SPECT or PET for Planning of Coronary Intervention

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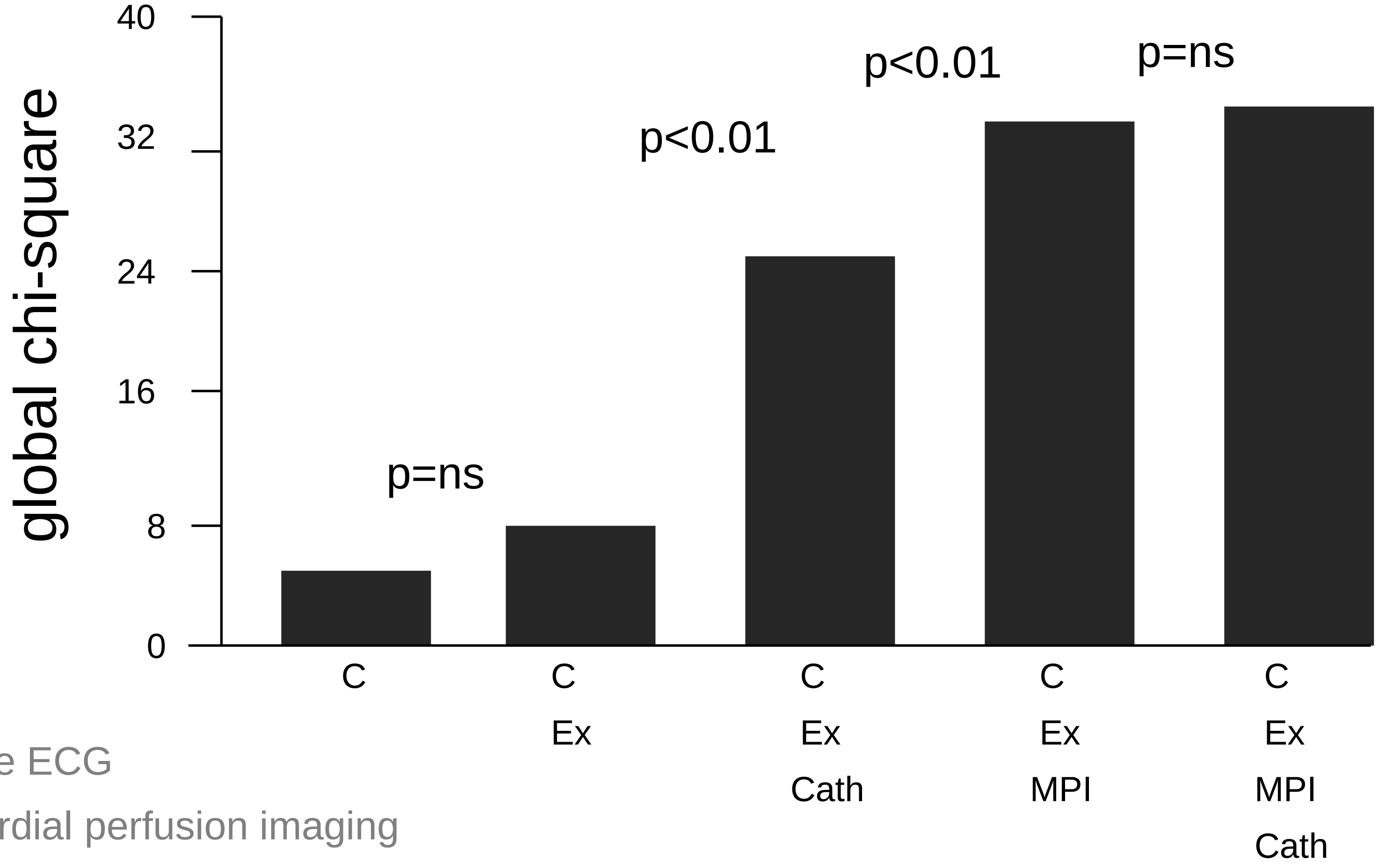
Incremental Prognostication in Patients with Ischemic Heart Disease

Iskandrian et al. JACC 1993

Medically treated 316 pts

35 hard events



C: clinical

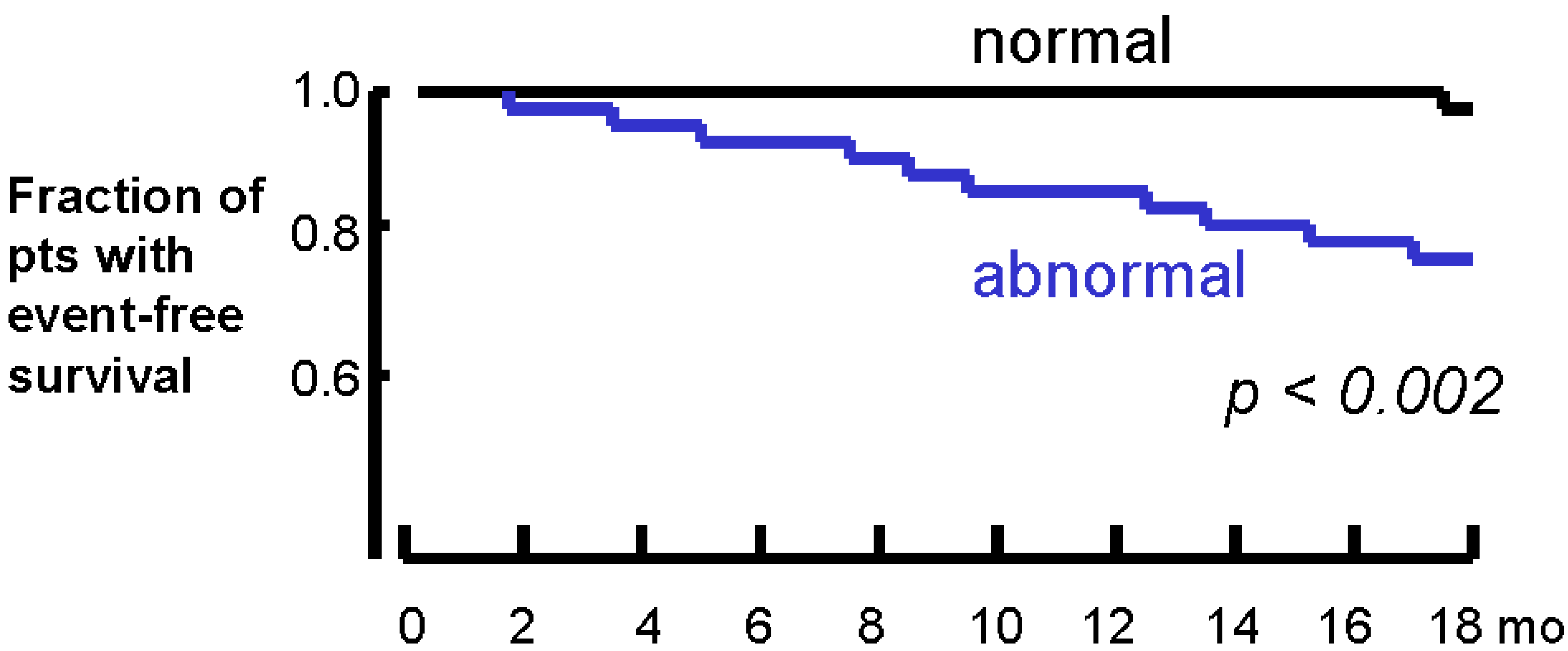
Ex: exercise ECG

MPI: myocardial perfusion imaging

Normal vs. Abnormal myocardial perfusion imaging

(Stratmann HG, et al. Circulation 1994; 89:615-22)

myocardial perfusion imaging	annual event rate
normal	0.5 %/yr
abnormal	7 %/yr



- **Normal myocardial perfusion imaging**
  - Low risk of future cardiac events
  - Benign prognosis, even in strongly positive exercise ECG or angiographycally significant CAD

Iskanderian JACC 1998:32:57-62

MPS in known CAD

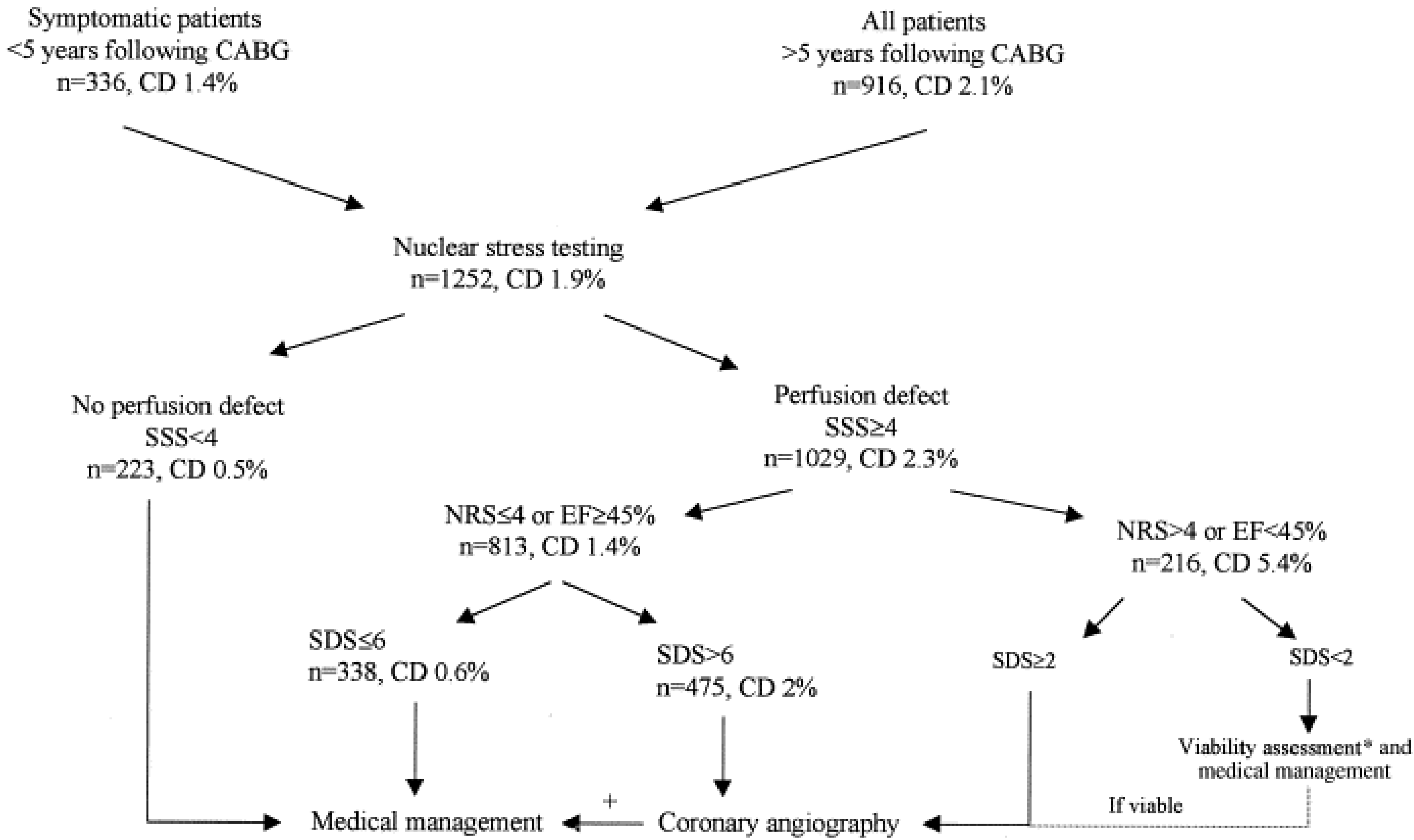
- Myocardial perfusion imaging
  - Distinguish High risk from low risk patients
  - For management of patients with known coronary disease
- Normal MPS
  - Low risk of future cardiac events
  - Benign prognosis even in strongly positive exercise ECGs or angiographically significant coronary artery disease
- Extent and severity of ischemic zone in MPS
  - Quantify the magnitude of myocardium at risk

MPS and revascularization procedures

- Prior to revascularization procedures
  - Useful in documenting ischemia and determining the functional impact of single or multiple lesions identified subsequently
  - Identifying the lesion responsible for the ischemic symptoms (culprit lesion)
  - Prognosis of intermediate lesions
    - Determined by the extent and severity of reversible ischemia
  - Excellent prognostic marker
    - Low annual event rate in case of absence of reversible ischemia in known CAD

MPS and revascularization procedures

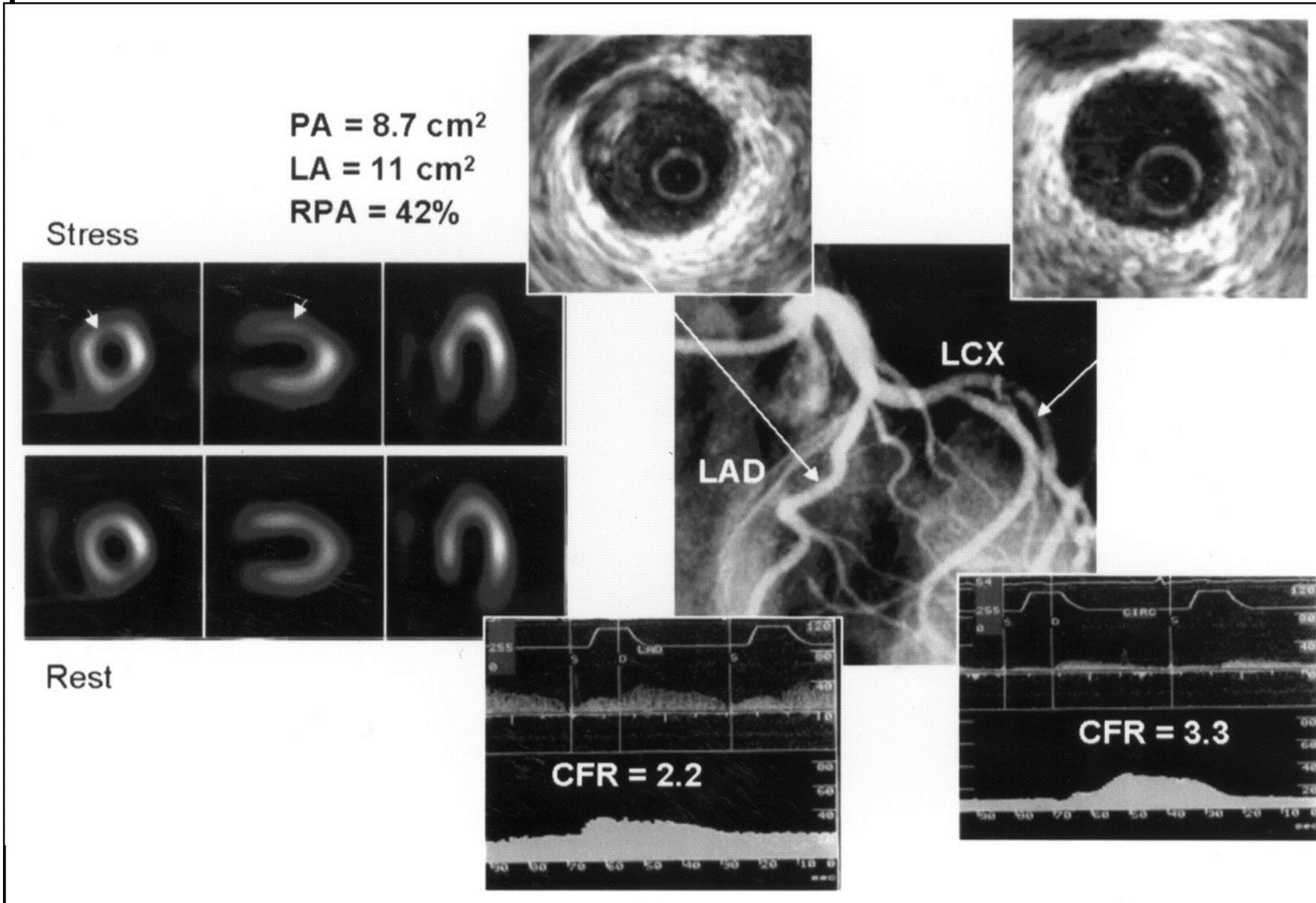
- **After CABG**
  - **Assessment of selected symptoms-free patients**
    - **Abnormal ECG response to exercise**
    - **Resting ECG changes**
  - **Effective method for risk stratification**
    - **late post-CABG(>5 years), irrespective of symptoms**



Outcomes (annual cardiac death rates) with optimized nuclear strategy

Zellweger MJ, et al. J Am Coll Cardiol. 2001;37:144-52

56-y-old woman with chest pain on exercise and reversible perfusion defect of anterior left ventricular wall

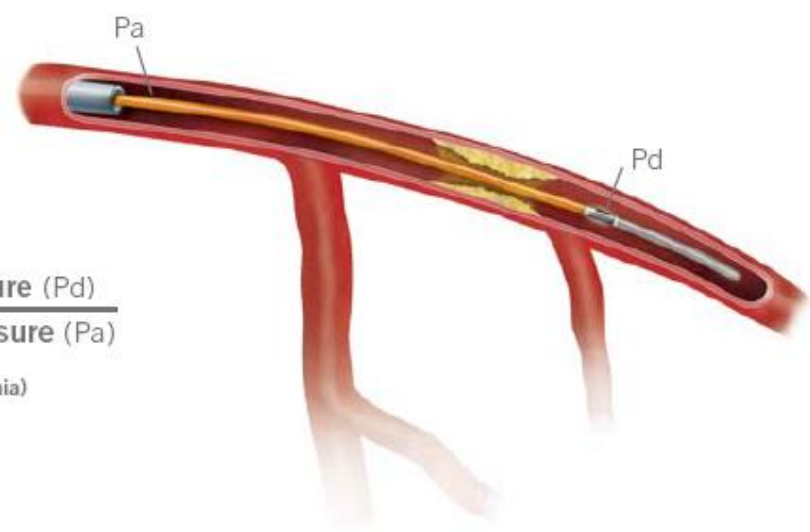


• Verna E, at al. J Nucl Med 2000;4:1935-40.

Fractional Flow Reserve (FFR)

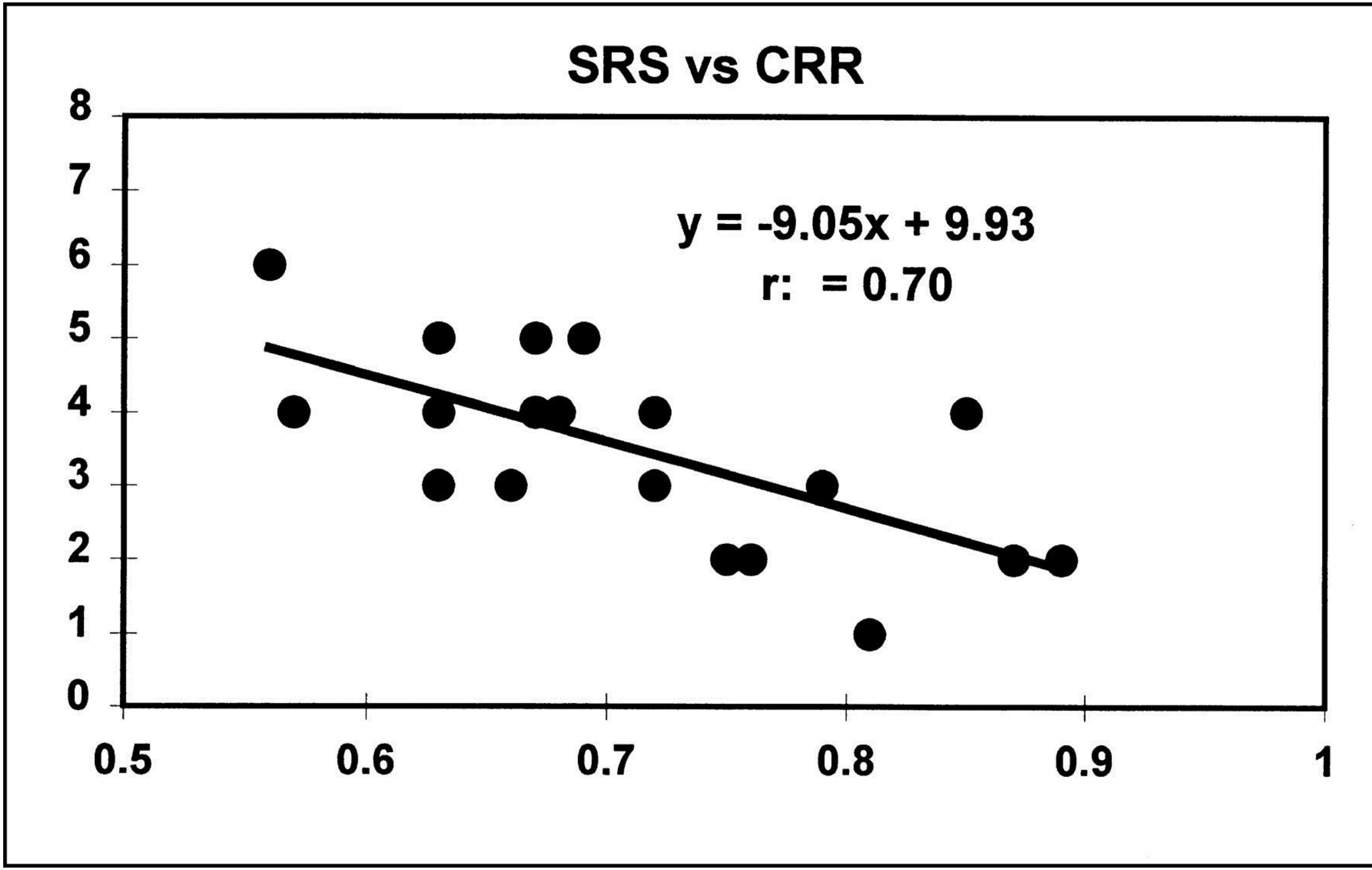
Definition:

the pressure behind (distal to) a stenosis relative to the pressure before the stenosis



$$FFR = \frac{\text{Distal Coronary Pressure (Pd)}}{\text{Proximal Coronary Pressure (Pa)}}$$

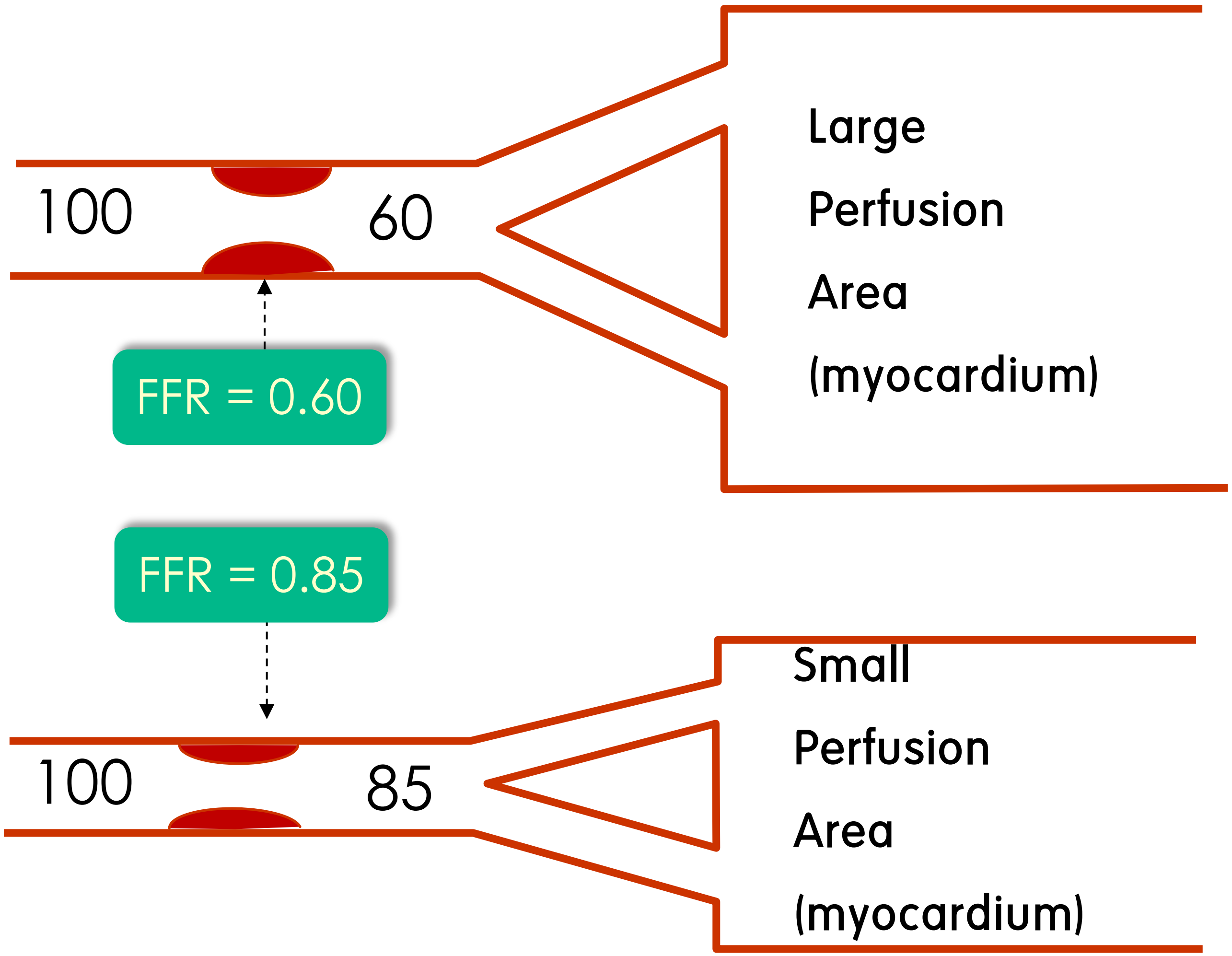
(During Maximum Hyperemia)



Relationship between summed reversible defect score (SRS) by MPS and ratio of CFR of target and reference vessels (coronary reserve ratio [CRR]).

• Verna E, at al. J Nucl Med 2000;4:1935-40.

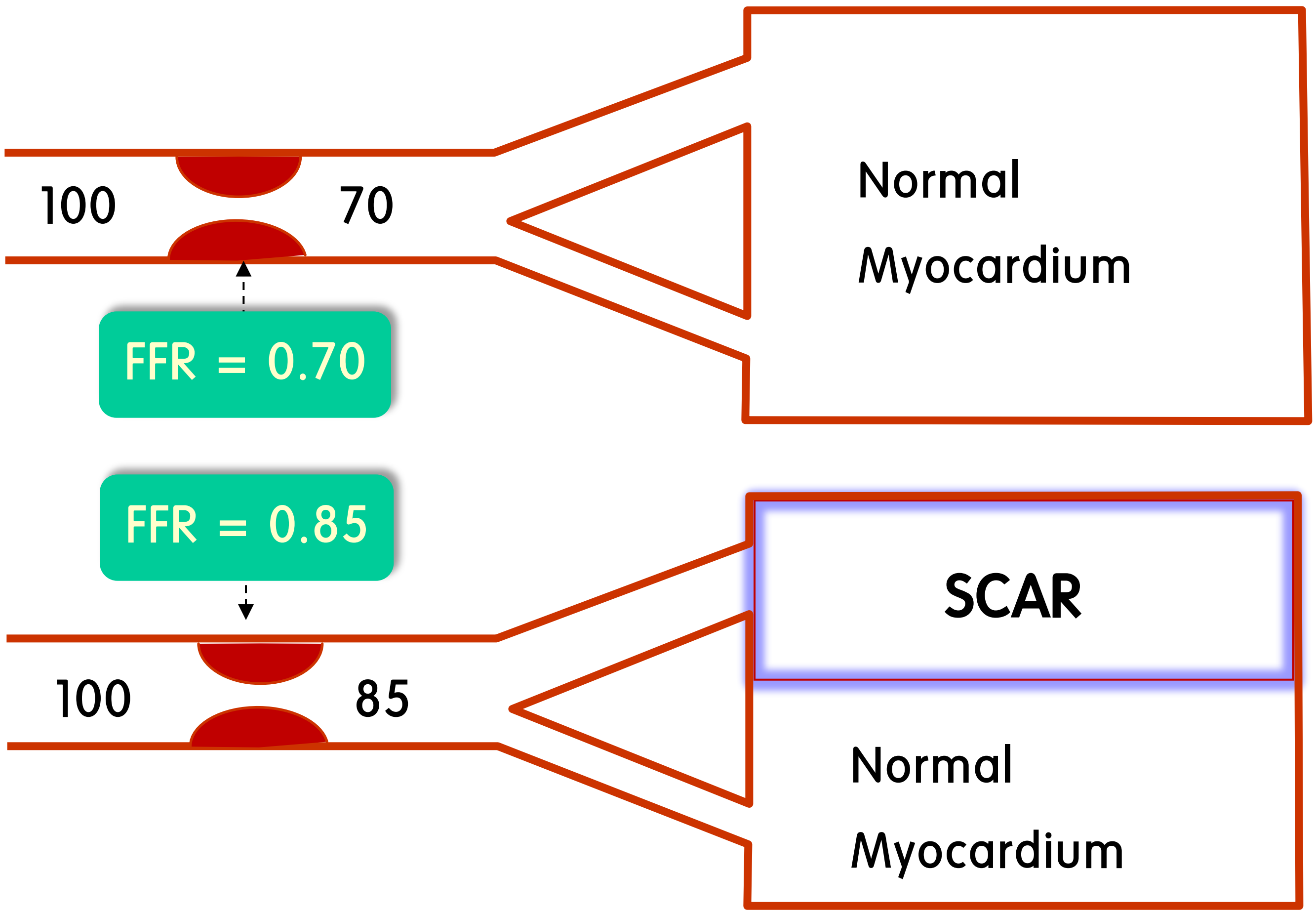
IDENTICAL % STENOSIS BUT DIFFERENT PHYSIOLOGIC SIGNIFICANCE



MLD, cross-sectional area, and stenosis resistance are identical,
but due to the different sizes of the perfusion territory the physiologic severity is different!

Pijls, N. (2009). Concepts and Practical Set-Up of Coronary Pressure Measurements.

PREVIOUS MYOCARDIAL INFARCTION (DECREASED PERFUSION TERRITORY)



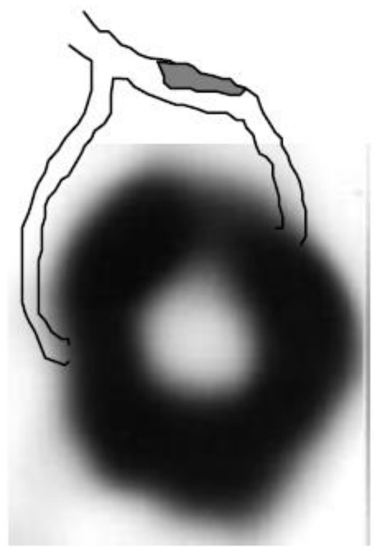
Anatomic stenosis
severity remains u
nchanged but phy
siologic severity h
as decreased.

FFR accounts for t
hose changes an
d always gives th
e right result!

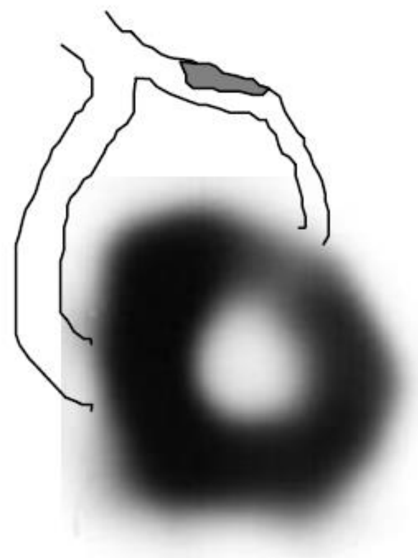
Pijls, N. (2009). Concepts and Practical Set-Up of Coronary Pressure Measurements.

Impaired CFR with significant coronary stenosis

REST



STRESS

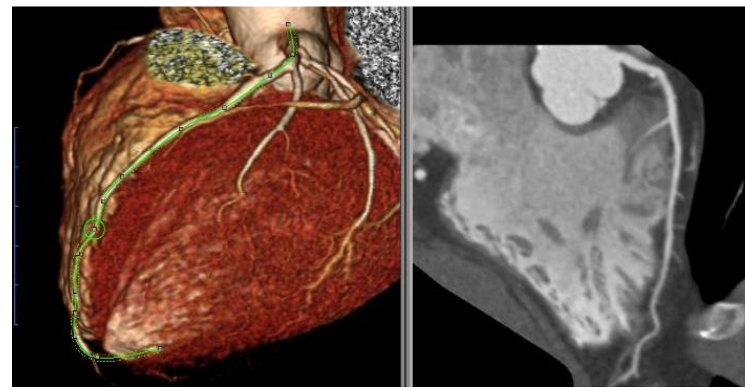


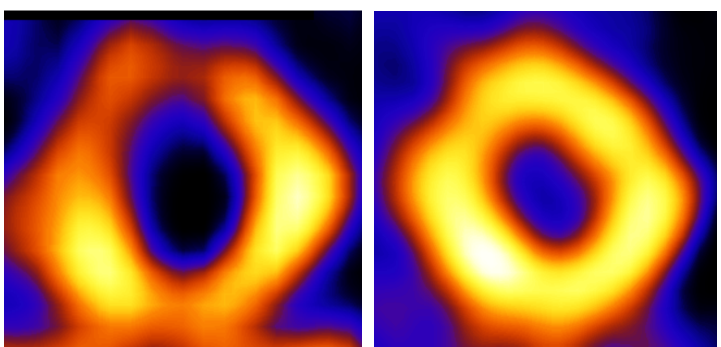
blood flow	100	100	300	100 ml/min/100g
relative conc.	100	100	100	33 %

Myocardial Perfusion SPECT or PET

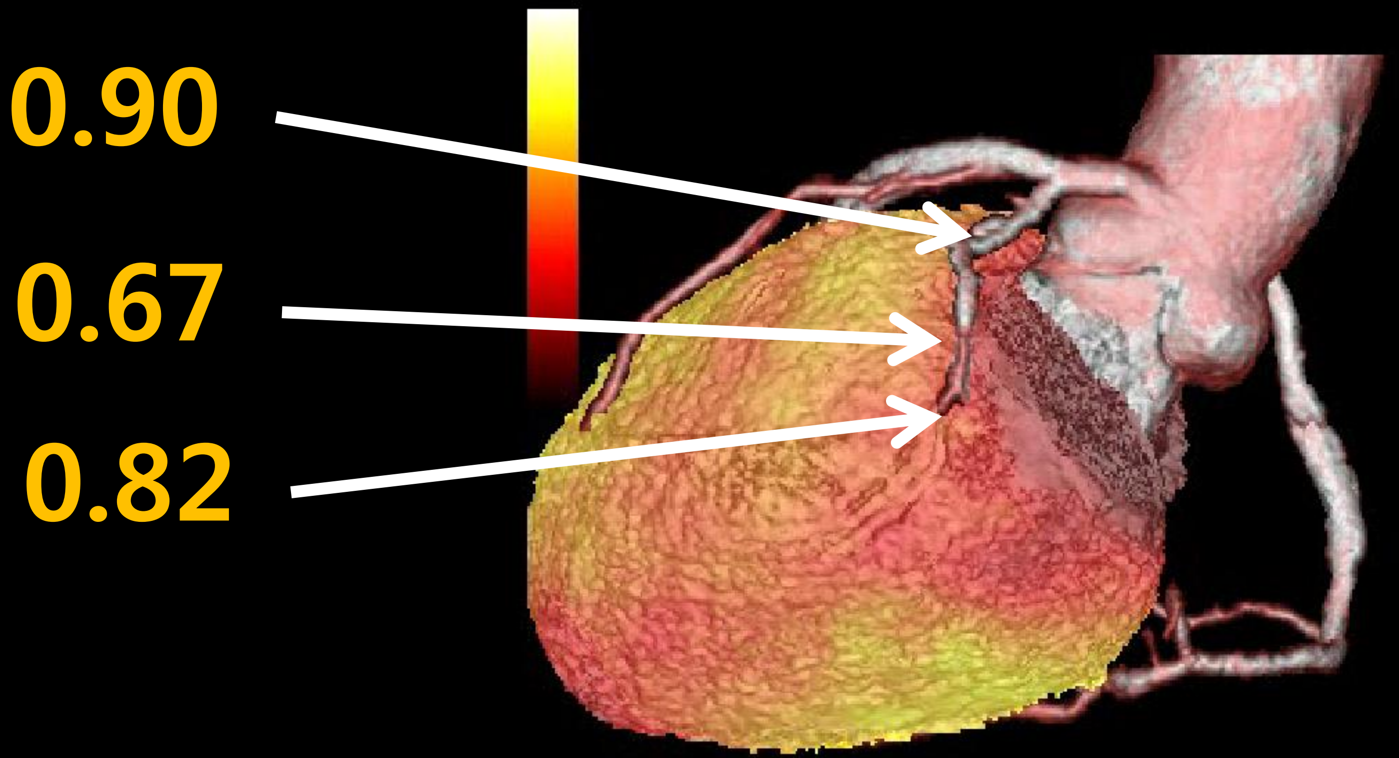
- **Myocardial Perfusion**
- **Signal = Radiotracer Activity = Perfusion (Blood Flow)**

Anatomy		Perfusion
Normal	~~⟷~~	Normal
Abnormal	~~⟷~~	Abnormal

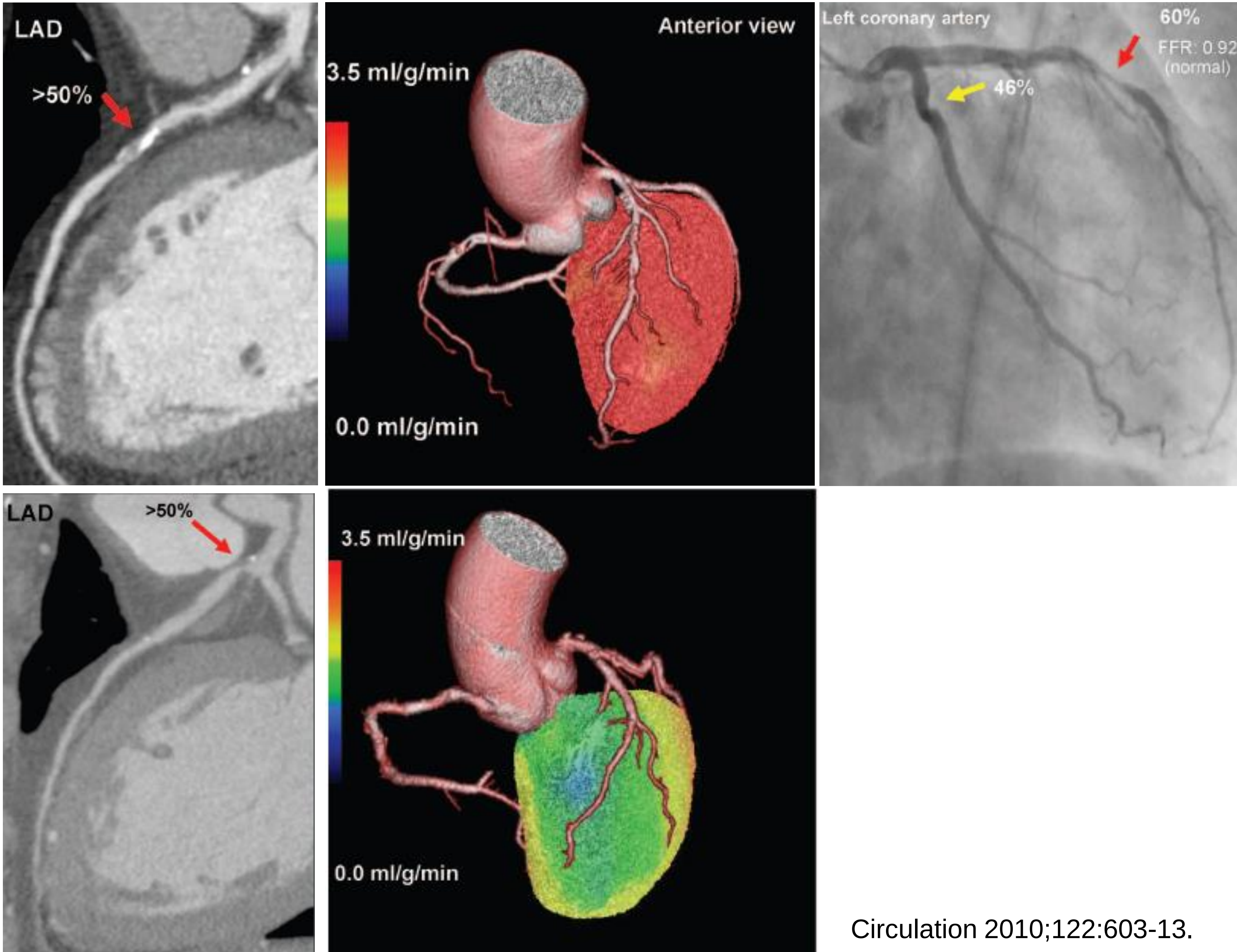




Fractional Flow Reserve (FFR)



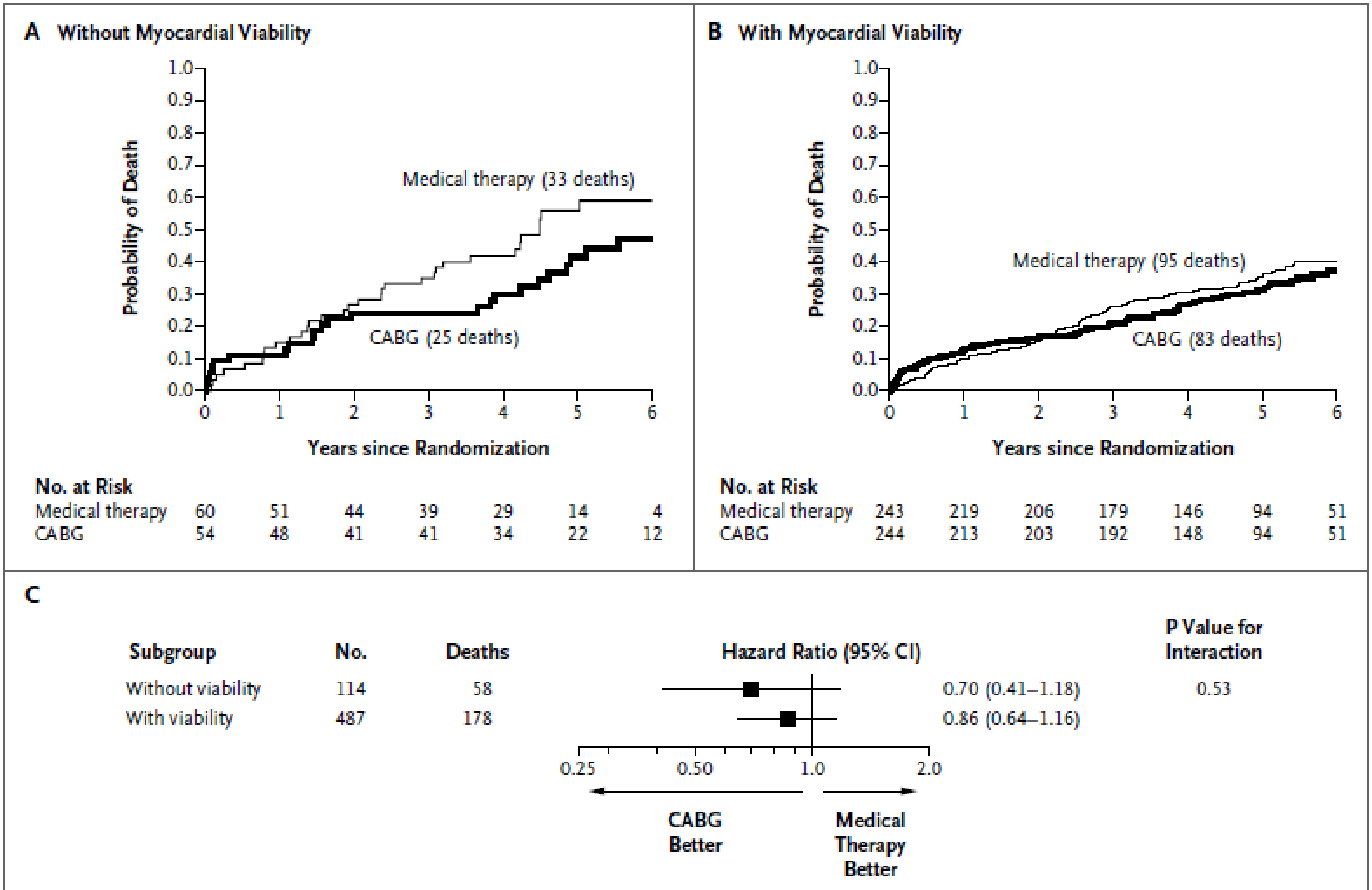
MPI & CTA Beauty of Fusion !



Circulation 2010;122:603-13.

Surgical Treatment for Ischemic Heart Failure (STICH)

NEJM 2011



Viability studies in STITCH trial

- SPECT protocols
  - Tl-201 stress-redistribution-reinjection
  - Tl-201 rest-redistribution
  - Nitrate-enhanced Tc-99m perfusion imaging
- Dobutamine echo protocol
  - Staged increase in dobutamine starting at 5 ug/kg/min

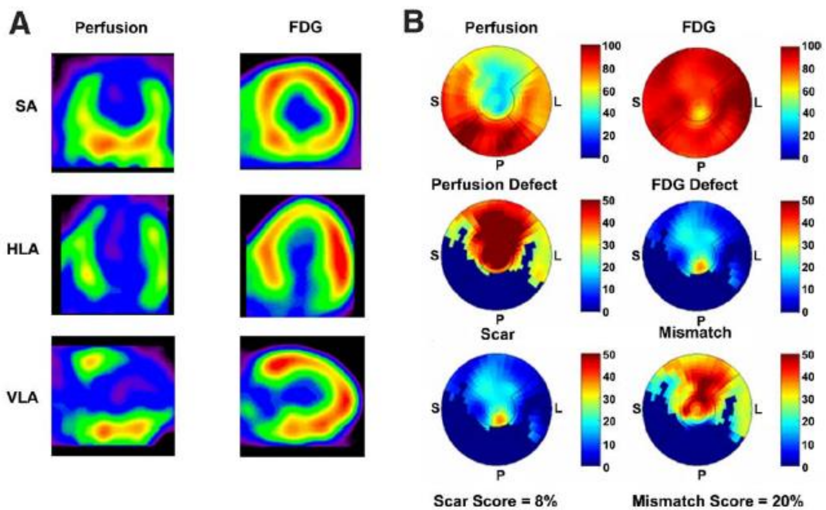
Bonow et al. NEJM 2011

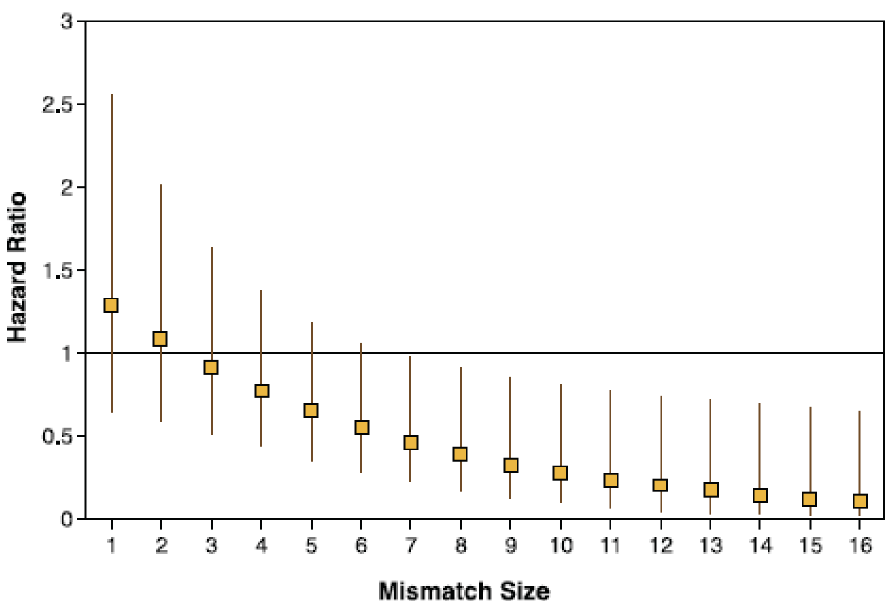
A Substudy of PARR-2 trial

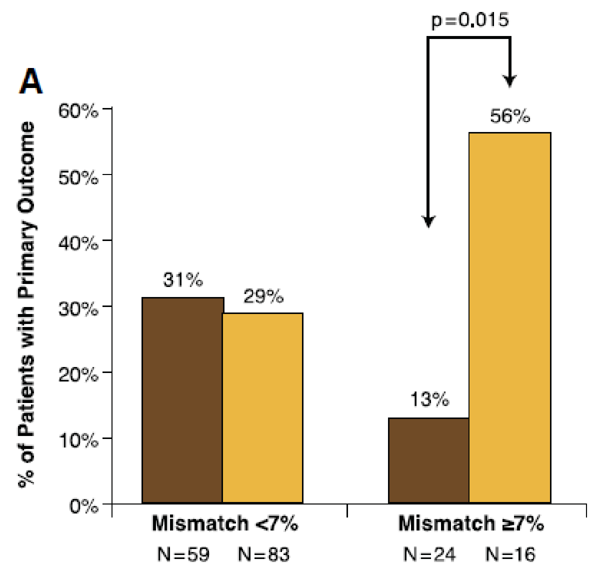
- A Substudy of PET and Recovery following Revascularization – 2 trial

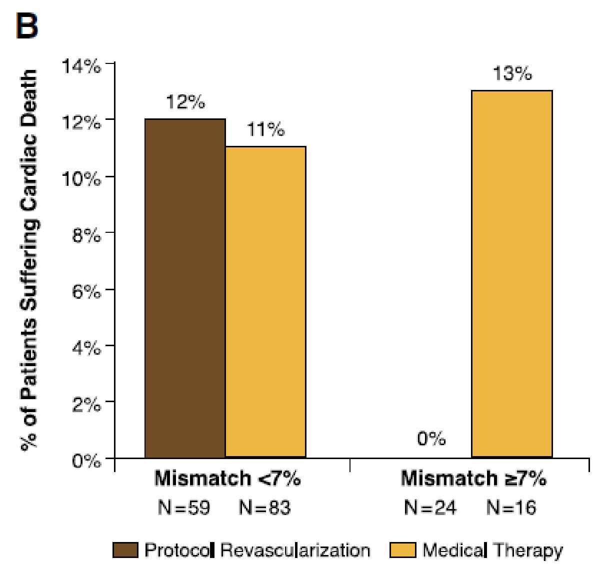
JACC 2007

JACC Img 2009





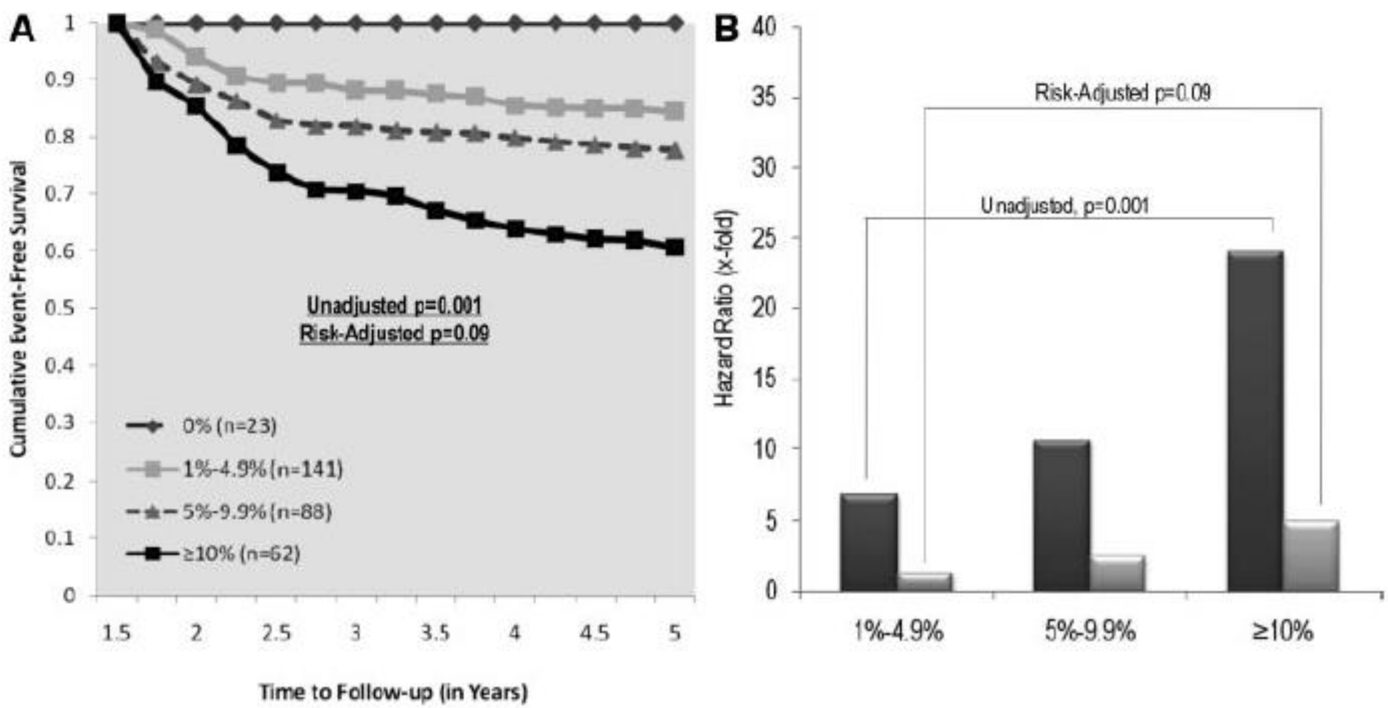




COURAGE Trial Nuclear Substudy

314 patients with serial MPS imaging

- **PCI+OMT: greater reduction in ischemia compared with OMT alone**
- **Benefit was greater in patients with more severe baseline ischemia**
- **Magnitude of residual ischemia on F/U MPS was proportion to risk of hard events**
- **Suggested treatment target: $\geq$5% ischemic reduction**



Shaw et al. *Circulation* 2008

- **Extent and severity of ischemia**
  - To quantify the ischemic zone at risk
  - To distinguish high risk from low risk in patients with IHD
  - To guide management of patients with known IHD

Zellwefer et al. JACC 2001

Conventional Technology

- Limited photon energy resolution
- Limited spatial energy resolution
- Very low sensitivity
- Relative a large amount of radiation dose
- Prolonged imaging time
- Requiring large space
- Inconvenient patient position

Quantification in Emission Tomography

SPECT has traditionally been regarded as non-quantitative, while PET is inherently a quantitative imaging device

- PET vs. SPECT

	AC/SC* Correction	Reconstruction Image
SPECT	Challenging attenuation & scatter correction	Count-based reconstruction image (constant total count)
PET	Pretty straightforward attenuation & scatter correction	Radioactivity per unit volume [kBq/cm^3]

* AC: Attenuation correction / SC: Scatter correction

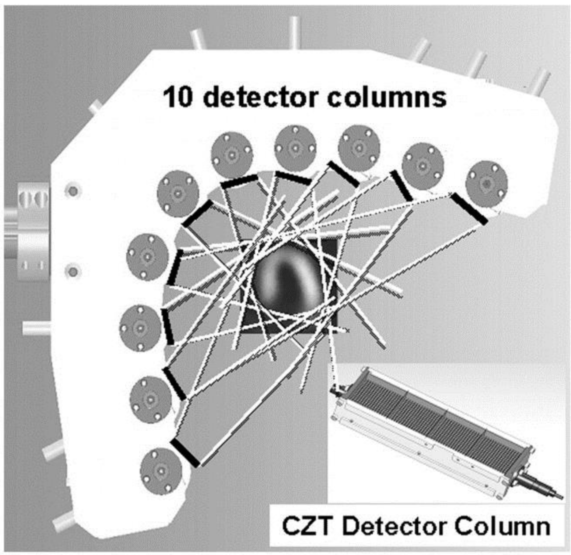
SPECT quantification is viable now, in a similar manner compared to PET

- Advances in multimodality γ–cameras (SPECT/CT)
  - CT data provides information about the density of body tissues
- Advances in AC/SC algorithms
  - Sophisticated algorithms to correct for attenuated or scattered photons

Lee JS et al.

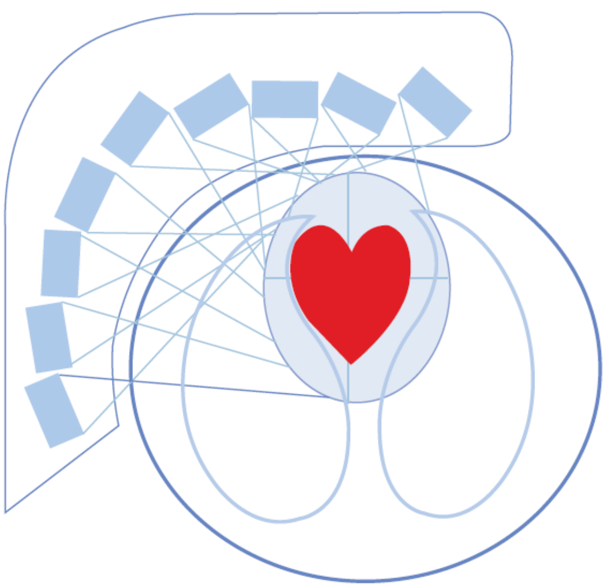
BroadView™ technology

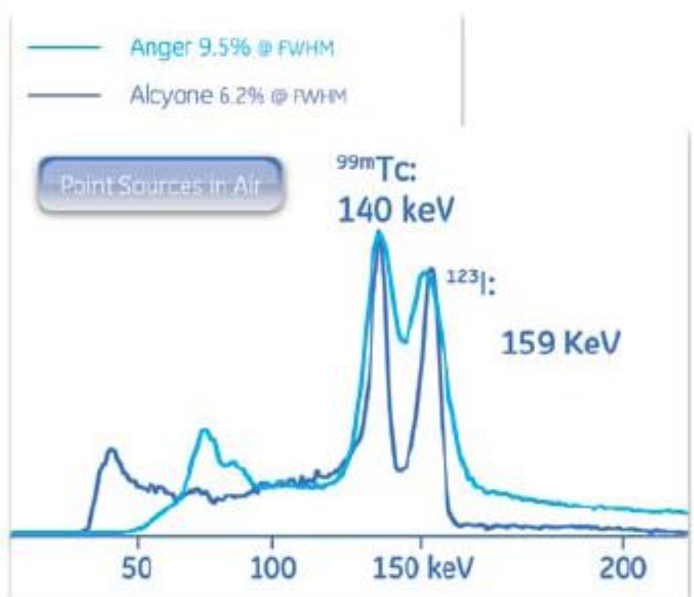
- **D-SPECT, Spectrum-Dynamics Ltd. of Haifa, Israel**
- **Improved sensitivity and spectral resolution**



Alcyone technology

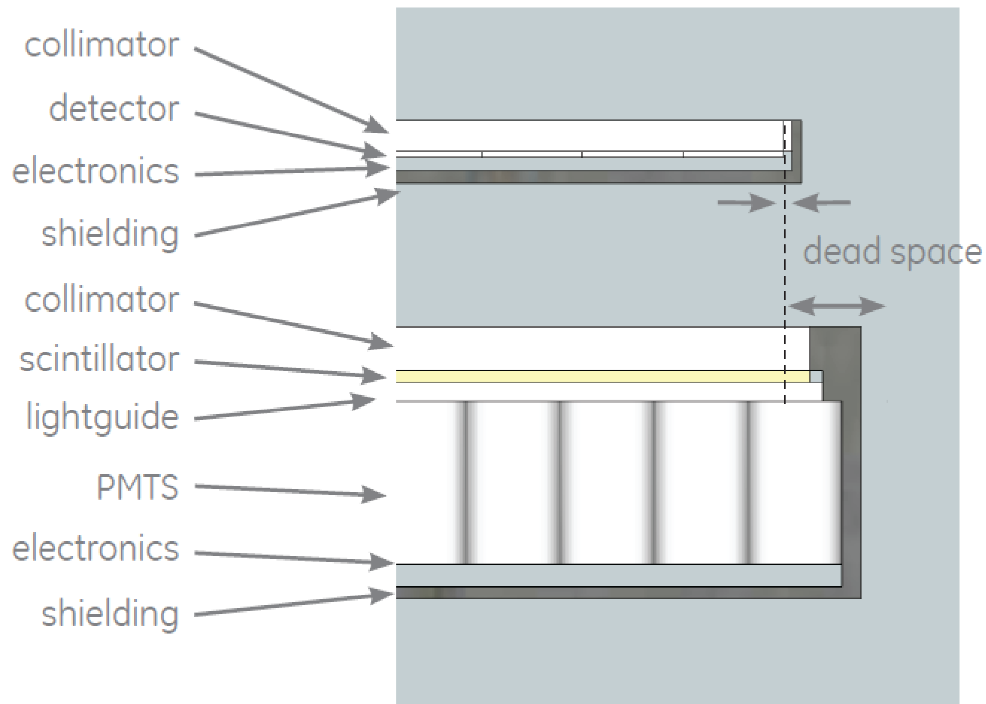
- Discovery NM 530c, NM/CT 570c, GE Healthcare
- CZT detectors
- Focused collimation
- 3D reconstruction
- Stationary data acquisition



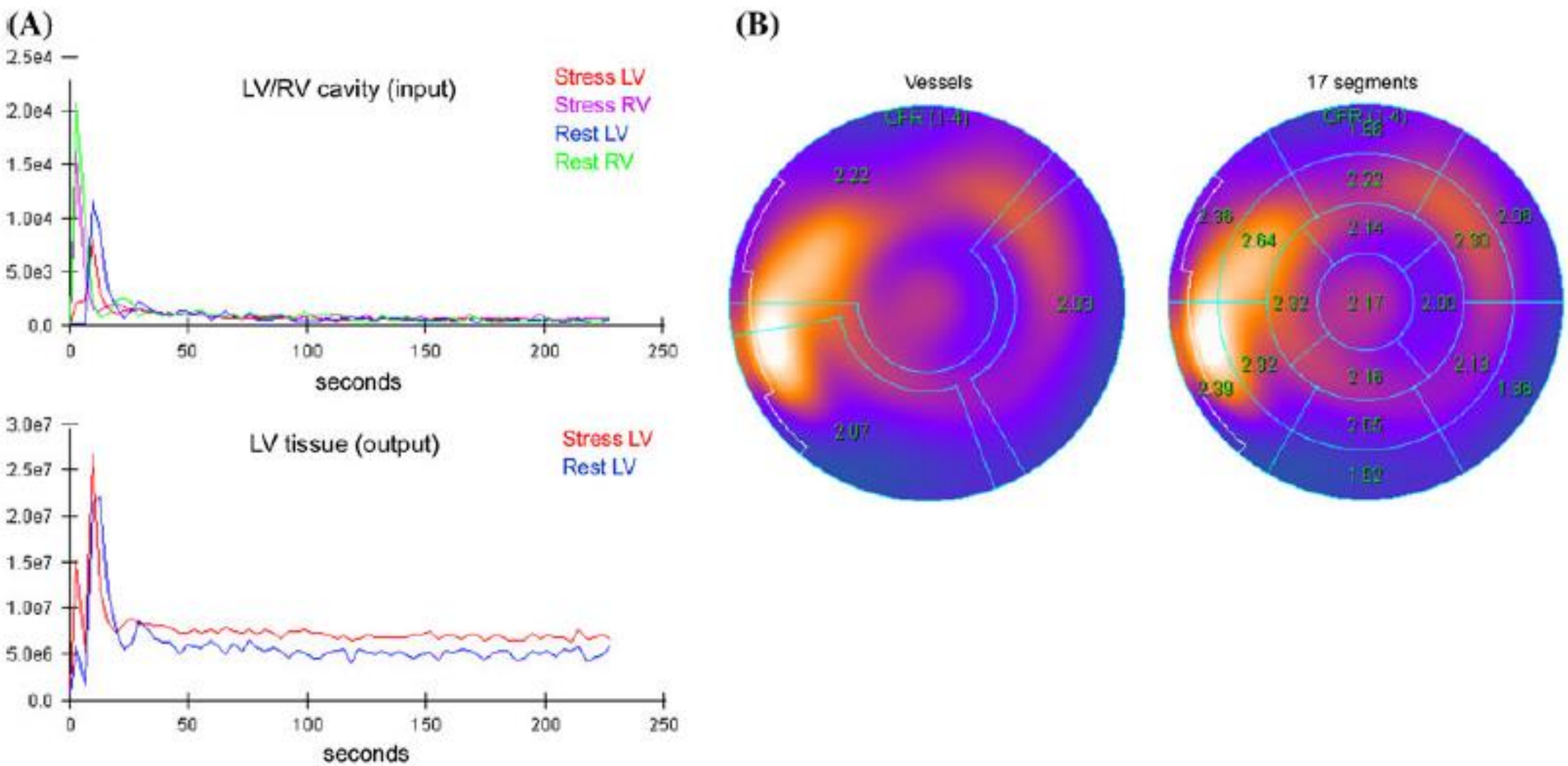


Solid-state SPECT technology: basic principles

- Utilizing Semiconductors for detecting gamma photons
- Directly produce electron currents
- Combined functions of scintillation crystals and photomultiplier tubes
- Cadmium-Zinc-Telluride (CZT): most common



Myocardial Flow Reserve



J Nucl Cardiol 2010;17:890–6.

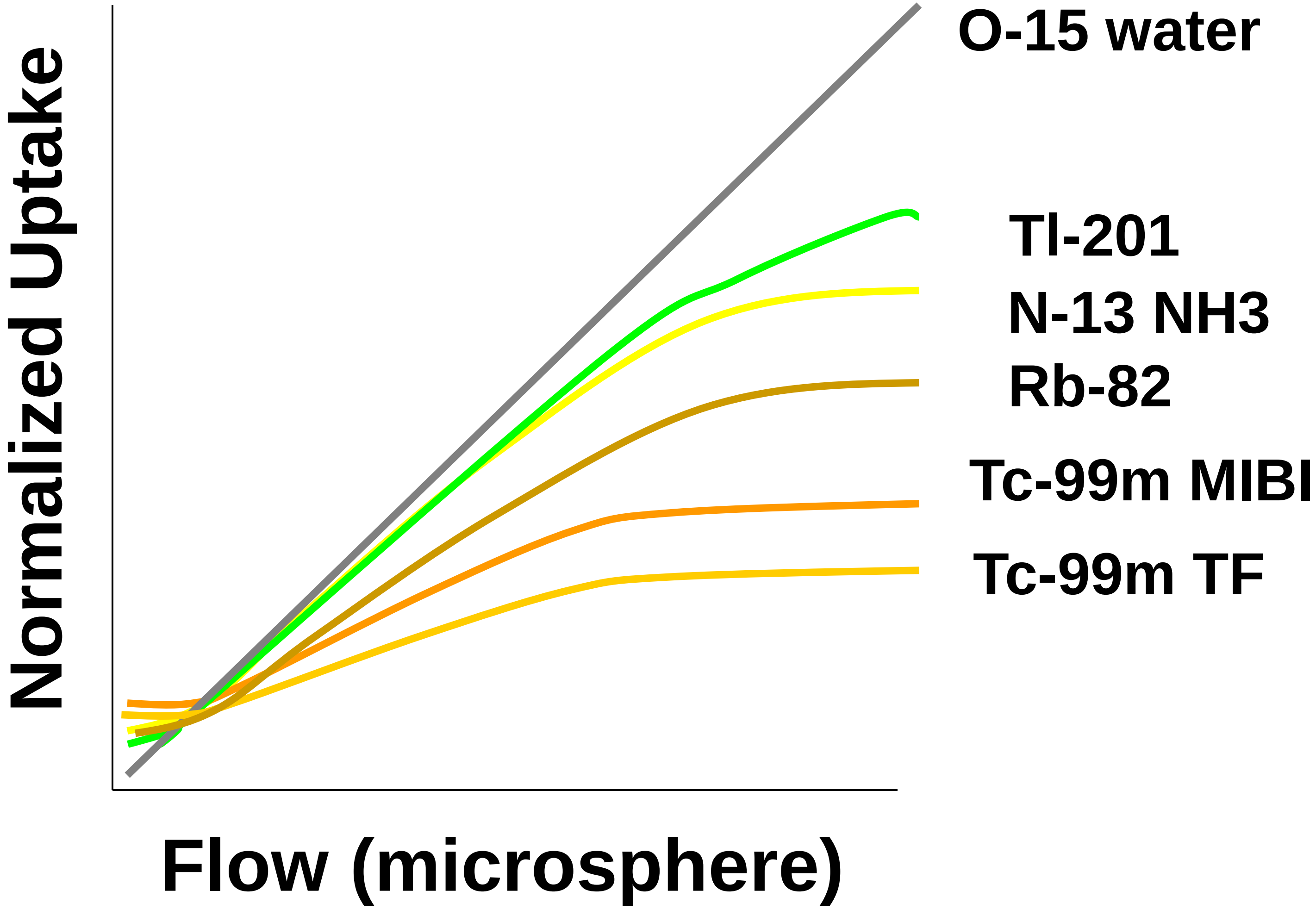
PET Perfusion Agents

Diffusible tracers

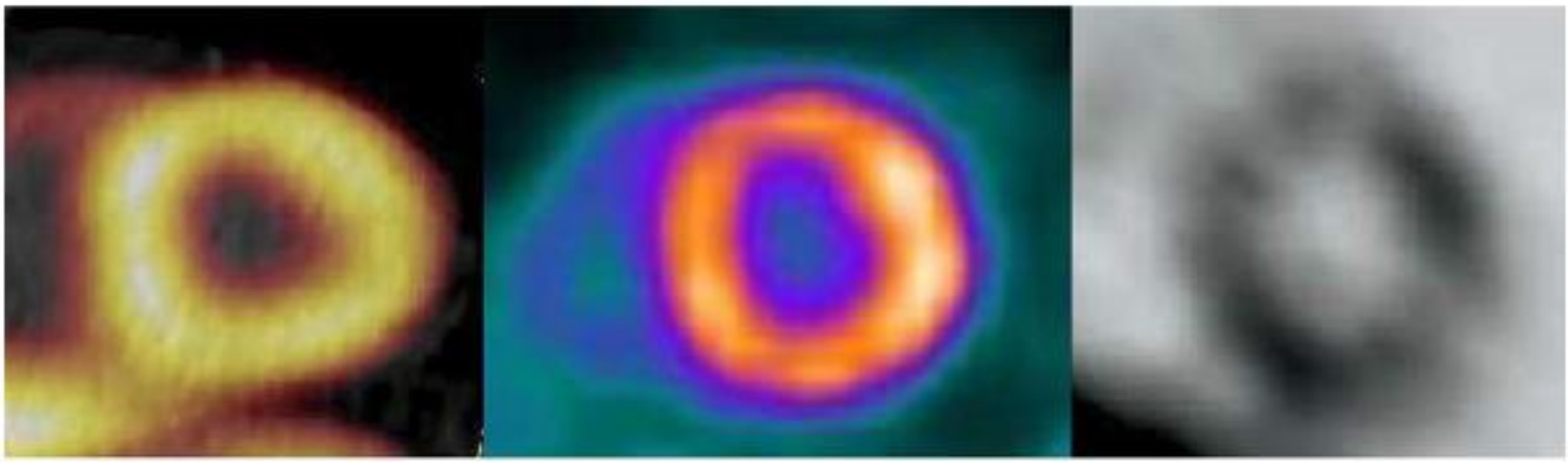
Radioisotope	Form	Half-life	MeV
Rubidium-82 (^{82}Rb)	Chloride	75 sec	3.15
Nitrogen-13 (^{13}N)	Ammonia	10 min	1.19
O-15 (^{15}O)	Water	110 sec	1.72
Copper-62 (^{62}Cu)	PTSM	9.8 min	2.94
Potassium-38 (^{38}K)	Chloride	7.6 min	2.70
Carbon-11 (^{11}C)	Butanol	20 min	0.96

PTSM, pyruvaldehyde methylthiosemicarbazone

Uptake vs. Flow



PET Perfusion Imaging

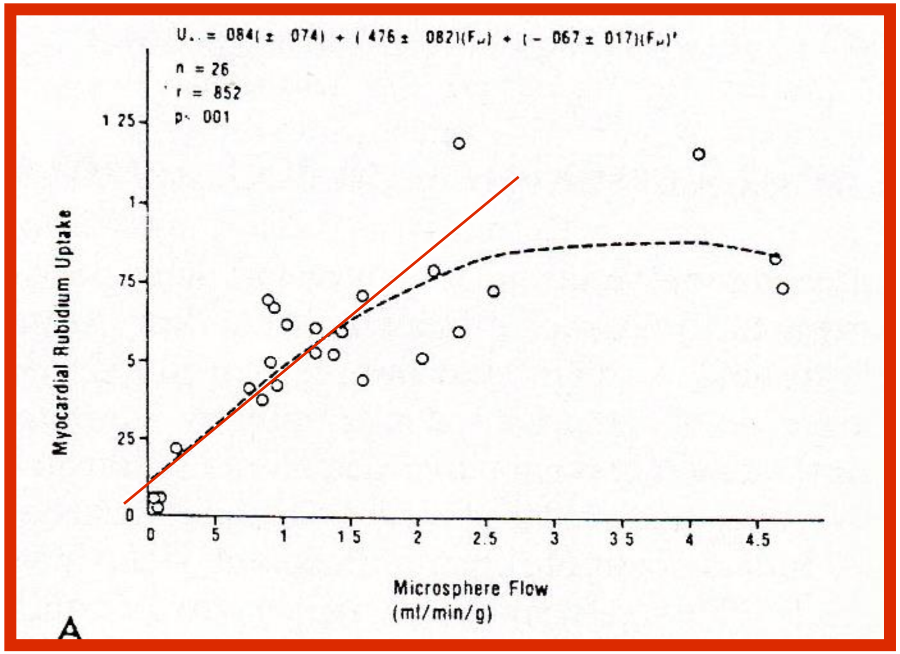


N-13 Ammonia | Rubidium-82 | O-15 Water

JACC Cardiovasc Imaging 2010

PET Perfusion Agents

Relationship to CBF



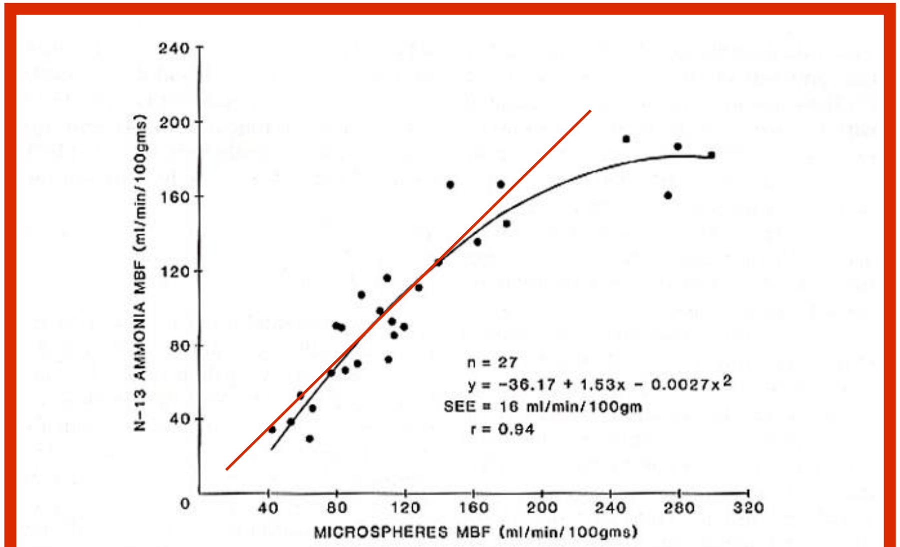


FIG. 12-9. Measurement of RMBF noninvasively with [^{13}N]ammonia and PET. Relation between RMBF determined with the microsphere technique and *in vivo* with [^{13}N]ammonia and PET in 27 dog experiments. (From Shah et al., ref. 217, with permission.)

Rb-82 Chloride

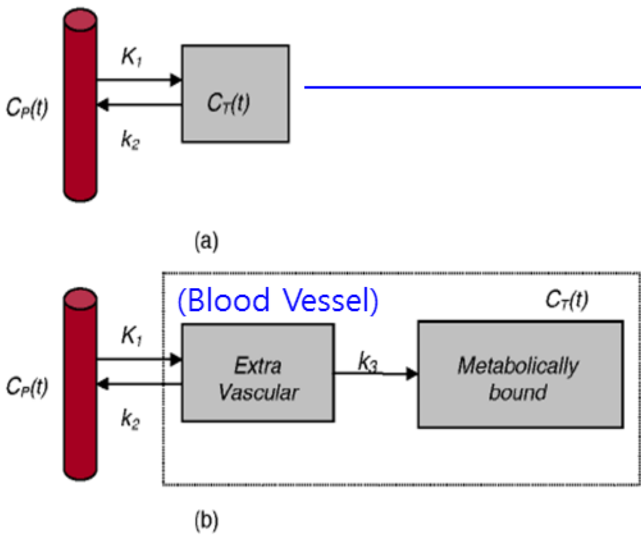
N-13 ammonia

Bergman SR. In: PET of the Heart. Eds: Bergmann SR, Sobel BE. 1992

Schelbert Hr, Schwaiger M. In: PET and Autoradiography. Eds: Phelps ME, Mazziotta JC, Schelbert H 1986

Cardiac MBF basic principle

Tracer Kinetic Model



1 compartment
82Rb

2 compartment
13NH(3)

Cp(t) : blood input function
Ct(t) : myocardial tissue compartment
K1 : myocardial extraction
K2 : rate of transport back to the blood
K3 : rate of 13NH(3) metabolic conversion into N13-glutamin

Cardiac MBF basic principle
CFR definition

CFR(Coronary Flow Reserve)

-> ratio of the myocardial blood flow at peak stress, or maximal vasodilatation to the flow at rest.

(peak stress MBF / peak rest MBF)

Normal ratio is usually 2.0 or higher.

Normal coronary arteries, resting blood flow is in the range of 0.8~1.2 ml/gm/min

Advantages of perfusion PET/CT

- **Kinetic modeling**

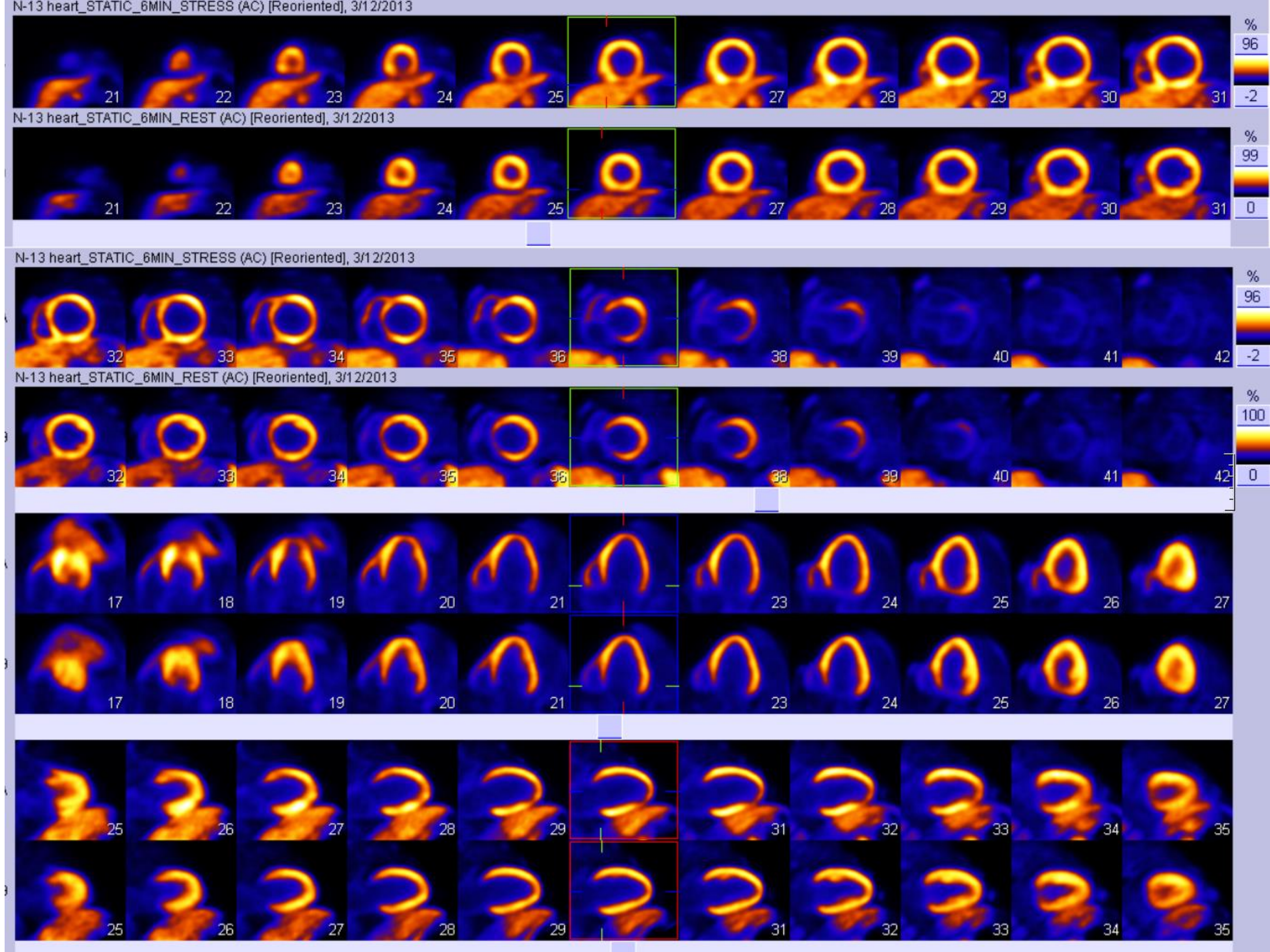
  : can obtain absolute values of flow

  - About 5-10% of patients with CAD are impacted by a balanced reduction in myocardial perfusion

  - A rapidly growing population of diabetic patients is particularly at risk for microcirculation defects

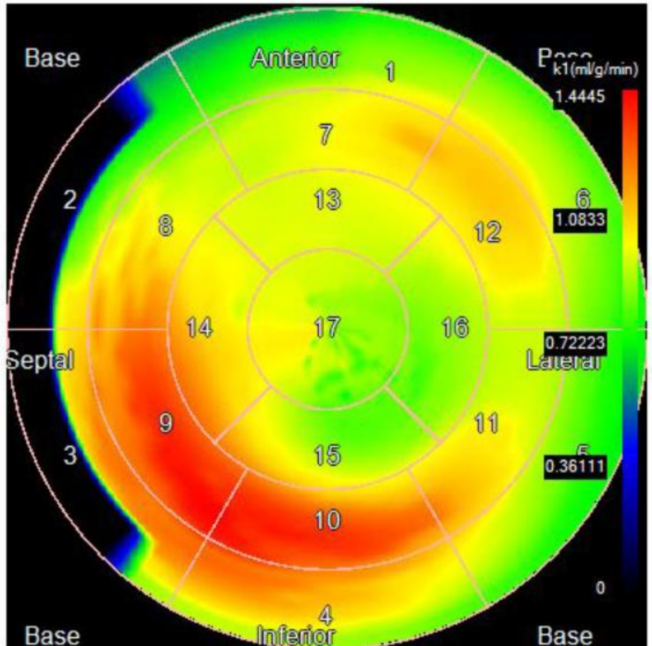
- **Better resolution**
- **Lower radiation dose : 3mSv vs. 25mSv**
- **CT based Attenuation correction**

Knuuti, ey al J Nunl Cardiol 2009


N-13 heart_STATIC_6MIN_STRESS (AC) [Reoriented], 3/12/2013
21 22 23 24 25 27 28 29 30 31
%
96
-2
N-13 heart_STATIC_6MIN_REST (AC) [Reoriented], 3/12/2013
21 22 23 24 25 27 28 29 30 31
%
99
0
N-13 heart_STATIC_6MIN_STRESS (AC) [Reoriented], 3/12/2013
32 33 34 35 36 38 39 40 41 42
%
96
-2
N-13 heart_STATIC_6MIN_REST (AC) [Reoriented], 3/12/2013
32 33 34 35 36 38 39 40 41 42
%
100
0
17 18 19 20 21 23 24 25 26 27
17 18 19 20 21 23 24 25 26 27
25 26 27 28 29 31 32 33 34 35
25 26 27 28 29 31 32 33 34 35

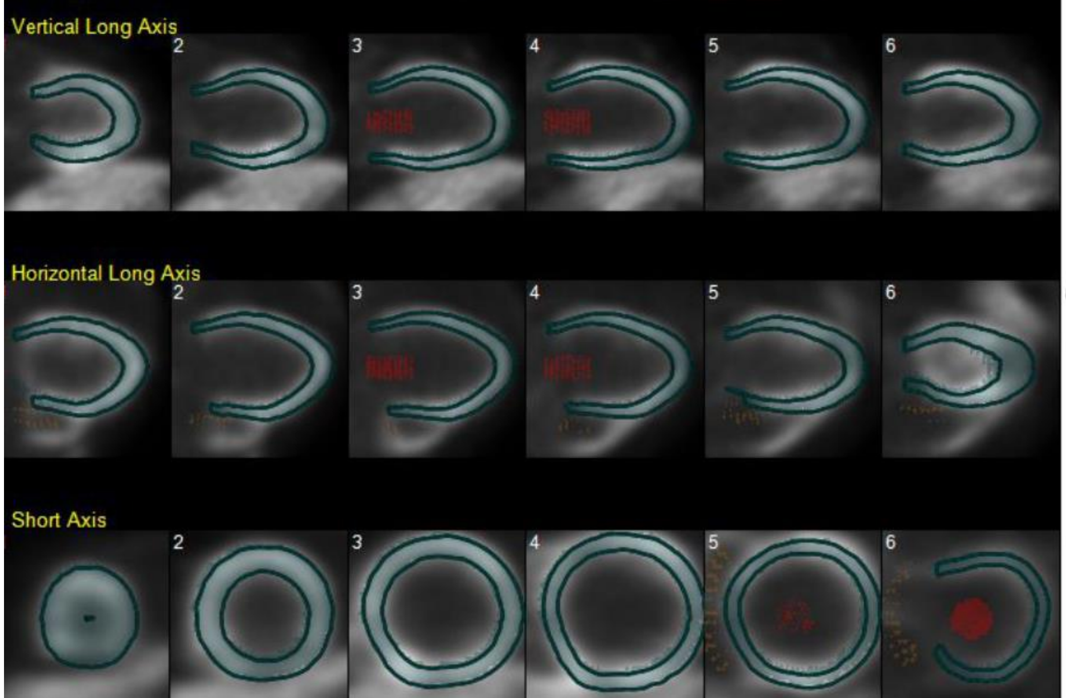
Name	
ID	31692580
Gender	M
Age	N/A
Height	N/A
Weight	N/A
Study Des	Specials^N13_REST_L
Institute	SNUH_PET / BST X m
Isotope	No_isotope

STRESS



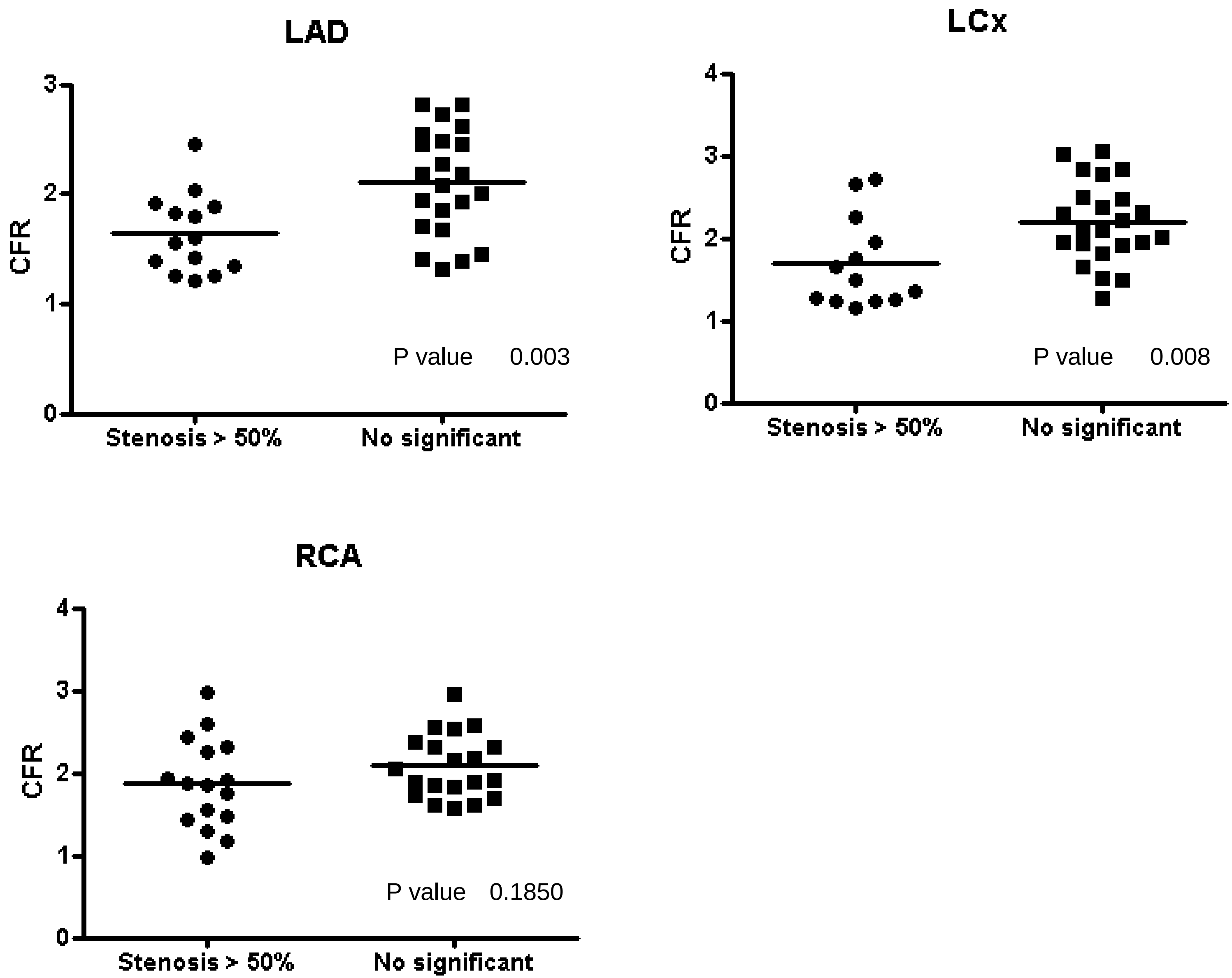
Modelling Results

(mL/min)	Stress	Rest	Reserve
GLOBAL	0.954	0.675	1.413
Bas_Ant	0.833	0.565	1.474
Bas_AS	0.794	0.535	1.483
Bas_IS	1.207	0.600	2.012
Bas_Inf	1.119	0.619	1.808
Bas_IL	0.875	0.659	1.328
Bas_AL	0.895	0.677	1.323
Mid_Ant	0.997	0.690	1.444
Mid_AS	0.994	0.661	1.503
Mid_IS	1.308	0.711	1.839
Mid_Inf	1.294	0.738	1.754
Mid_IL	1.037	0.742	1.398
Mid_AL	1.054	0.745	1.414
Ap_Ant	0.972	0.677	1.435
Ap_Sep	1.043	0.713	1.463
Ap_Inf	0.926	0.786	1.179
Ap_Lat	0.886	0.710	1.247
Apex	0.935	0.654	1.430



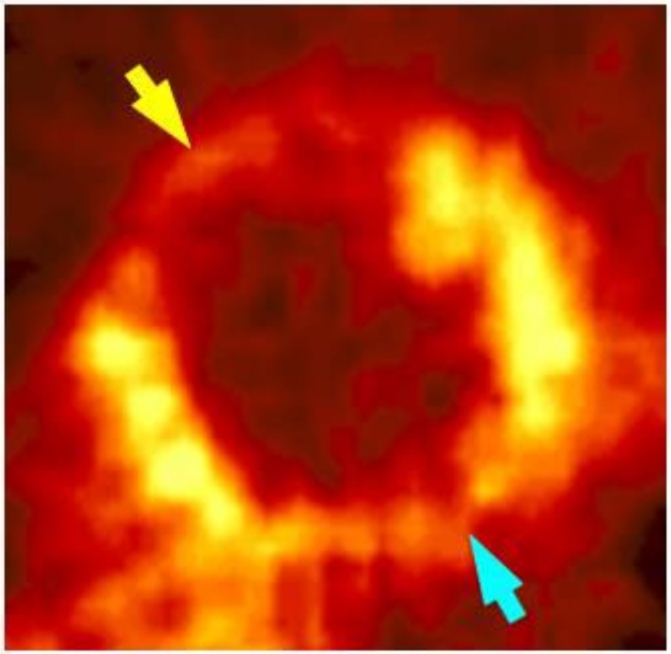
General information

	Value
Model name	Michigan model
Frame (min)	0.00----10.00
Tolerance	0.01
Max iteration	100
Input function	LV_input
Carimas core v	2.2.44.7002
Heart plugin v	2.2.0.6998
TPClib v	0.10.0.6540
Date	2013-03-12 오전 10:51:33

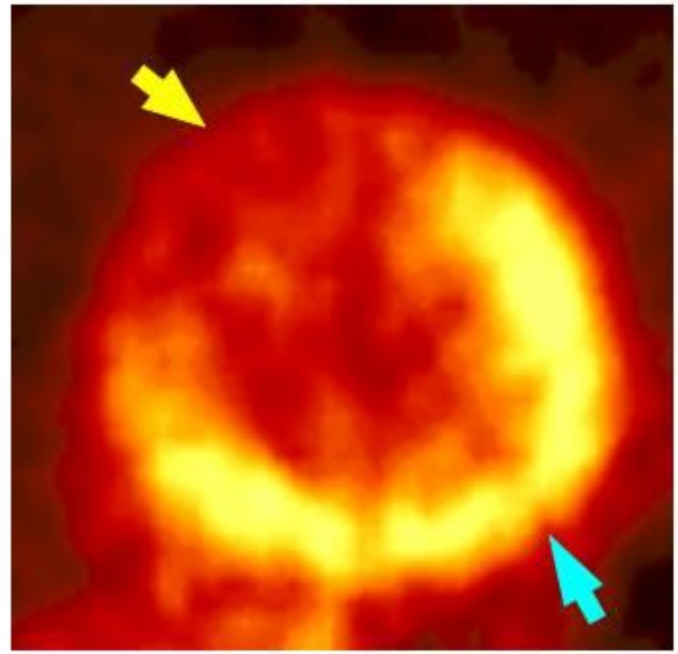


LAD
CFR
3
2
1
0
P value 0.003
Stenosis > 50%
No significant
LCx
CFR
4
3
2
1
0
P value 0.008
Stenosis > 50%
No significant
RCA
CFR
4
3
2
1
0
P value 0.1850
Stenosis > 50%
No significant

Q/M Match vs. Mismatch



$^{13}NH_3$ - PET



^{18}FDG - PET

Myocardial FDG PET

- Increase insulin level is mandatory for increasing glucose utilization and decreasing FFA levels
  - Oral glucose loading (inadequate in 10%)
  - Insulin clamp (gold standard but cumbersome)
  - Simplified IV insulin and oral glucose loading (practical)
  - Oral acipimox

    : inhibits lipolysis and decrease FFA levels

FDG Viability Criteria

- **Perfusion-FDG match and mismatch is the most accurate.**
- Normalized FDG uptake > 50% maximum
  - Not accurate as perfusion match-mismatch
- Absolute glucose utilization: same limitation as for normalized uptake

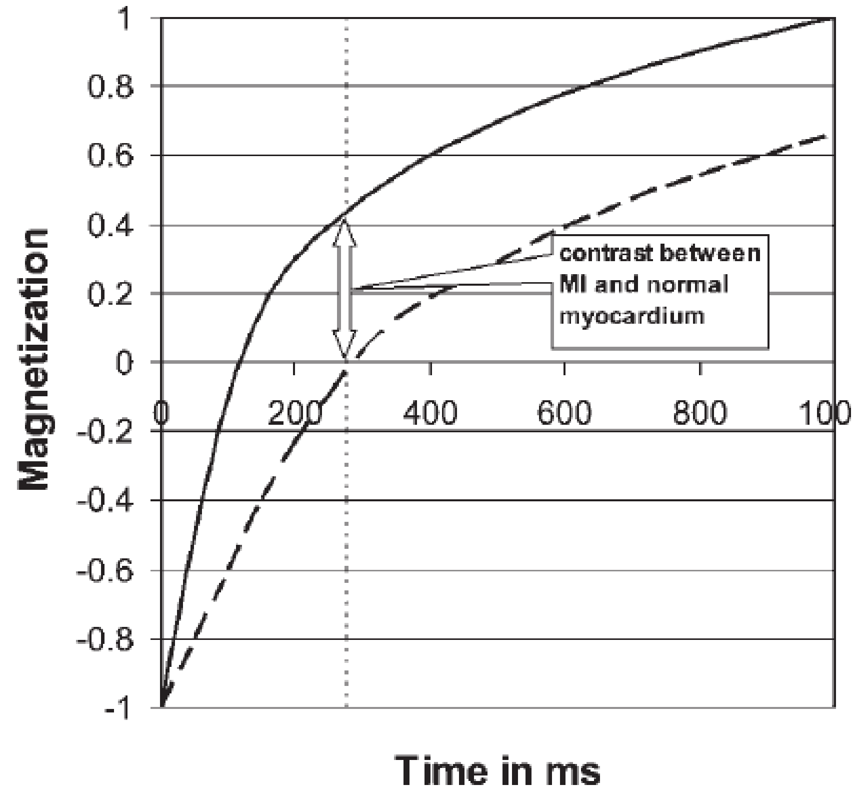
•Bax JJ et al. J Nucl Med 1999;40:1866-1873.

•Pagano D et al. J Thorac Cardiovasc Surg 1998:115:791-799.

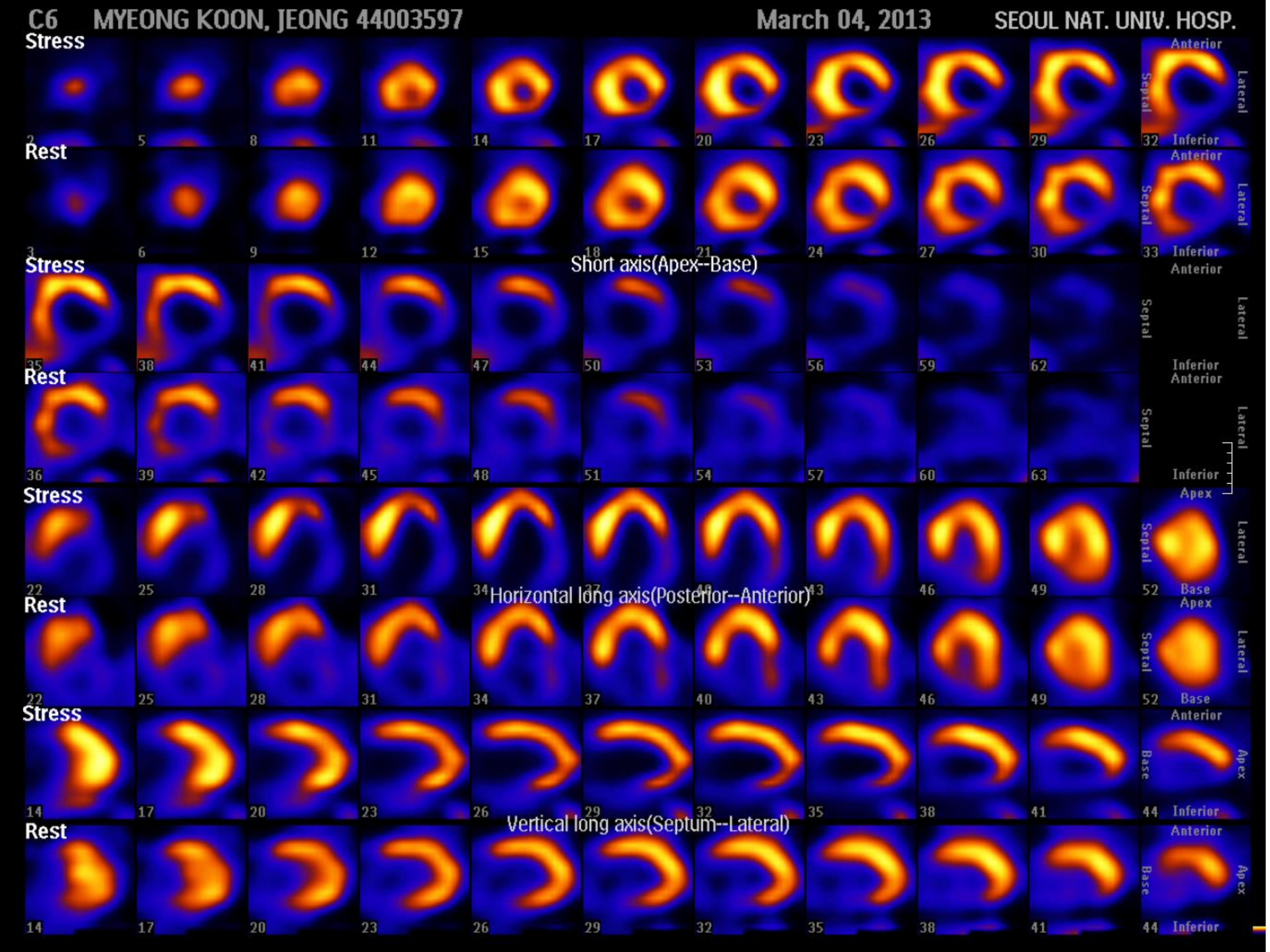
•Schelbert HS et al. Guidelines….J Nucl Cardiol 2003;10(5): 557-571.

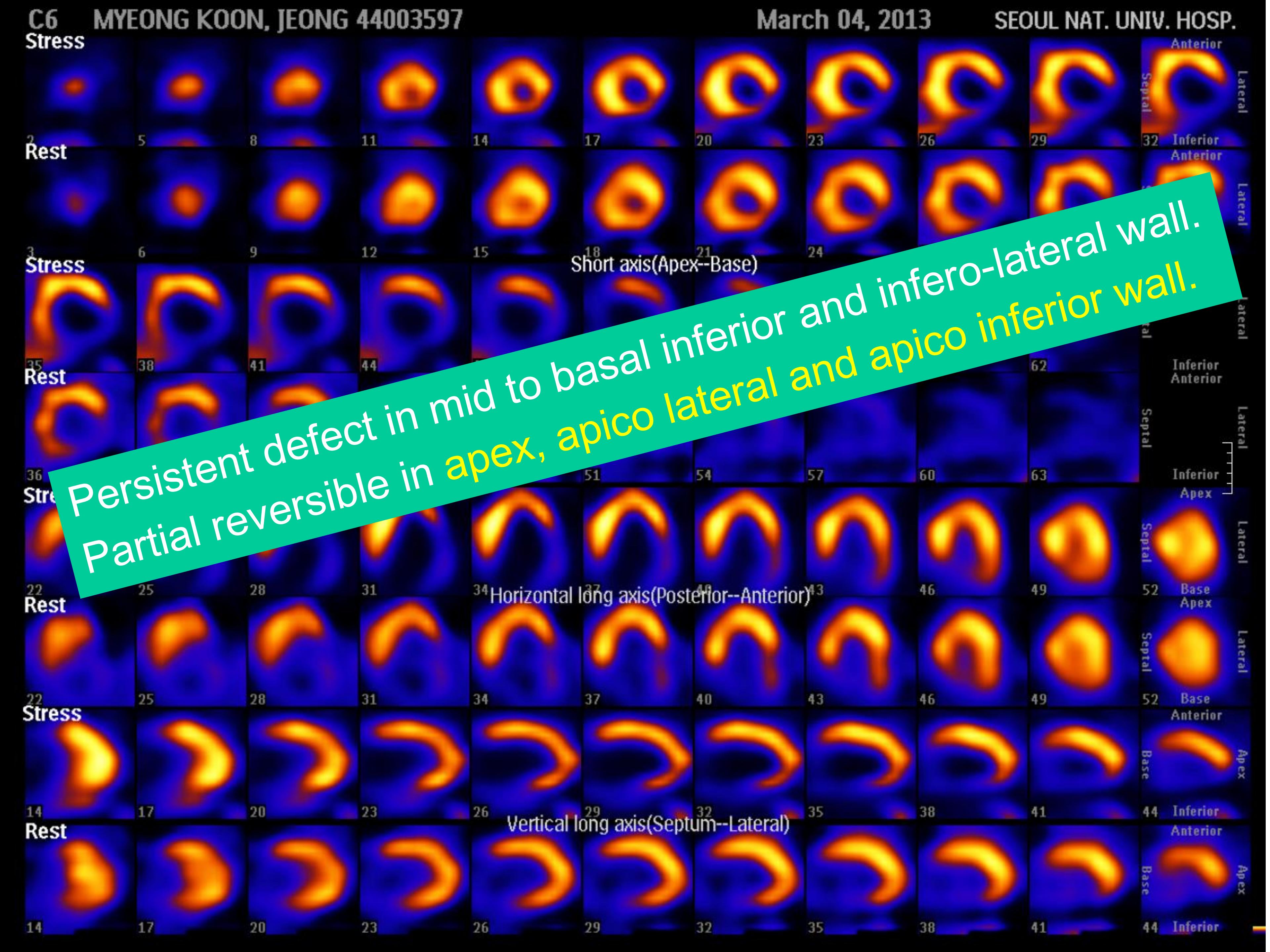
Delayed enhancement in MR

- Delayed enhancement → Myocardial Infarct
- Chronic MI
  - Retention by fibrous tissue
- Acute MI
  - Large volume of distribution
- False Positives
  - Inflammatory or infectious diseases of the myocardium
  - Cardiomyopathy
  - Cardiac neoplasms,

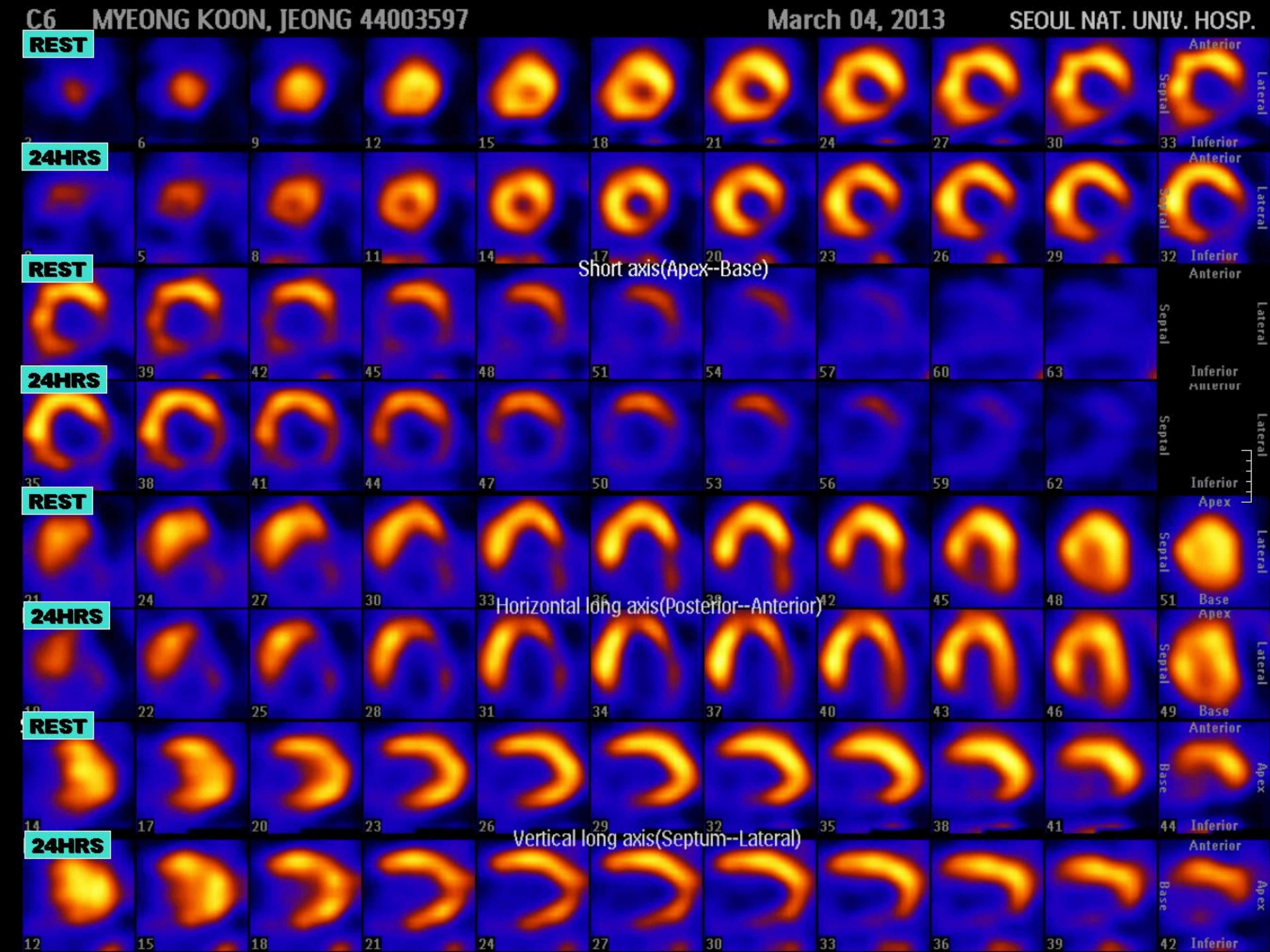


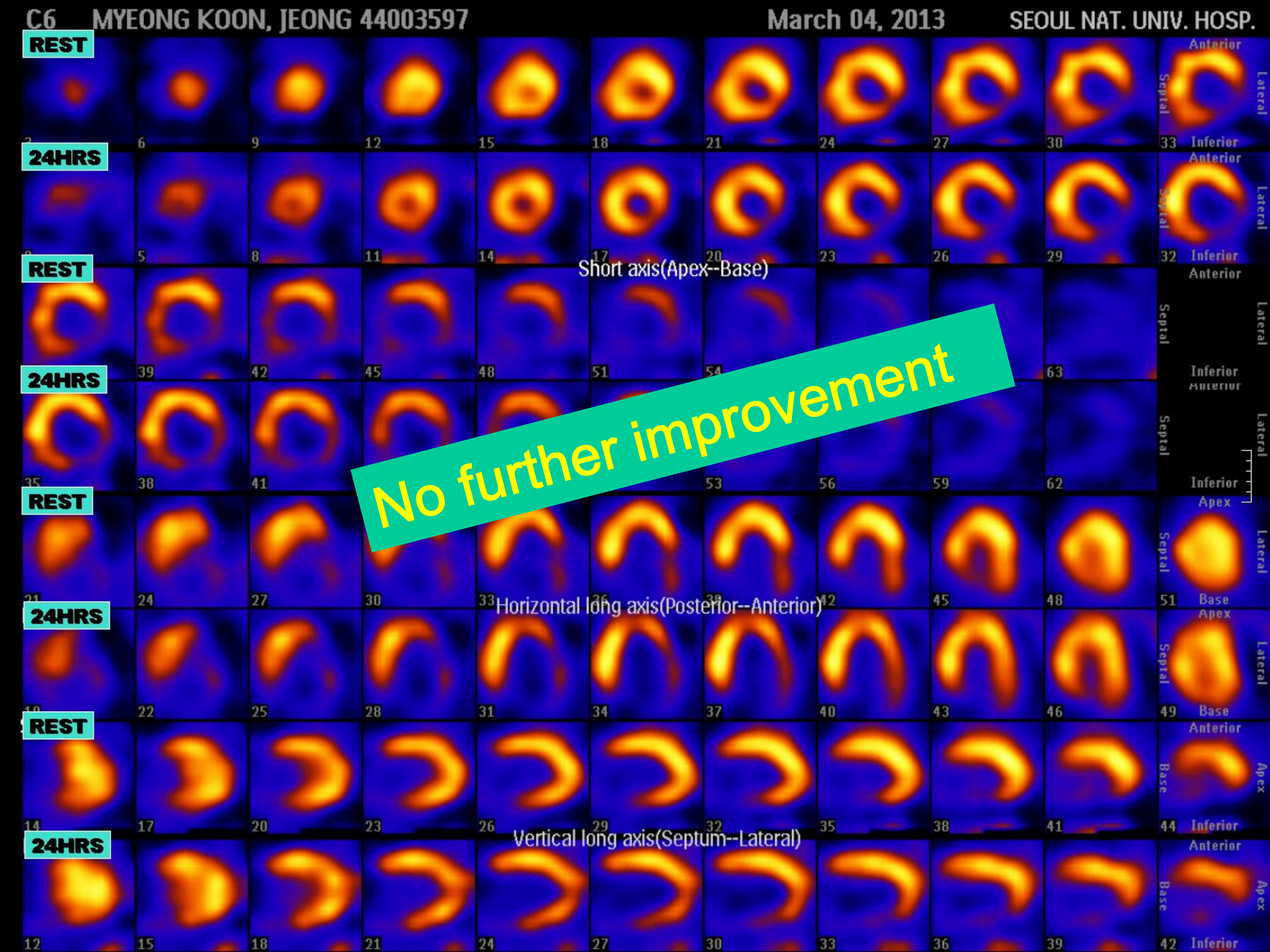
RadioGraphics 2006; 26:795–810


C6 MYEONG KOON, JEONG 44003597
March 04, 2013
SEOUL NAT. UNIV. HOSP.
Stress
Rest
Short axis(Apex--Base)
Horizontal long axis(Posterior--Anterior)
Vertical long axis(Septum--Lateral)
Anterior
Inferior
Septal
Lateral
Apex
Base

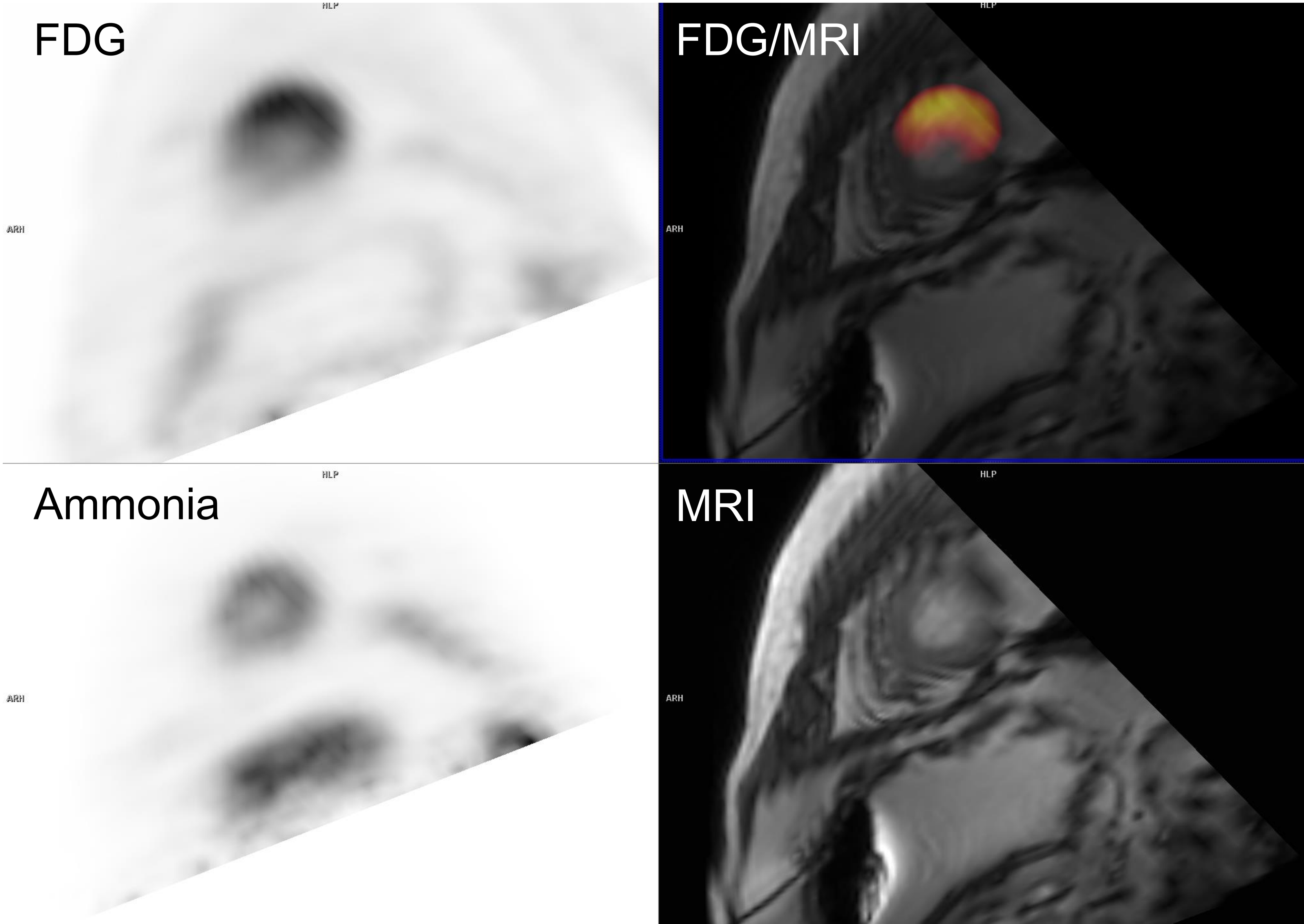


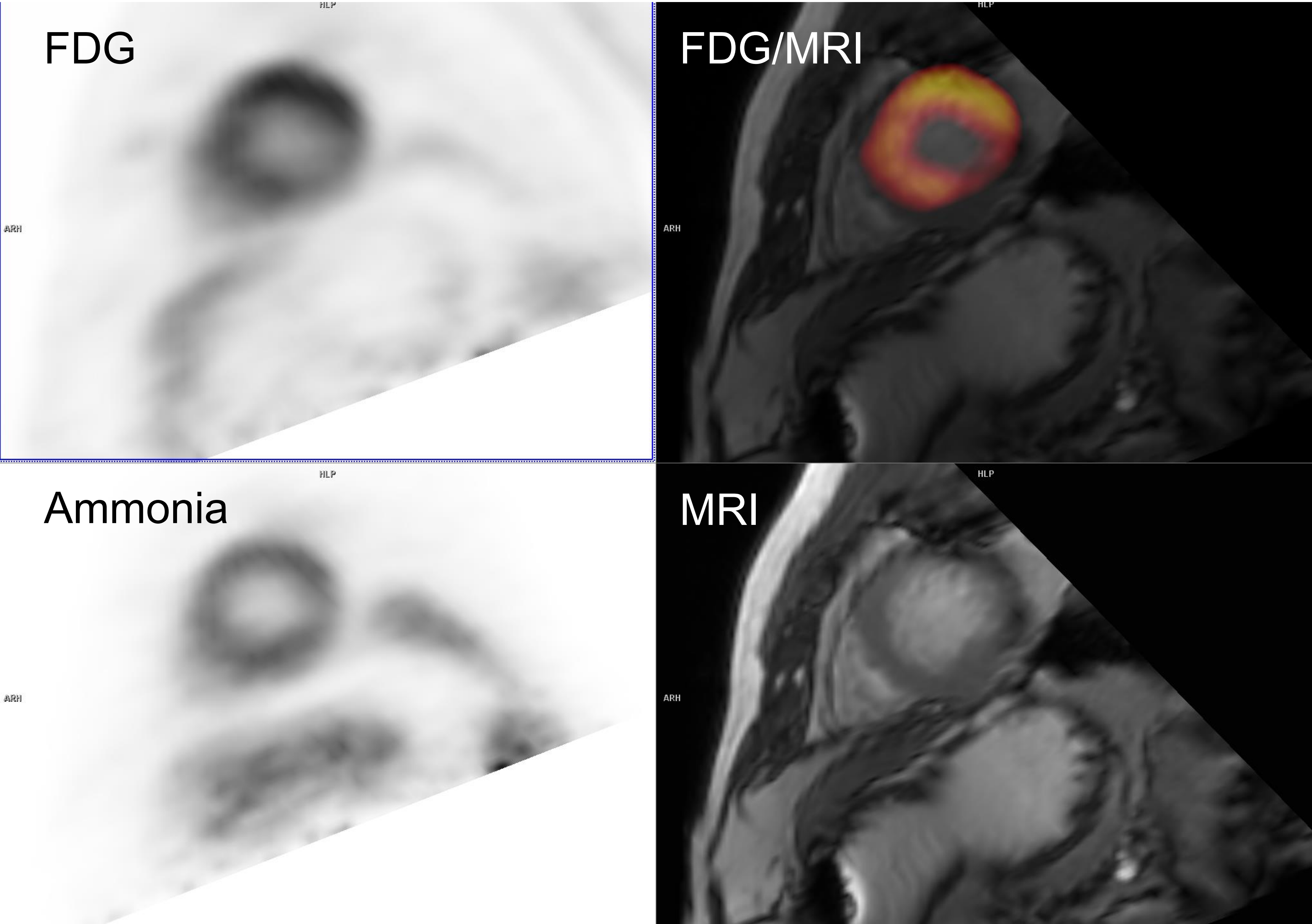
Persistent defect in mid to basal inferior and infero-lateral wall.
Partial reversible in apex, apico lateral and apico inferior wall.

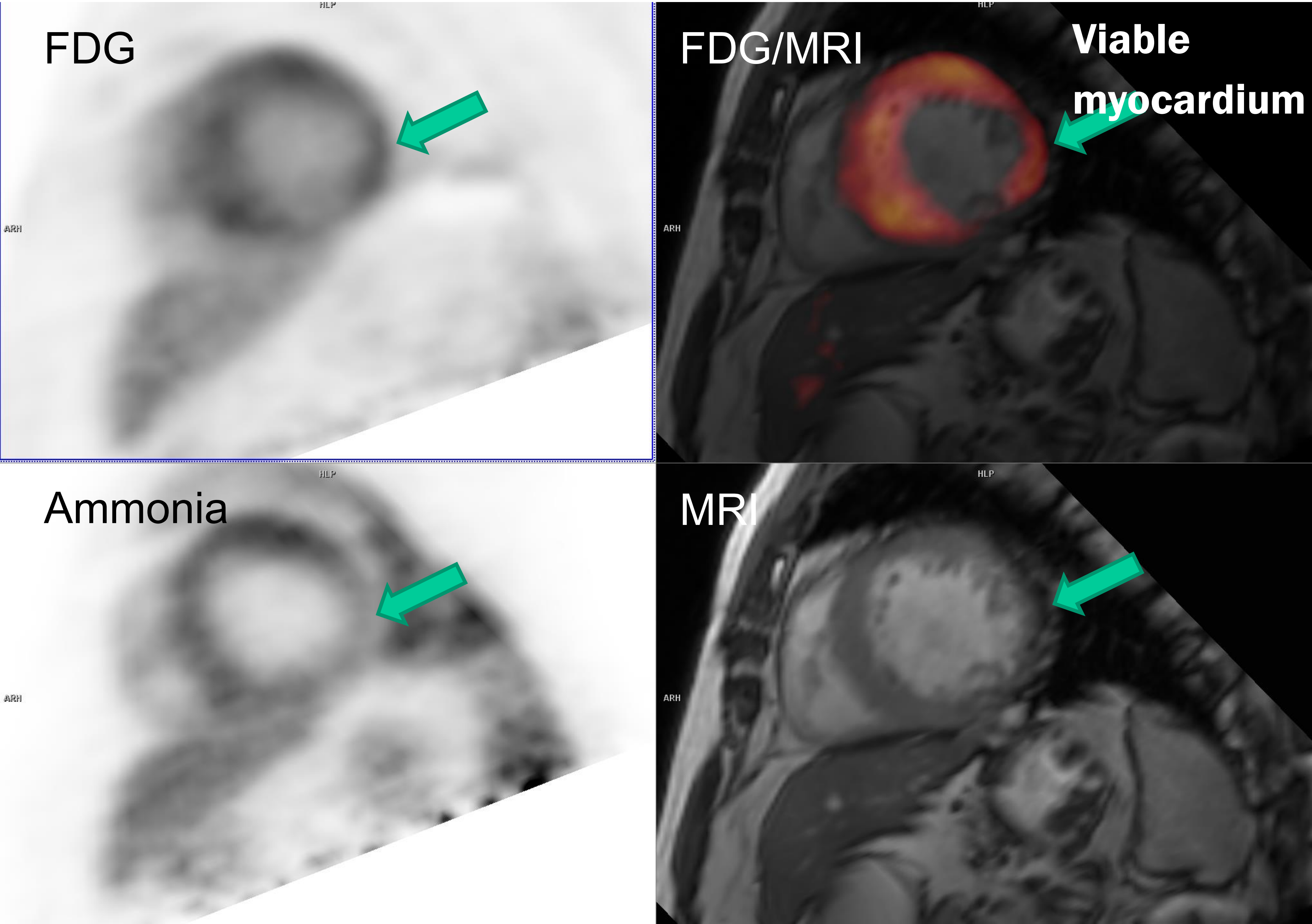

C6 MYEONG KOON, JEONG 44003597
March 04, 2013
SEOUL NAT. UNIV. HOSP.
REST
24HRS
Short axis(Apex--Base)
Horizontal long axis(Posterior--Anterior)
Vertical long axis(Septum--Lateral)
Anterior
Inferior
Septal
Lateral
Apex
Base

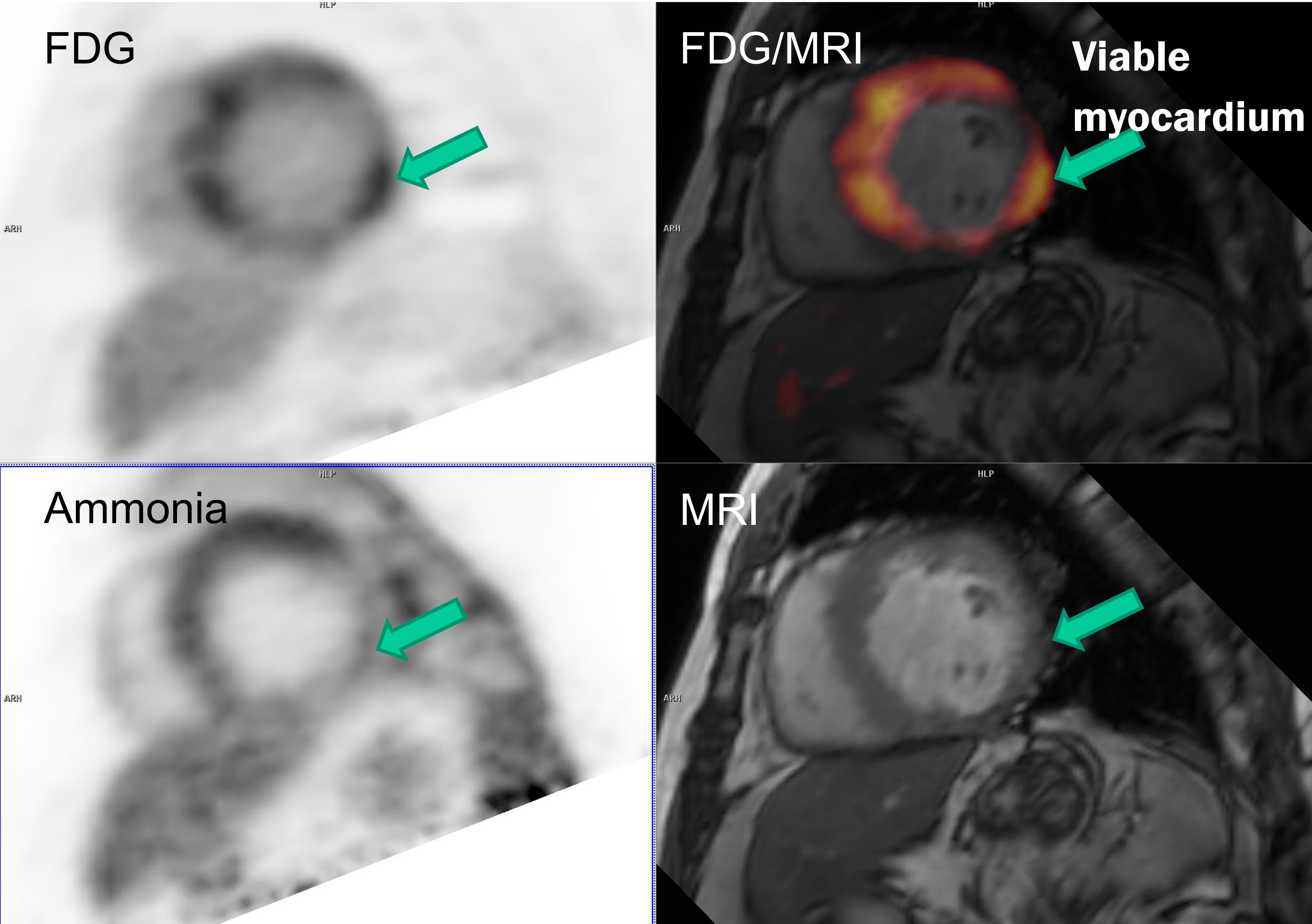


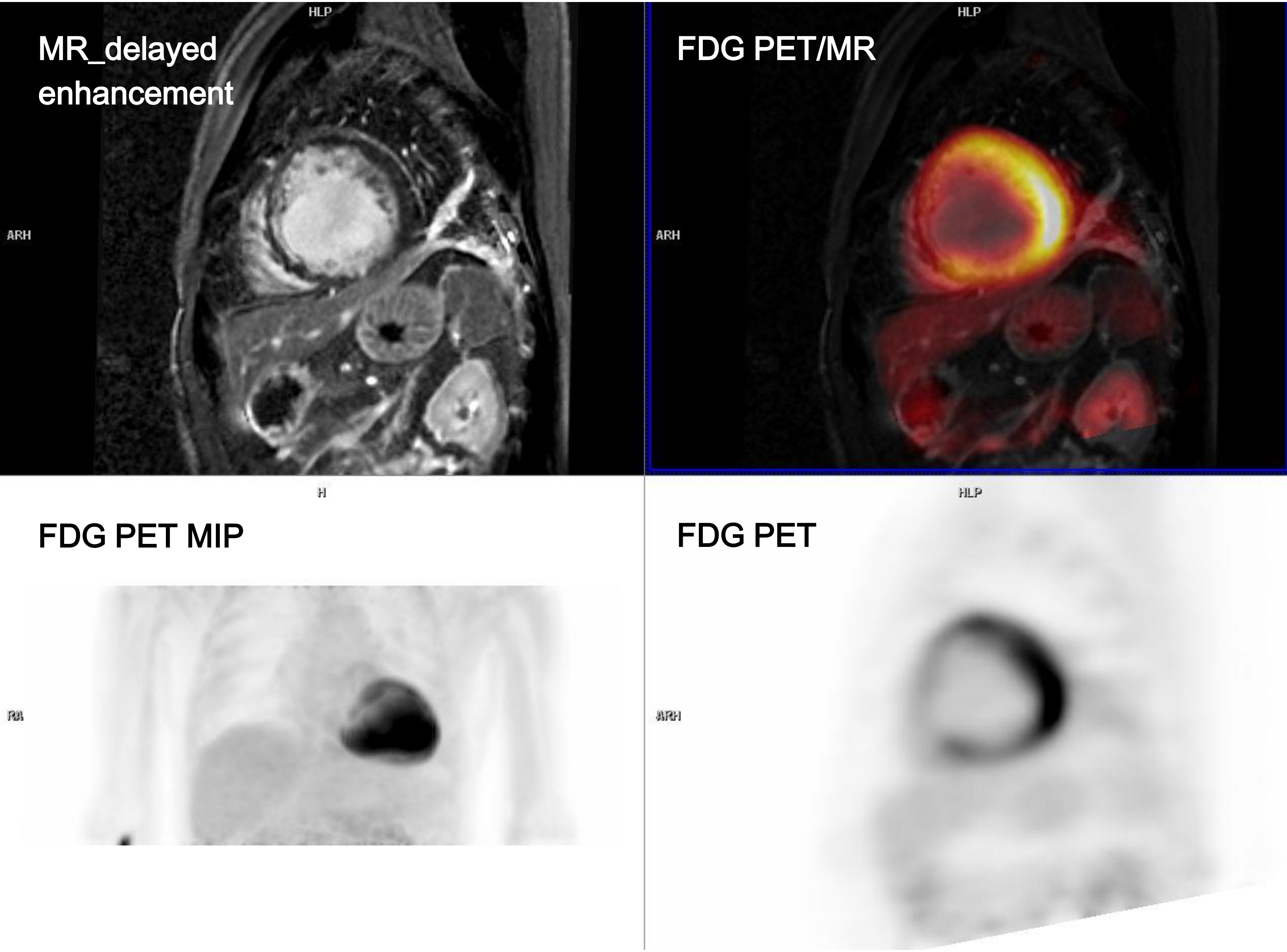
C6 MYEONG KOON, JEONG 44003597
March 04, 2013
SEOUL NAT. UNIV. HOSP.
REST
24HRS
Short axis(Apex--Base)
Horizontal long axis(Posterior--Anterior)
Vertical long axis(Septum--Lateral)
Anterior
Inferior
Septal
Lateral
Apex
Base
No further improvement


FDG
HLP
ARH
FDG/MRI
HLP
ARH
Ammonia
HLP
ARH
MRI
HLP
ARH

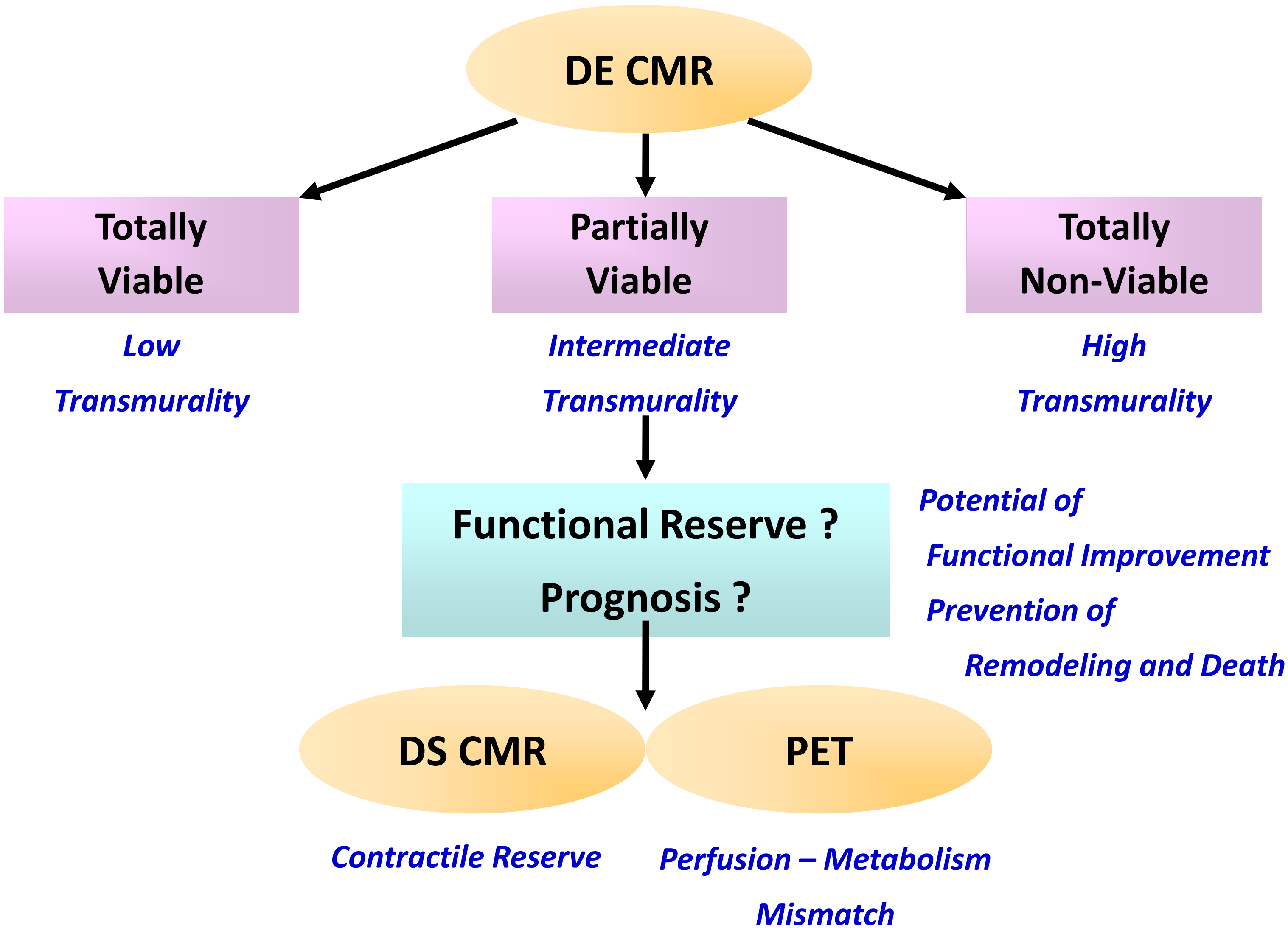

FDG
FDG/MRI
Ammonia
MRI
HLP
ARH


FDG
FDG/MRI
Viable
myocardium
Ammonia
MRI
HLP
ARH


FDG
FDG/MRI
Viable myocardium
Ammonia
MRI
HLP
ARH


MR_delayed
enhancement
HLP
ARH
FDG PET/MR
HLP
ARH
FDG PET MIP
H
RA
FDG PET
HLP
ARH

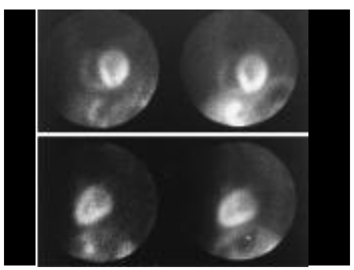
DE CMR & FDG PET
at Stunning & Hibernation

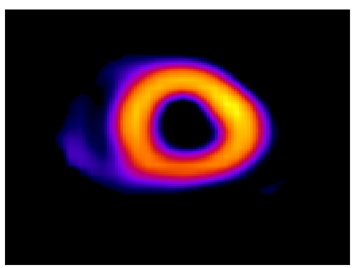


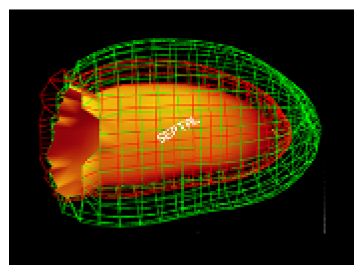
SPECT

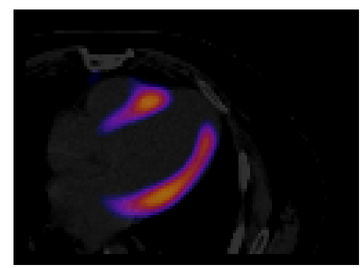
PET

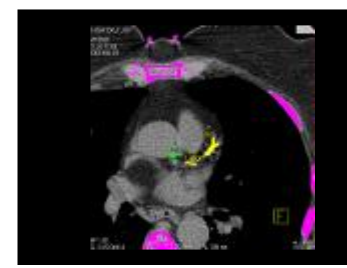
1970's	1980's	1990's	2000's	2010's
Planar	SPECT	Gated SPECT	SPECT-CT	SPECT/PET











Tl-201

Tc-99m agents

PET agents

Reversible defect
Lung uptake/TID

Reversible defect
LVEF/SSS

Percentage of ischemia

Absolute flow