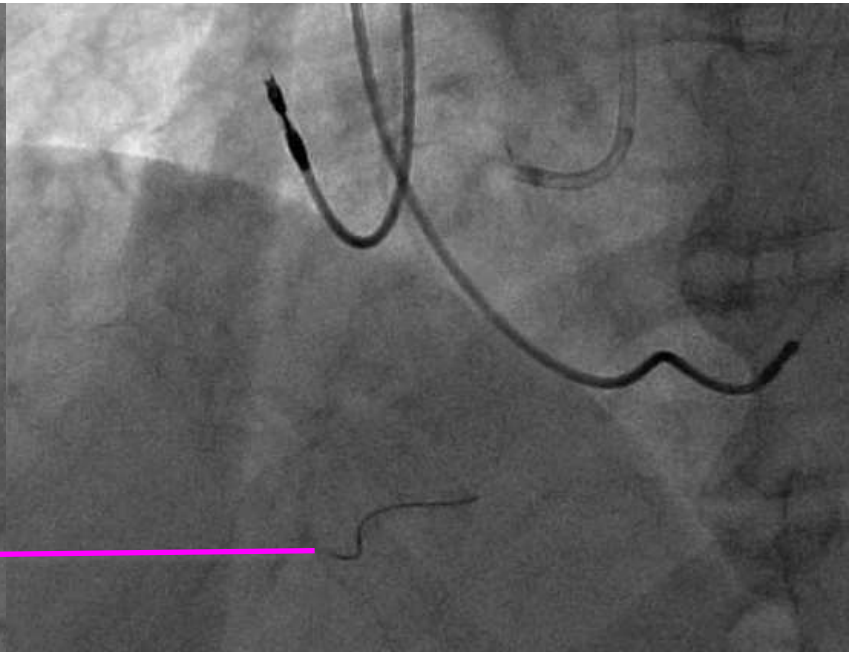
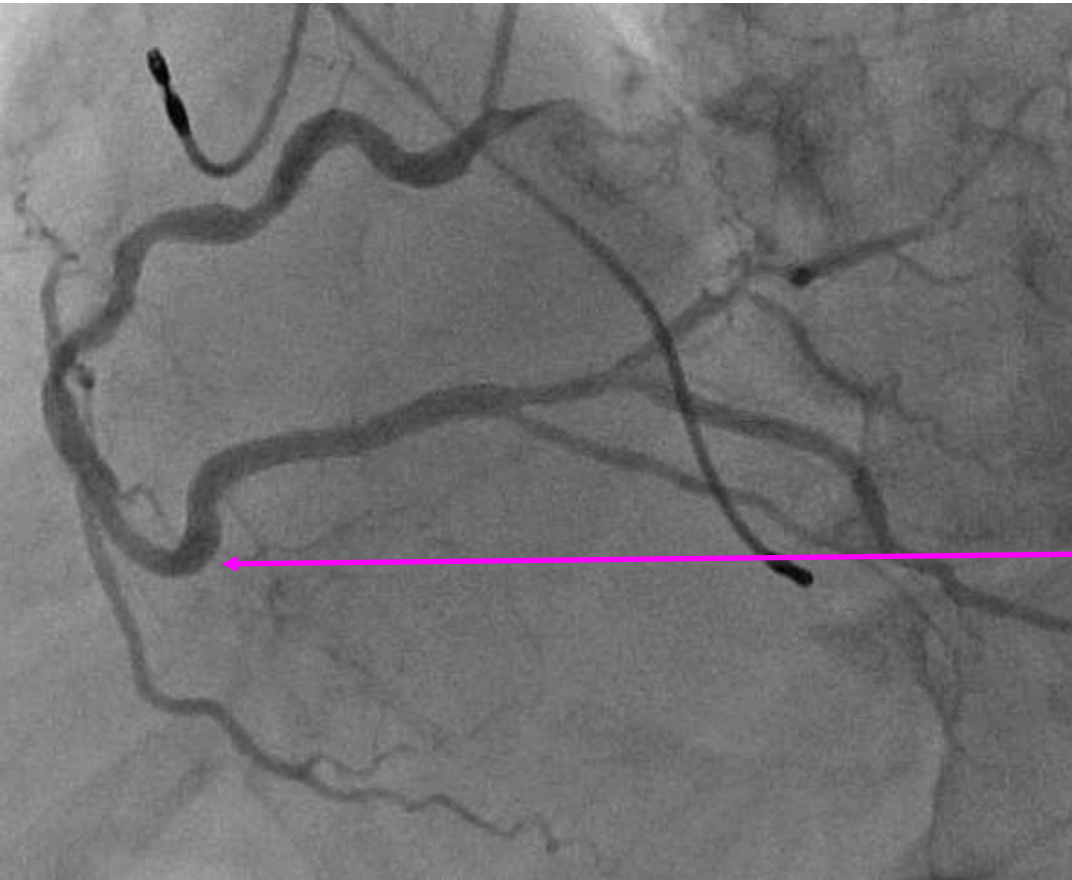


Coronary Flow Capacity Map



LCx with *subtotal lesion*
(no FFR due to severity
and +PET defect)

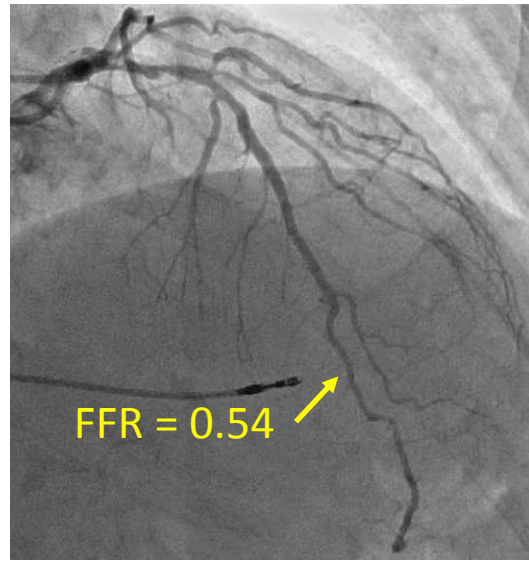
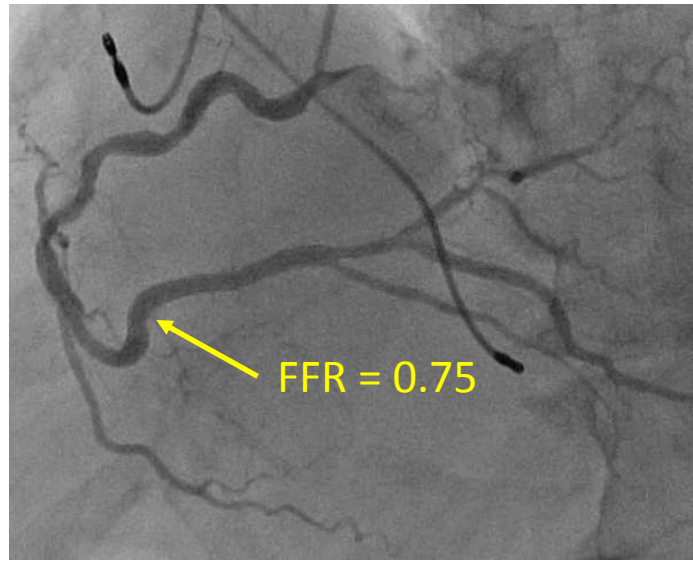
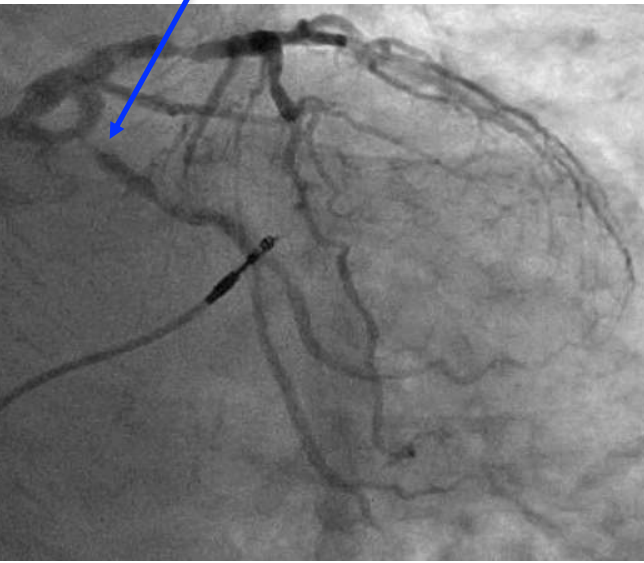
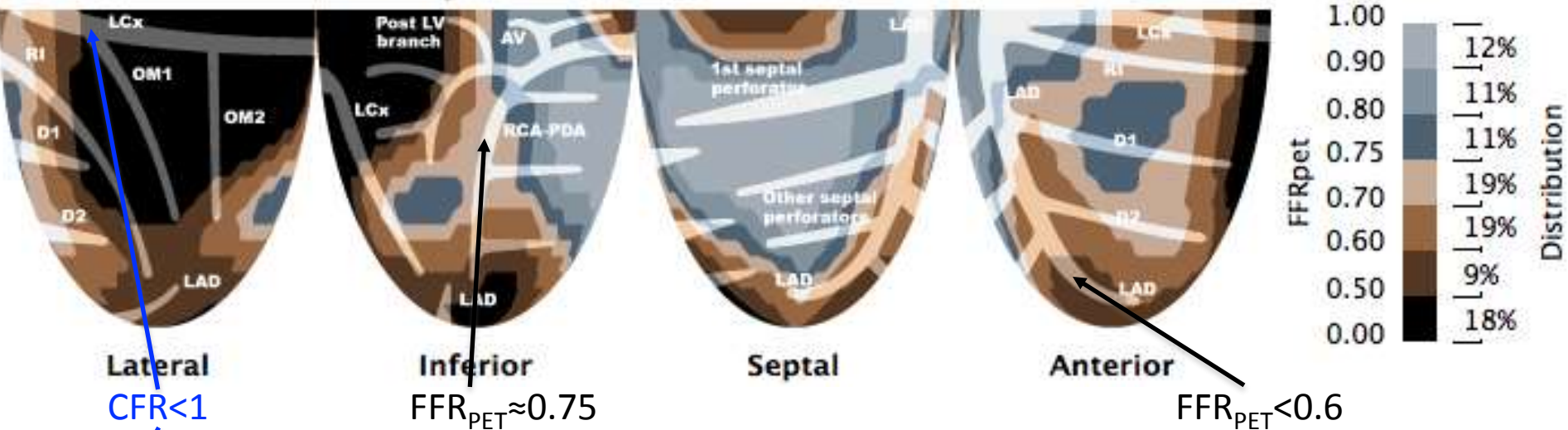
RCA angiogram and physiology



Diffuse RCA disease with
FFR 0.75 in mid segment

PET ≈ “physiologic angiogram”

Fractional Flow Reserve (FFR_{pet})

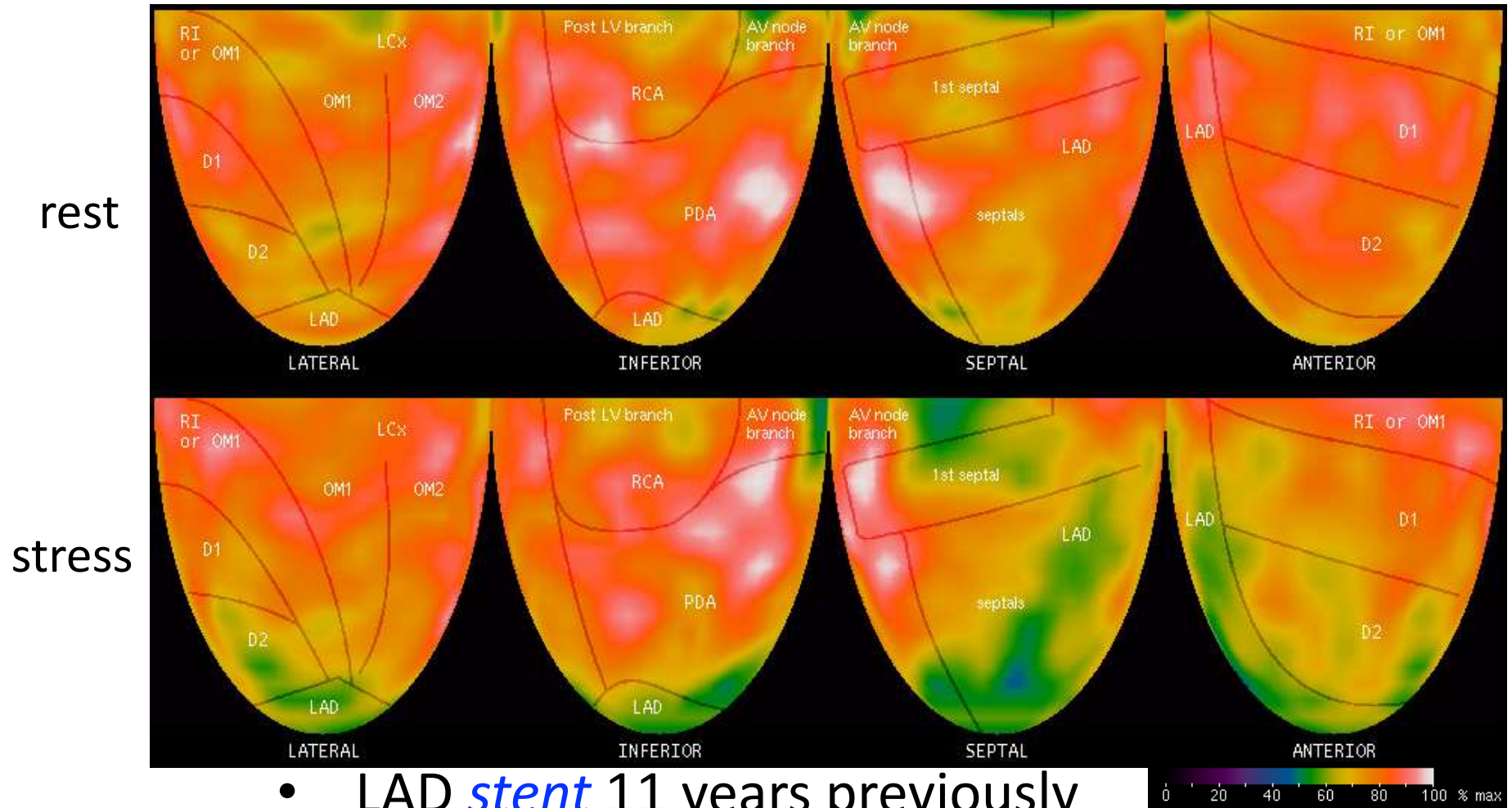


Clinical course

- Underwent CABG
 - LIMA-LAD
 - SVG-OM
 - SVG-PDA
- Last clinic follow-up 15 months after CABG
- No angina, working out 3x/week

Case 1. Asymptomatic, 65 year-old

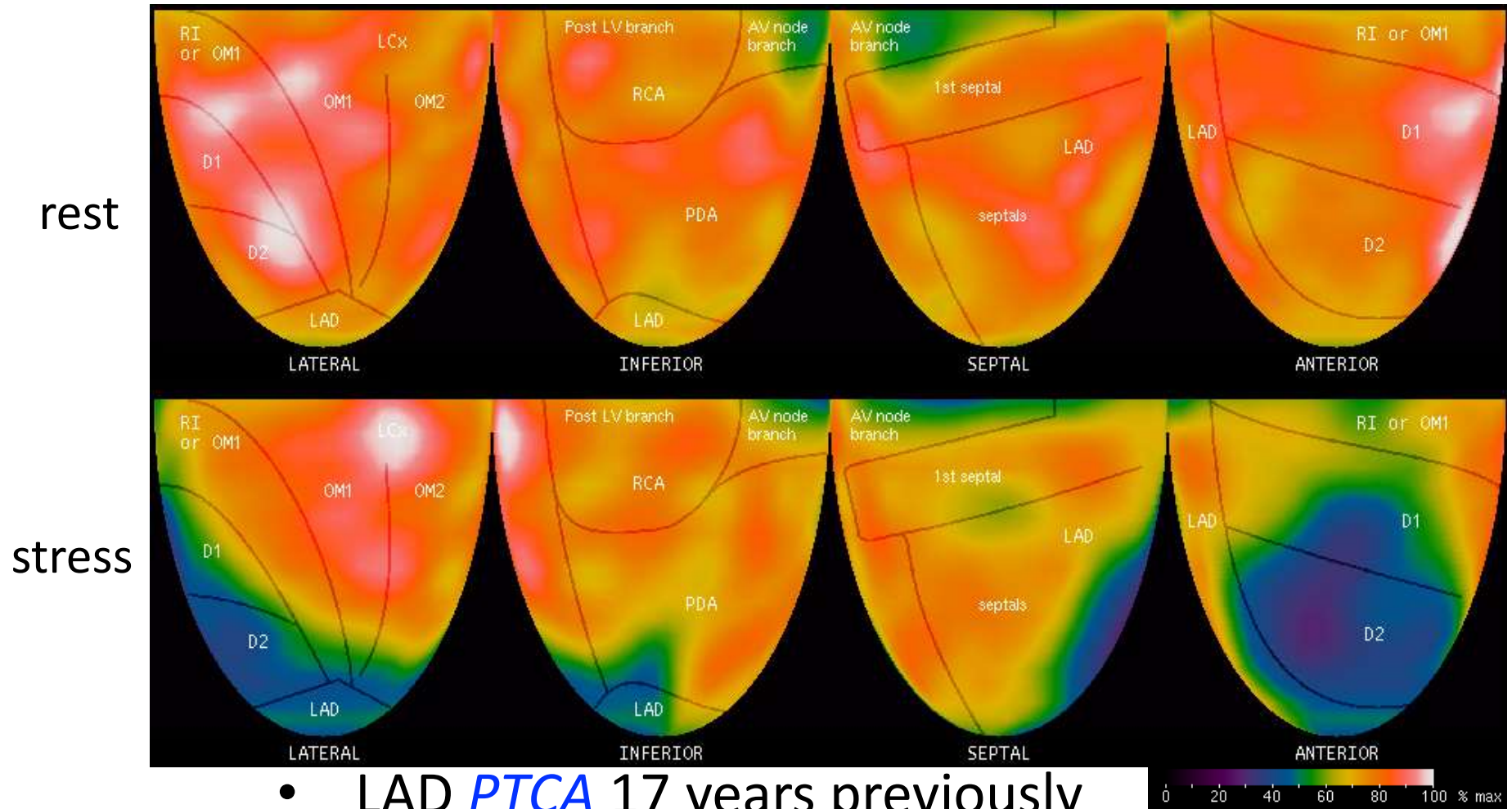
man



- LAD stent 11 years previously
- PET performed for research protocol (no symptoms or changes)

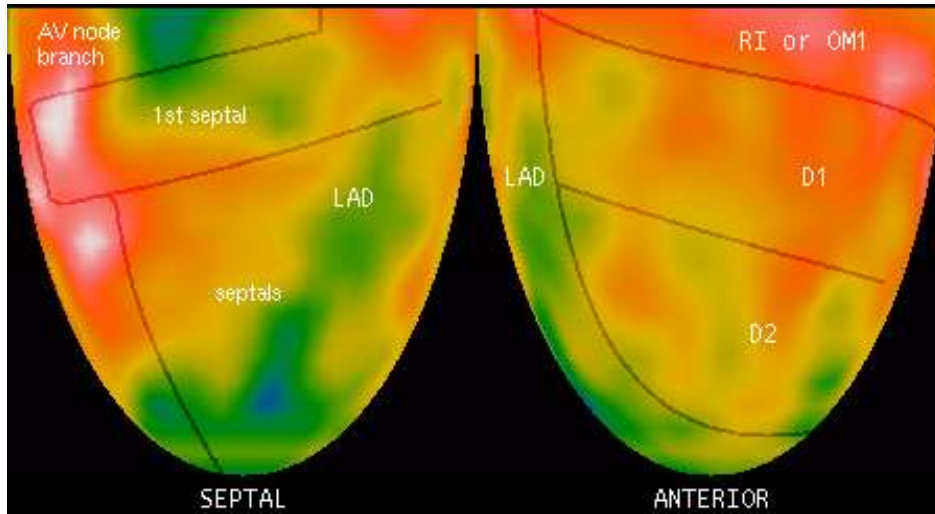
Case 2. Asymptomatic, 63 year-old

man

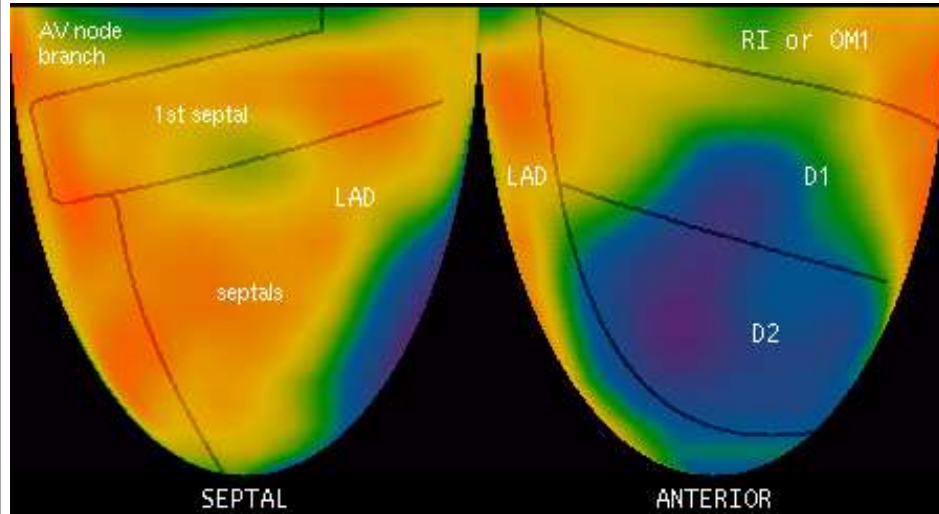


- LAD [PTCA](#) 17 years previously
- PET performed for [research protocol](#) (no symptoms or changes)

Who has the vulnerable plaque?



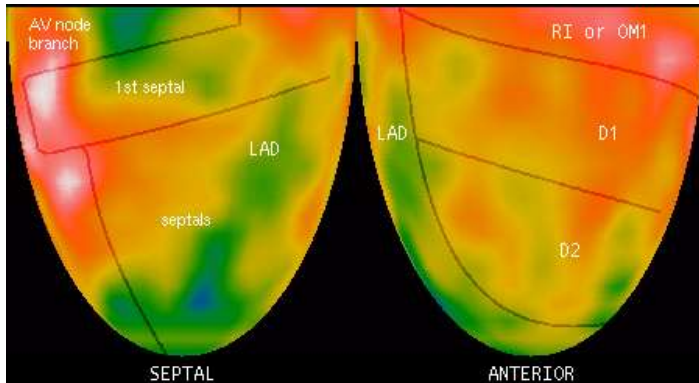
Case 1.



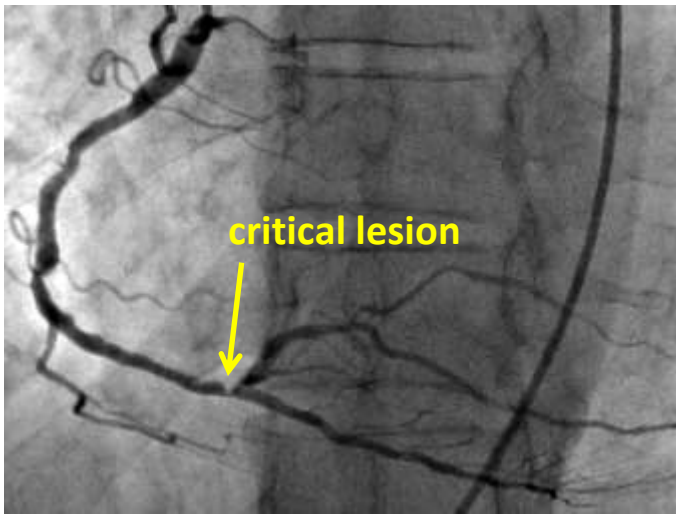
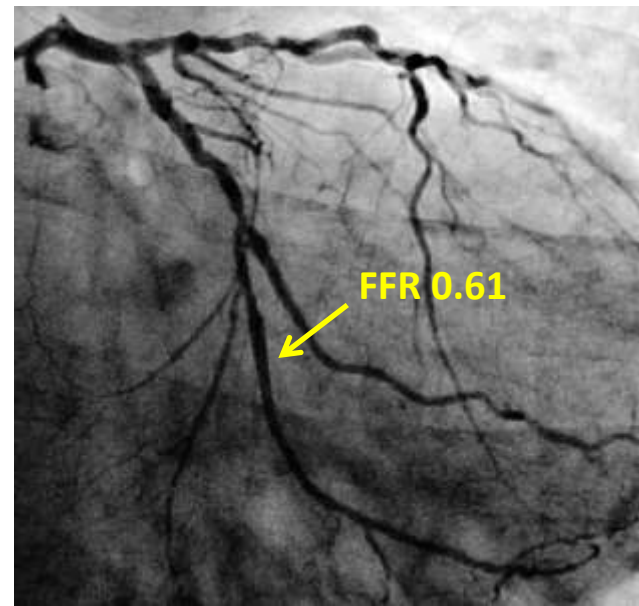
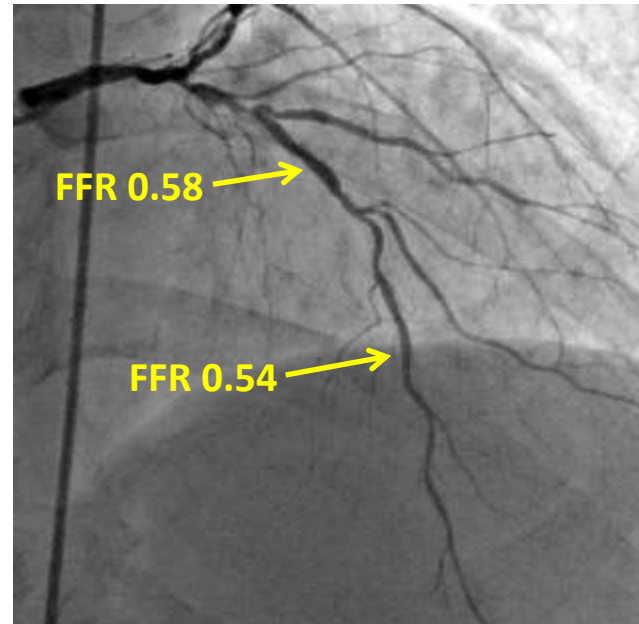
Case 2.

- both men aged ~65 years
- both PCI of LAD >10 years previously
- both asymptomatic and stable

Case 1 had vulnerable plaque

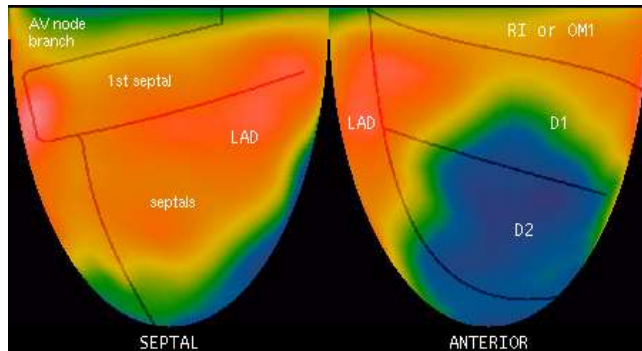


- biked 2 days later
- *cardiac arrest*
- resuscitated
- CABG when recovered

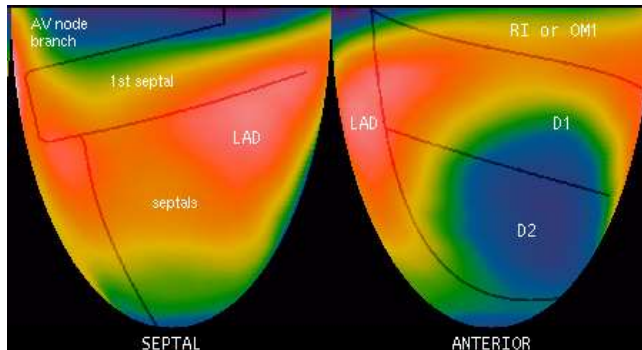


Case 2 had stable plaque

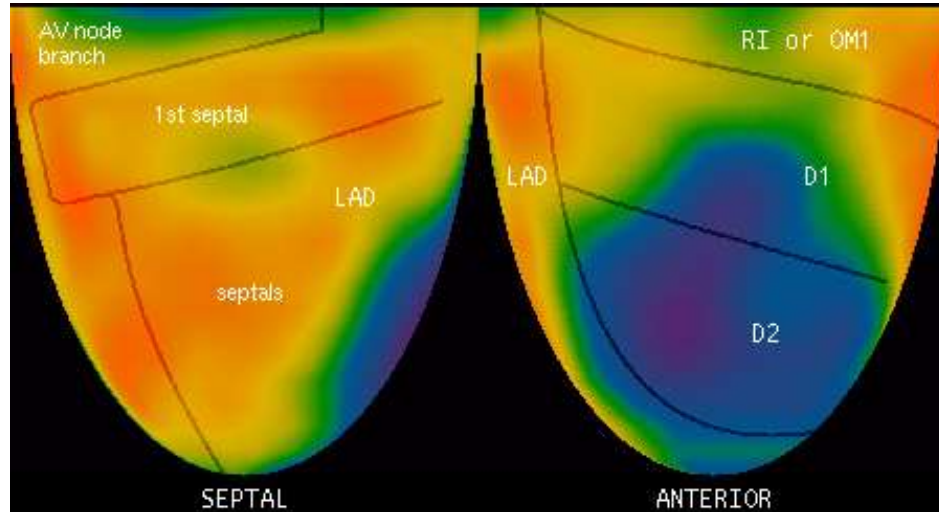
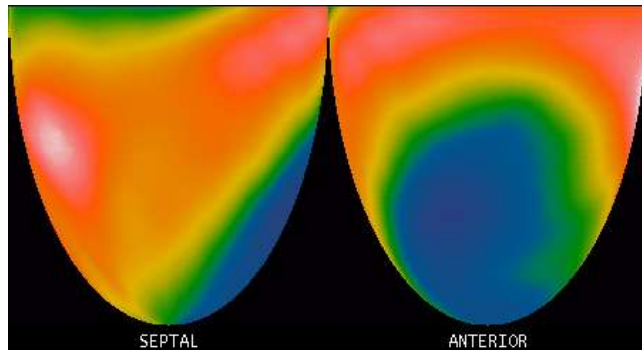
2001



1999



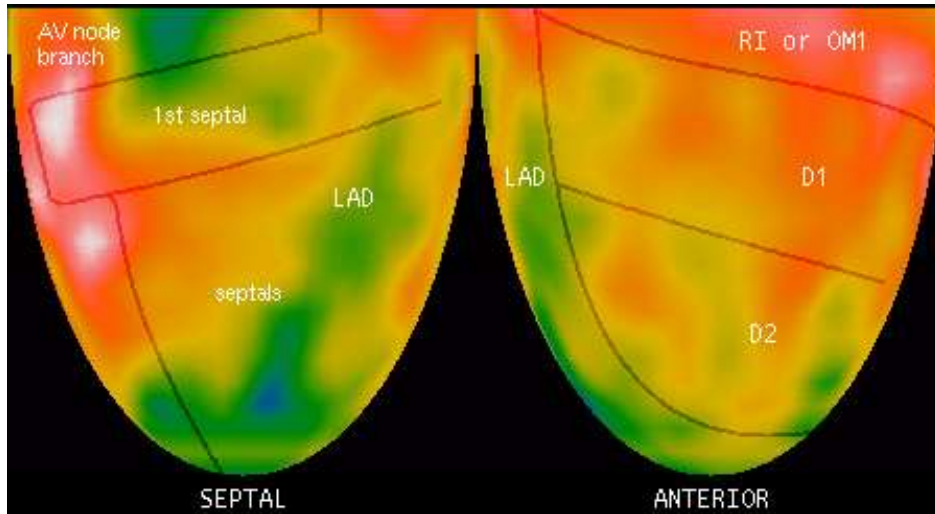
1996



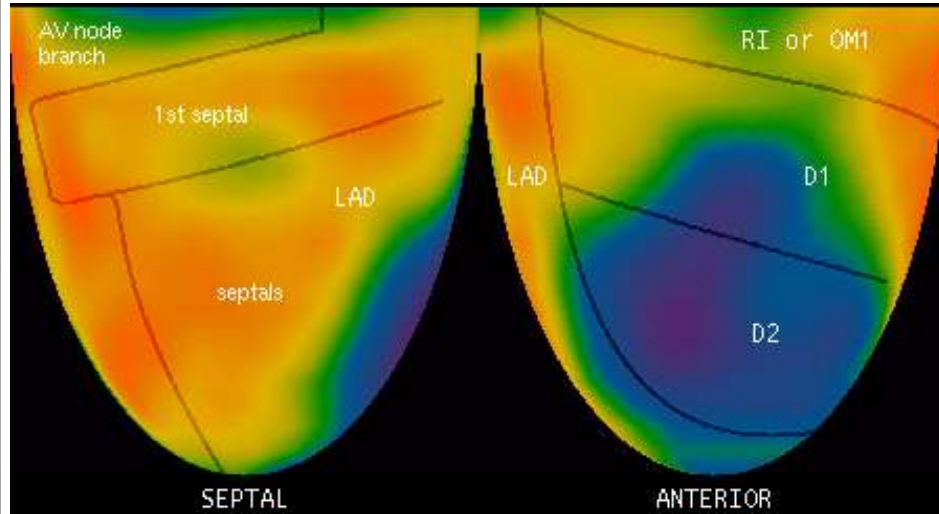
2013

- same PET scan for over 15 years
- caths confirm occluded 2nd diagonal branch

vulnerable versus stable plaque

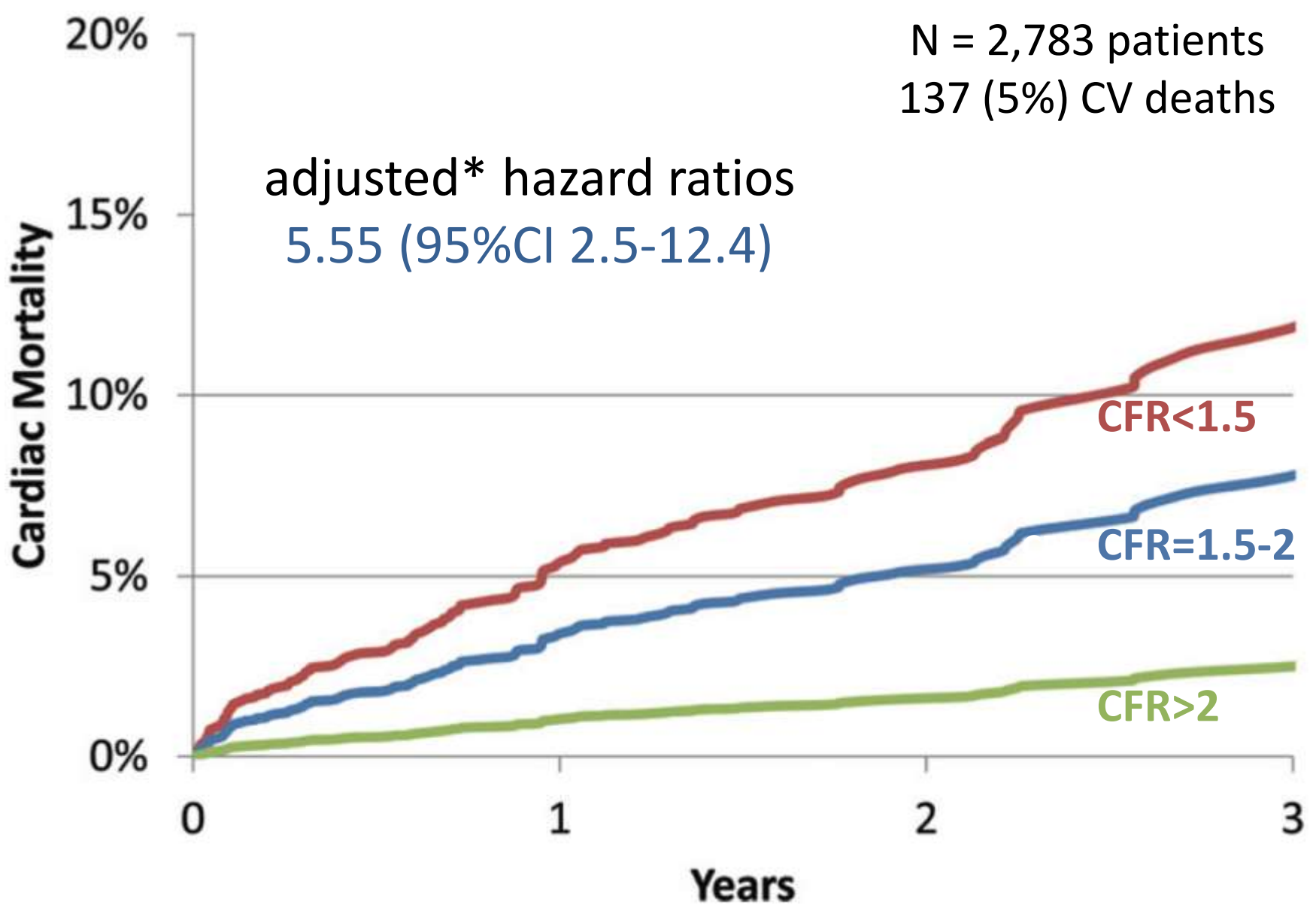


Case 1. VULNERABLE



Case 2. STABLE

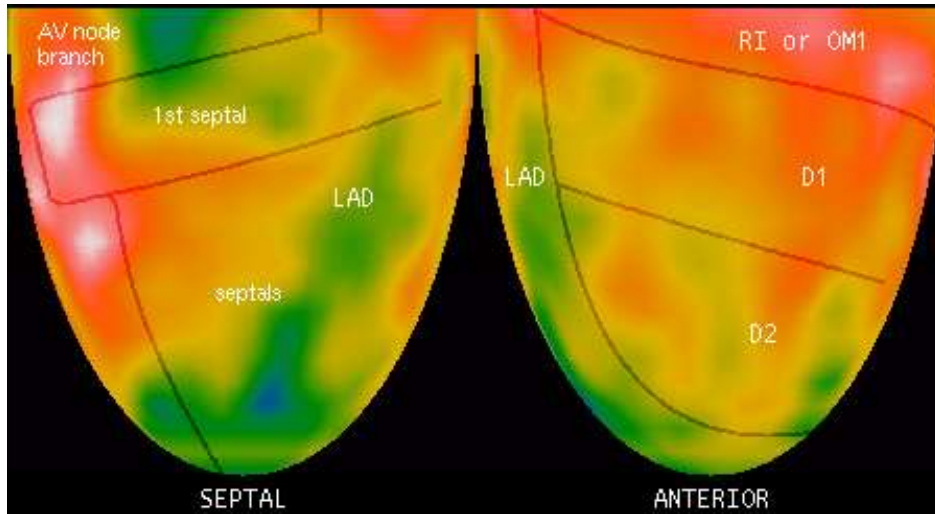
Why is worse relative defect **stable**?



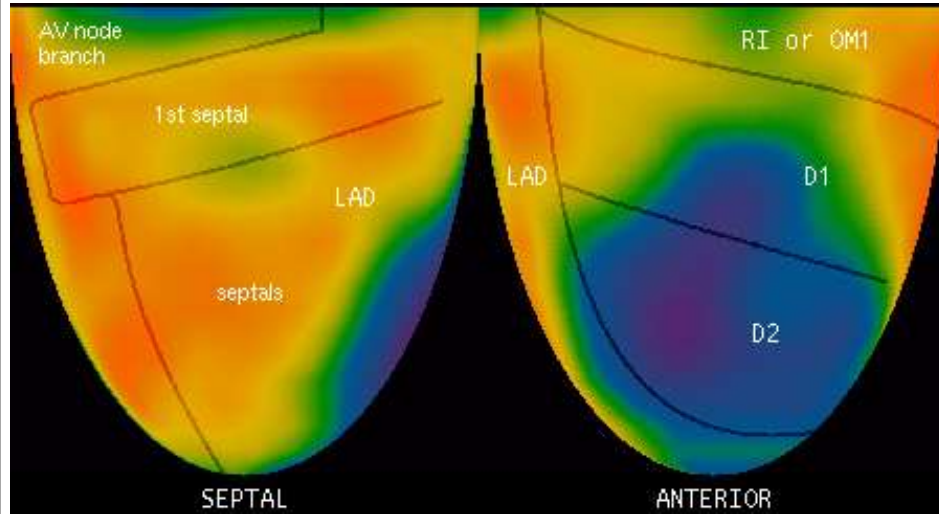
N = 2,783 patients
137 (5%) CV deaths

* = adjusted for age, standard risk factors, known CAD, BMI, symptoms, EF, perfusion

vulnerable versus stable plaque



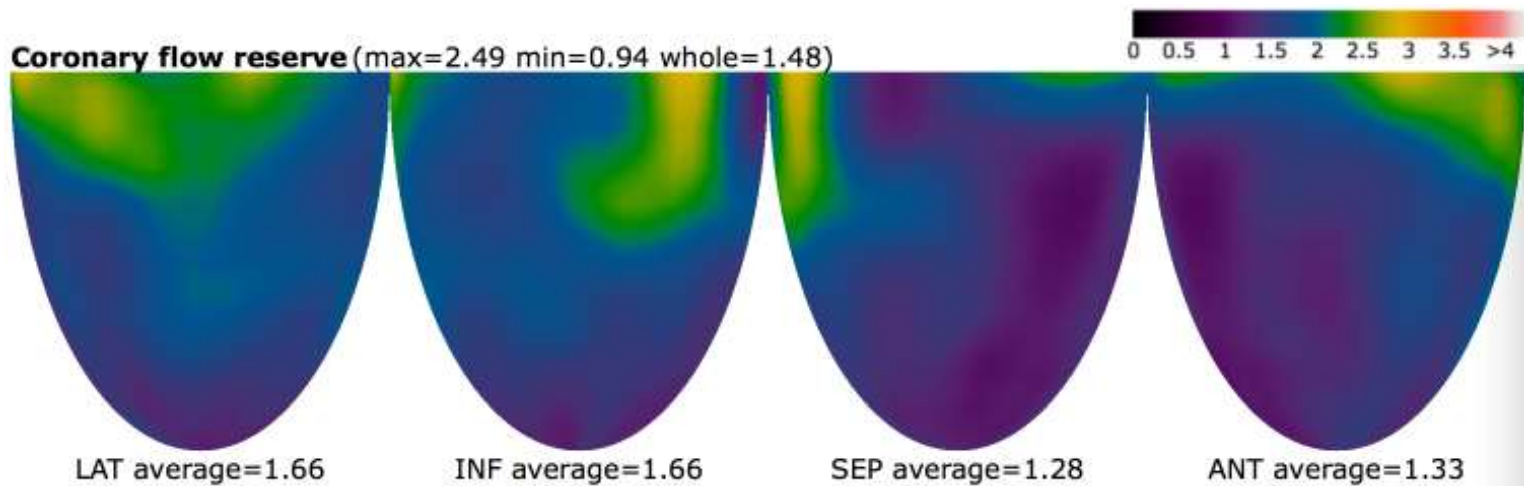
Case 1. VULNERABLE



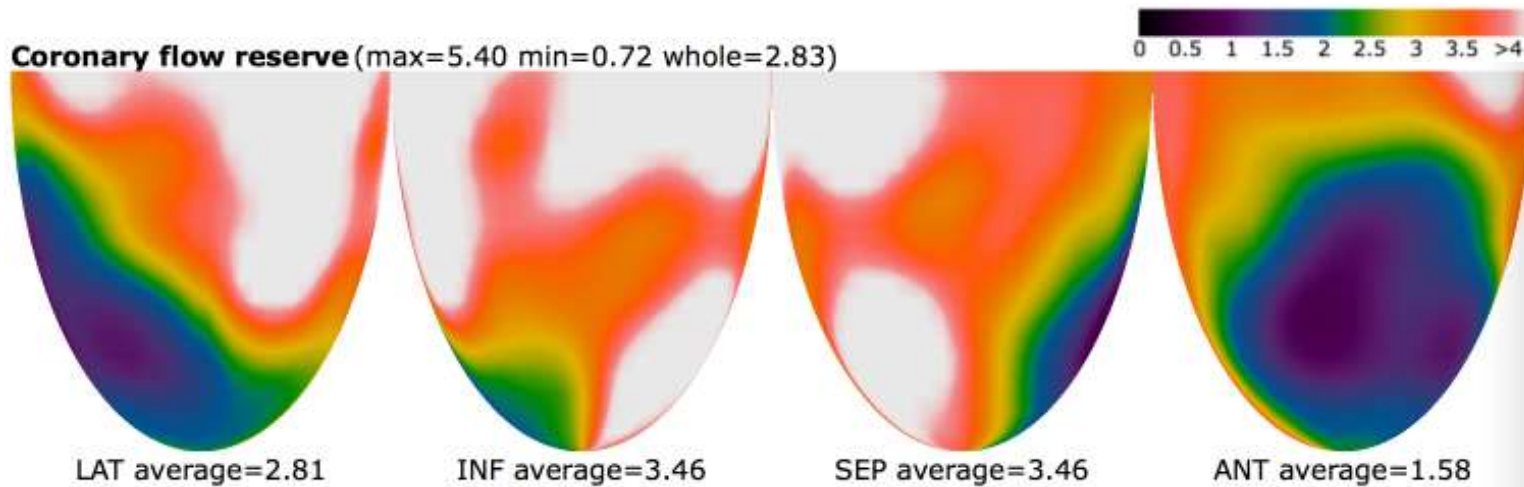
Case 2. STABLE

Why is worse relative defect **stable**?

vulnerable versus stable plaque



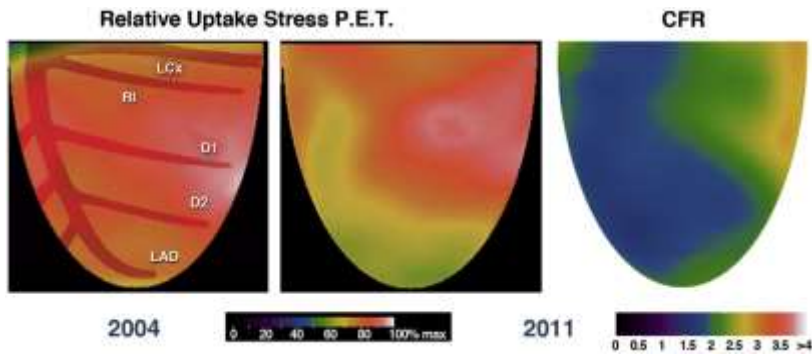
Case 1. VULNERABLE (global CFR = 1.5)



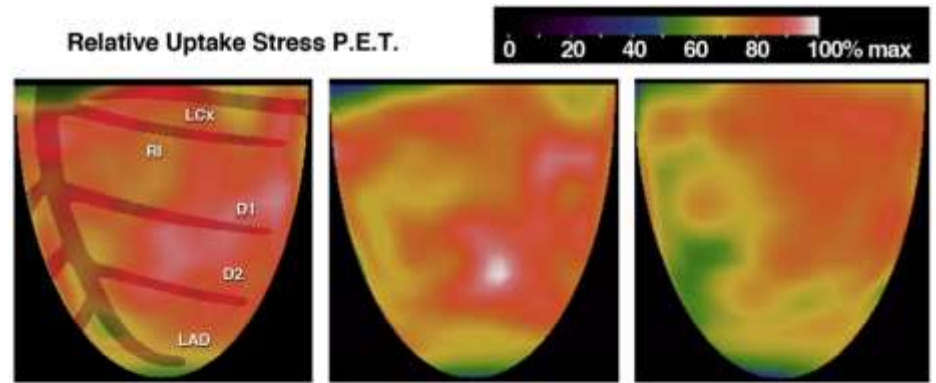
Case 2. STABLE (global CFR = 2.8)

Serial Quantitative Assessment of Absolute Coronary Flow and Flow Reserve With CAD Progression to Events

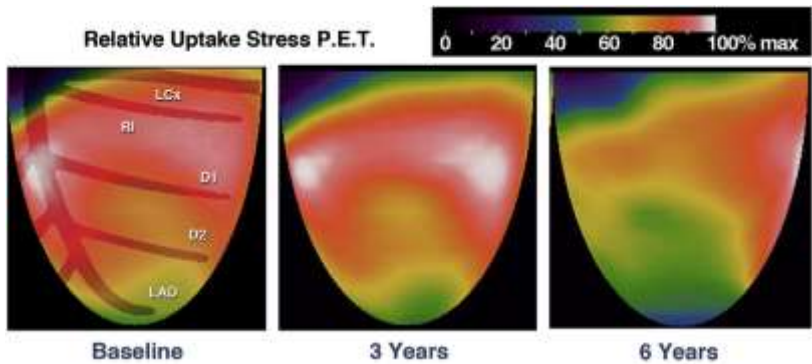
Stefano Sdringola, MD,* Nils P. Johnson, MD, MS,* Jagat Narula, MD, PhD,†
K. Lance Gould, MD*



progression to MI



progression to PCI



progression to VT

What is cause of angina?



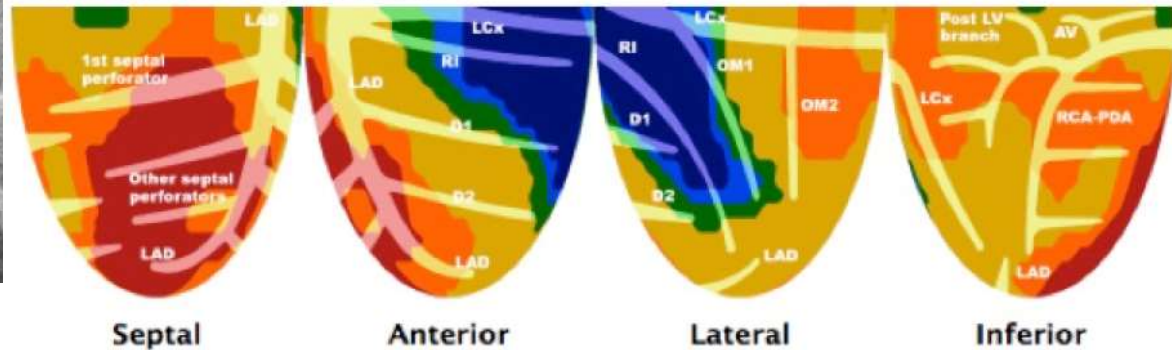
- PCI of LAD
- Residual angina
- Why?

What is cause of angina?



- PCI of LAD
- Residual angina
- Why?

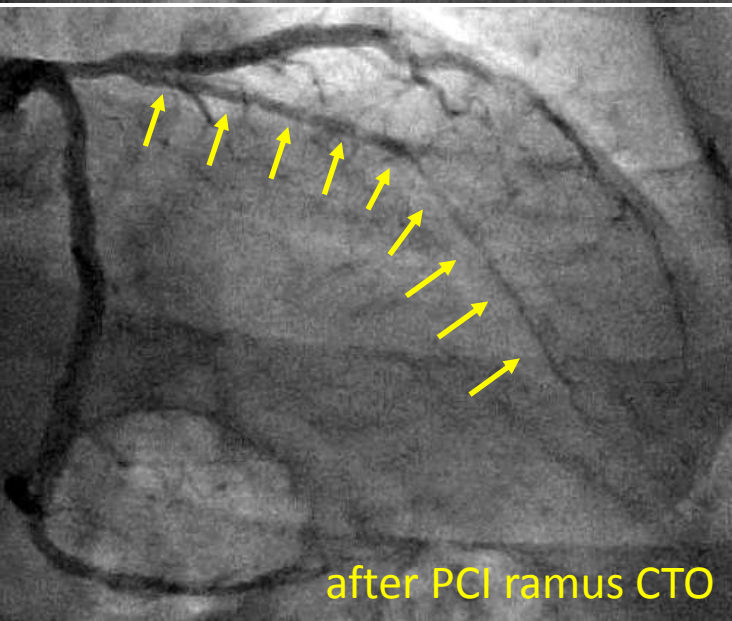
Coronary Flow Capacity Map



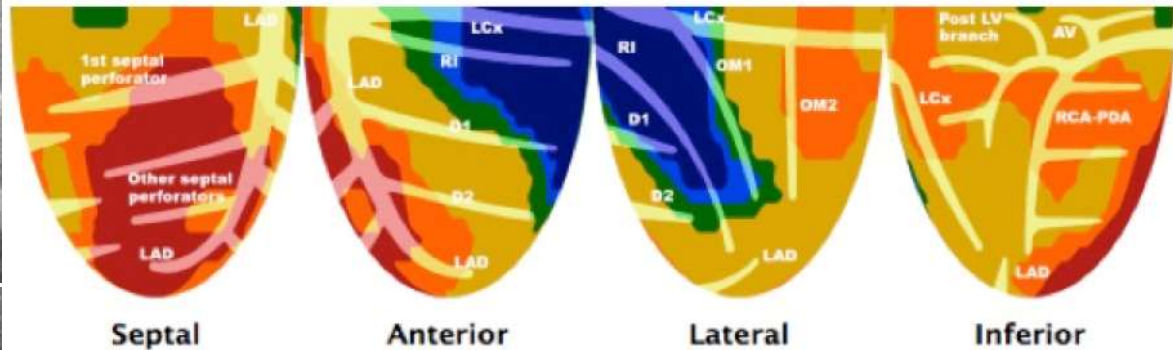
- 17% Normal flow capacity comparable to healthy young volunteers.
- 24% No ischemia. Minimally reduced flow capacity.
- 40% No ischemia. Mildly reduced flow capacity.
- 6% Moderately reduced, sometimes angina or STΔ with dipyridamole stress.
- 12% Severely reduced, usually angina and STΔ with dipyridamole stress (single contiguous region).
- (10% Myocardial steal)

What is cause of angina?

- PCI of LAD
- Residual angina
- Why?

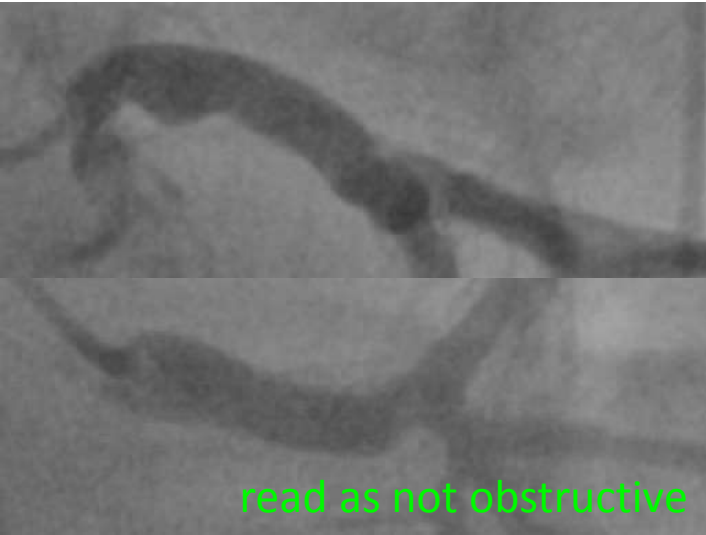


Coronary Flow Capacity Map



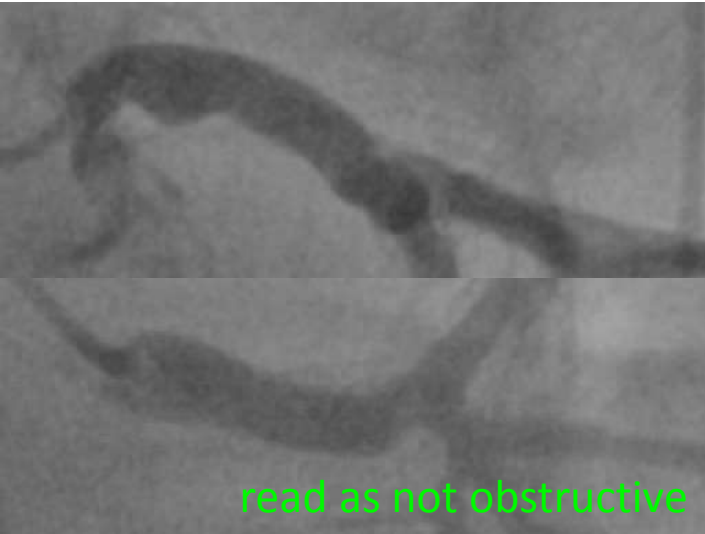
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What is cause of angina?

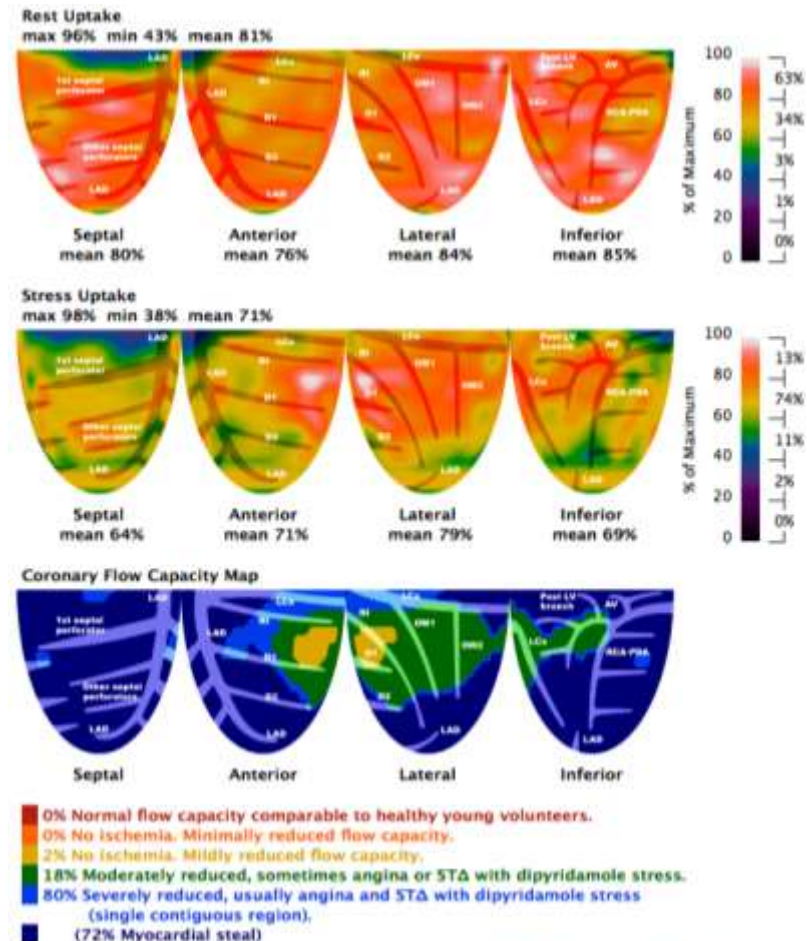


- Non-obstructive LM by cath
- Residual angina
- Why?

What is cause of angina?

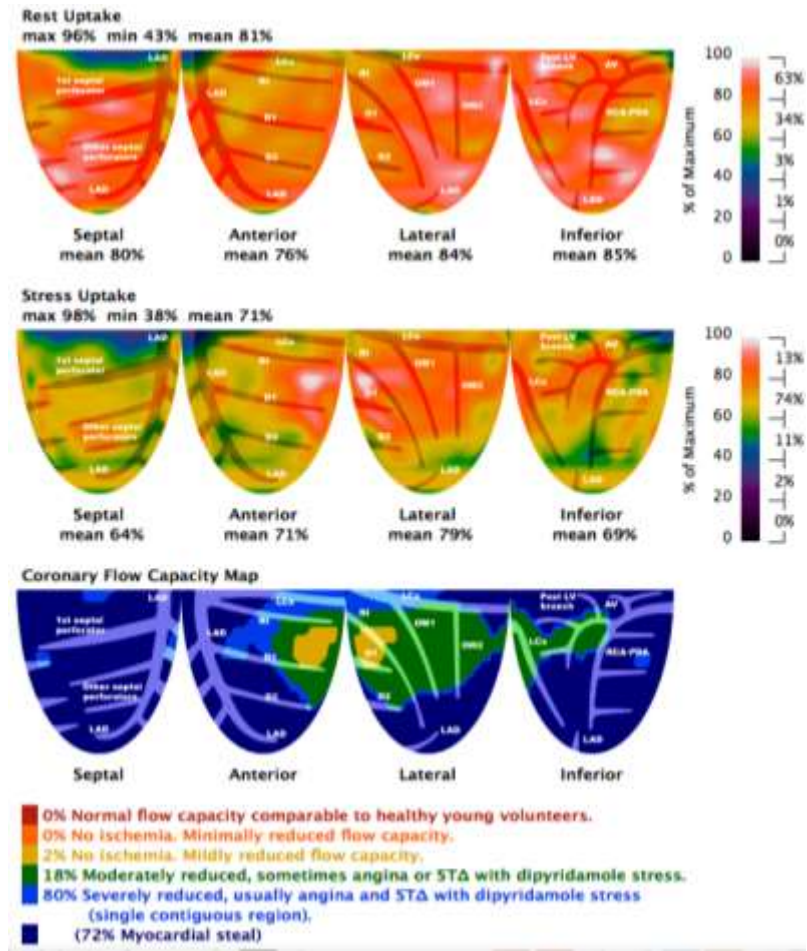
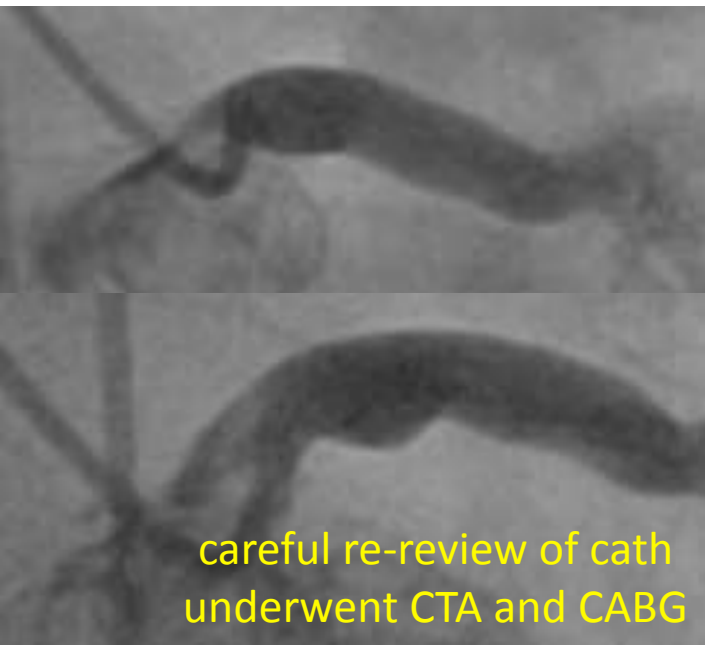
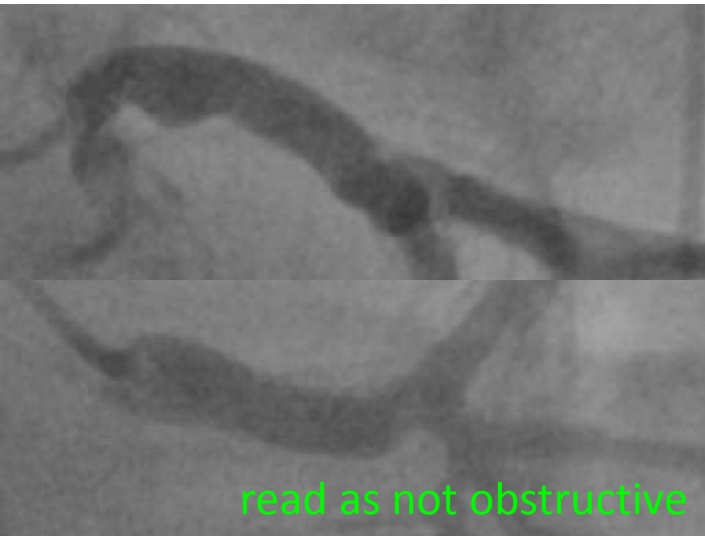


- Non-obstructive LM by cath
- Residual angina
- Why?



What is cause of angina?

- Non-obstructive LM by cath
- Residual angina
- Why?



Noninvasive Flow Reserve to Guide and Verify Percutaneous Coronary Intervention

Colin M. Barker, MD,* Nils P. Johnson, MD, MS,*† Stefano Sdringola, MD,*†
K. Lance Gould, MD*†

Houston, Texas

