Advances in PET/CT, SPECT/CT and SPECT for Cardiology

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CEDARS-SINAI HEALTH SYSTEM

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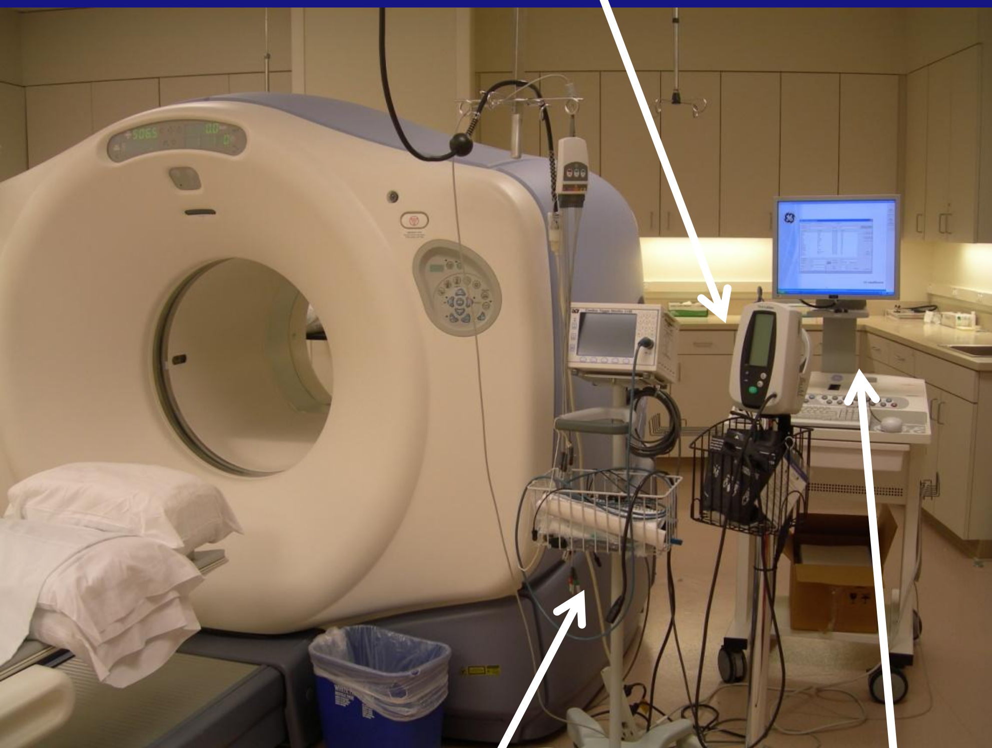
Cedars-Sinai Medical Center

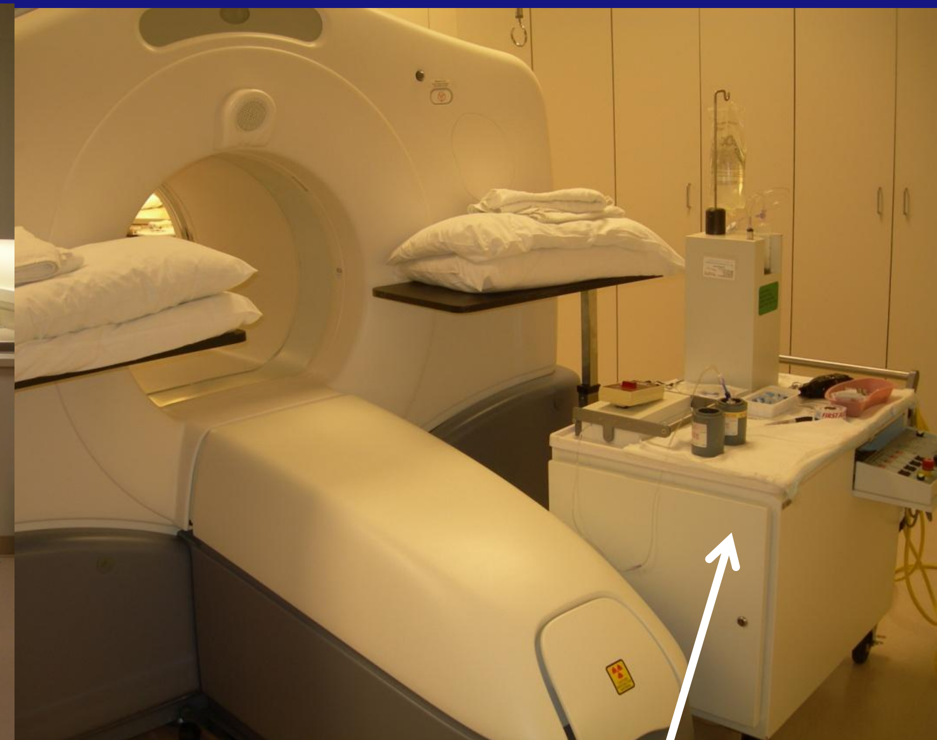
OUTLINE

- Latest PET/CT hardware
- Latest SPECT hardware
- Low dose imaging
- Perfusion quantification
- Attenuation correction
- Kinetic modelling
- Motion
- Hybrid quantification

Cardiac PET/CT setup

BP



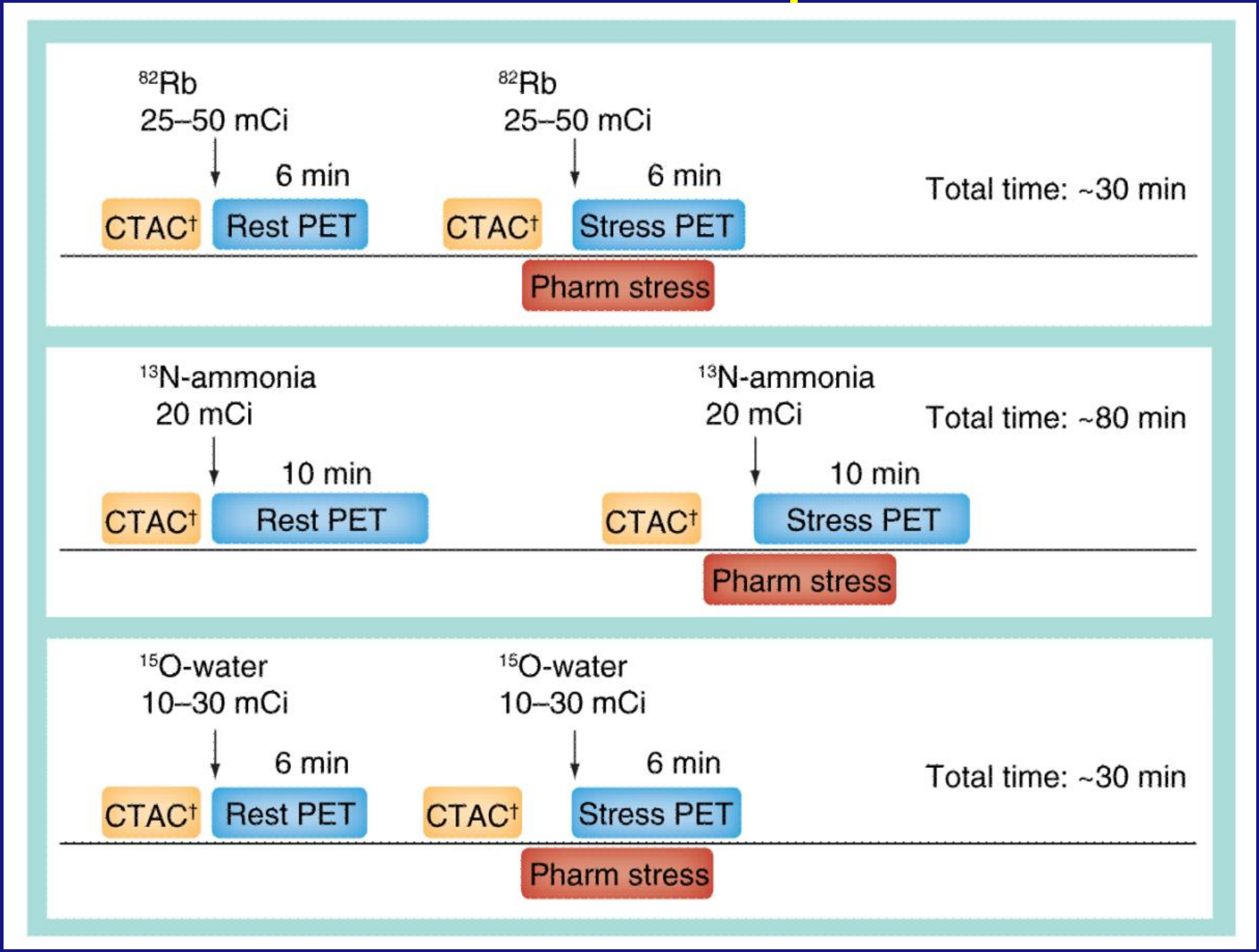


ECG for gating

12 leads ECG

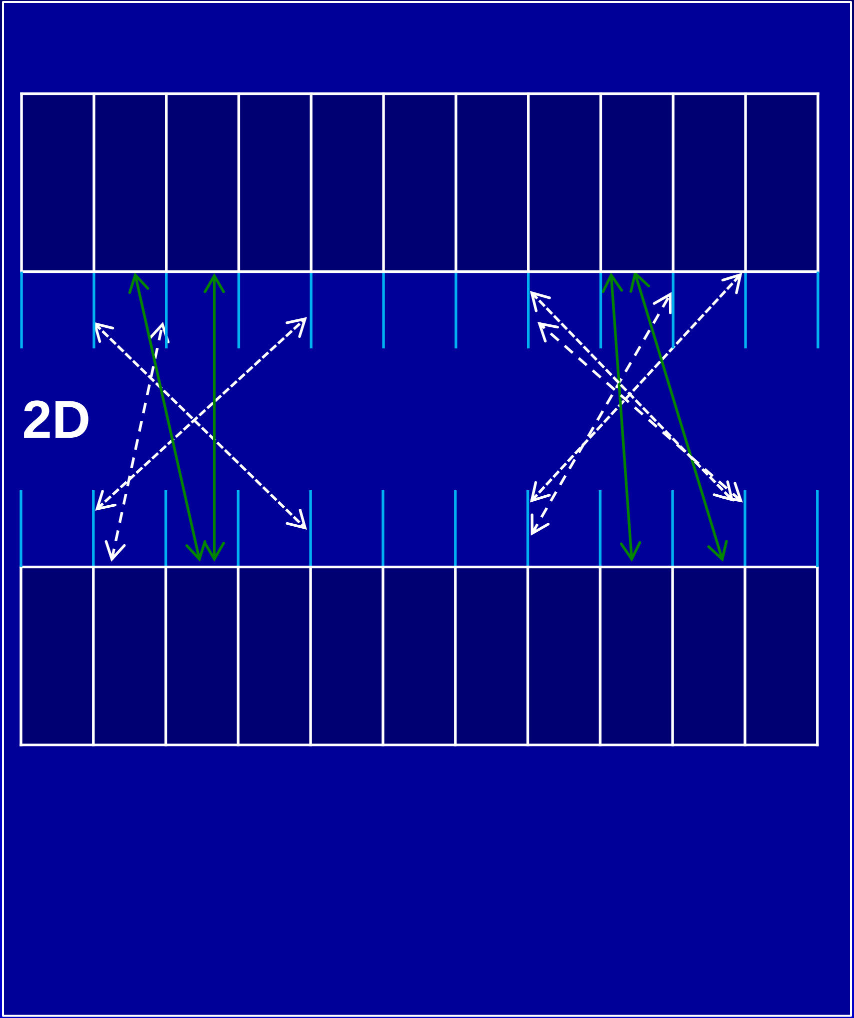
82Rb generator

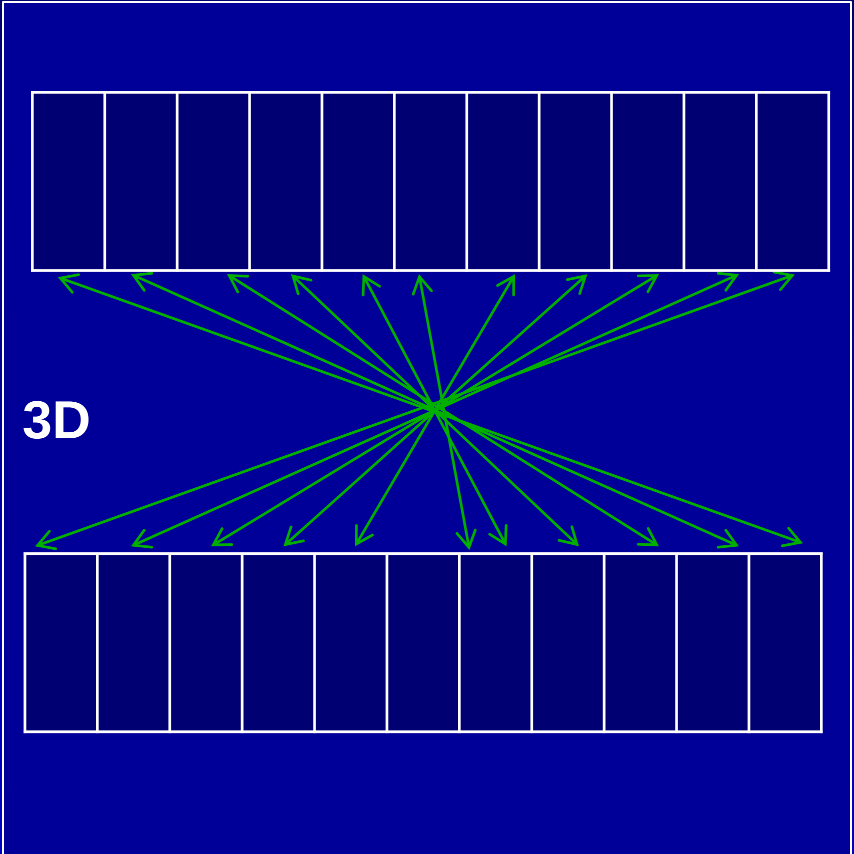
Cardiac PET/CT protocols



Imaging Med Nakazato et al 2013

2D vs. 3D PET acqusition

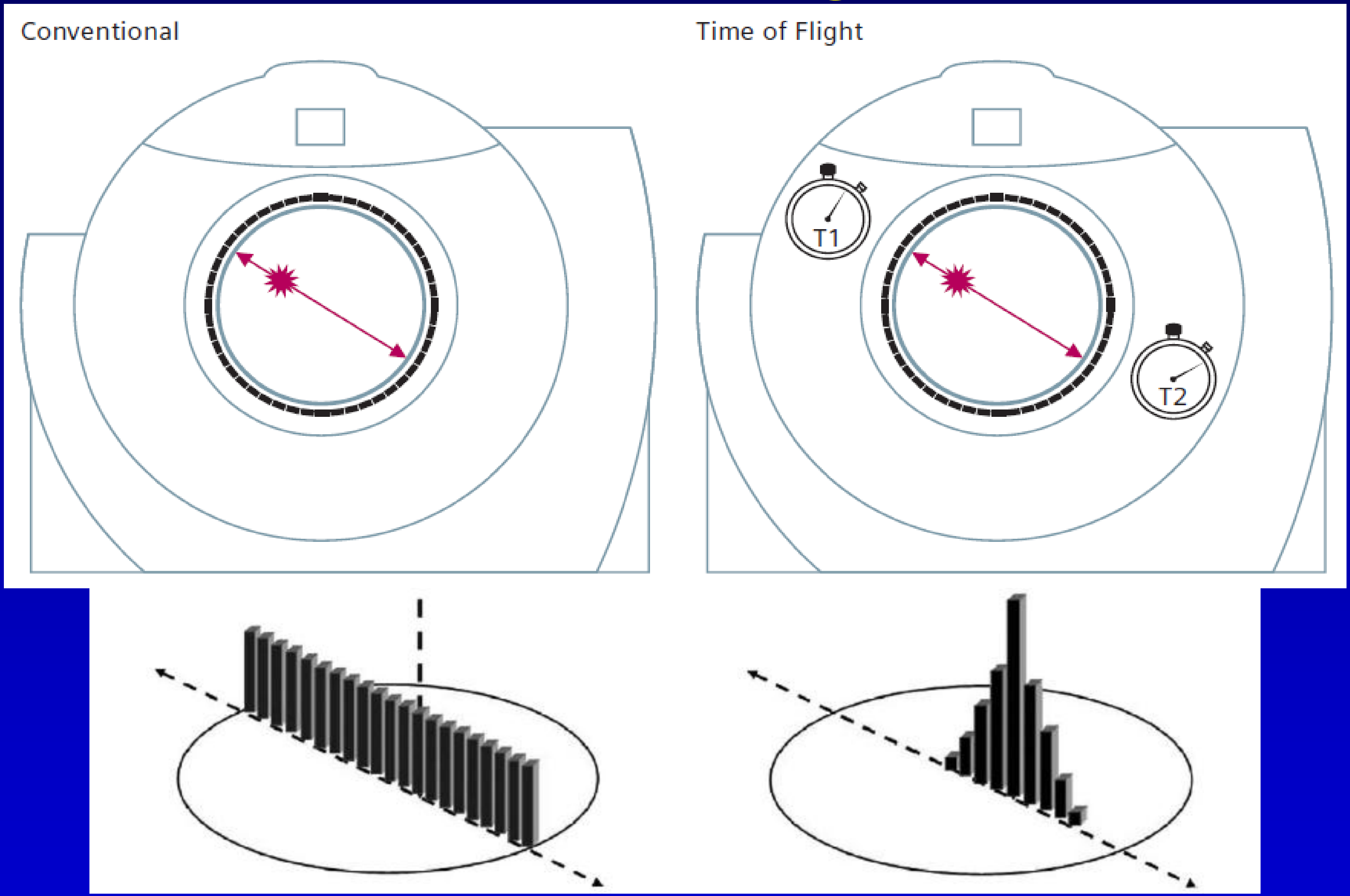




Higher sensitivity
More scatter

Most hybrid PET/CT systems are 3D

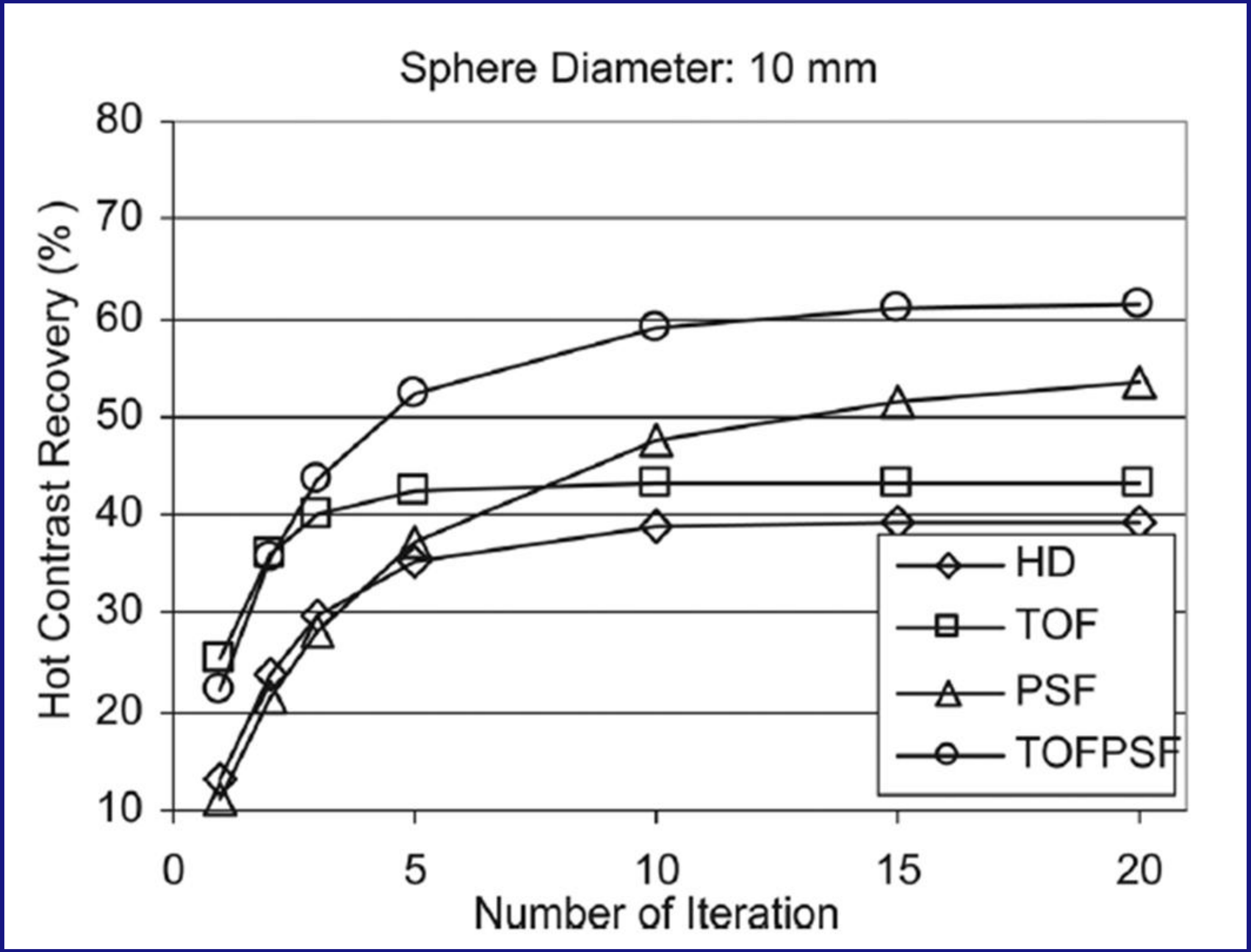
Time of flight



Townsend, PMB 2008

Time-of-flight (TOF) PET reconstruction

Improved contrast with TOF



HD= 3DOSEM PSF=resolution recovery TOFPSF =TOF + resolution recovery

Bettinardi et al Med Phys 2011

TOF improves cardiac image quality

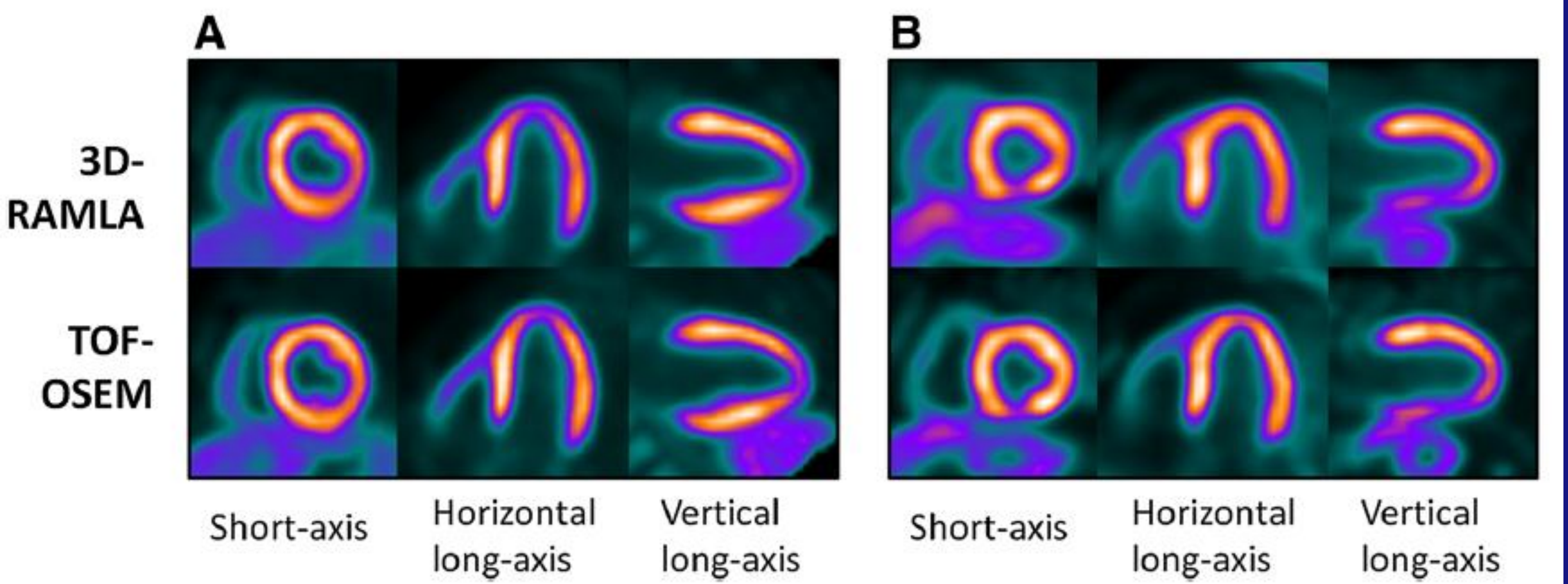
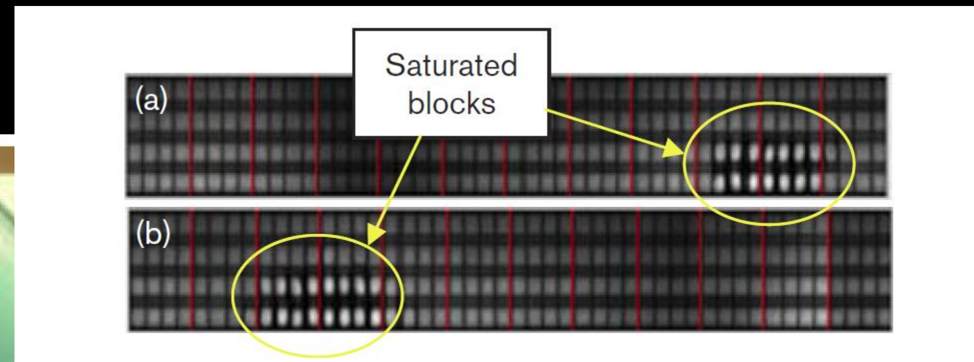


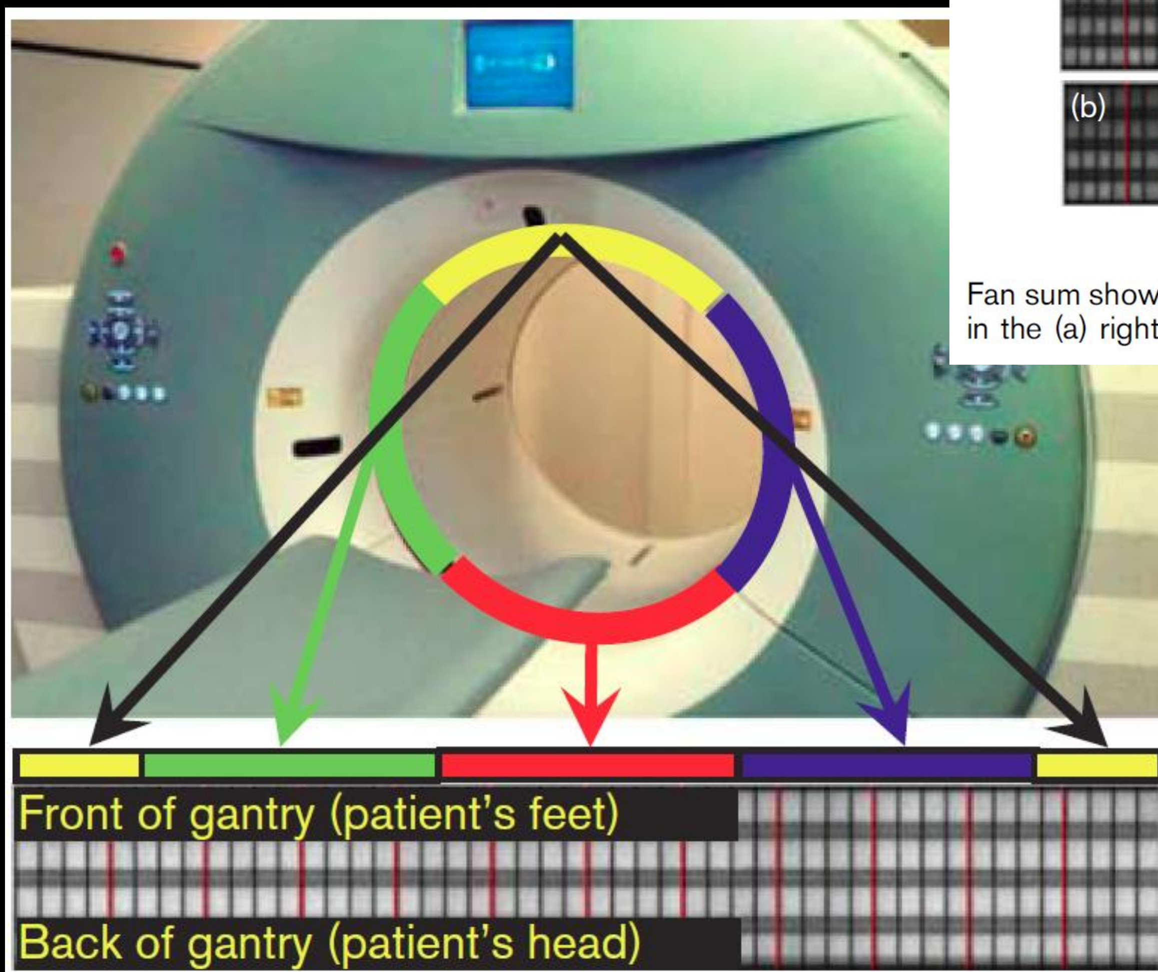
Figure 1. Comparison of images between TOF-OSEM and 3D-RAMLA. (**A**) A representative case of a 53-year-old normal, female volunteer. (**B**) A case with three-vessel coronary artery disease. There was a severe decrease of uptake in the inferior wall.

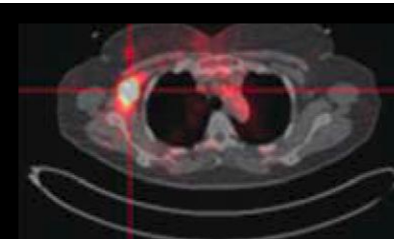
Tomiyama et al J Nucl Cardiol 2014

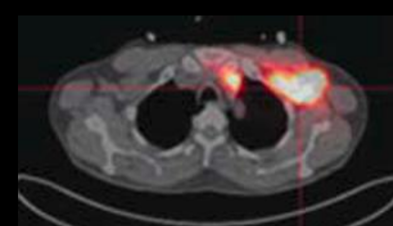
Saturation during Rb-82 infusion



Fan sum showing detector block saturation during rubidium-82 infusion in the (a) right and (b) left arm.

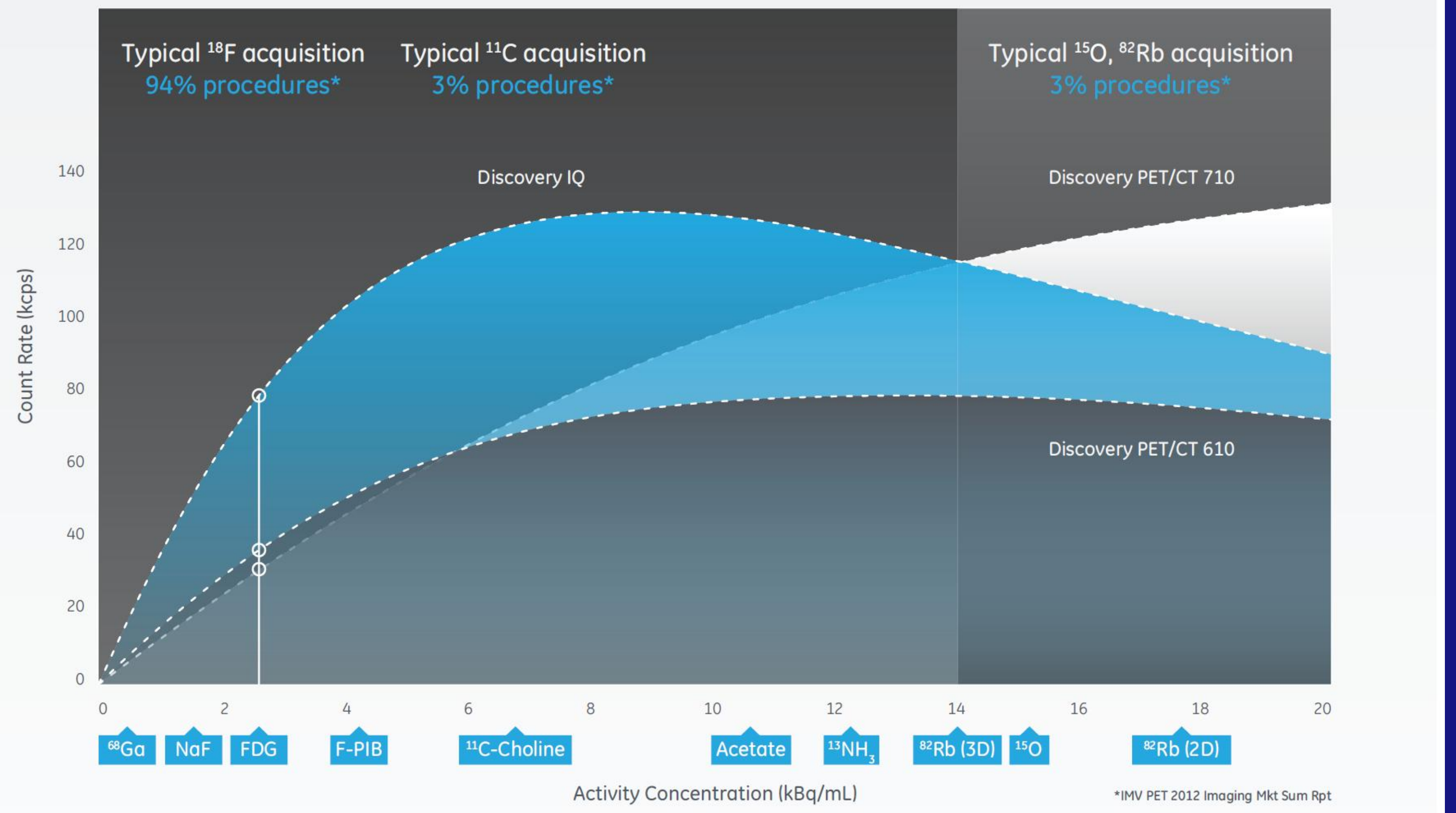






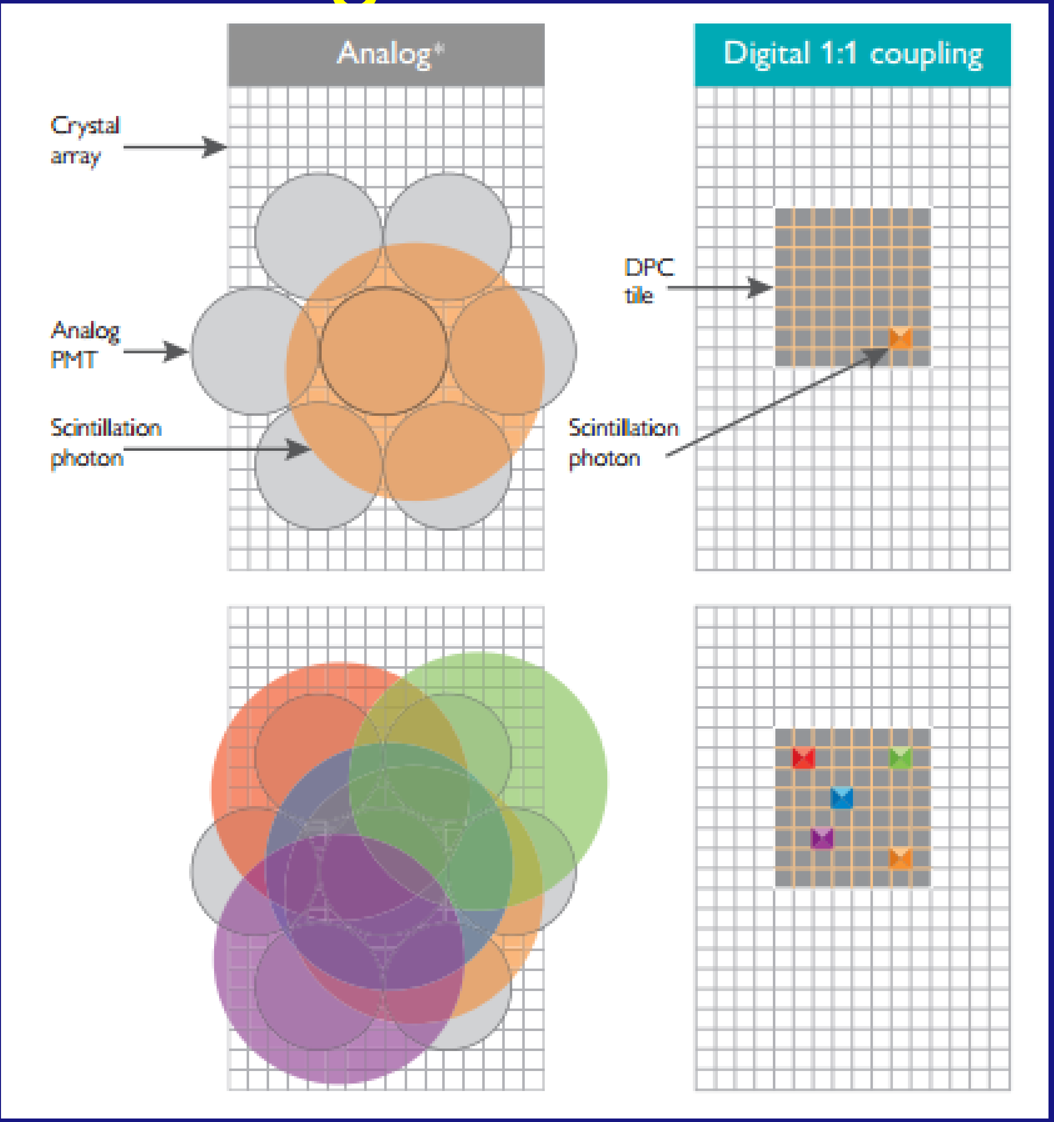
Taut et al. Nucl Med Commun 2012

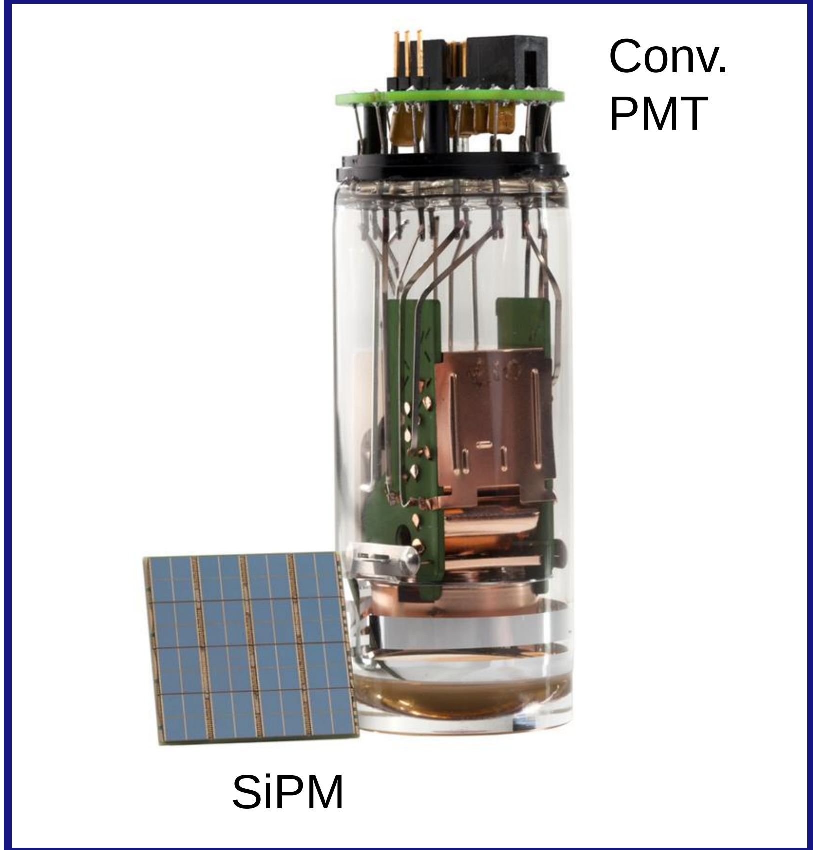
NECRs of Discovery IQ and 710



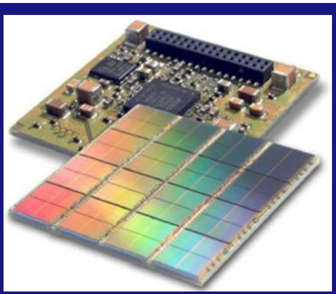
NECR curves for the Discovery IQ, 5 ring configuration[2]

Digital Photon Counting in PET





Digitial Silicon PMT (SiPM)



SiPM – faster timing resolution, insensitive to MR

Philips

Current PET/CT systems

	Ingenuity TF	Discovery 710	Biograph mCT	Vereos
Patient port [cm]	70 OpenView	70	78	70
Patient scan range [cm]	190	200	195	190
Acquisition modes	3D S&S	3D S&S	3D S&S, continuous	3D S&S
Number of image planes	45 or 90	47	109	72
Plane spacing [mm]	2 or 4	3.27	2	1, 2, or 4
Crystal size [mm]	4 x 4 x 22	4.2 x 6.3 x 25	4 x 4 x 20	4 x 4 x 22
Number of crystals	28,336	13,824	32,448	23,040
Number of PMTs	420	256	768	**23,040 SiPM's**
Physical axial FOV [cm]	18	15.7	21.8	16.3
Detector material	LYSO	LYSO	LSO	LYSO
System sensitivity 3D, [%]*	**0.74**	**0.75**	**0.95**	**2.2**
Trans axial resolution @ 1 cm [mm]*	4.7	4.9	4.4	4.0
Trans axial resolution @ 10 cm [mm]*	5.2	5.5	4.9	4.5
Peak NECR [kcps]	**120 @19 kBq/ml**	**130 @29.5 kBq/ml**	**175 @28 kBq/ml**	**650 @50 kBq/ml**
Time-of-Flight resolution [picoseconds]	591	544	540	307
Time-of-Flight localization [cm]	8.9	8.2	8.1	4.6
Coincidence window [nanoseconds]	4.5	4.9	4.1	1.5

Question 1. Which 3D PET/CT parameter will be most critical for ^{82}Rb imaging __________ .

16%	a.	Trans axial resolution
6%	b.	Crystal size
3%	c.	Patient port
72%	d.	NECR
3%	e.	Scatter fraction

Question 1. Which 3D PET/CT parameter will be most critical for ^{82}Rb imaging ________ .

(a) Trans axial resolution

(b) Crystal size

(c) Patient port

(d) NECR

(e) Scatter fraction

1. ✗
2. ✗

✗

3. ✓

4. ✗

The correct answer is D: reference
Assessment of a protocol for routine simultaneous myocardial blood flow measurement and standard myocardial perfusion imaging with rubidium-82 on a high count rate positron emission tomography system. Tout D, Tonge CM, Muthu S, Arumugam P. Nucl Med Commun. 2012;33:1202-11

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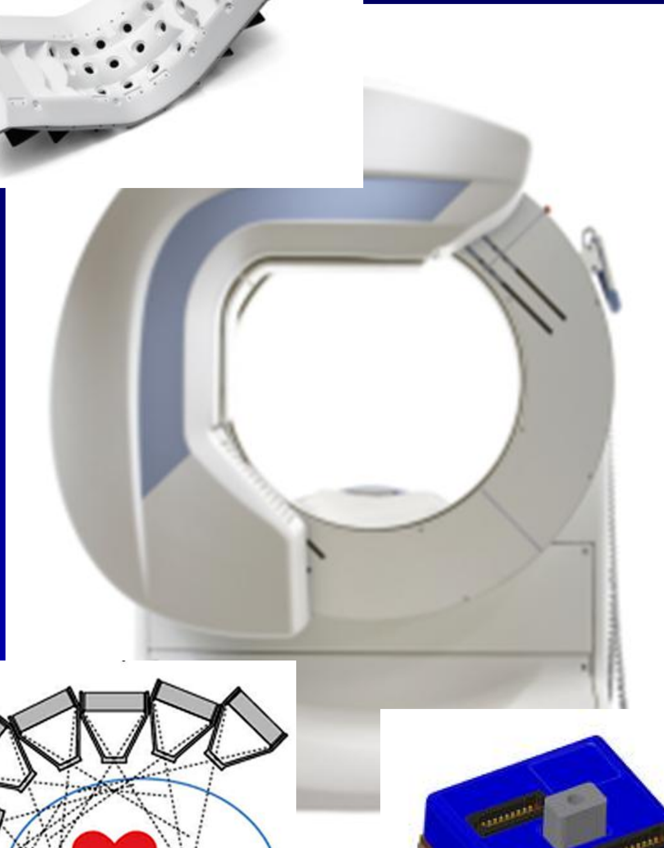
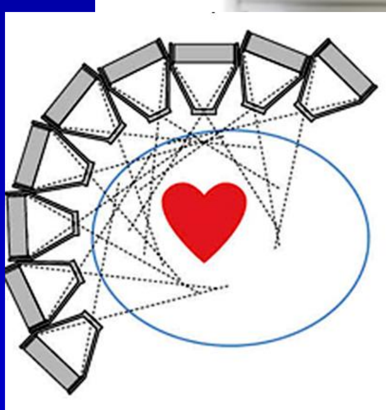
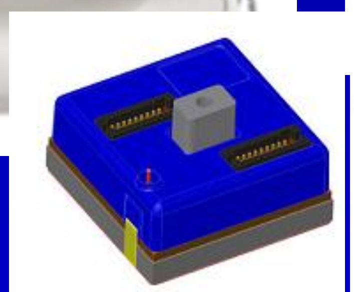
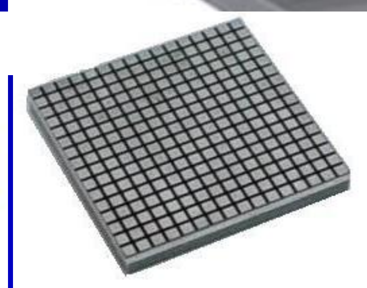
Fast SPECT cameras





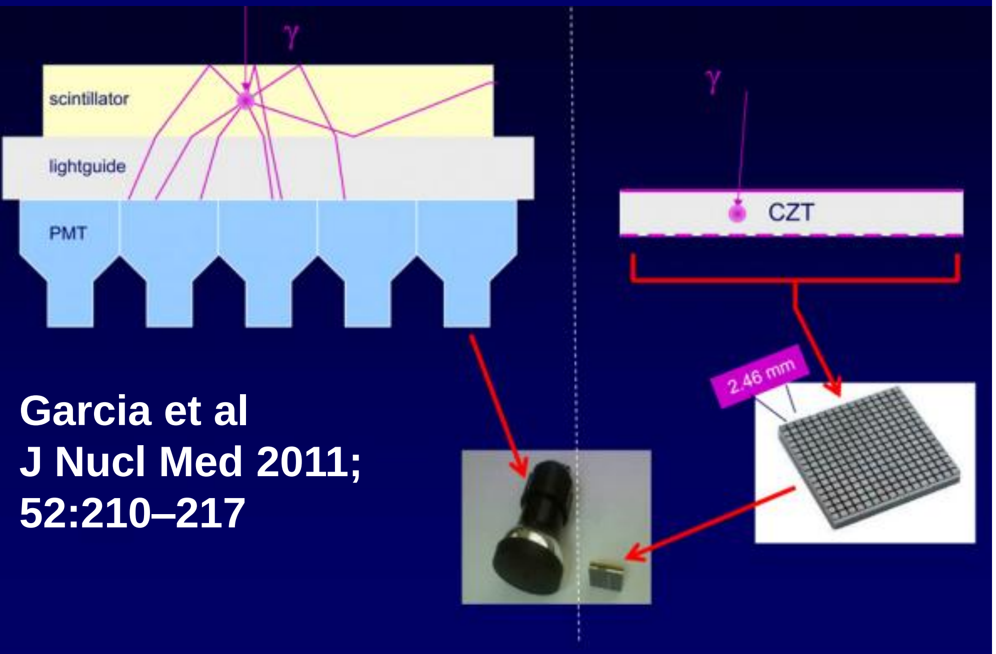




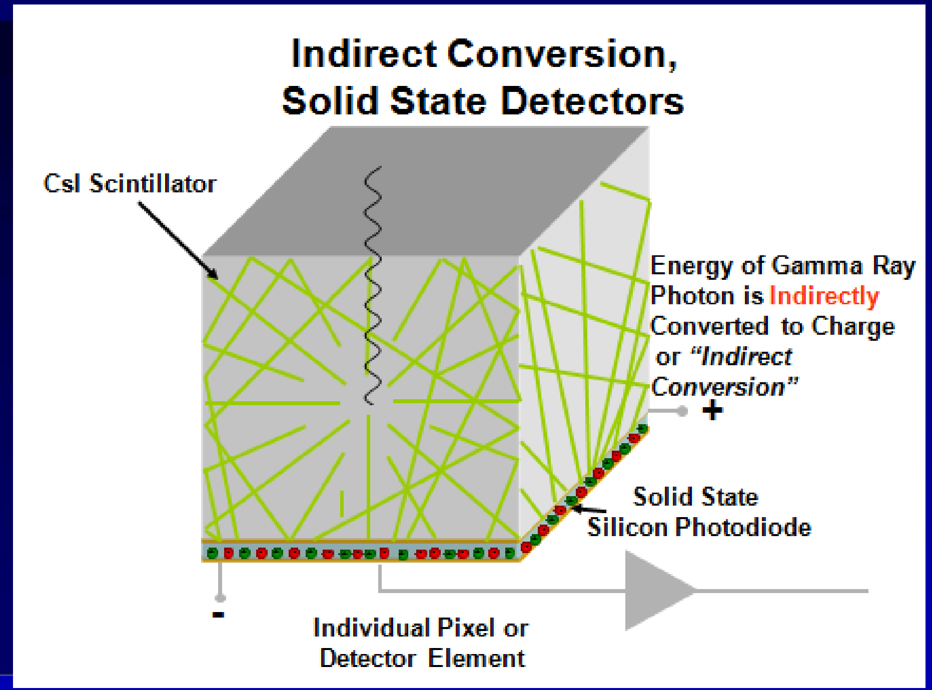
>300 installed worldwide
2015 estimate

New collimators → high sensitivity
Solid-state detectors → better resolution, compact design

Solid state detectors



Garcia et al
J Nucl Med 2011;
52:210–217



Improved spatial resolution 2x
energy resolution 1.6 x to < 6%

Cadmium Zinc Telluride (CZT)

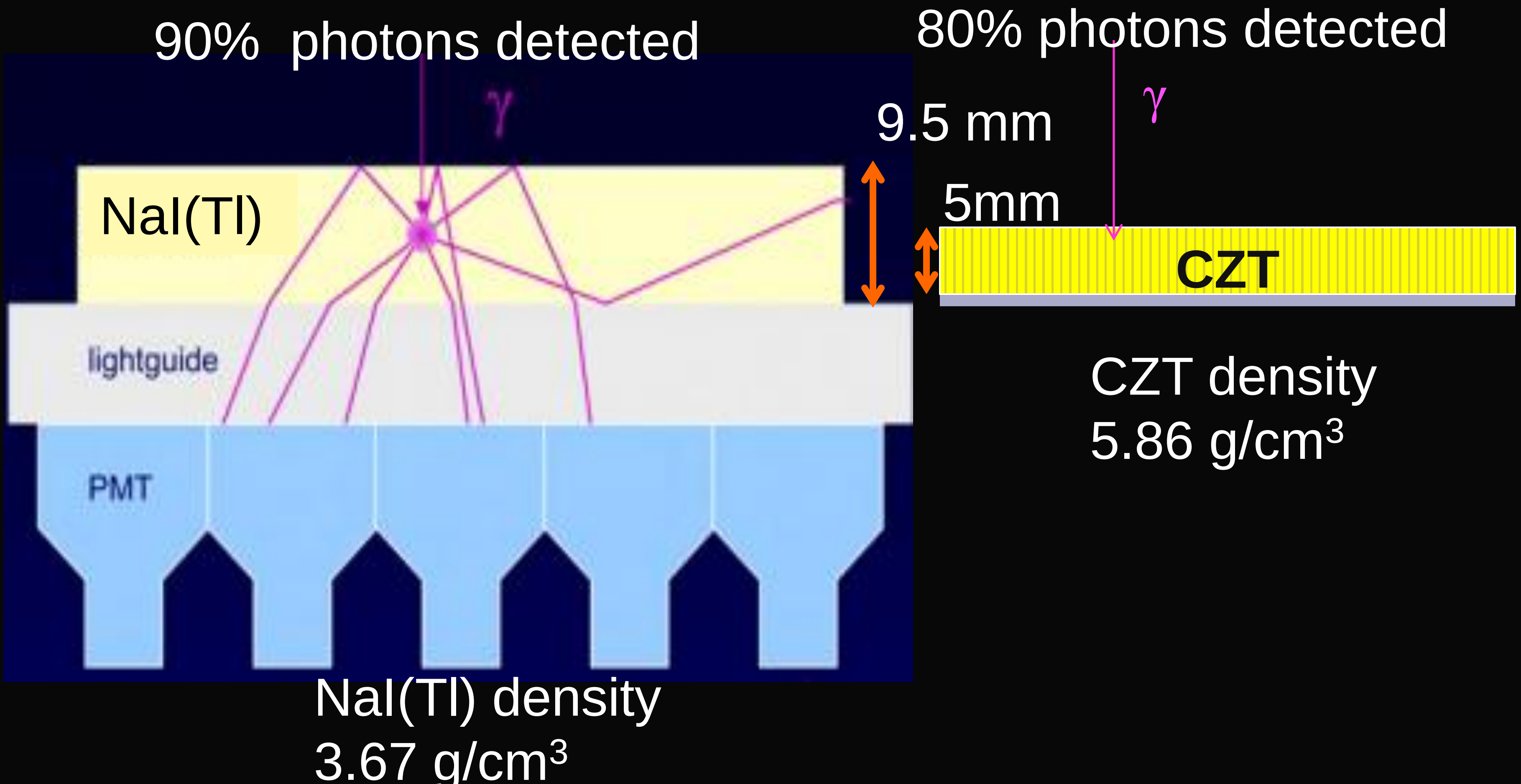
DSPECT: J Nucl Med 2009; 50:635–643
NM530c J Nucl Cardiol. 2008;15(suppl):S3.

Improved spatial resolution

Cesium Iodide (CsI)

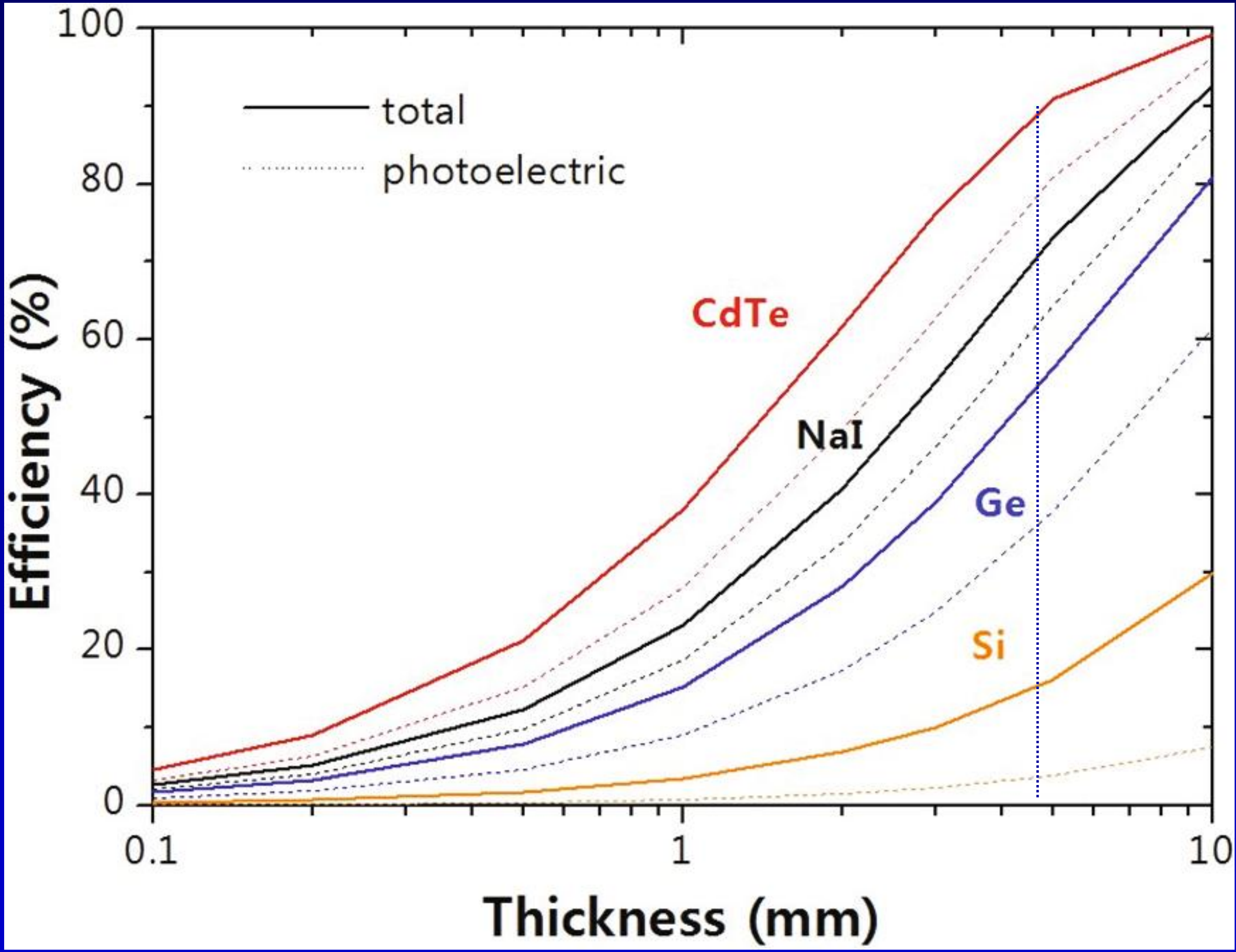
Digirad
Bai et al. JNC 2010;17:459-69

NaI(Tl) vs. CZT crystal intrinsic efficiency at 140keV



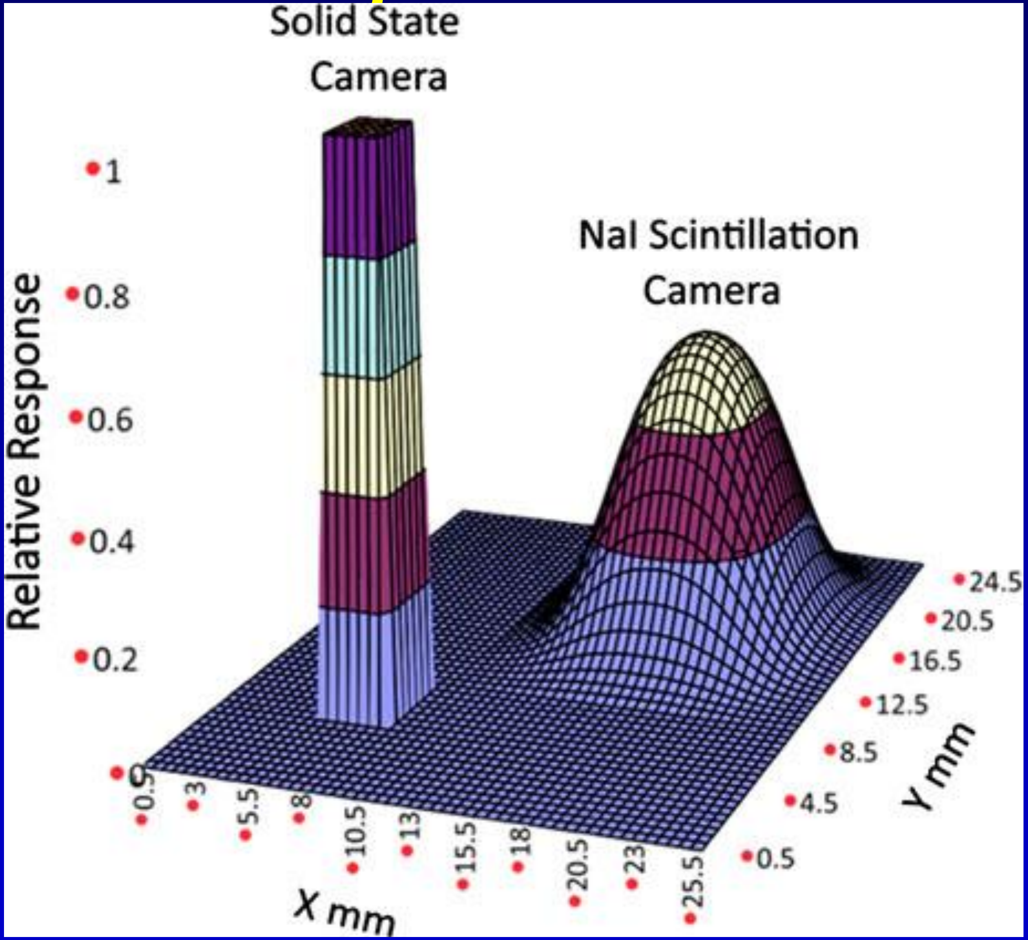
CZT <u>not the reason</u> for increased sensitivity for new scanners

Photon efficiency: solid-state vs NaI (Tl)



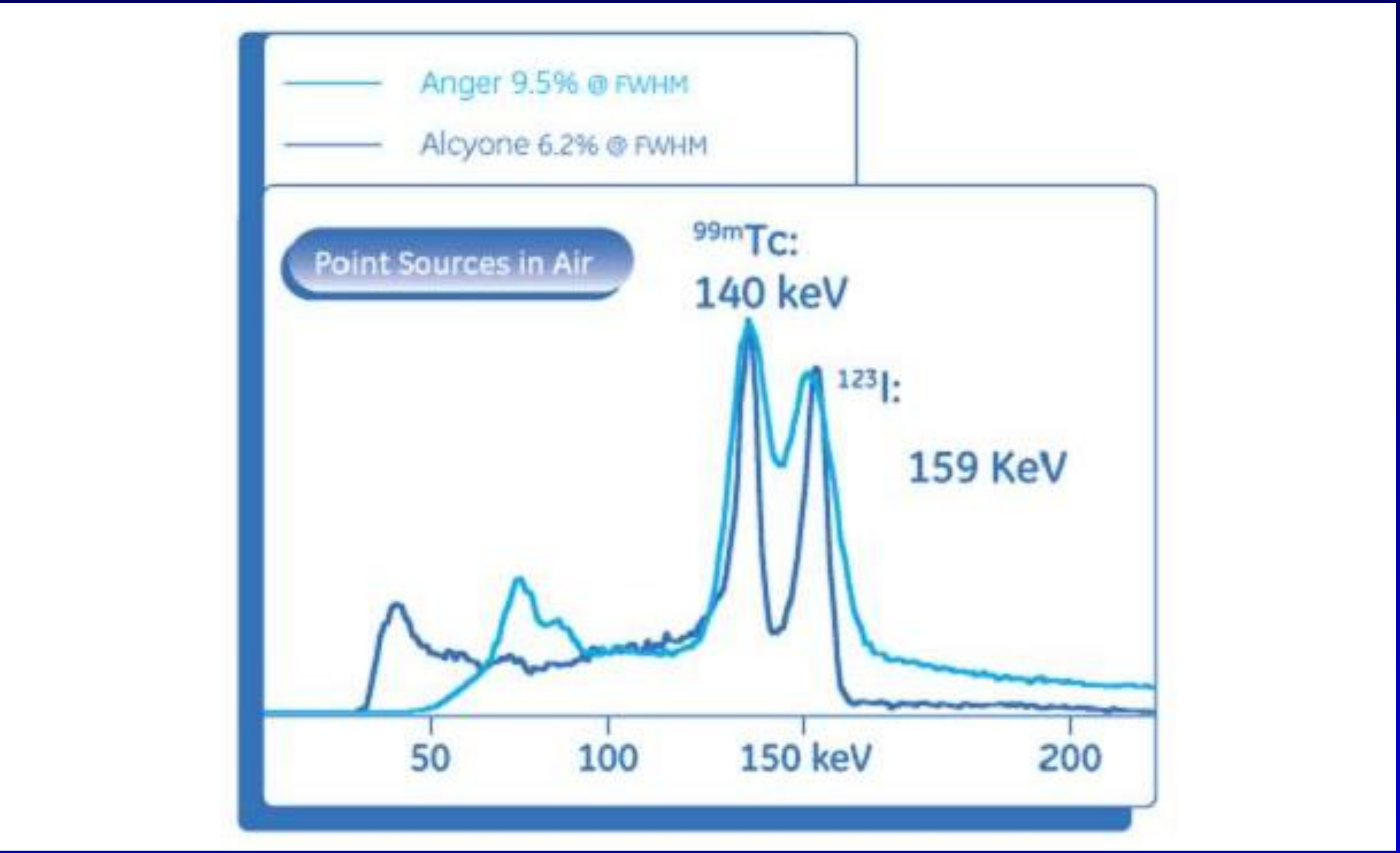
Lee Y-J et al Journal of the Korean Physical Society, 2014;64:1055~1062

Solid-state superior intrinsic image resolution



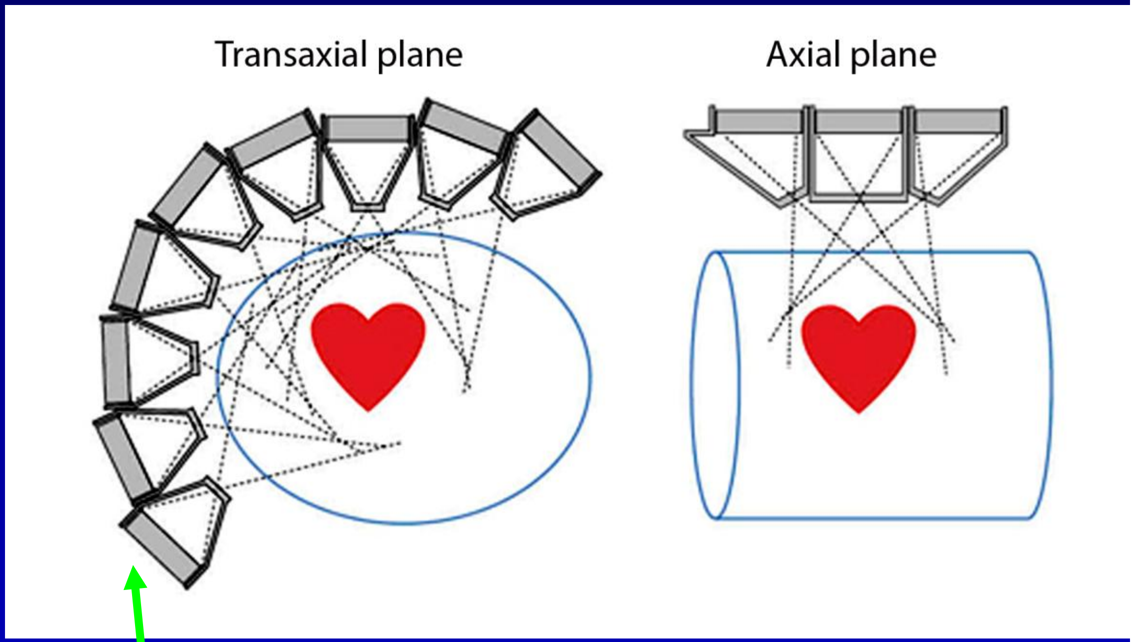
DePuey EG J Nucl Cardiol 2012 56119;551–81

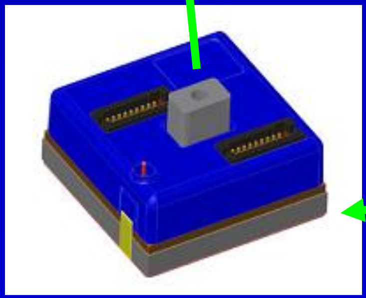
CZT superior energy resolution

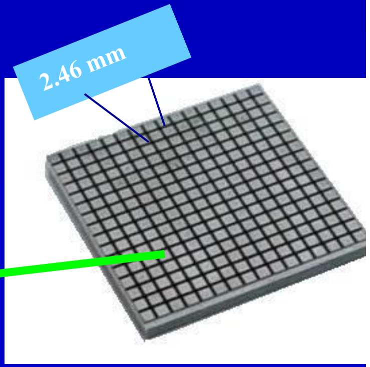


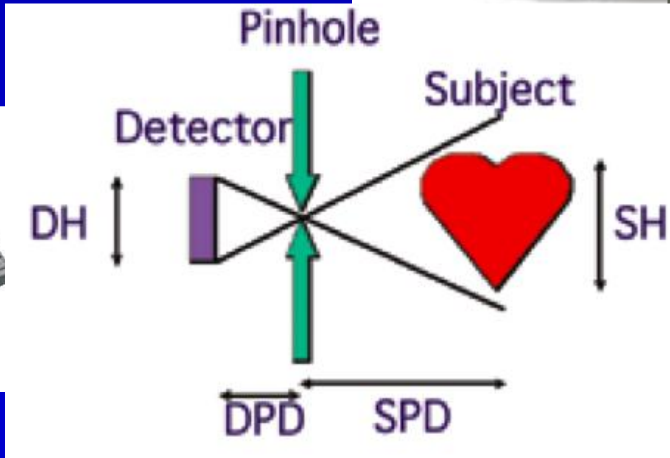
Overlay of ^{99m}Tc and ^{123}I spectra, showing greater crosstalk between two peaks for the Anger camera with its poorer energy resolution

Multi-pinhole collimation with CZT





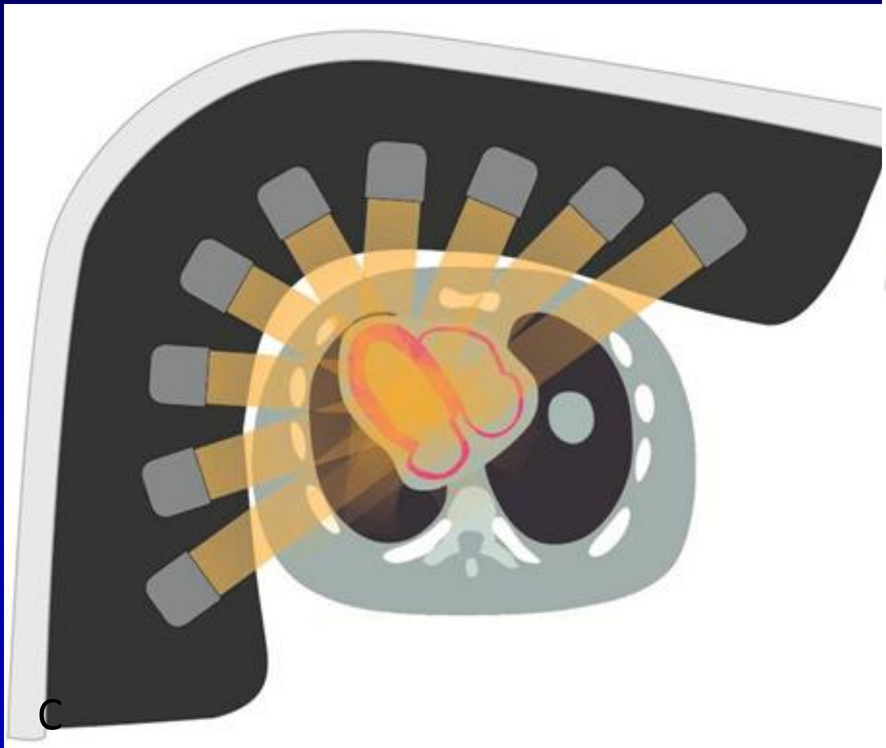




Focusing high sensitivity paralell collimators

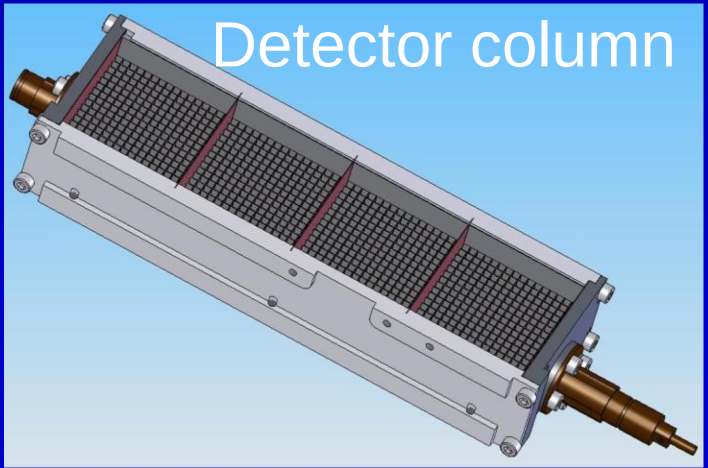
A

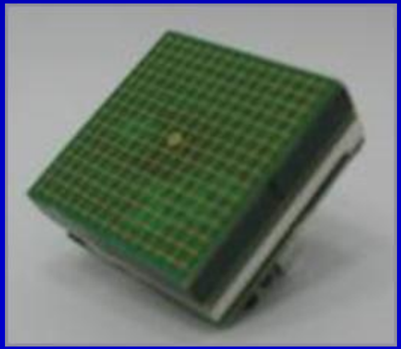
B



C

D





Sharir et al, JACC imaging 2008; 1: 156
Kacperski et al IEE MIC 2008

Reduced cost CZT

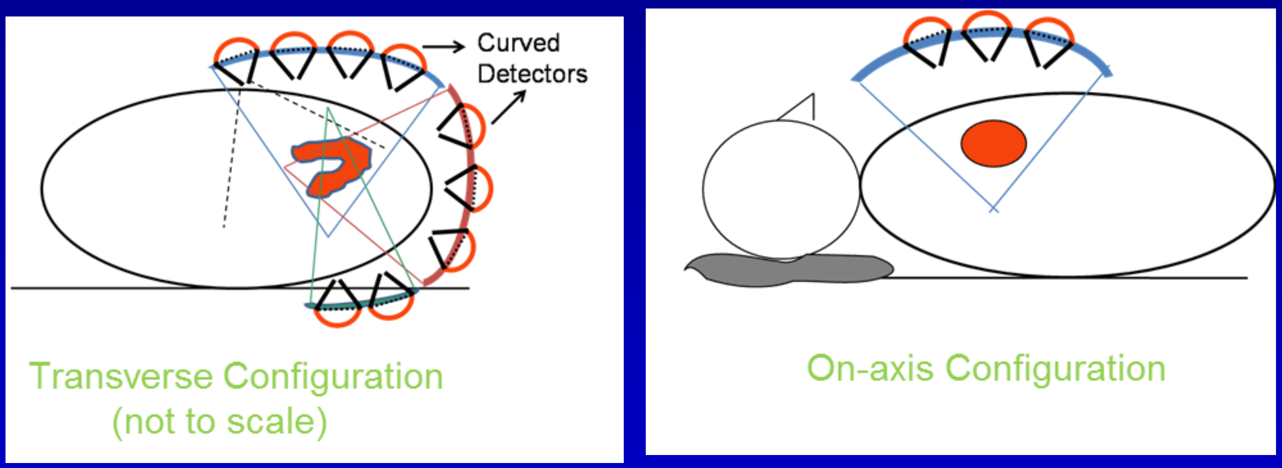
6 rotating detectors (instead of 9)

Sensitivity reduced approximately 33%

Future designs: Improved Detector Sensitivity

Curved Detectors with Pinhole:

- Increase *Sensitivity* (> 2 times) by opening pinhole
- Maintain same resolution



21 Pinholes arranged in surface-sectors around upper torso of body; Pinholes are pointed towards the heart

J. Dey, IEEE TNS, *vol.59,no.2,Apr 2012,pp.334-347*

Fan beam collimators with indirect conversion solid state detectors

Triple head and
Fan beam allow
Increase sensitivity

Courtesy of Richard Conwell Digirad

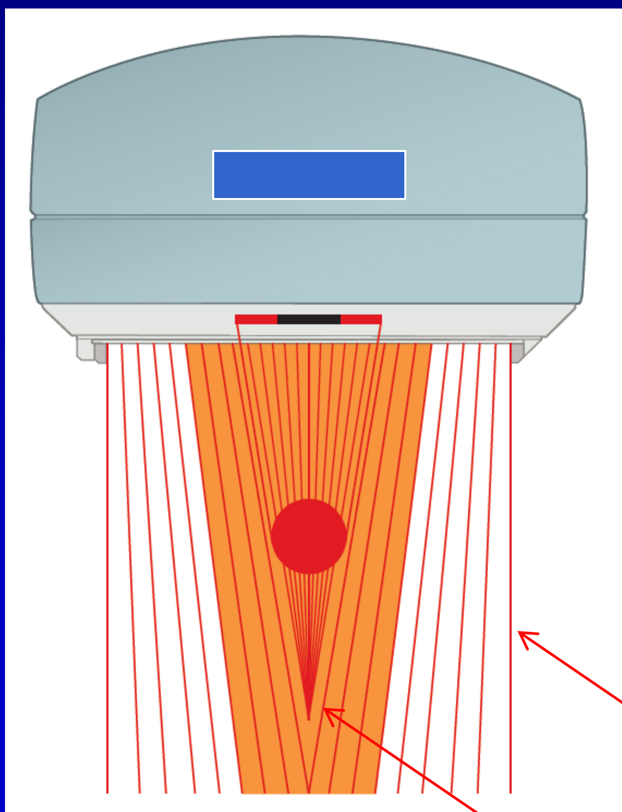
Anger camera: technologies for efficiency improvements

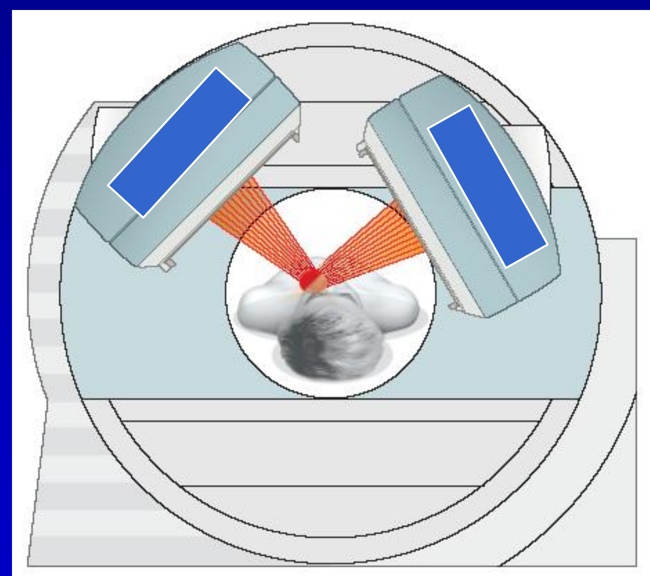
Cardiofocal collimation

4 x more counts from the heart

No truncation

- **Heart is in maximum zoom area**
- ***Heart is the center of rotation***



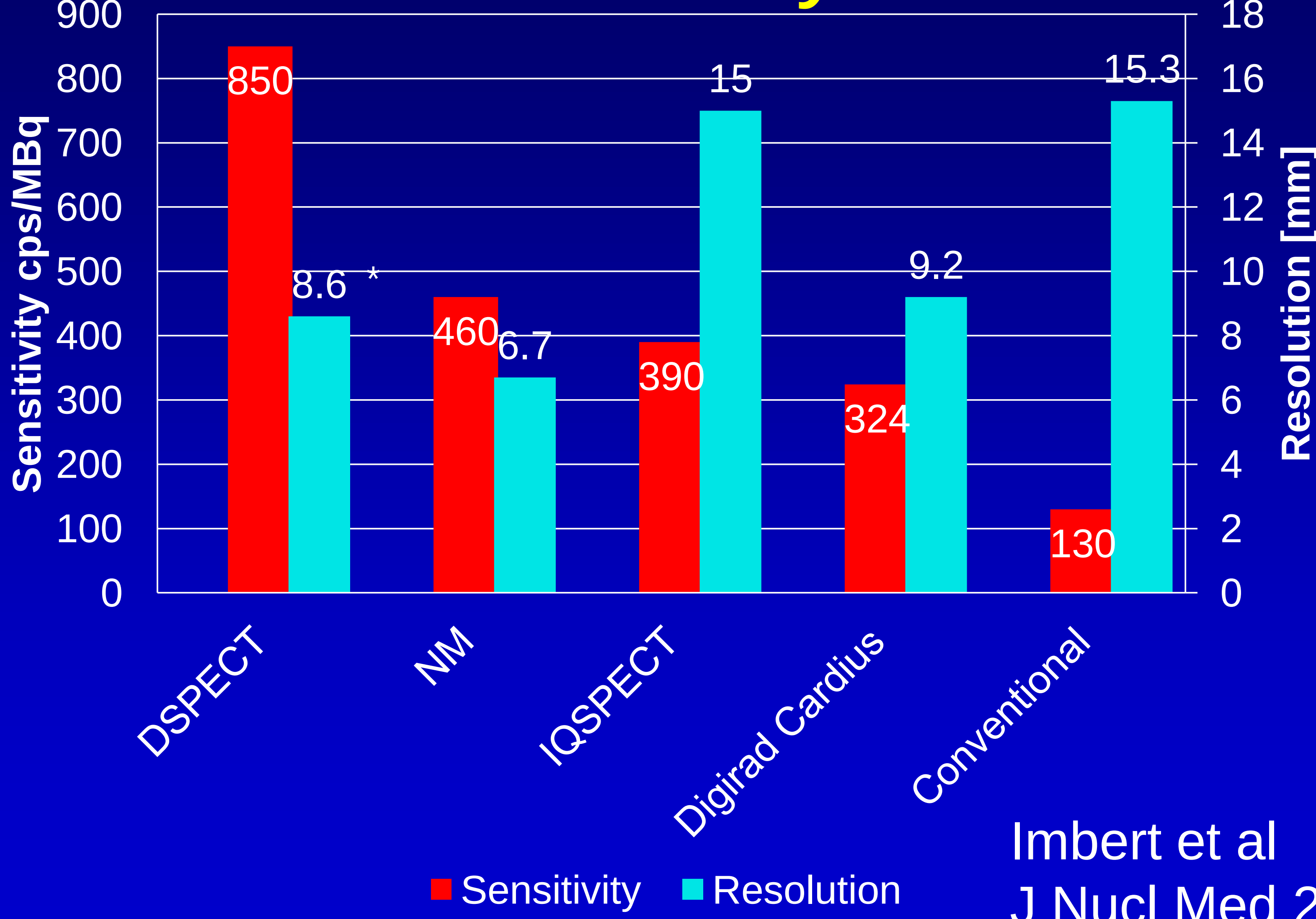


Cardiofocal

Conventional

Courtesy of Siemens Medical Systems

Fast-MPS resolution and sensitivity



* Reconstruction without heart priors

Imbert et al
J Nucl Med 2012

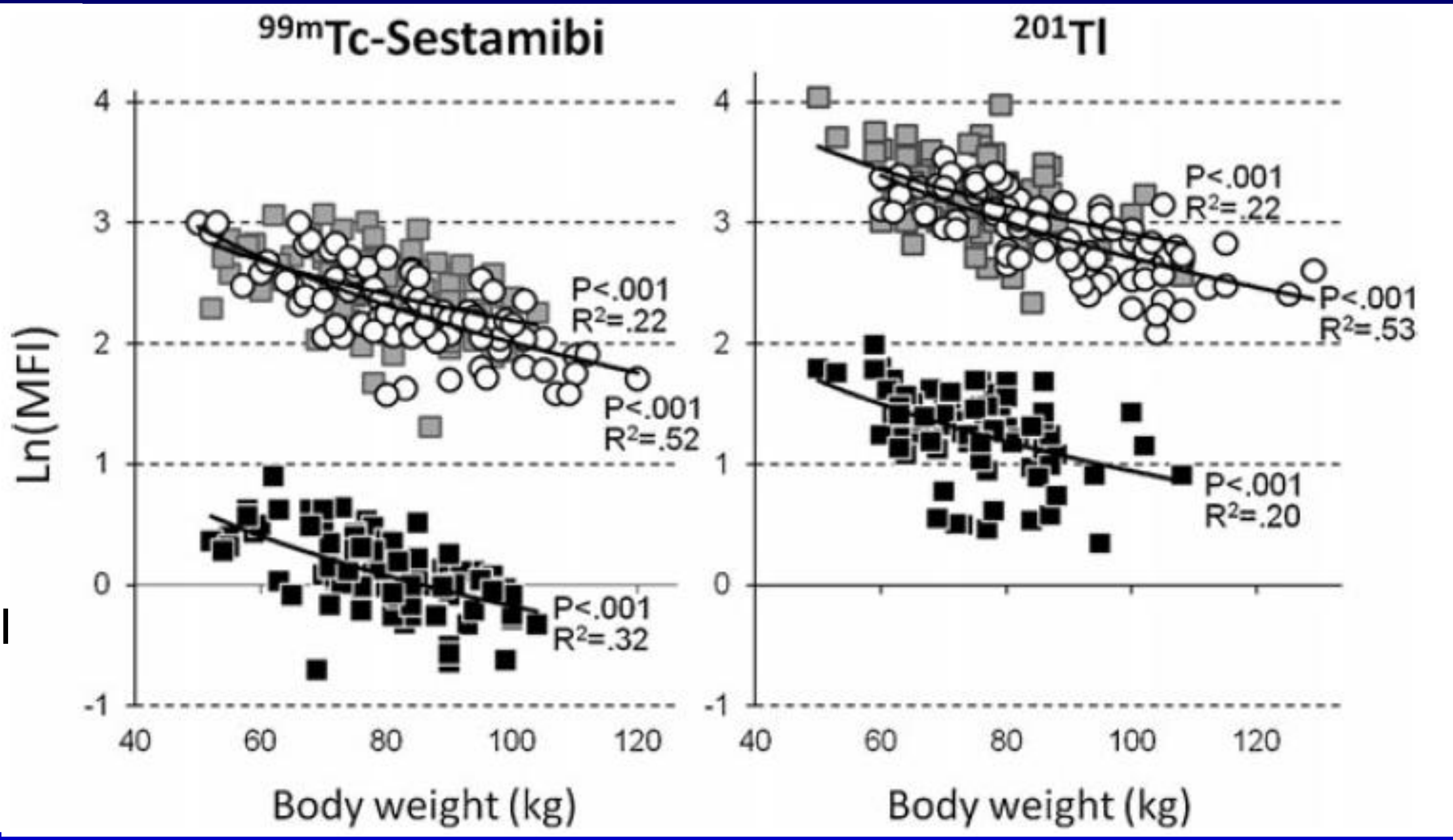
Counts in high-sensitivity SPECT

Myocardial fraction of injected activity (MFI) vs body weight

MFI 9 times higher for high-sensitivity SPECT

High-sensitivity SPECT 18 ppm (13-23) 95% CI

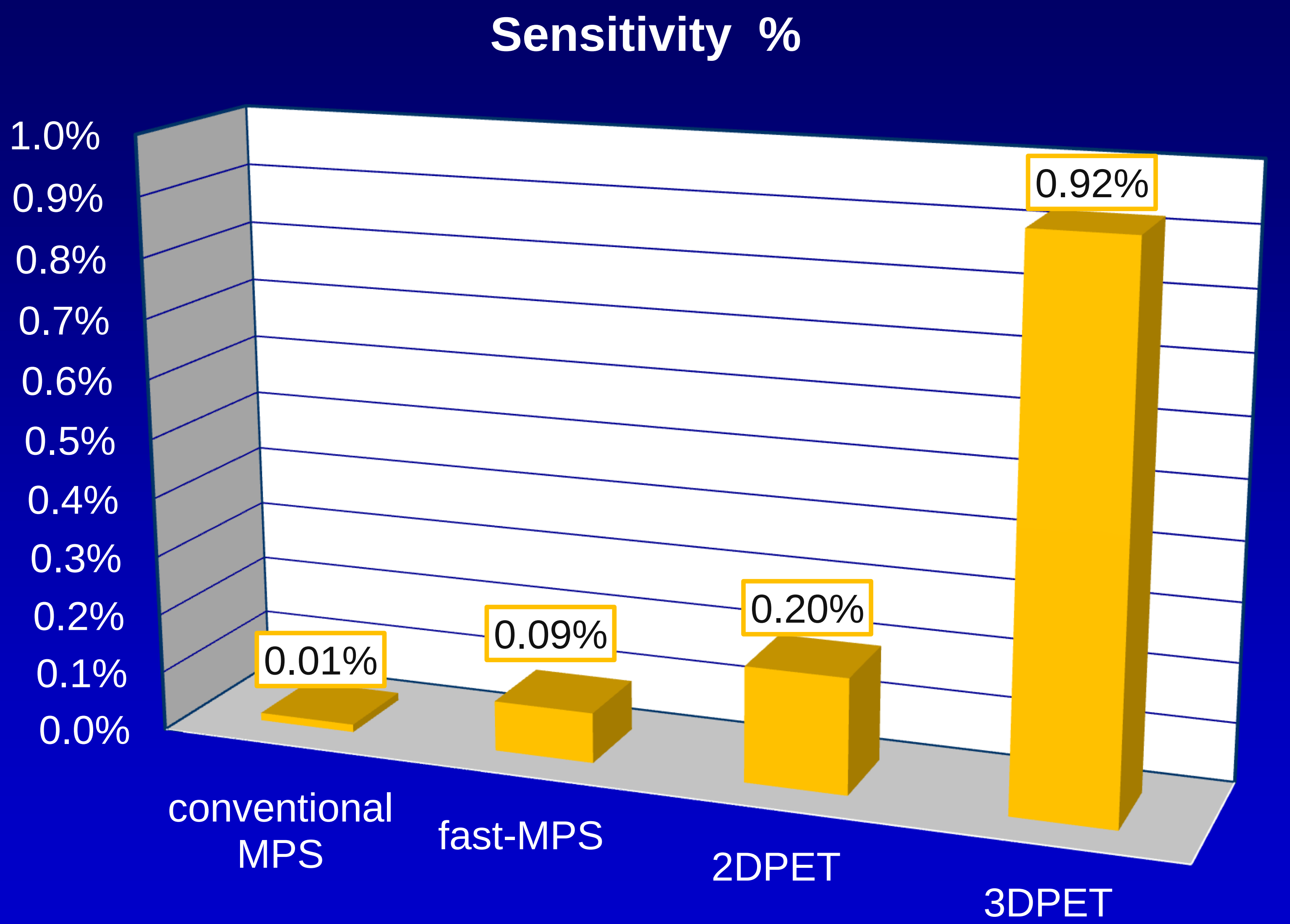
Anger camera 2 ppm (1.5-2.5) 95% CI



MFI (ppm)= 10^6 x myocardial counts per second /injected activity

Verger et al. Eur J Nucl Med Mol Imaging 2014;41-522-528

Fast-MPS sensitivity vs. PET



Slomka et al JNC 2014 based on Imbert et al J Nucl Med 2012, Mawlawi et al J Nucl 2004

Question 2. The primary reason for improved photon sensitivity in newer cardiac cameras is __________ .

34% a. The use of new cadmium zinc telluride (CZT) detectors

0% b. Faster digital processing by the camera electronics

59% c. New collimators and optimized camera geometry

3% d. Closer position to the patient

3% e. Better energy resolution

Question 2. The primary reason for improved photon sensitivity in newer cardiac cameras is ________ .

(a) The use of new cadmium zinc telluride (CZT) detectors ✘

(b) Faster digital processing by the camera electronics ✘

(c) New collimators and optimized camera geometry ✔

(d) Closer position to the patient ✘

(e) Better energy resolution ✘

The correct answer is C, because:

- Newer cameras: **more sensitive collimators & optimized geometry**
- CZT detectors are about **2 times thinner**
- Overall photon efficiency: similar to **scintillation crystals used in a traditional Anger camera**.

Slomka PJ, Berman DS, German G. New cardiac cameras: single-photon emission CT and PET. *Semin Nucl Med*. 2014;44:232-51

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Radiation dose

U.S. Lawmakers Want to Know More About Low-Dose Radiation, Draft Bill for Further Research

By **James Maynard**, Tech Times | January 13, 9:00 AM

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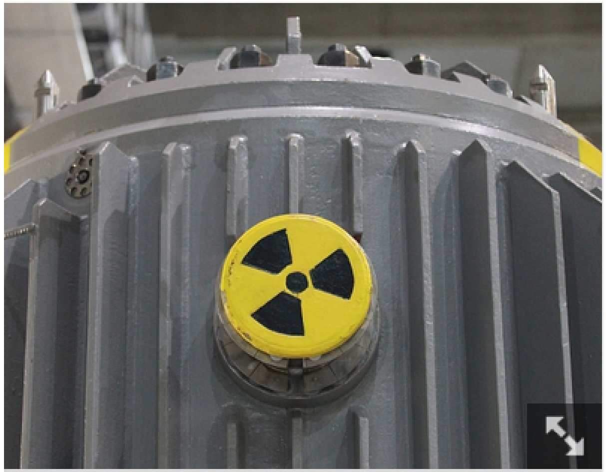


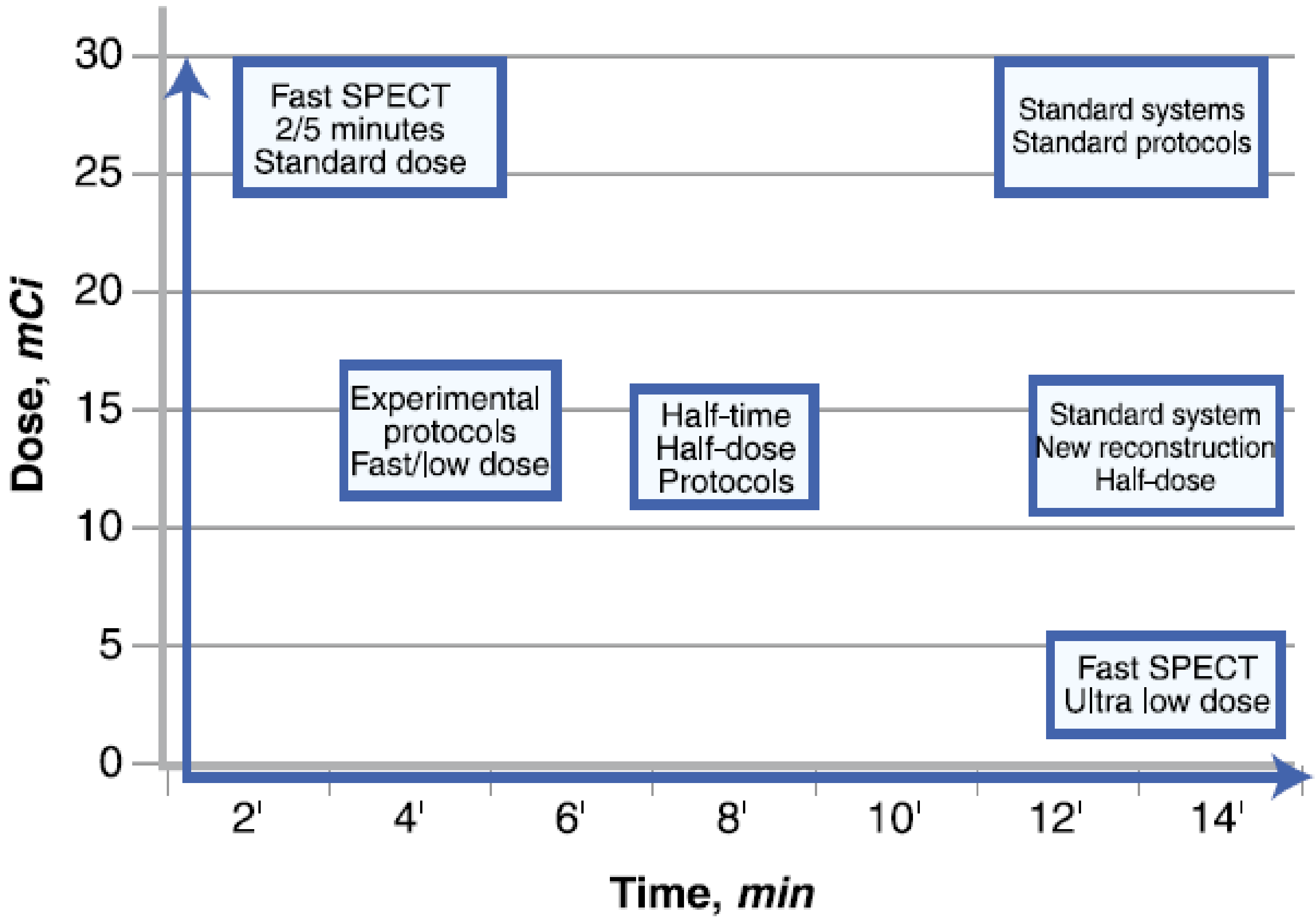
Low-dose radiation will be studies by the Department of Energy, to determine health risks to Americans. What brought about this new study?
(Photo : Getty Images / Sean Gallup)

Low-dose radiation is the subject of a new investigation initiated in Congress. The news study was spurred by concerns over radiation, following the 2011 accident at the Fukushima nuclear plant in Japan.

Radiation constantly bombards everyone. The Earth itself contains radioactive elements, and air travelers receive additional doses every time they fly. Many medical treatments and tests also involve the use of low-level ionizing radiation.

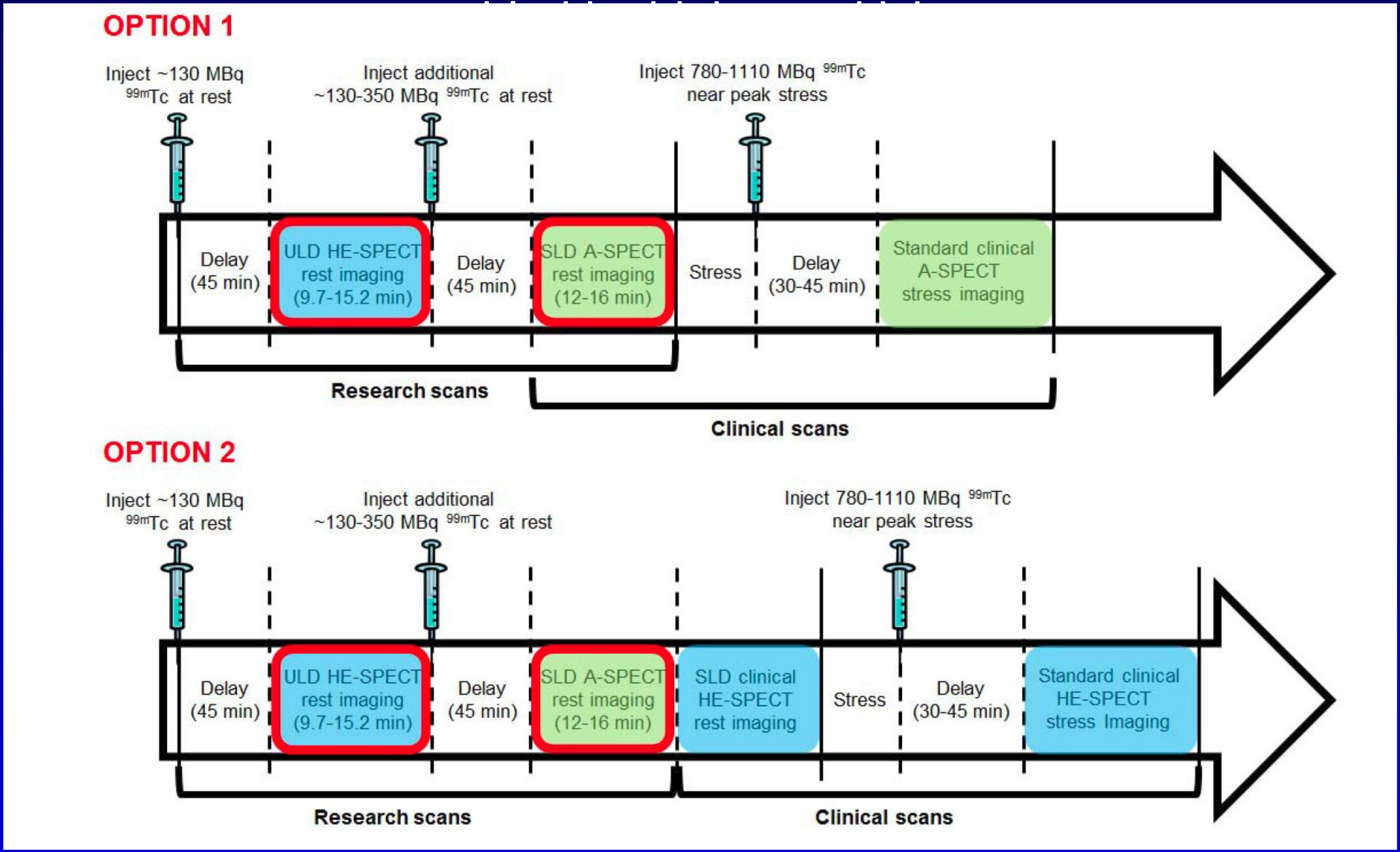
"The research program involves using advances in modern molecular biology and instrumentation unavailable during the previous 50 years of radiation biology research. Scientists will be able to examine - at a systems level - the relationship between normal oxidative damage and radiation-induced damage, using studies conducted at very low doses and dose-rates," the Department of Energy (DOE) reports.

United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) highlighted the need for caution in extrapolating the effects of low radiation doses on large populations.   Dec 2012



Slomka et al. Curr Cardiol Rep (2012) 14:208–216

Ultra-low dose (ULD) cardiac SPECT



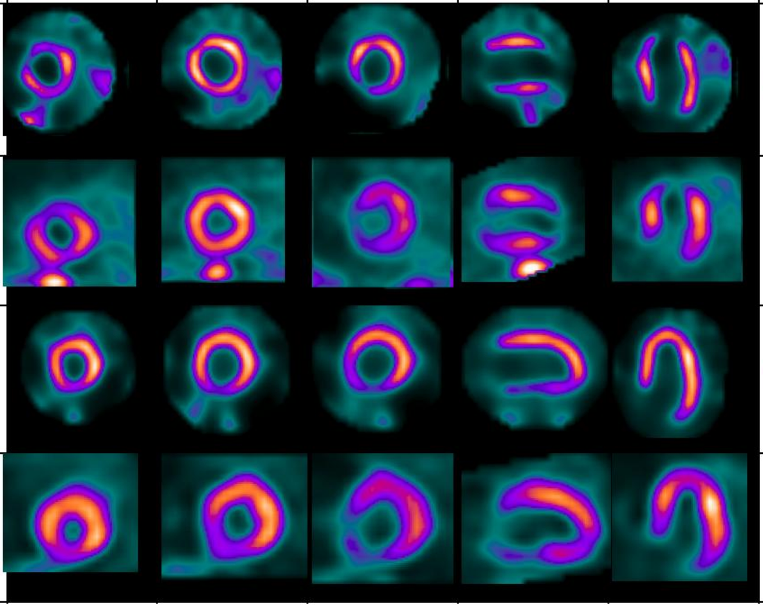
Einstein A. et al. J Nucl Med 2014 :1430-7

Ultra-low dose (ULD) cardiac SPECT

enabled by high-sensitivity

101 patients ULD rest scans on high-efficiency scanner

Average ULD:3.6 mCi -injected 1.16 mSv-received

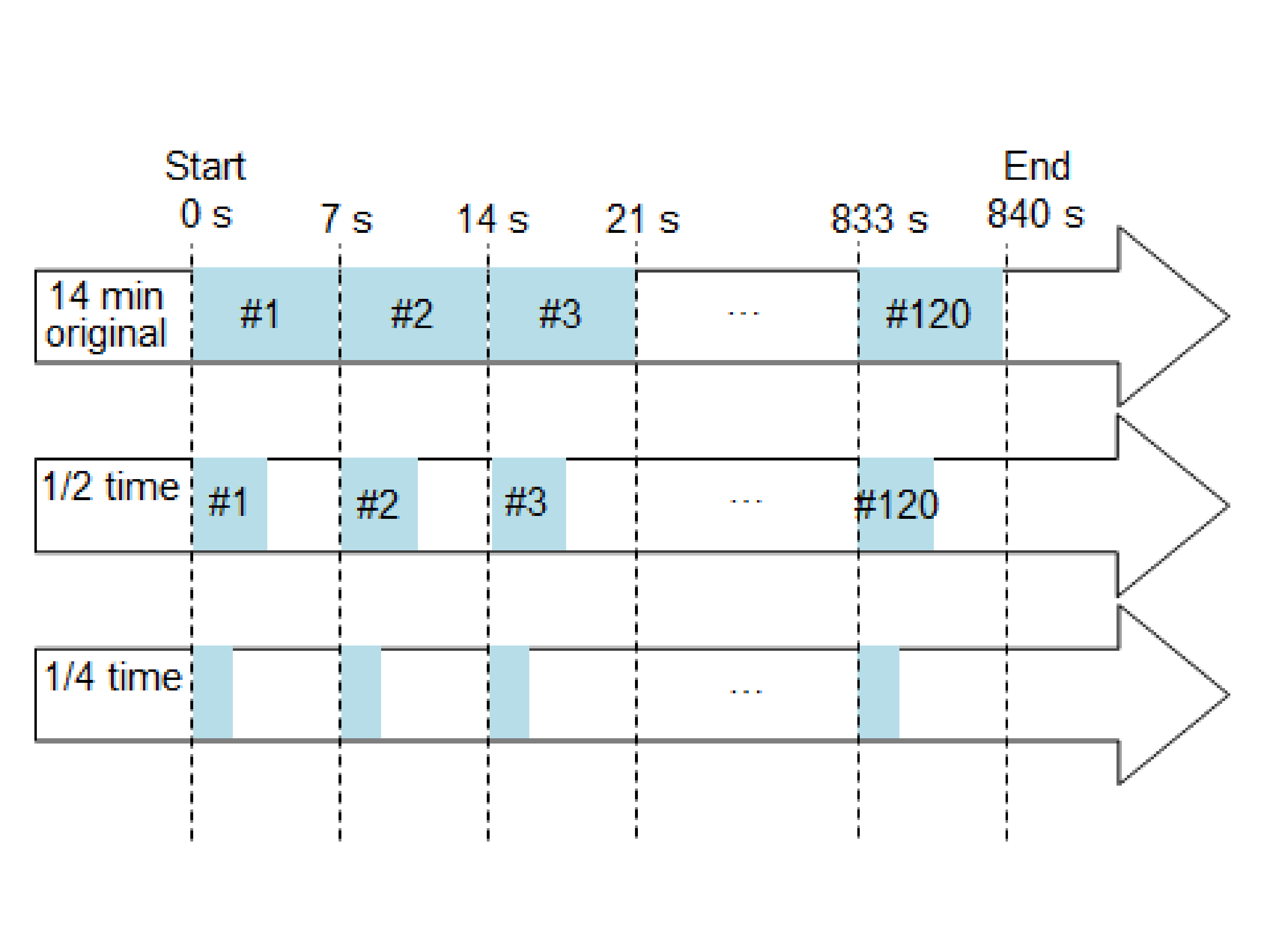


		Short axis			Long axis		Image assessment				Received dose	
		Apical	*Mid*	*Basal*	*Vertical*	*Horizontal*	*Study quality*	*Extracardiac activity*	*SRS*	*Total perfusion defect (%)*	*Activity (MBq)*	*Effective dose (mSv)*
Brigham and Women's Hospital: case 003	***HE-SPECT***						Excellent	None	18	27.2	134	1.15
	A-SPECT						Good	Mild and probably without any interference with scan interpretability	14	23.2	497	4.29
Cedars-Sinai Medical Center: case 033	***HE-SPECT***						Excellent	None	5	6.3	134	1.16
	A-SPECT						Good	None	4	4.4	248	2.14

ULD image quality superior to low-dose (2x ULD) Anger-SPECT

*Einstein A. et al. J Nucl Med 2014:*1430-7

Optimal lowest dose can be determined from list-mode data

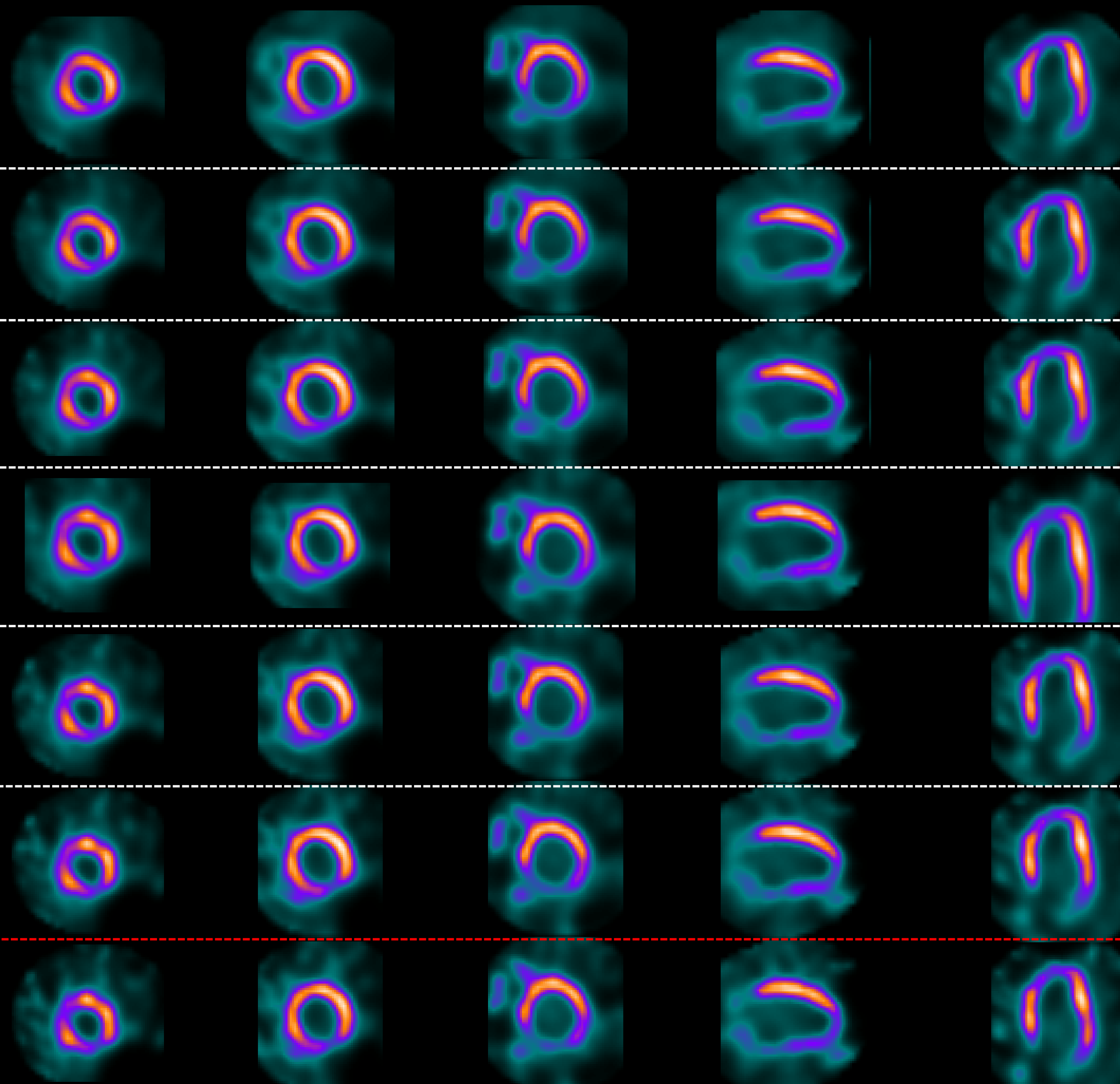


79 patients
Full dose
21.7 ± 5.4 mCi
full time 14 min

Nakazato et al JNM 2013:373-9

Very-low dose stress MPS and reproducibility of TPD

Gradually lowered count level (list mode reconstruction)



Counts in left ventricle	TPD
8.0 million	11%
3.6 million	12%
2.0 million	12%
1.3 million	12%
1.0 million Effective dose 1mSv	12%
0.7 million	12%
0.5 million	9%

Nakazato .. Slomka PJ et al J Nucl Med 2013 :373-9

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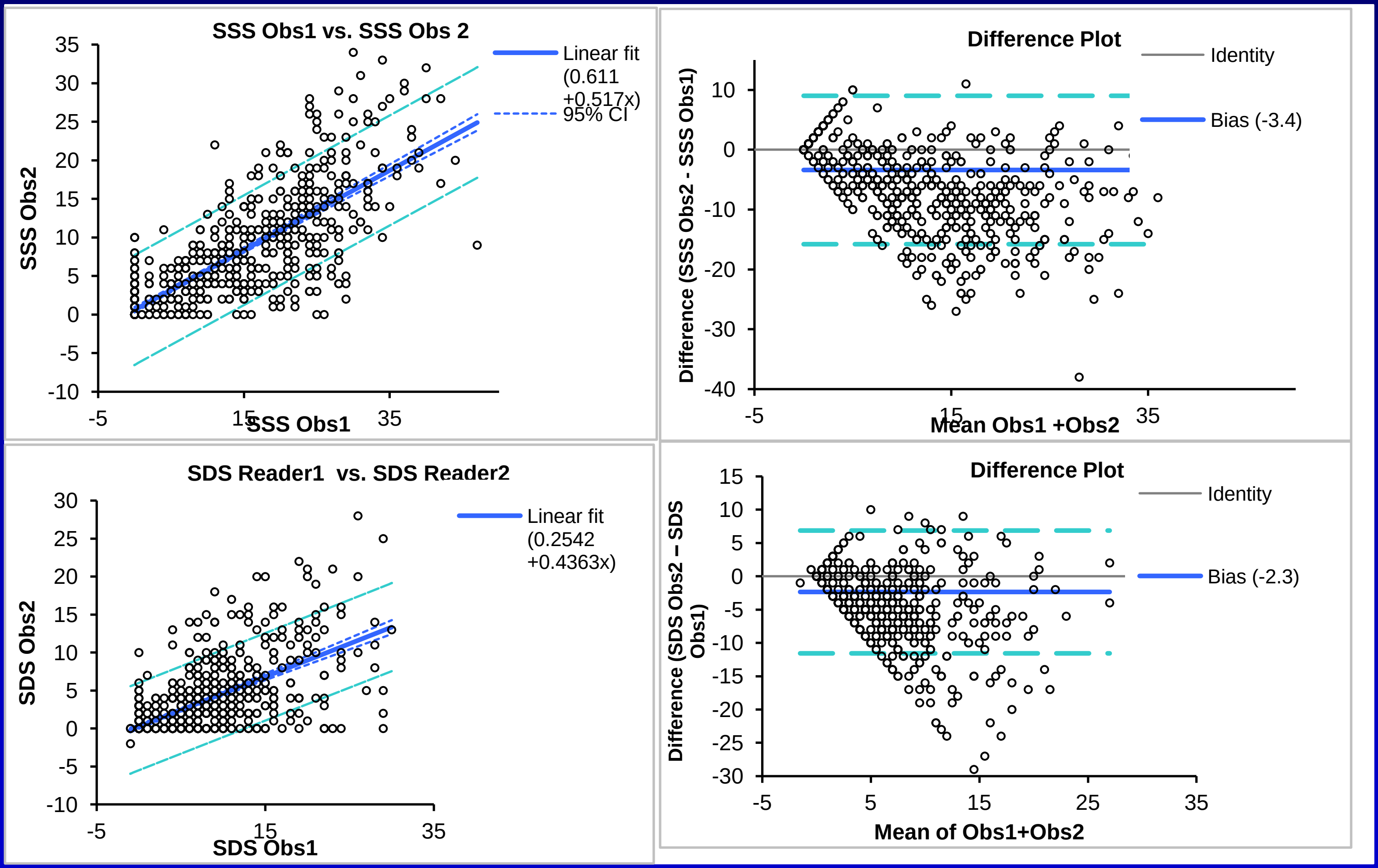
Perfusion: weakness of visual analysis

~7 mln scans per year in US

Inter observer agreement
2 expert observers (core readers)

Summed stress score

Summed difference score



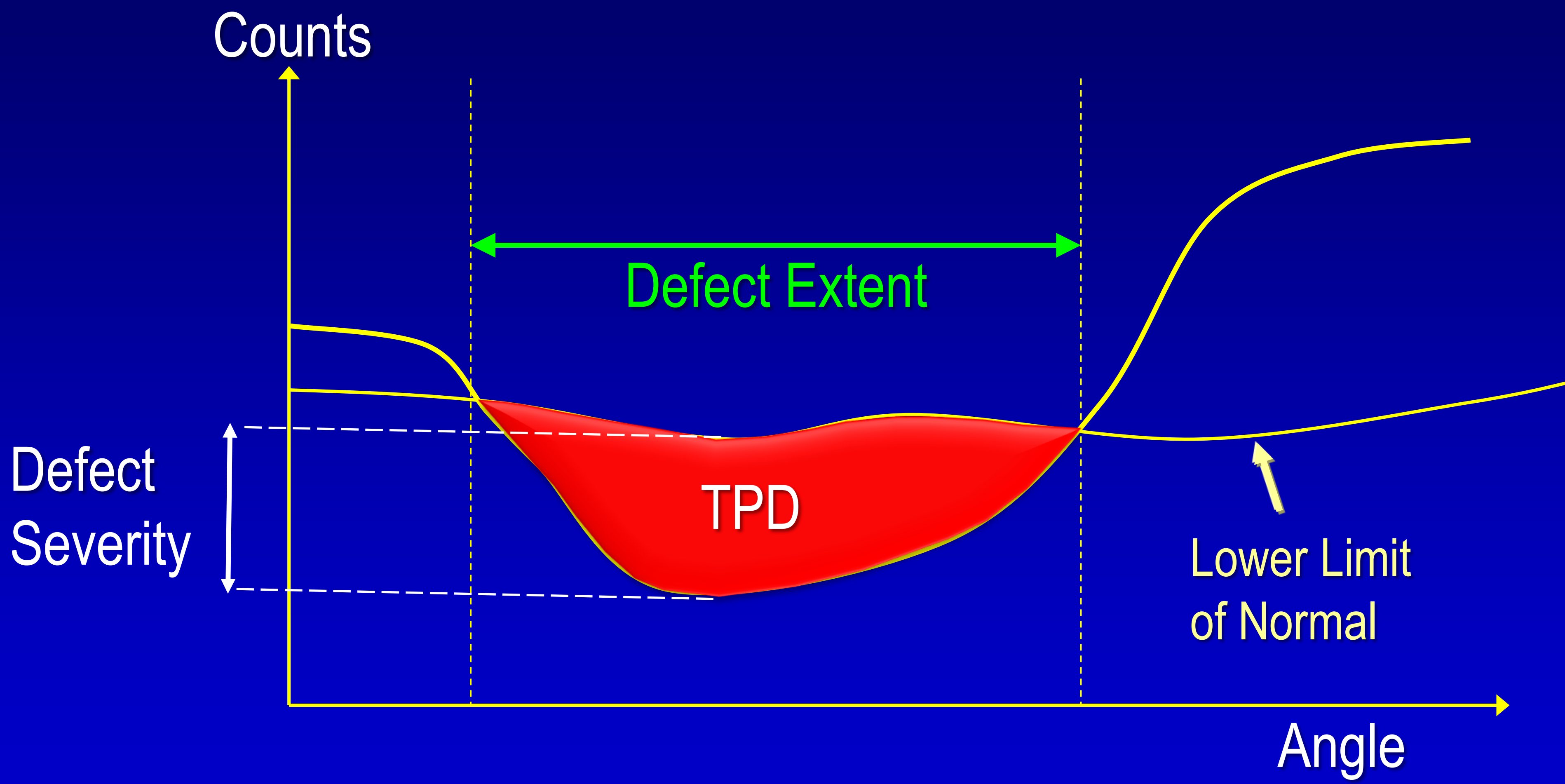
Diagnostic agreement (normal-abnormal) 87%

995 pts with no known CAD

Unpublished data (NIH R0HL089765)

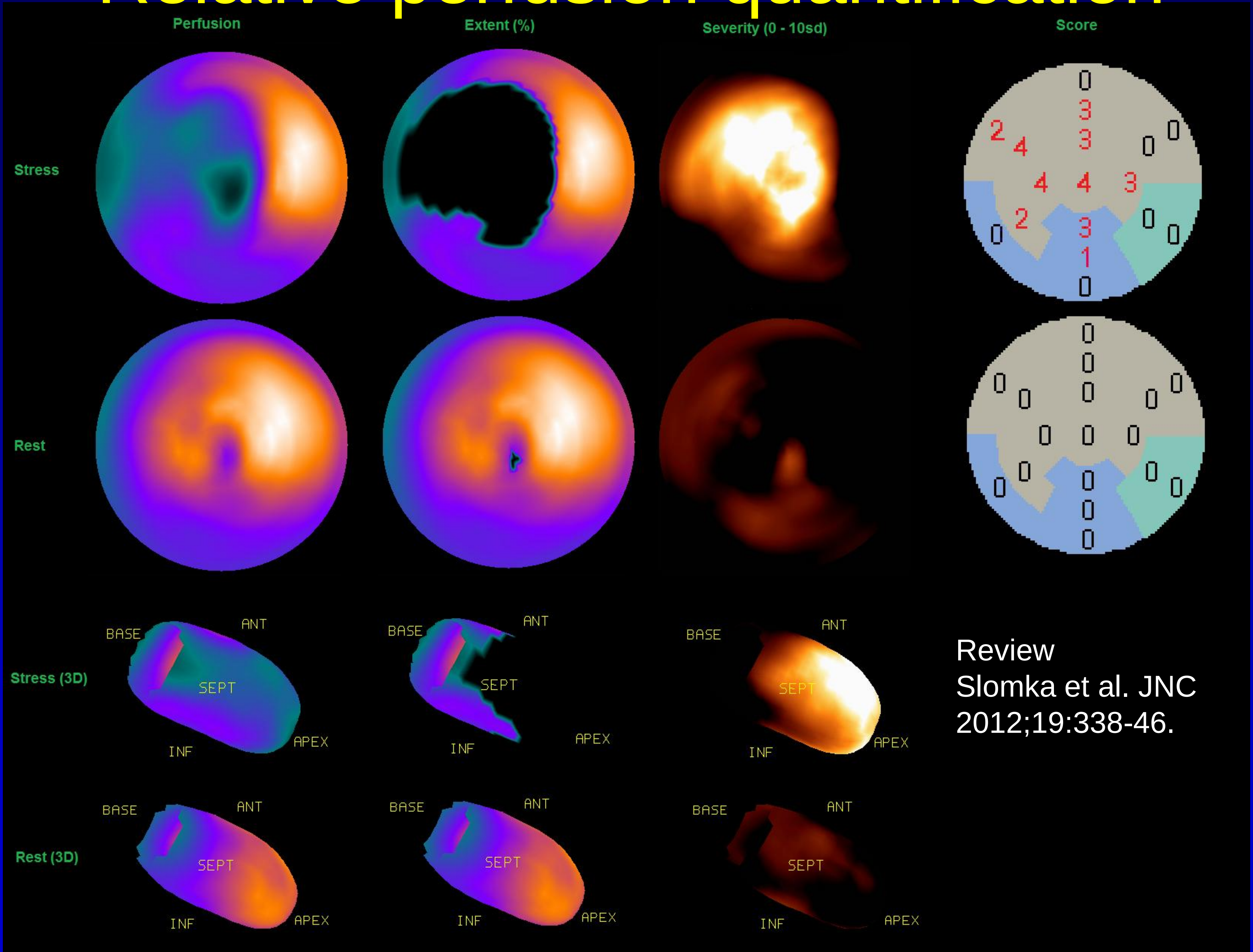
Automated Total Perfusion Deficit (TPD)

Combines Defect Extent & Severity



Slomka et al. J Nucl Cardiol 2005;12:66-77

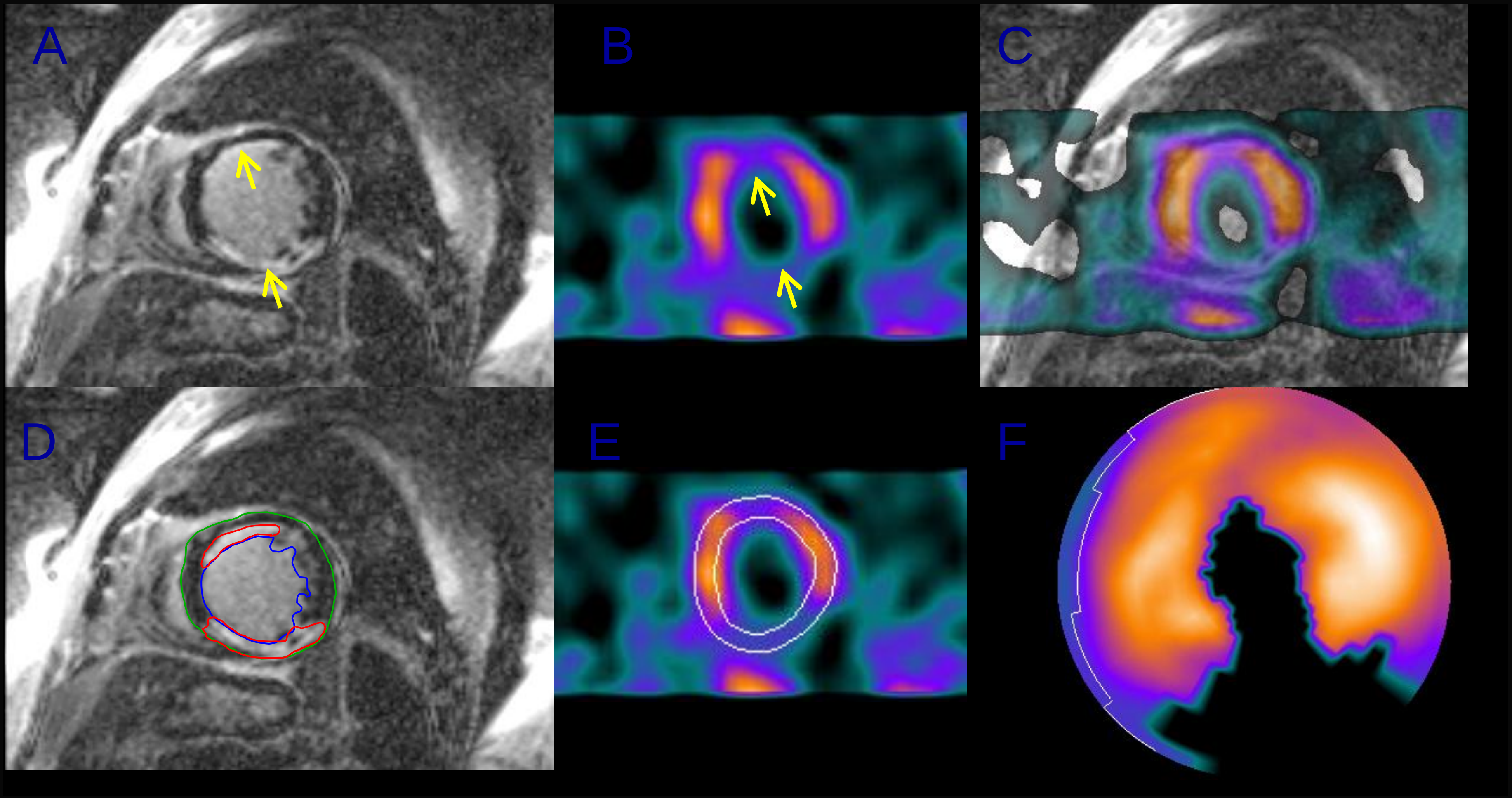
Relative perfusion quantification



Review
Slomka et al. JNC
2012;19:338-46.

Infarct sizing and detection: DE MRI vs. SPECT

27% by DE-MRI, 31% by SPECT

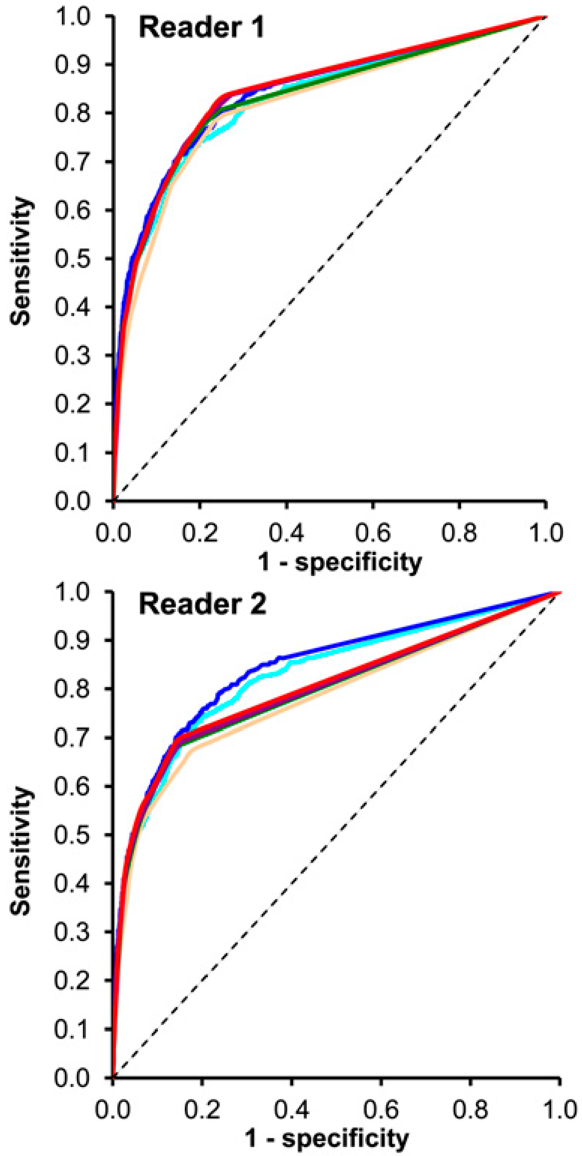


Sizing: N=26, r =0.85   Detection: N=82, Sens =87%, Spec=91%

Slomka et al J Nucl Med. 2005;46:728-35.

MPI diagnostic accuracy: Experts vs. software

per-vessel etection of > 70% stenosis <u>n=2985</u>



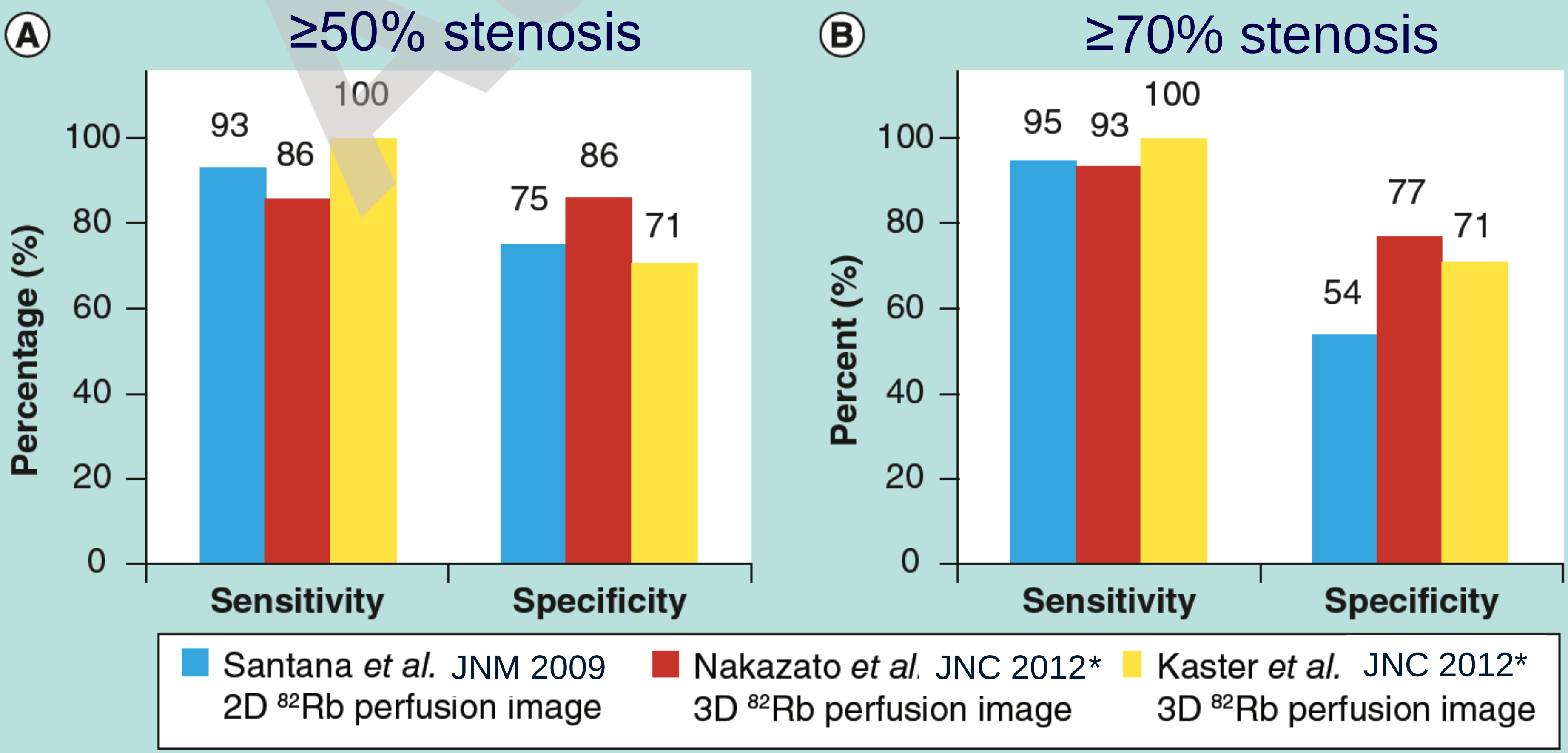
Software	ROC-AUC	ROC-AUC
NC-TPD	0.83	-
AC-TPD	0.84 *	-
Readers	**Reader 1**	**Reader 2**
V1	0.82	0.78 #
V2	0.83 *	0.79 *#
V3	0.84 *	0.80 #
V4	0.84	0.80 *#

*Comparison to prior step *P* < 0.01
#Auto vs. visual *P* < 0.01
Red = auto better than visual
V1 = NC only
V2 = NC + AC
V3 = NC + AC + computer
V4 = NC + AC + computer + clinical

Arsanjani et al
J Nucl Med
2013:221–8

Automatic PET perfusion analysis

High diagnostic performance with PET



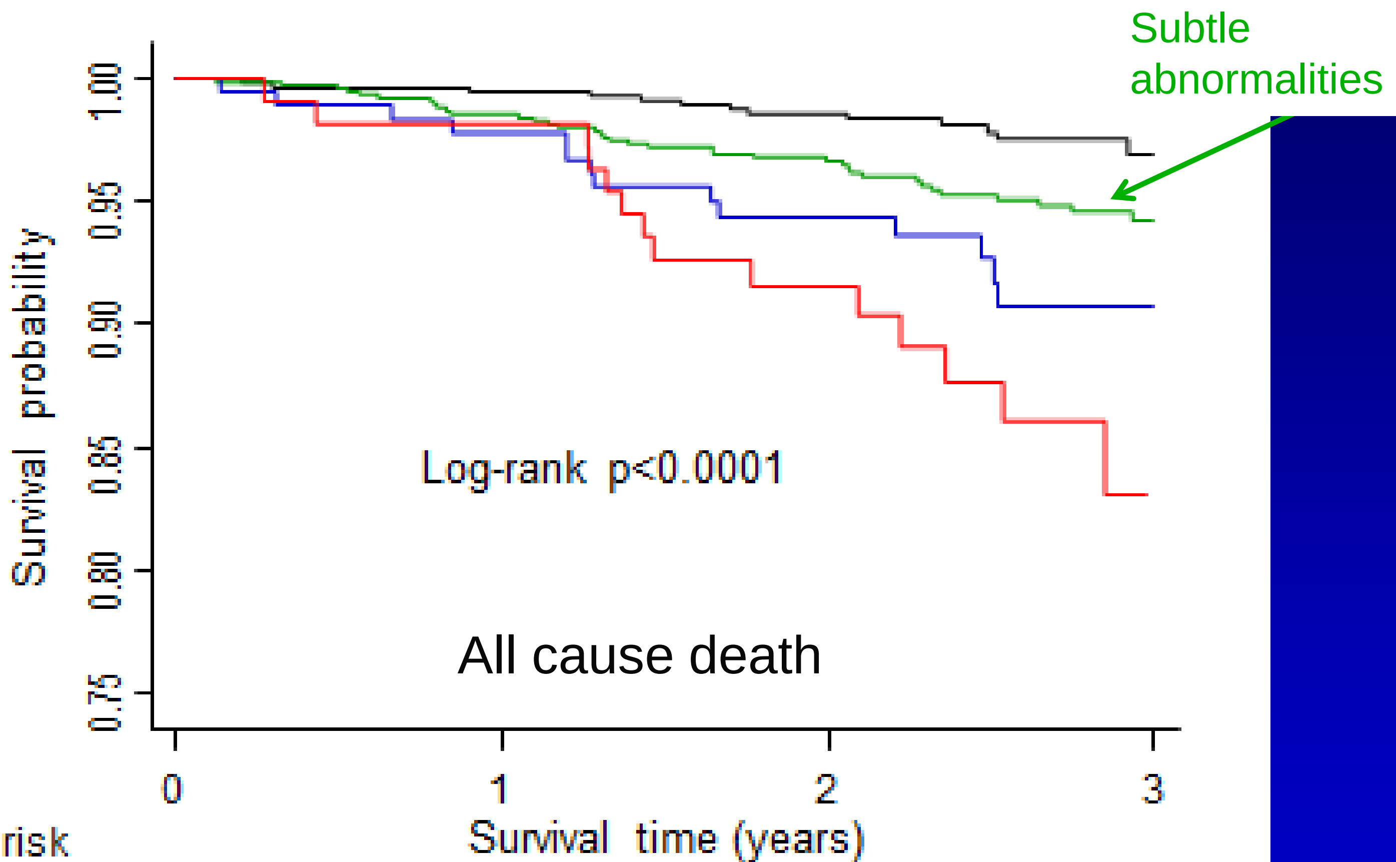
* 3D PET/CT

Nakazato et al. Imaging Med. 2013;1:35-46

Quantitative automatic prognosis from perfusion

n=1613 consecutive pts

sTPD:
stress
TPD



Number at risk	0	1	2	3
sTPD 0%	570	567	498	138
sTPD 1-4%	752	741	608	224
sTPD 5-10%	182	178	135	48
sTPD >10%	109	107	77	23

Nakazato et al. JNC 2012;19:1113-23.

Question 3. Total perfusion deficit is a measure of ___________.

7%	*a.*	*Absolute myocardial blood flow (at stress or rest)*
41%	*b.*	*Relative* myocardial perfusion (vs normal region)
3%	c.	Myocardial flow reserve
45%	d.	Difference between stress and rest perfusion
3%	e.	Ejection fraction reserve

Question 3. Total perfusion deficit is a measure of ___________.

(a) *Absolute* myocardial blood flow (at stress <u>or</u> rest) ✘

(b) *Relative* myocardial perfusion (vs normal region) ✓

(c) Myocardial flow reserve ✘

(d) Difference between stress and rest perfusion ✘

(e) Ejection fraction reserve ✘

The correct answer is B, because:

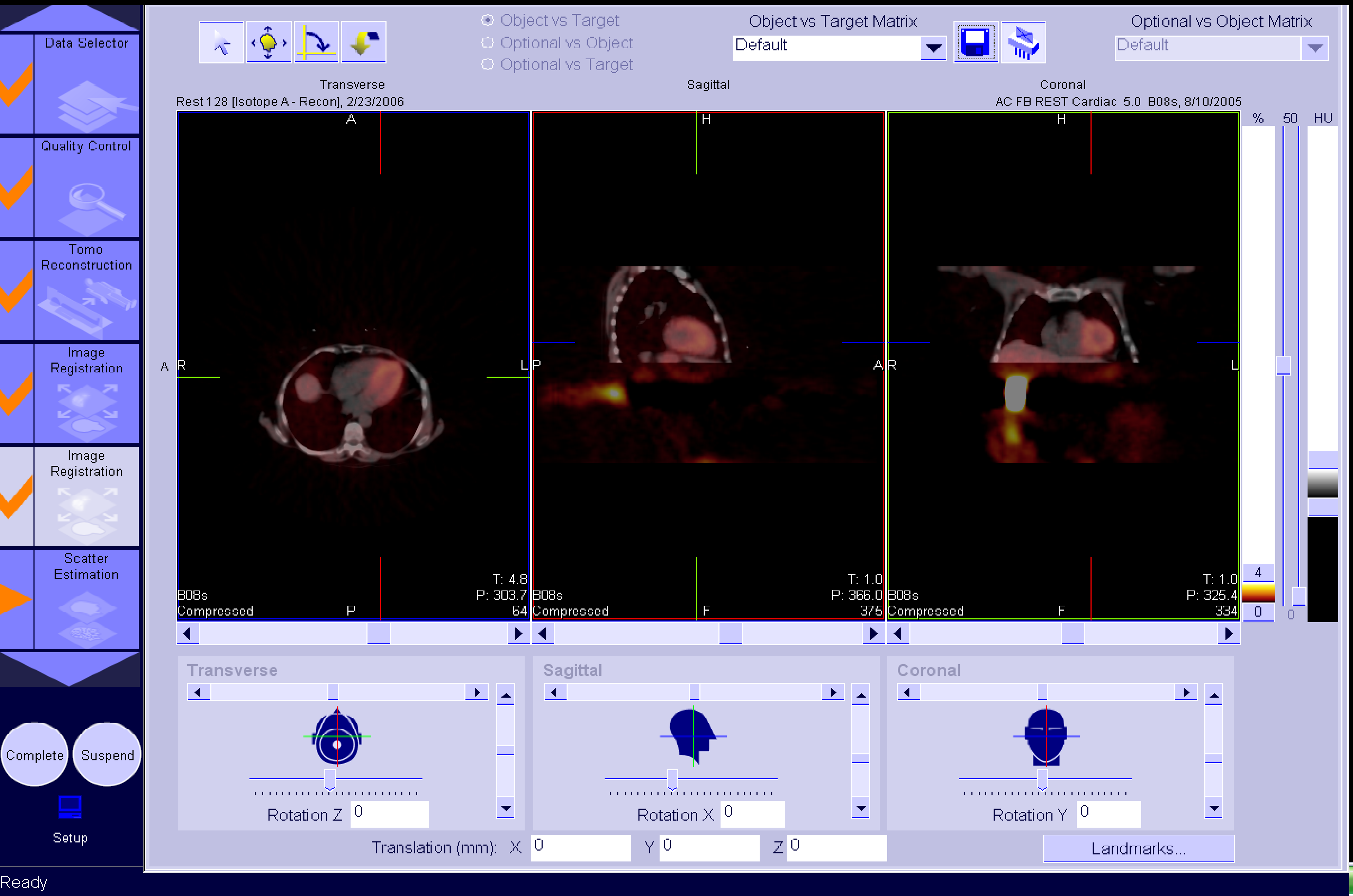
- Total perfusion deficit is estimated by comparing with the **<u>normal regional reference database</u>**
- **<u>Normalization of counts is with an *arbitrary* #</u>** in a patient study
- Thus, it is a **<u>measure of *relative* perfusion of the myocardium</u>**

Slomka PJ, Nishina H, Berman DS, et al. Automated quantification of myocardial perfusion SPECT using simplified normal limits. *J Nucl Cardiol*. 2005;12:66-77.

OUTLINE

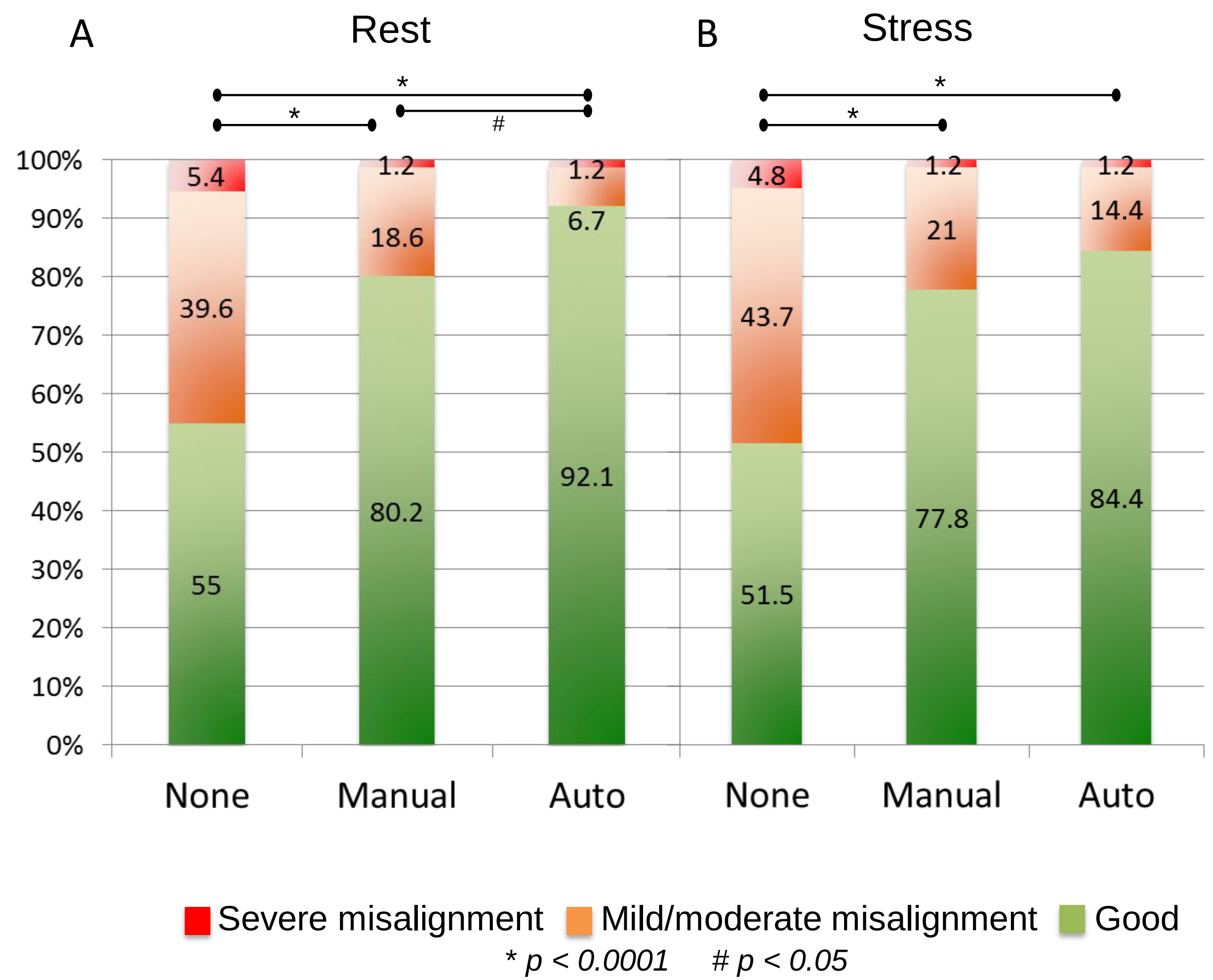
- Latest PET/CT hardware
- Latest SPECT hardware
- Low dose imaging
- Perfusion quantification
- Attenuation correction
- Kinetic modelling
- Motion
- Hybrid quantification

PET/CT –AC misregistration



Automatic alignment of PET CTAC maps

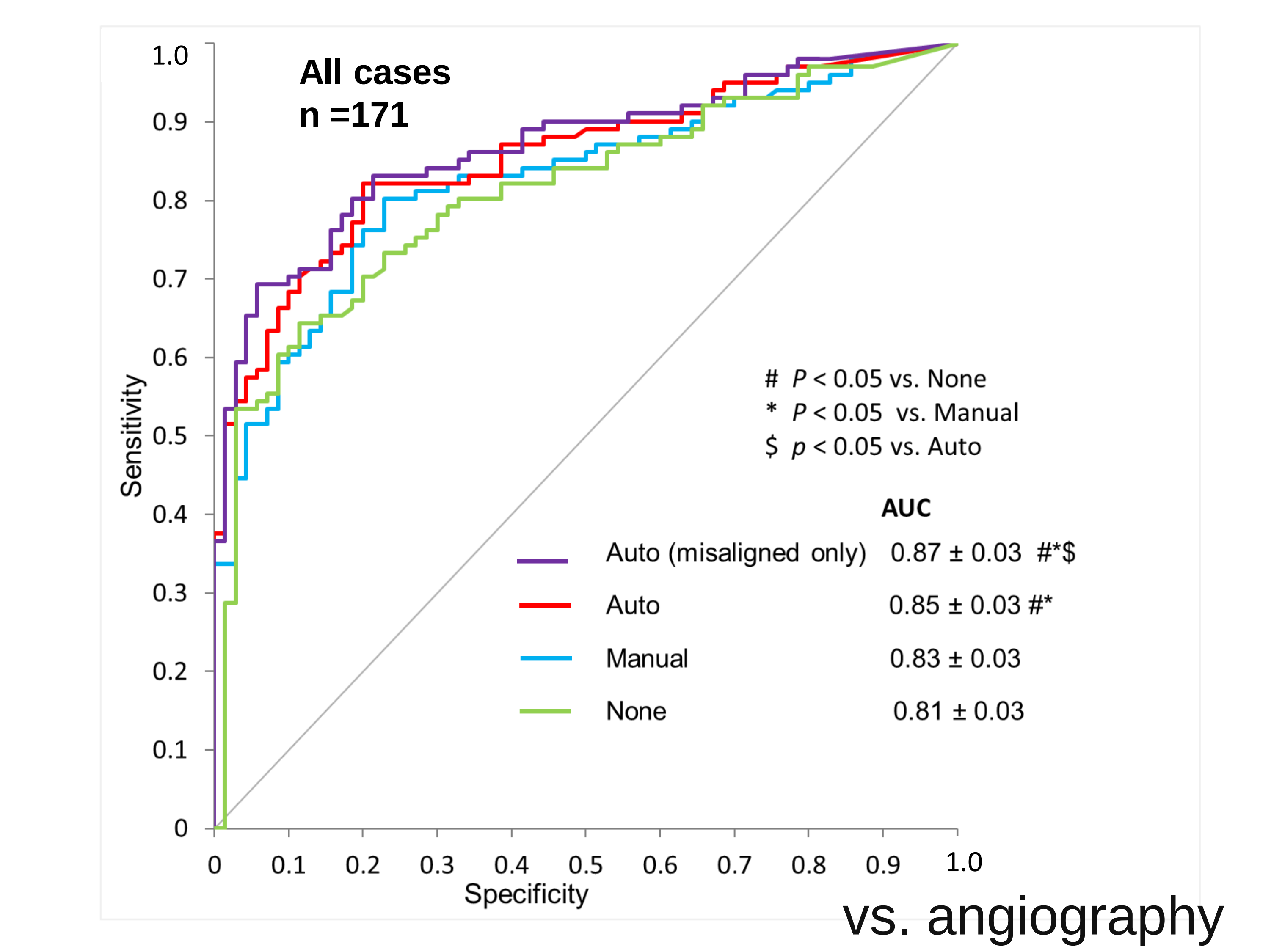
Registration increases correct alignment



JNC 2015 (in press) vs. Experienced radiologist

Automatic alignment of PET CTAC maps

Improved detection of CAD with automatic registration

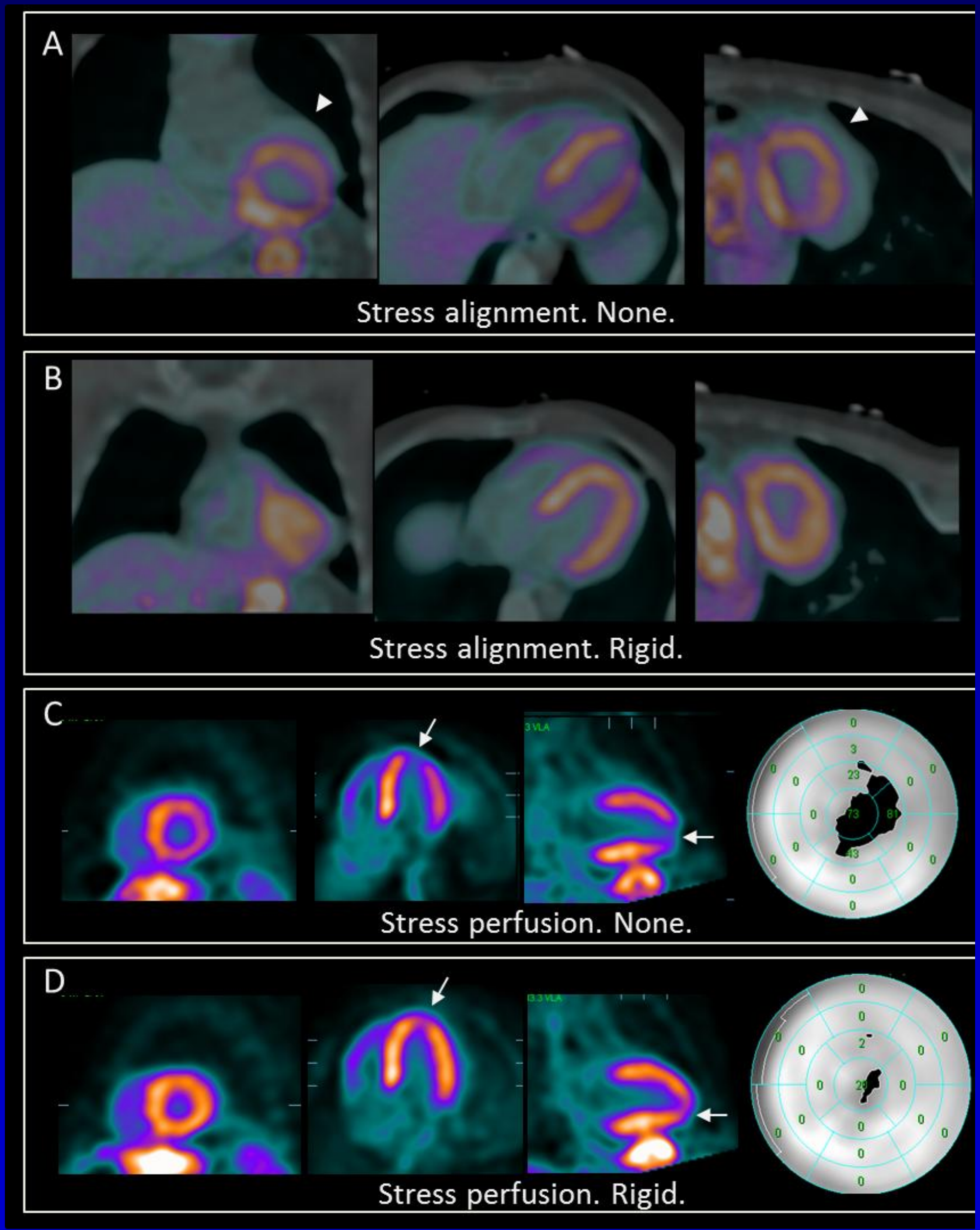


Slomka et JNC 2015 (in press)

Automatic alignment of PET CTAC maps

False positive resolved by CTAC alignment

44 y/o male with SOB



Stress perfusion before alignment TPD = 12%

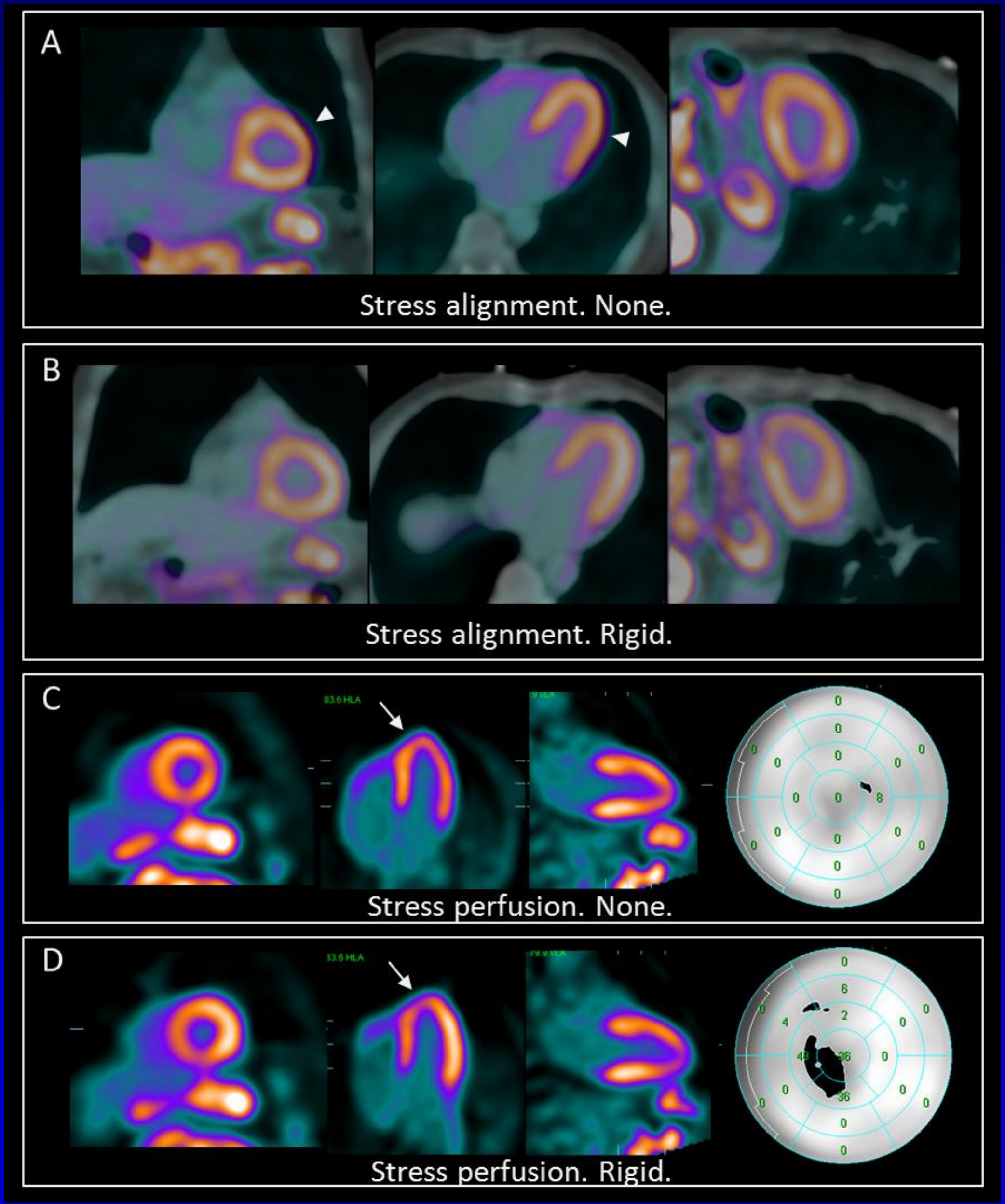
Stress perfusion after alignment TPD =1.8%

JNC 2015 (in press)

Automatic alignment of PET CTAC maps

False negative resolved by CTAC alignment

60 y/o male with atypical chest pain



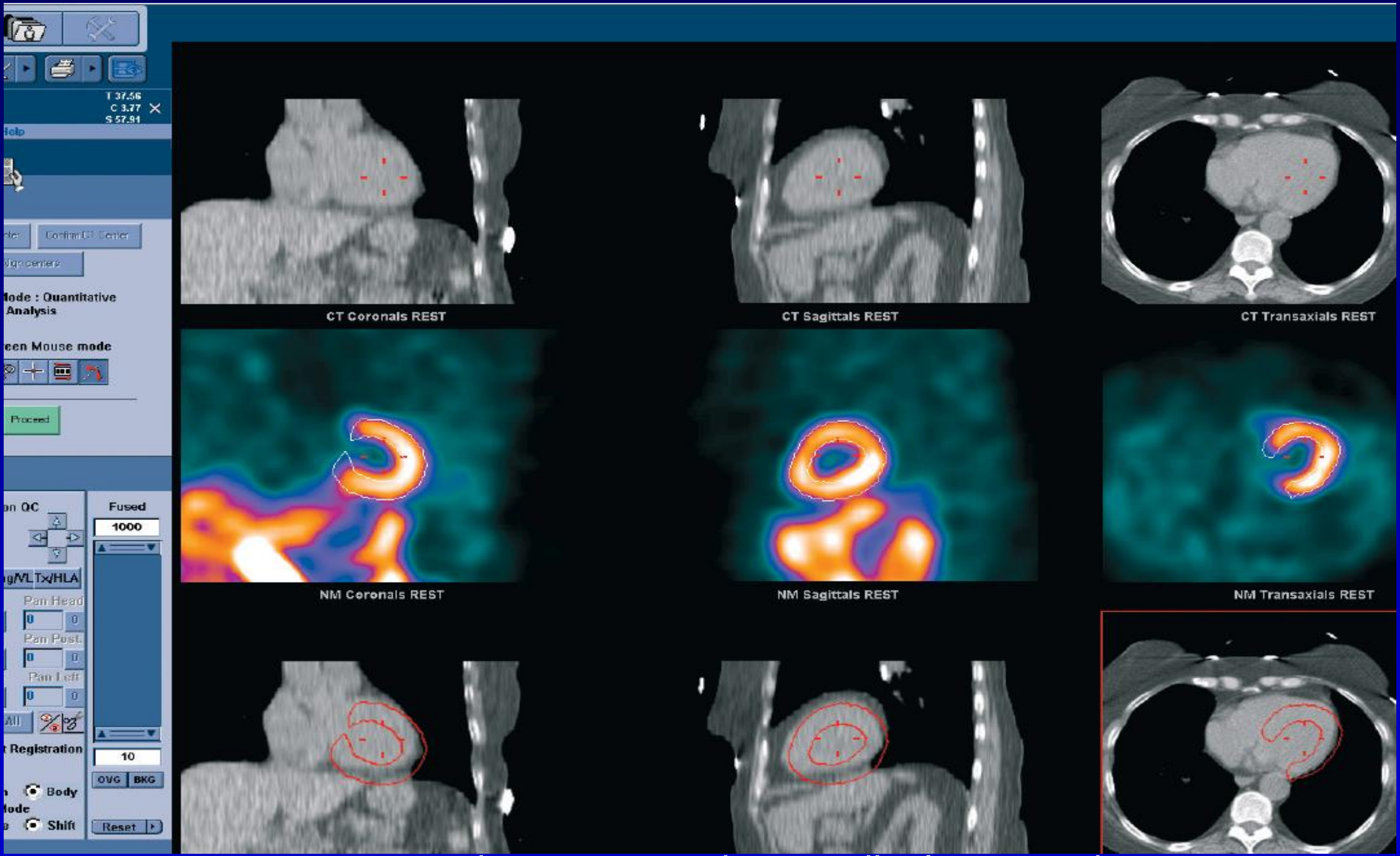
Stress perfusion before alignment TPD = 0%

Stress perfusion after alignment TPD =9%

JNC 2015 (in press)

Attenuation correction methods: SPECT/CT approach

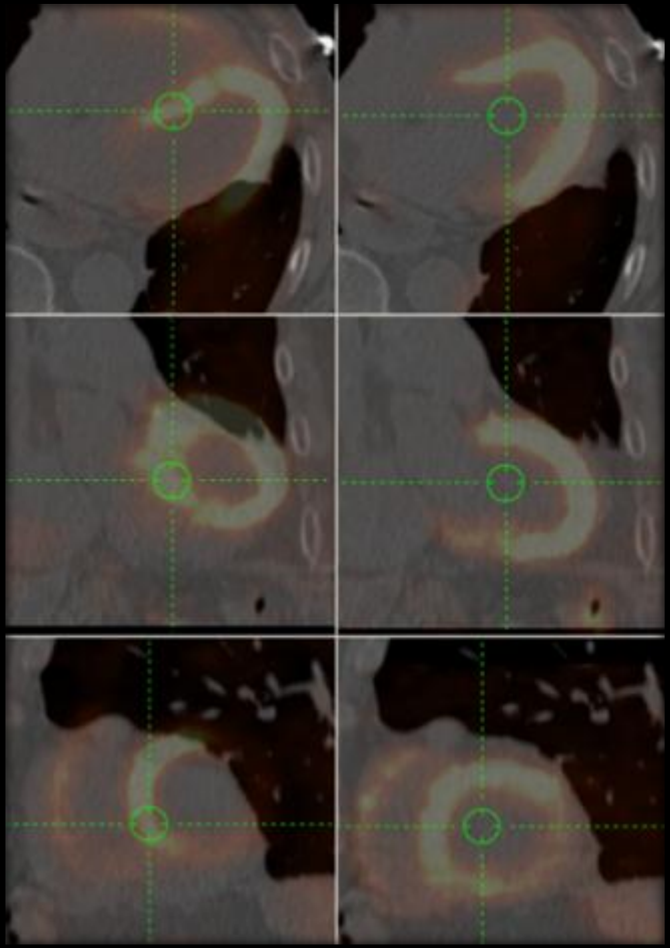
External CT attenuation correction for fast MPS



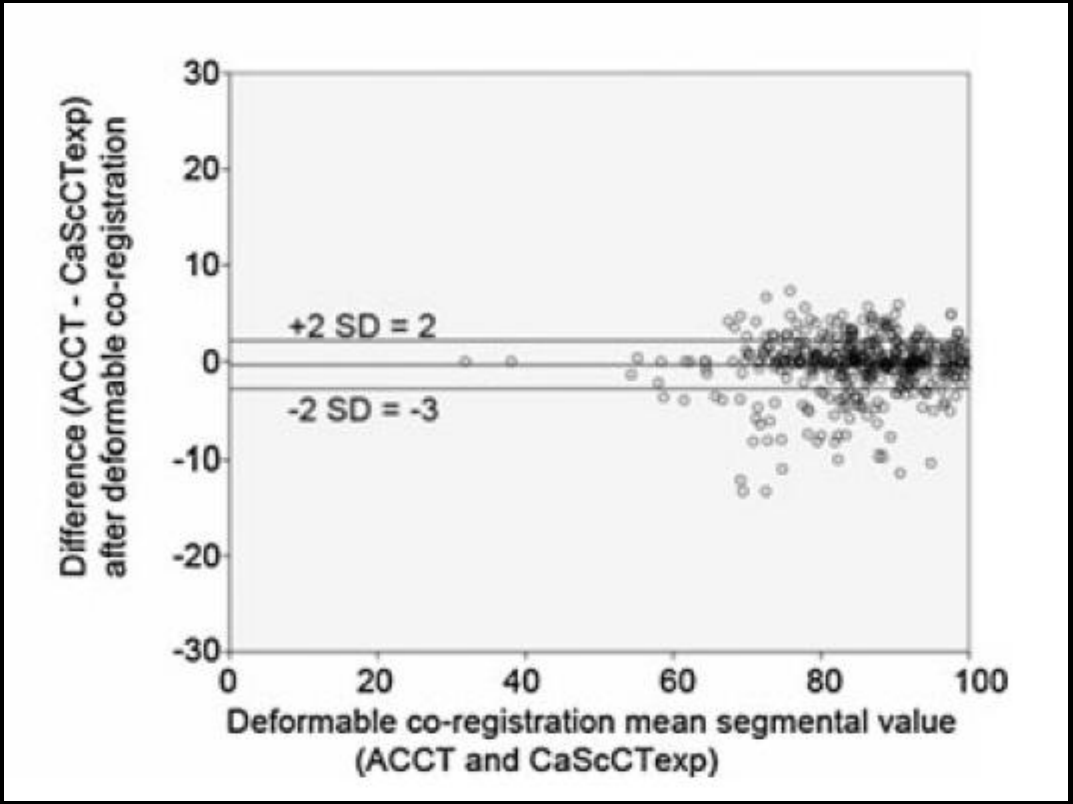
Courtesy Aharon Peretz (GE Medical Systems)

Schepis et al Eur J Nucl Med Mol Imaging 2007

Automatic alignment of Calcium CT scan for attenuation correction



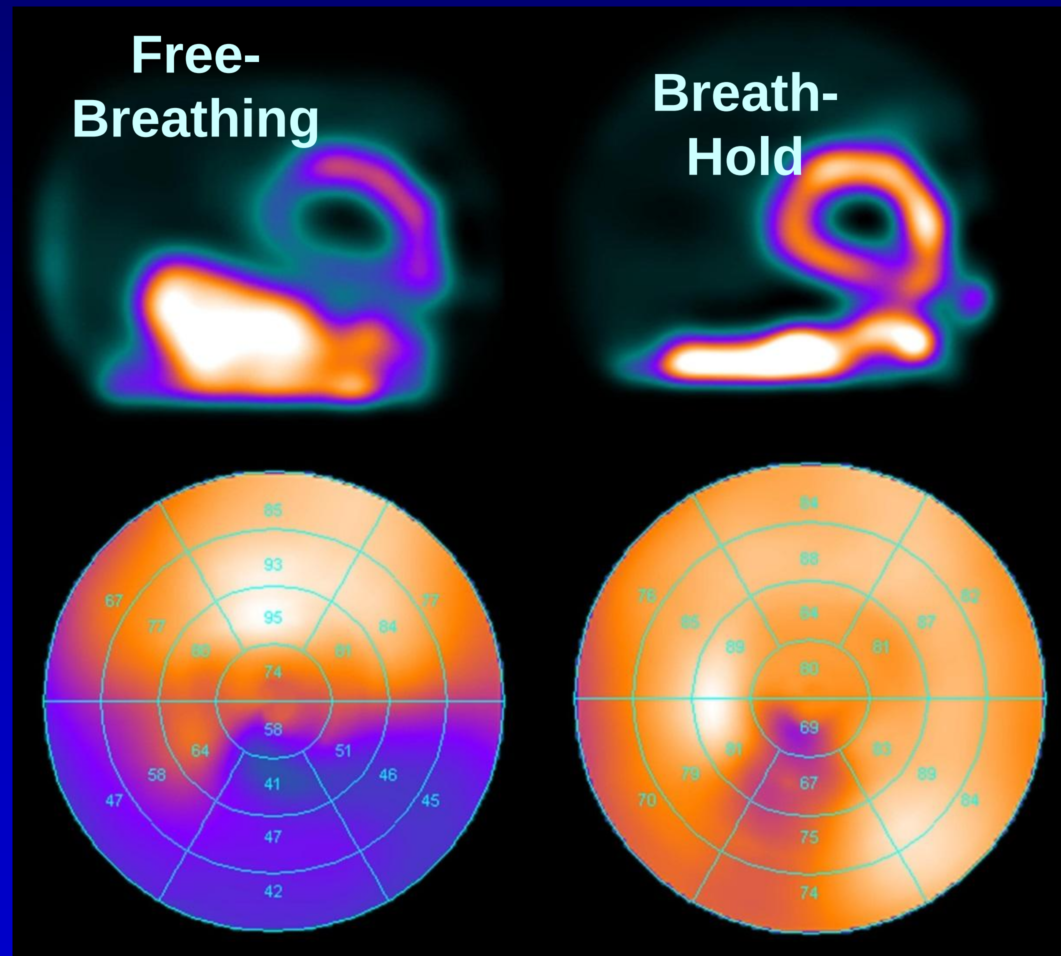
before after



Zaidi et al. Int J Cardiovasc Imaging 2013

Fast MPS Deep Inspiration Breath-Hold Acquisition

- Study of 40 pts
- Patients imaged 9-18 breath-hold intervals
- No respiratory motion
- Improved image quality
- Potential to utilize improved CZT image resolution



UniversitätsSpital Zürich

Oliver Cleric et al SNM 2014 Abstract #1767

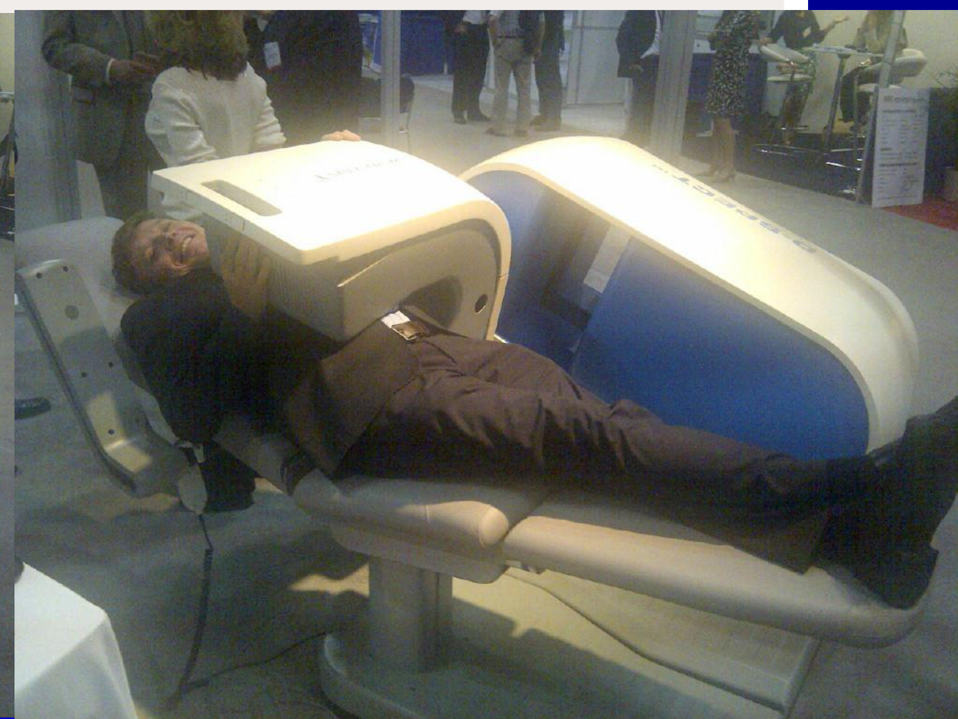
Abdominal activity correction

Quantitative Upright–Supine High-Speed SPECT Myocardial Perfusion Imaging for Detection of Coronary Artery Disease: Correlation with Invasive Coronary Angiography

J Nucl Med. 2010 Nov;51(11):1724-31

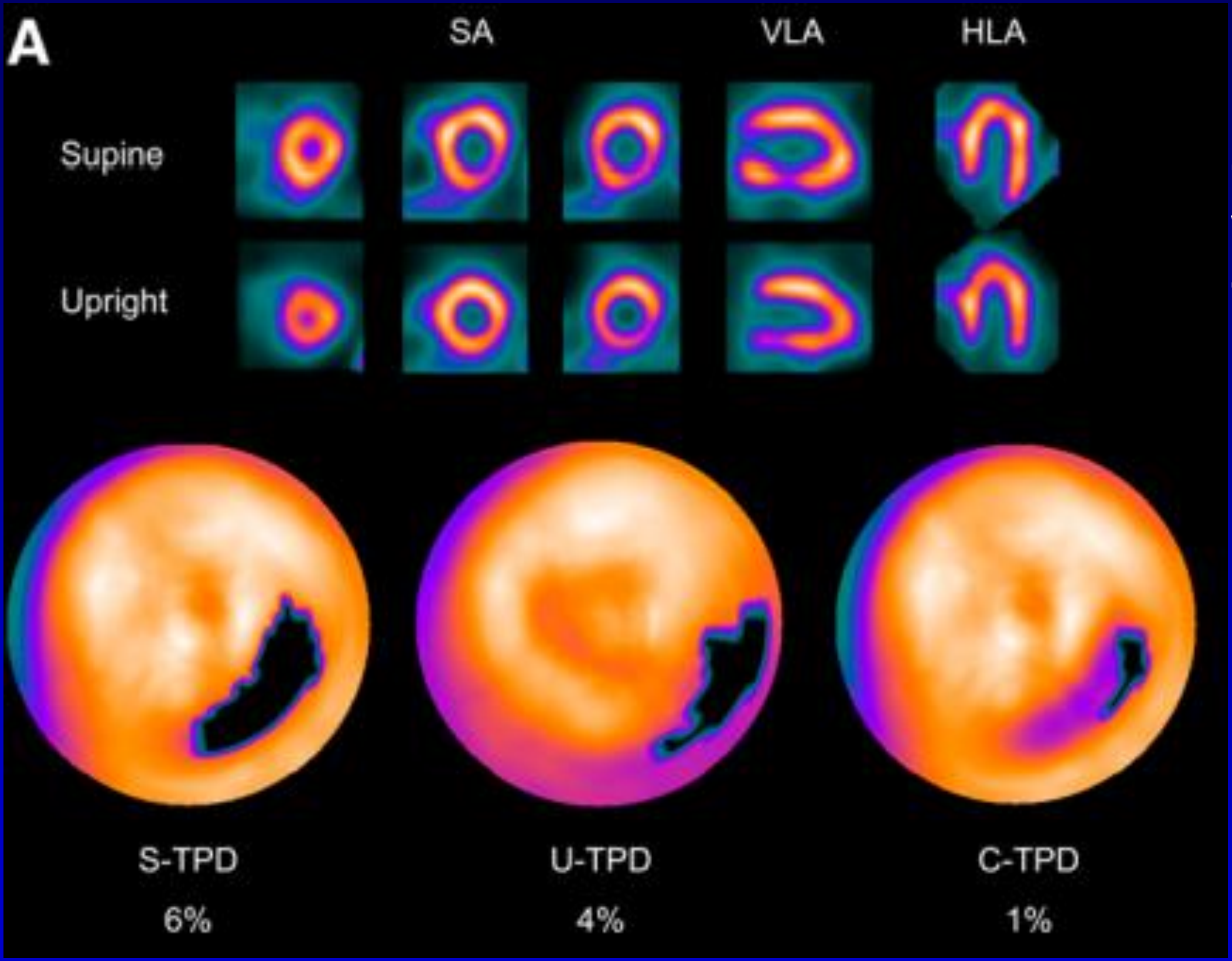
Ryo Nakazato*[1–3], Balaji K. Tamarappoo*[1–3], Xingping Kang[1–3], Arik Wolak[1–3], Faith Kite[1–3], Sean W. Hayes[1–4], Louise E.J. Thomson[1–4], John D. Friedman[1–4], Daniel S. Berman[1–4], and Piotr J. Slomka[1–4]

[1]Division of Nuclear Medicine, Department of Imaging, Cedars-Sinai Medical Center, Los Angeles, California; [2]Division of Cardiology, Department of Medicine, Cedars-Sinai Medical Center, Los Angeles, California; [3]Burns and Allen Research Institute, Cedars-Sinai Medical Center, Los Angeles, California; and [4]Department of Medicine, University of California at Los Angeles, School of Medicine, Los Angeles, California



Alternative to attenuation correction ?

Upright/supine fast MPS imaging



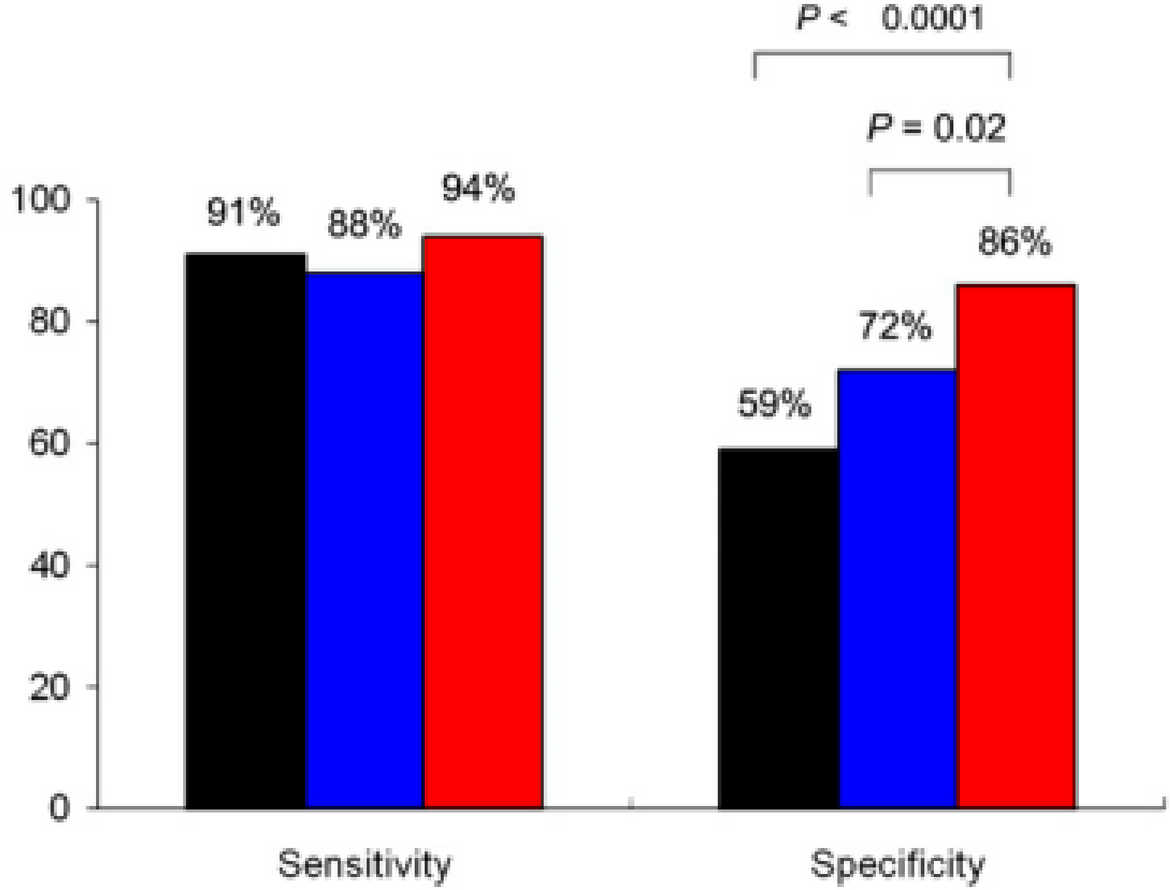
49-y-old woman with typical chest pain

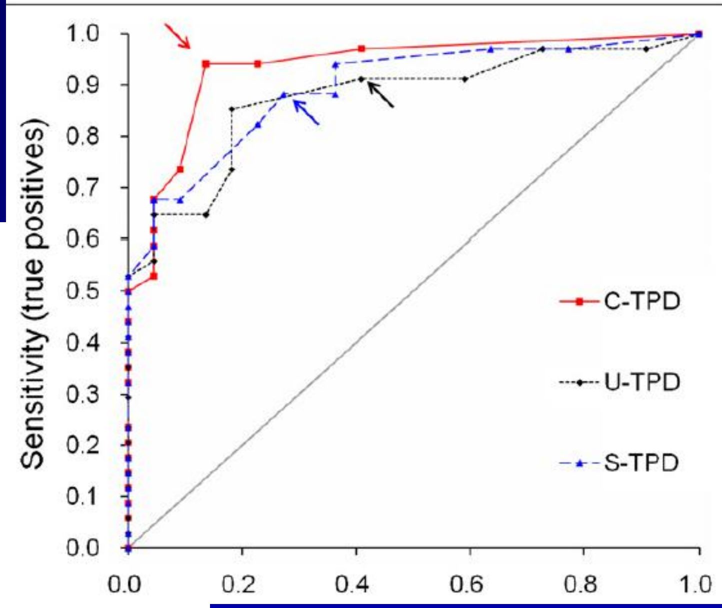
Normal angio

J Nucl Med. 2010 Nov;51(11):1724-31.

Combined upright/supine fast MPS

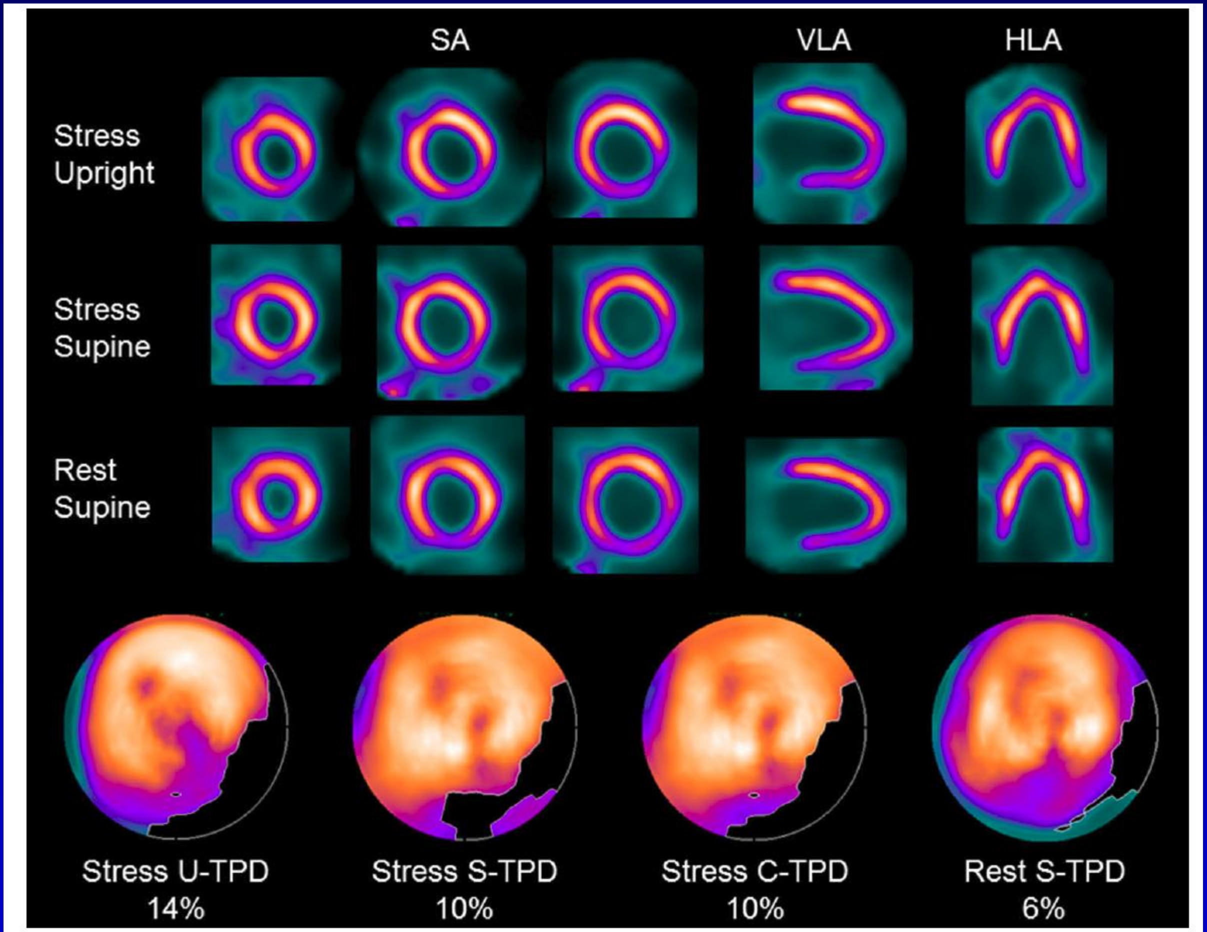
Angiographic validation n= 56



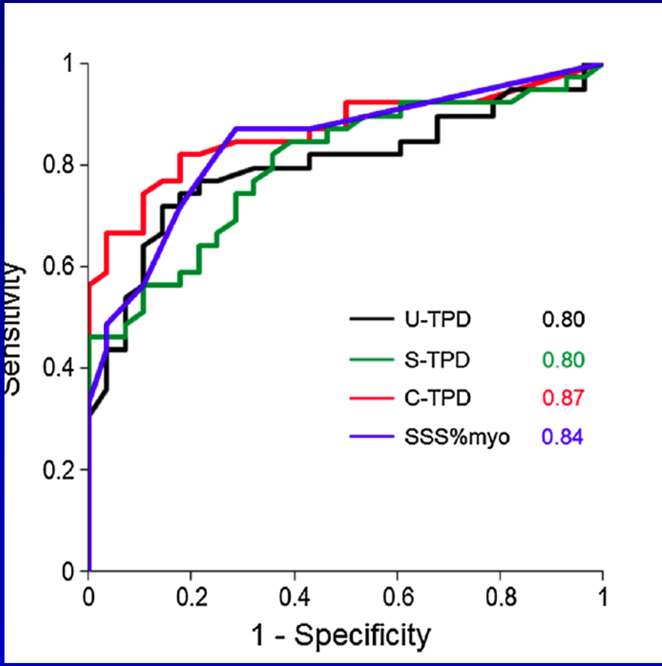


Nakazato R… Slomka PJ. J Nucl Med. 2010 Nov;51(11):172

Combined upright supine in obese patients



N=67
BMI = 41±6

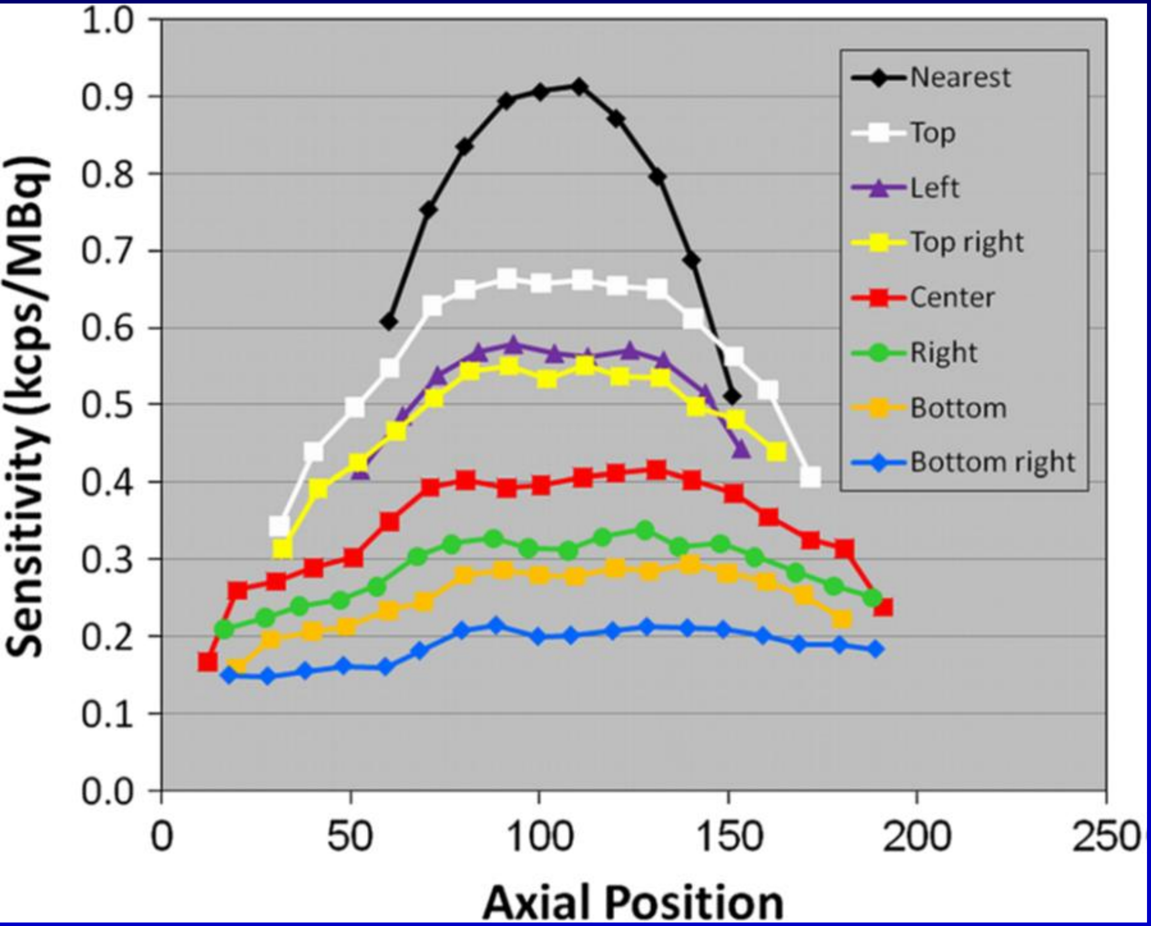


67 Y M BMI =43
RCA and LCX disease on angio

Nakazato et al
JNC 2015

3D sensitivity variation of stationary CZT scanners

Sensitivity gradient > 8%/cm

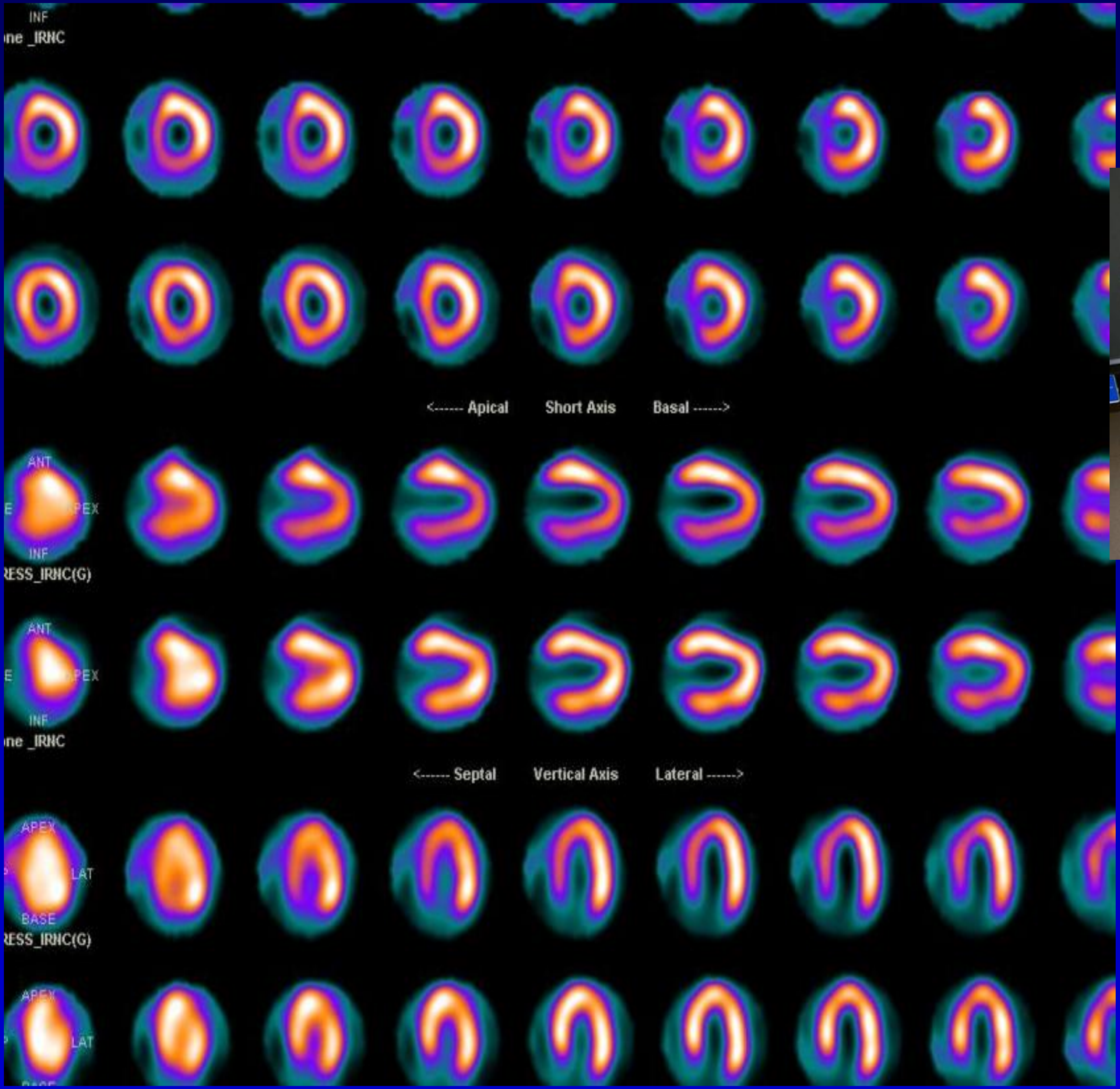


2-position imaging may help

Kennedy et al. J Nucl Cardiol 2014

Two position imaging on multi-pinhole system

S
P
S
P
S
P
S
P



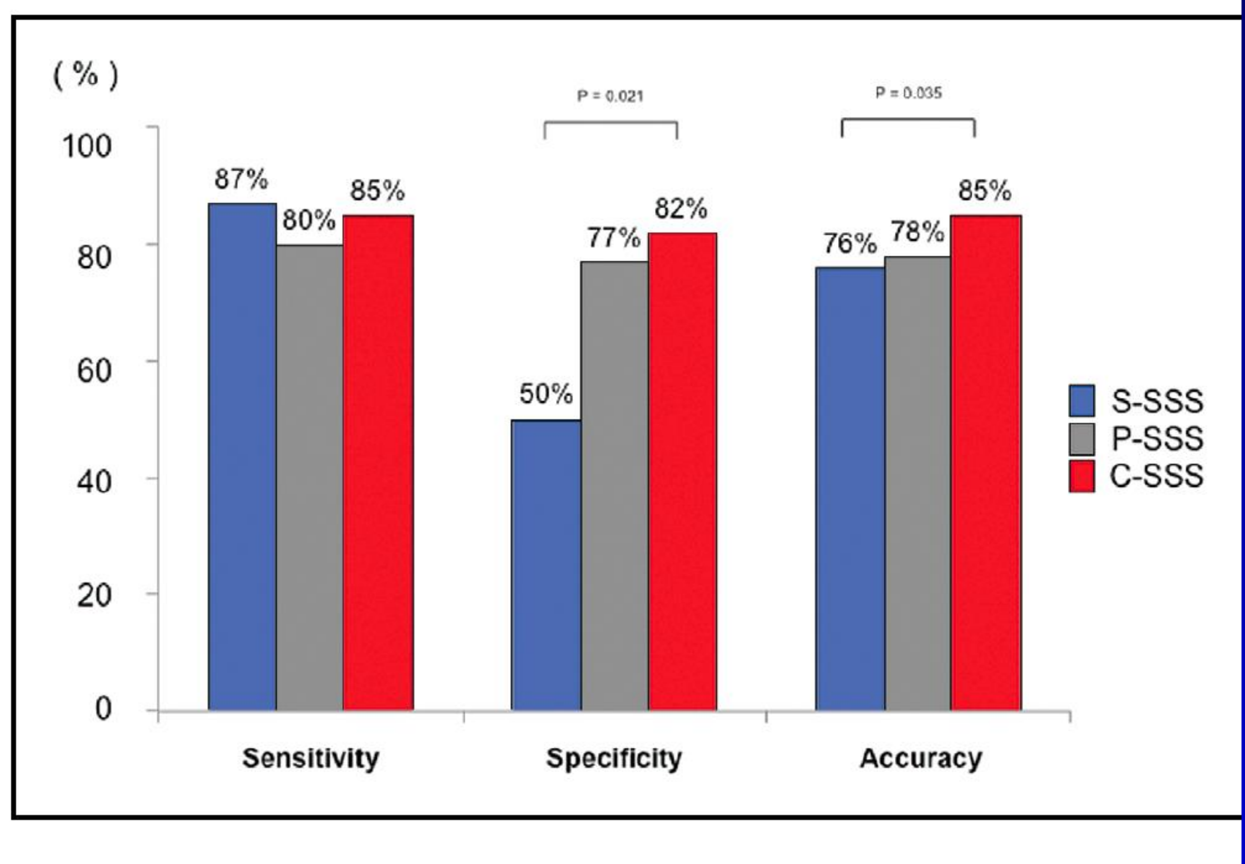
S-supine
P-prone

Duvall et al
J Nucl Cardiol 2013

Courtesy Dr Henzlova Mount Sinai

Two position imaging on multi-pinhole system

improved specificity for detection of CAD



S-SSS
Supine SSS

P-SSS
Prone SSS

C-SSS
Combined SSS

Nishiyama et al Circulation Journal May 2014

Also Duvall et al J Nucl Cardiol 2013

Question 4. Combined 2-position imaging & quantification can be used to mitigate __________ .

33% a. Attenuation artifacts

10% b. Patient motion artifacts

13% c. Patient positioning artifacts

0% d. Truncation artifacts

43% e. All of the above

Question 4. Combined 2-position imaging & quantification can be used to mitigate ________ .

(a) Attenuation artifacts ✘

(b) Patient motion artifacts ✘

(c) Patient positioning artifacts ✘

(d) Truncation artifacts ✘

(e) All of the above ✔

The correct answer is E, because:

- **<u>2-position imaging</u>**: technique where 2 SPECT scans (Supine + Prone <u>or</u> Supine + Upright) are quantified or visually analyzed *simultaneously*
- A true defect **<u>will be present at the same location</u>** in both scans
- *If only 1-position*: Any shifting of the defect or presence of the hypoperfusion area could indicate: attenuation artifact, motion artifact present **OR** truncation artifact (due to the incorrect patient position)

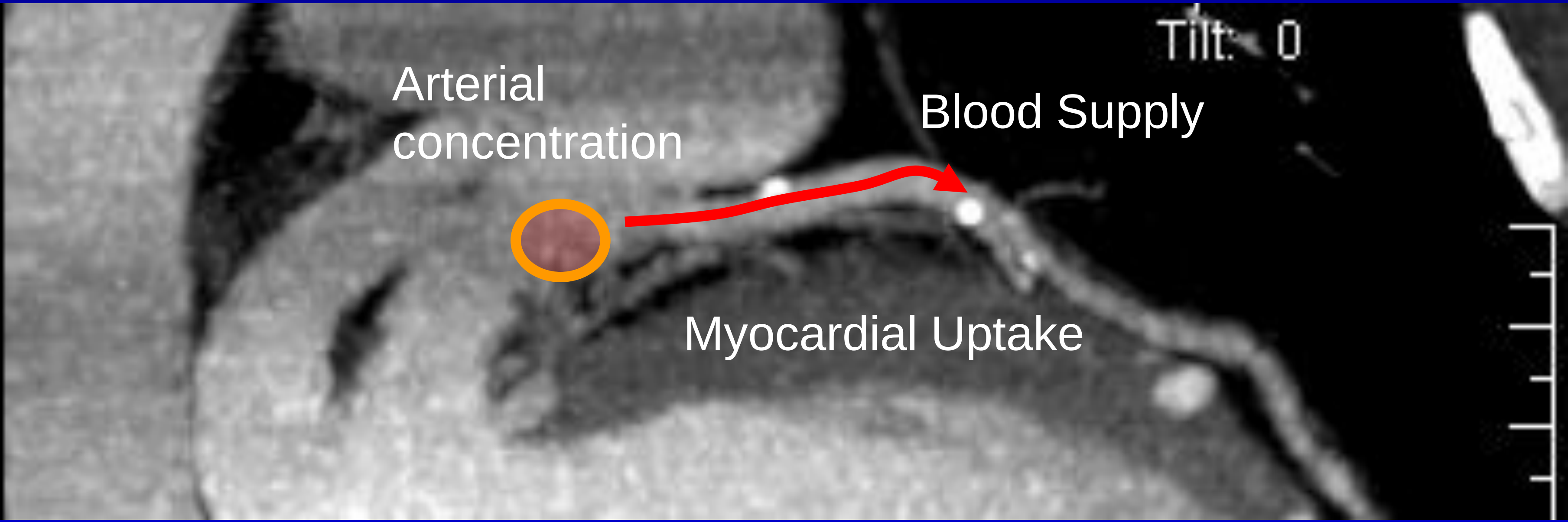
Nakazato R, Tamarappoo BK, Kang X, et al. Quantitative upright-supine high-speed SPECT myocardial perfusion imaging for detection of coronary artery disease: Correlation with invasive coronary angiography. *J Nucl Med*.2010;51:1724-1731.

OUTLINE

- Latest PET/CT hardware
- Latest SPECT hardware
- Low dose imaging
- Attenuation correction
- Perfusion quantification
- Kinetic modelling
- Motion
- Hybrid quantification

From Perfusion to Flow:

- The key measurements for calculating Quantitative Myocardial Perfusion are
  - Arterial Concentration
  - Myocardial Uptake

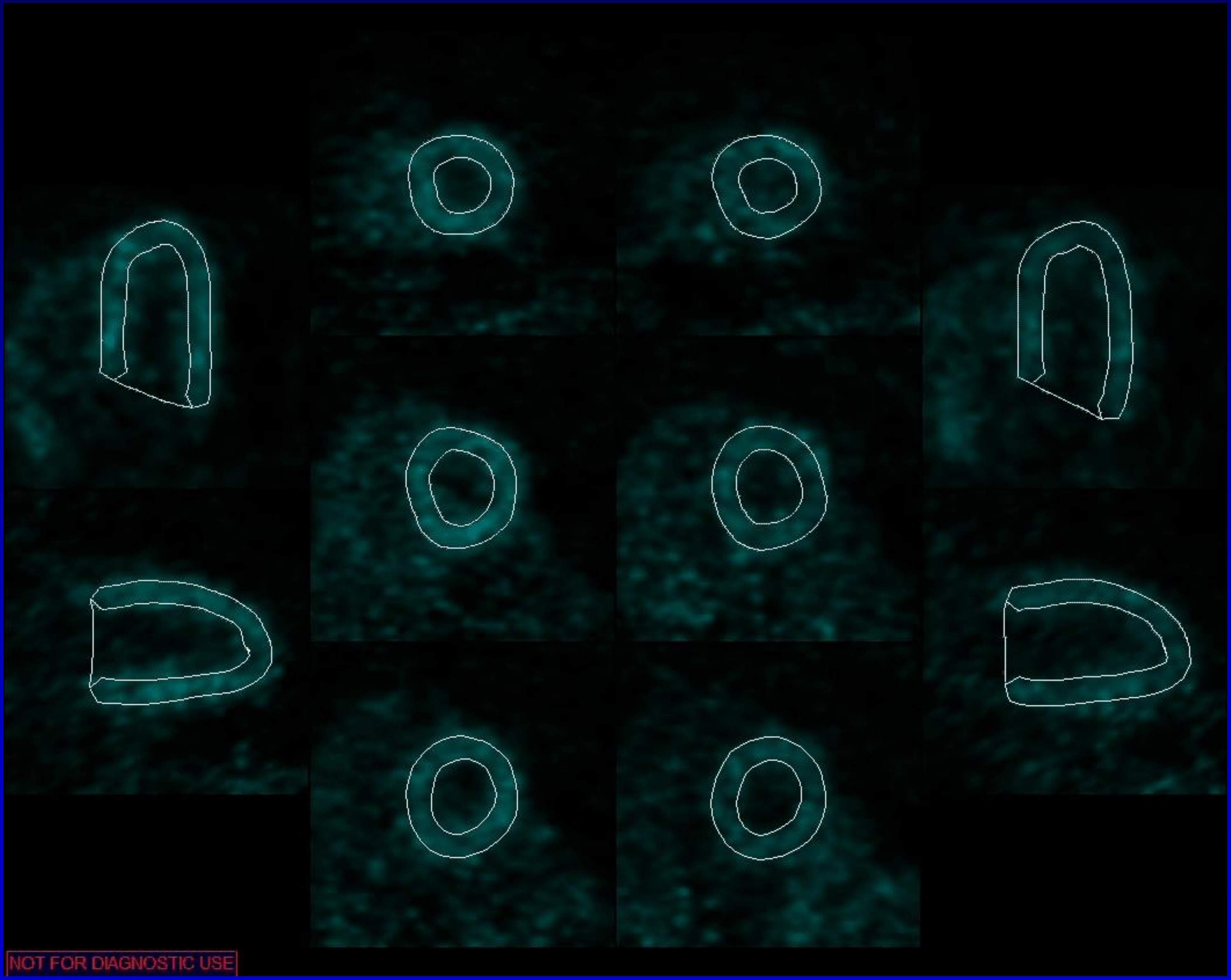


Courtesy: James Case , CVIT

Adenosine

Dynamic 82Rb PET imaging reconstructed from list mode data

Rest



Dynamic imaging

Myocardial compartmental model

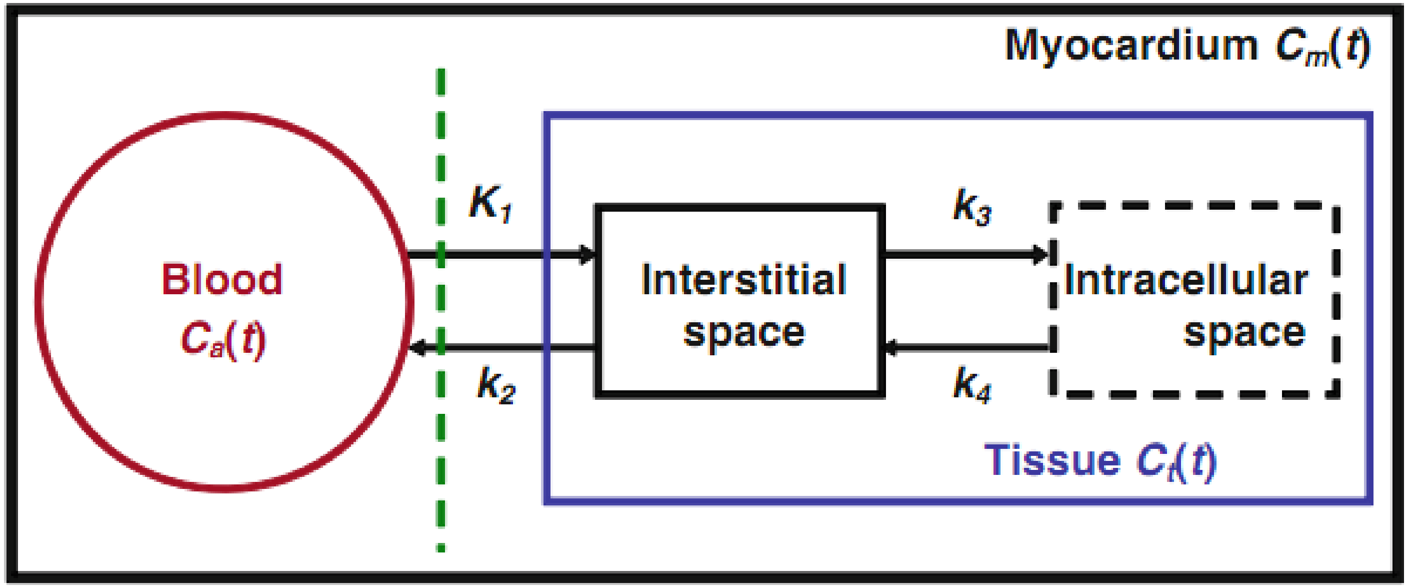
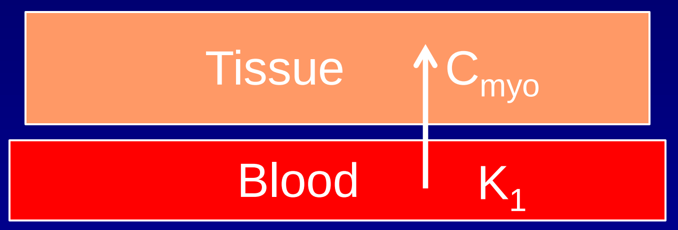


Figure 7. Myocardial compartmental model consisting of blood and tissue and the transport of tracer between compartments.

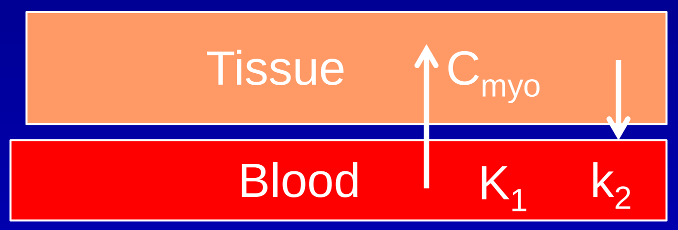
Klein et. al J Nucl Cardiol Volume 17, Number 4;555–70

Kinetic Modeling:
Increasing Complexity

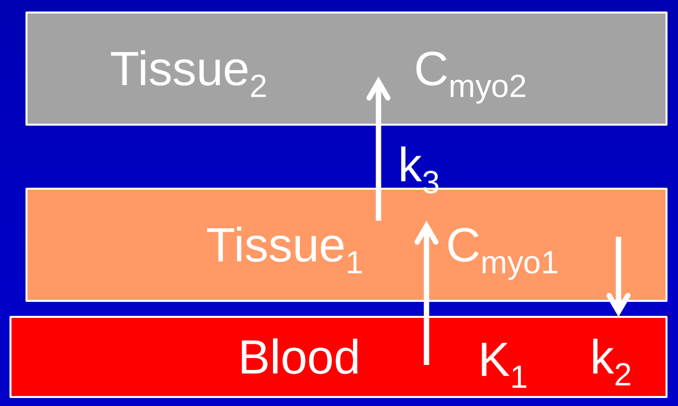
Net Retention: Uses Blood Concentration and and extraction to determine flow
(Yoshida, J Nucl Med 37: 1701–1712)



Single Compartment: Fits blood concentration (t), tissue uptake (t) and washout model (k_2):
(Lortie M, EJNM,2007; 34:1765-1774)



Two Compartments: Fits blood concentration (t), tissue uptake into two tissue compartments interstitial intercellular (K1,K3) and washout model (k_2): (Herrero, Circ Res, 1992; 70(3); 496)



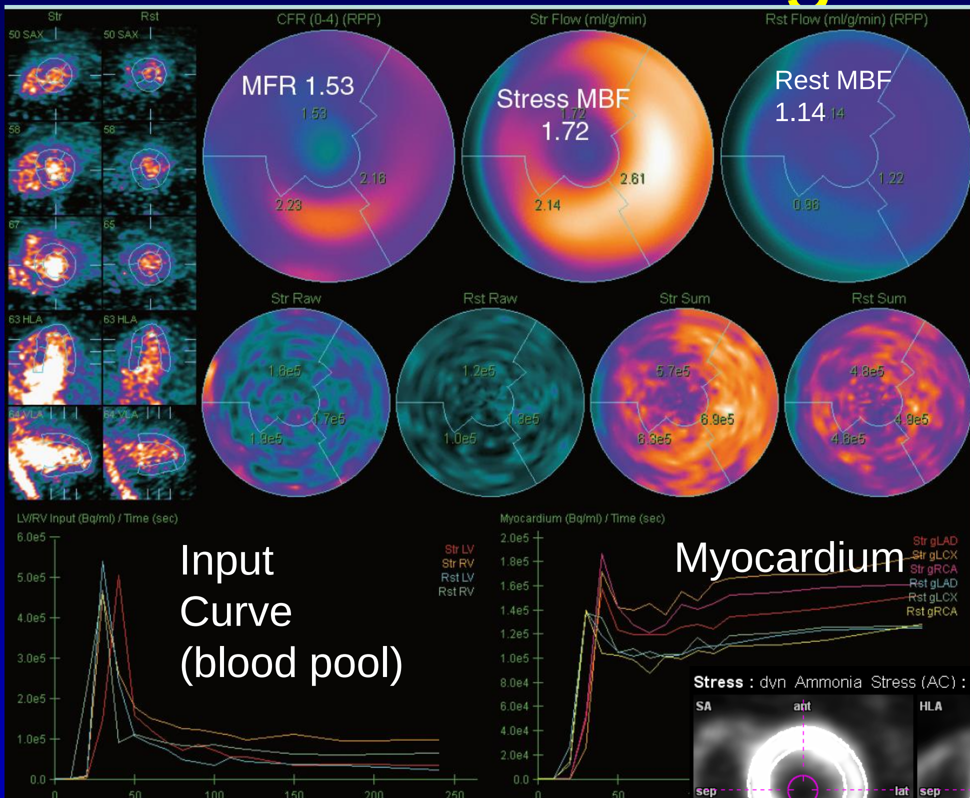
Classic Definitions

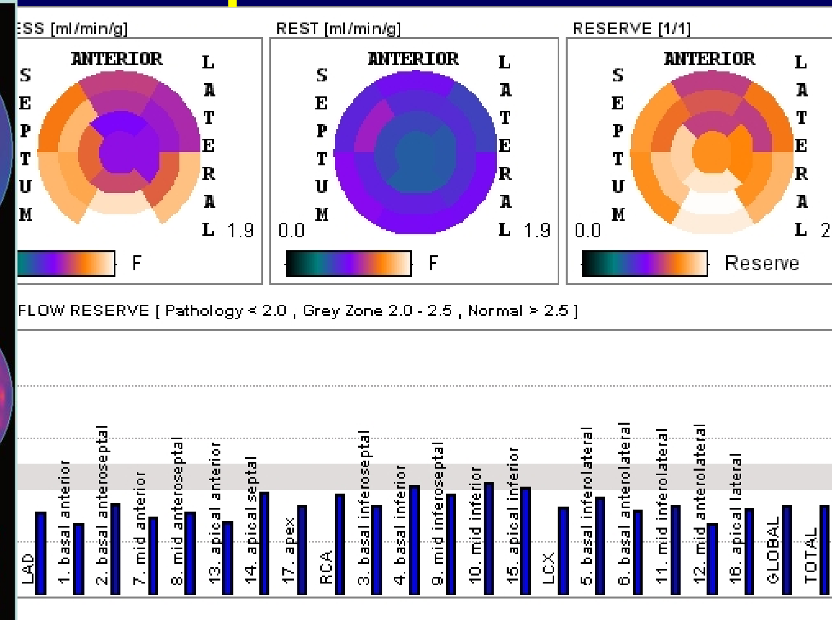
- "Absolute blood flow" is measured in units like volume per time (i.e. ml/min).
- *"Relative blood flow" is measured in units of volume/time/volume of tissue (i.e. ml/min/g)*.
- ml is a unit of volume
- g of myocardium = ml of myocardium * density
- Density of myocardium = 1.05 g / ml
- ml/min/g = $ml \cdot min^{-1} \cdot (1.05\ ml)^{-1}$ = 1/1.05 min ≈ min^{-1}

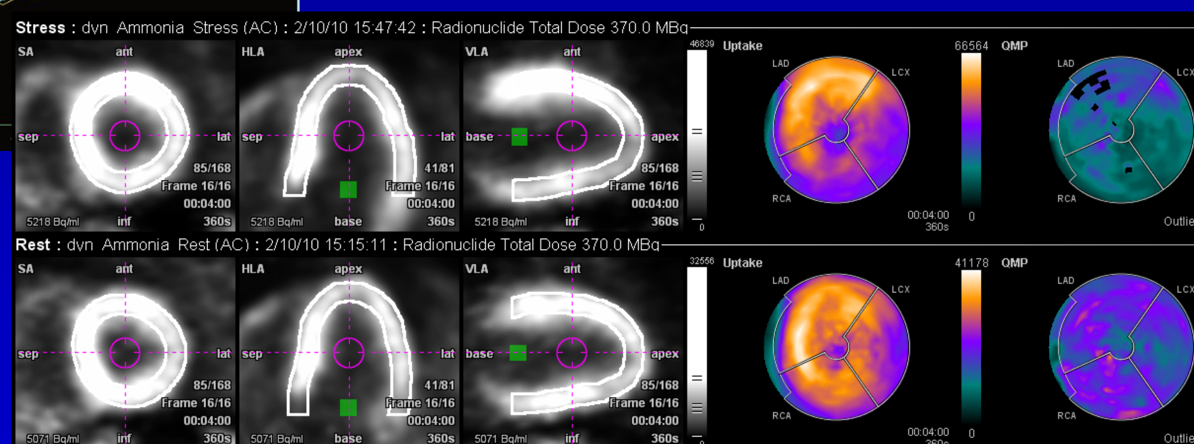
Courtesy Dr. Arai , NIH

Zierler KL Circ Research 196210:393-407

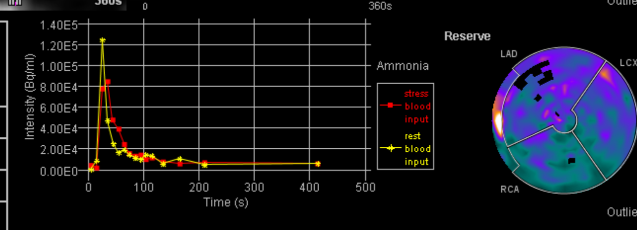
Kinetic modeling -Flow quantification





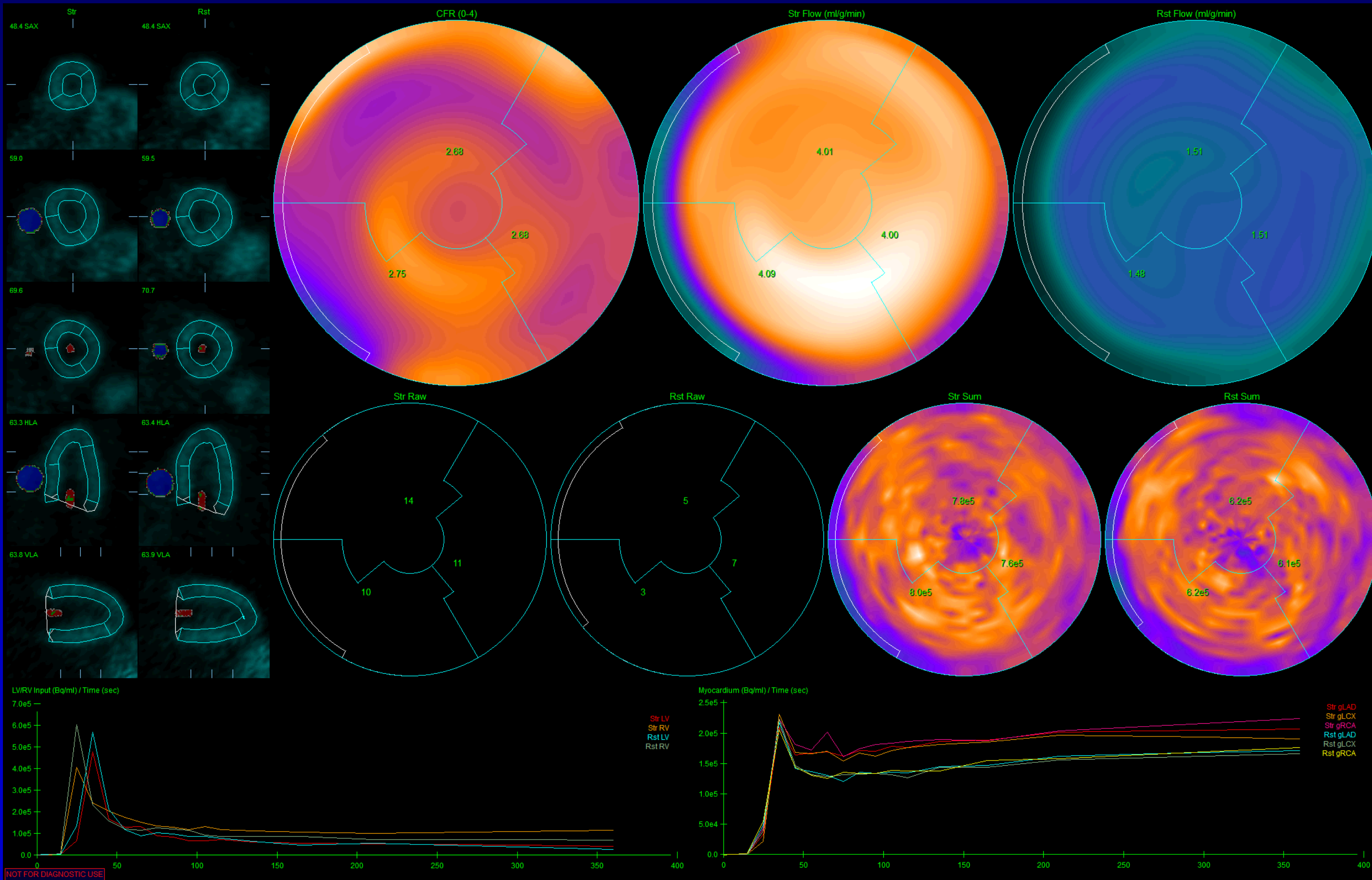


	QMP (ml/g/min)				Reserve	
	Stress		Rest			
	mean	std dev.	mean	std dev.	mean	std dev.
LAD	1.38	0.38	0.86	0.19	1.65	0.43
LCX	1.16	0.37	0.81	0.14	1.45	0.40
RCA	1.14	0.37	0.99	0.18	1.17	0.36



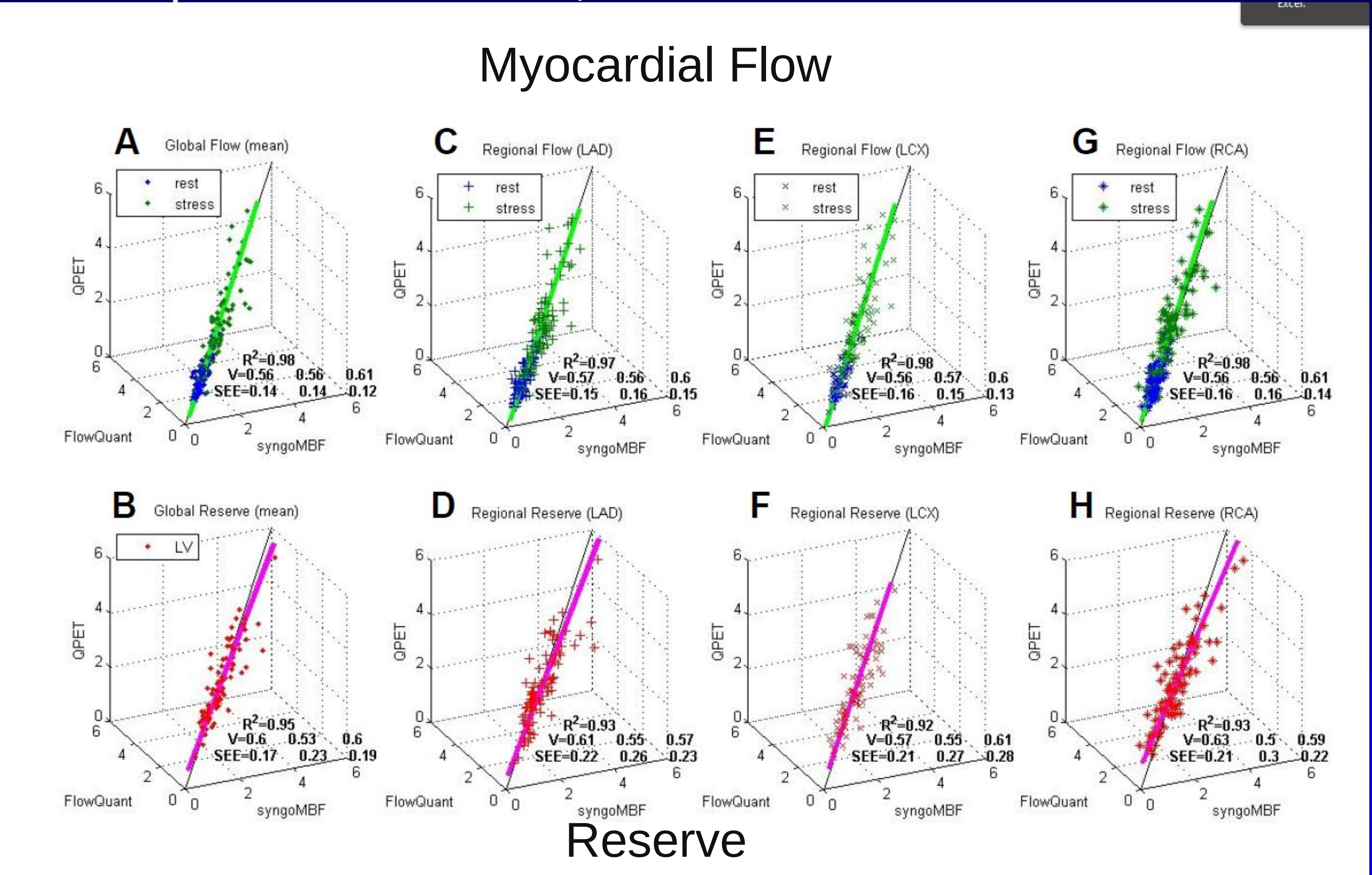
Various software tools are available

PET ^{82}Rb blood flow analysis



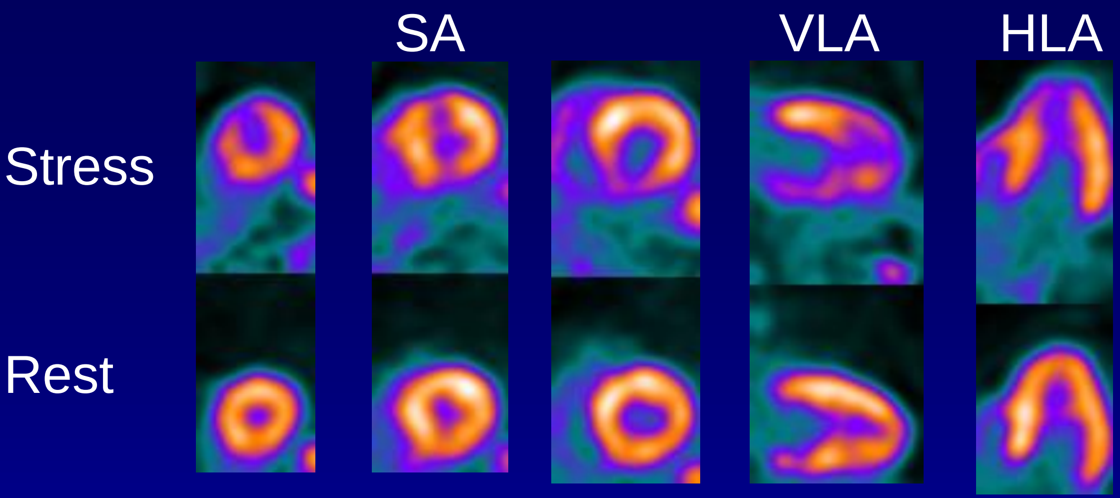
^{82}Rb flow PET/CT quantification:

comparison of 3 tools, data from 3 PET/CT centers

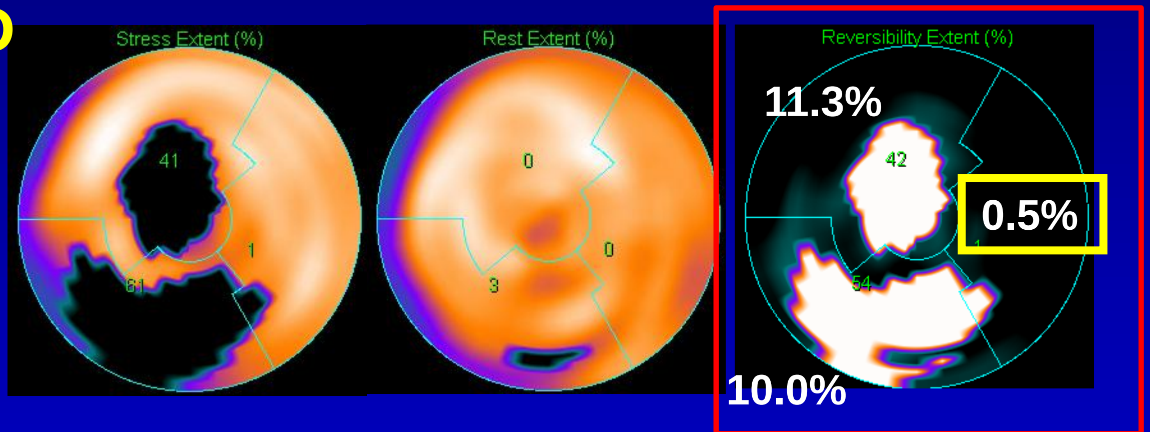


De Kemp et al J Nucl Med. 2013;54:373-379

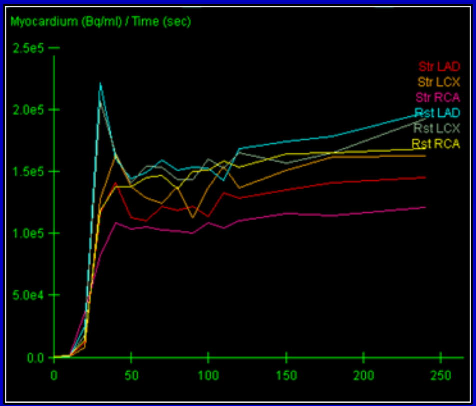
Example: Flow reserve In triple vessel disease

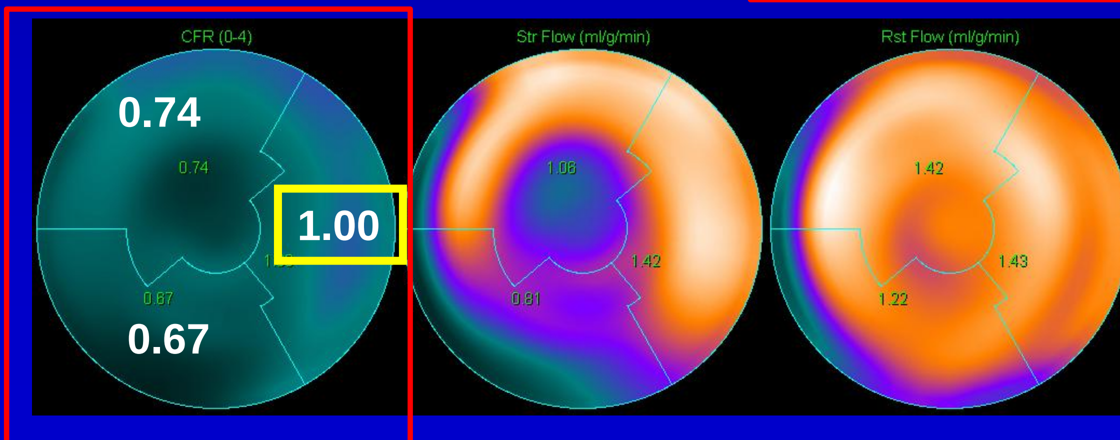


I-TPD

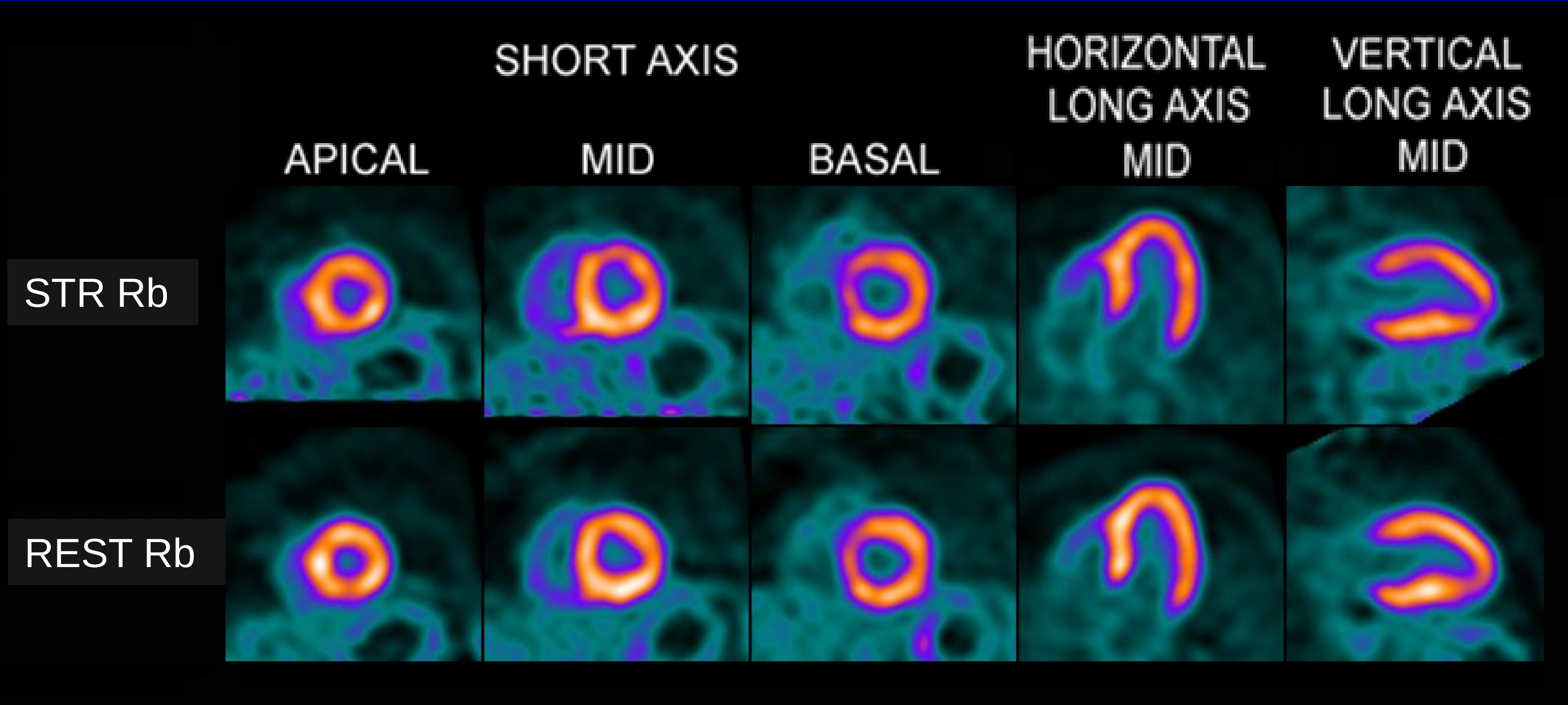


MFR





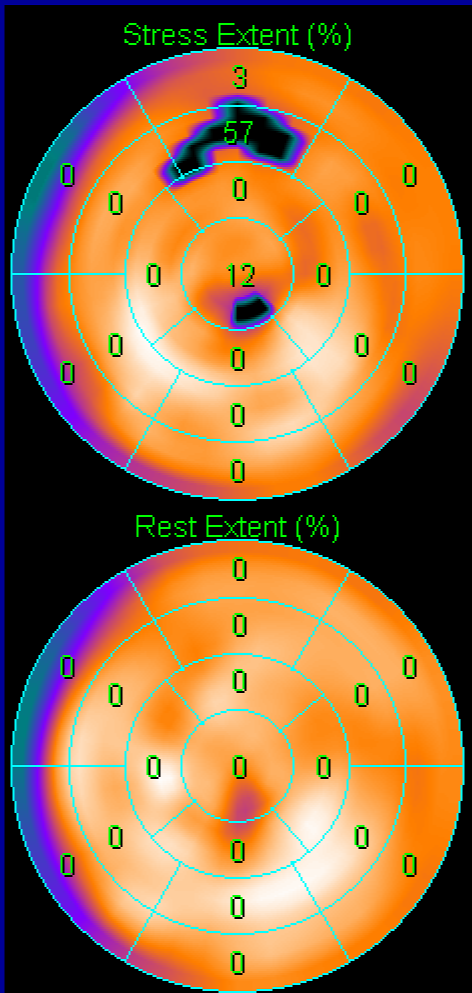
Flow + perfusion case 2

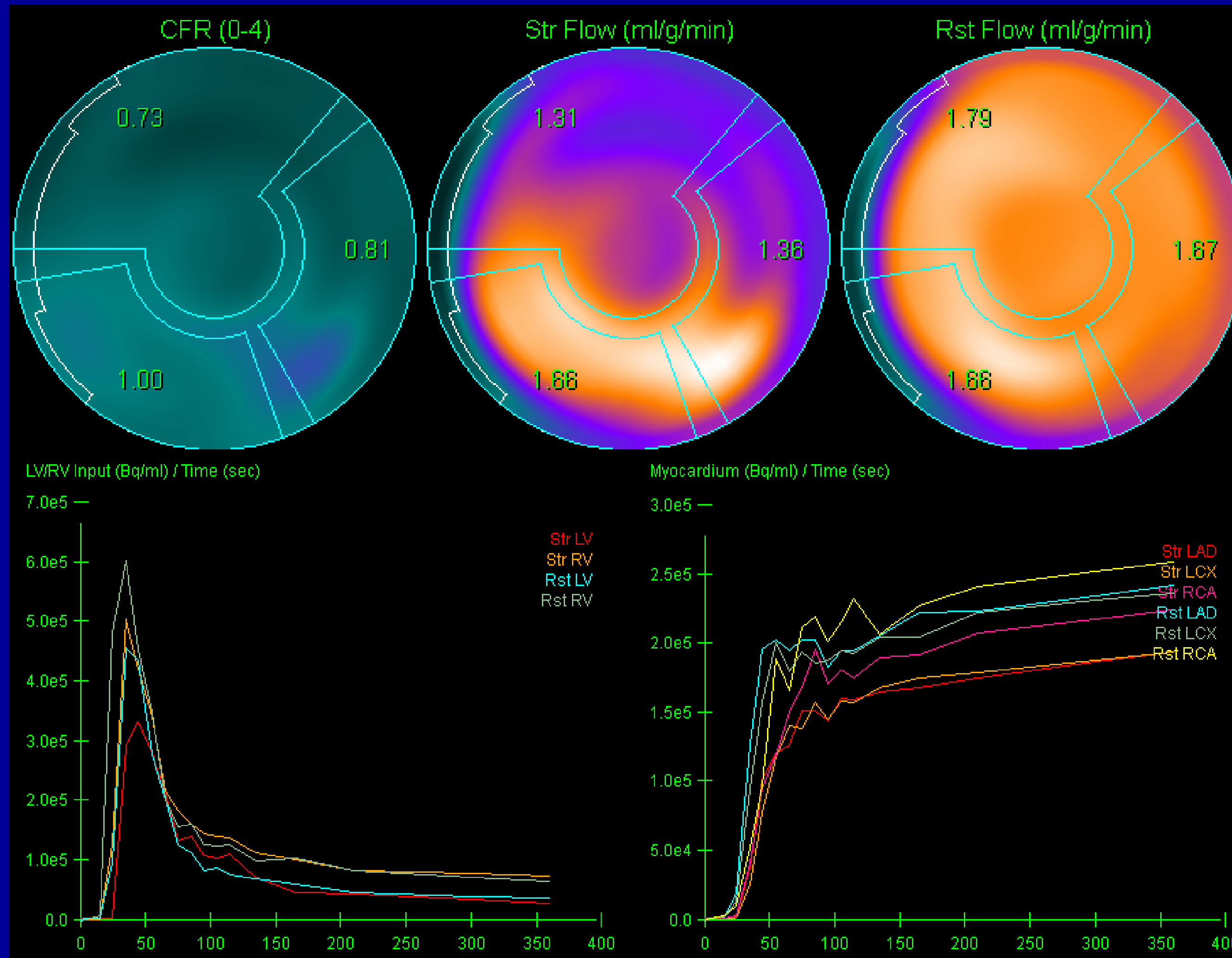


Flow + perfusion case 2

TPD

FLOW

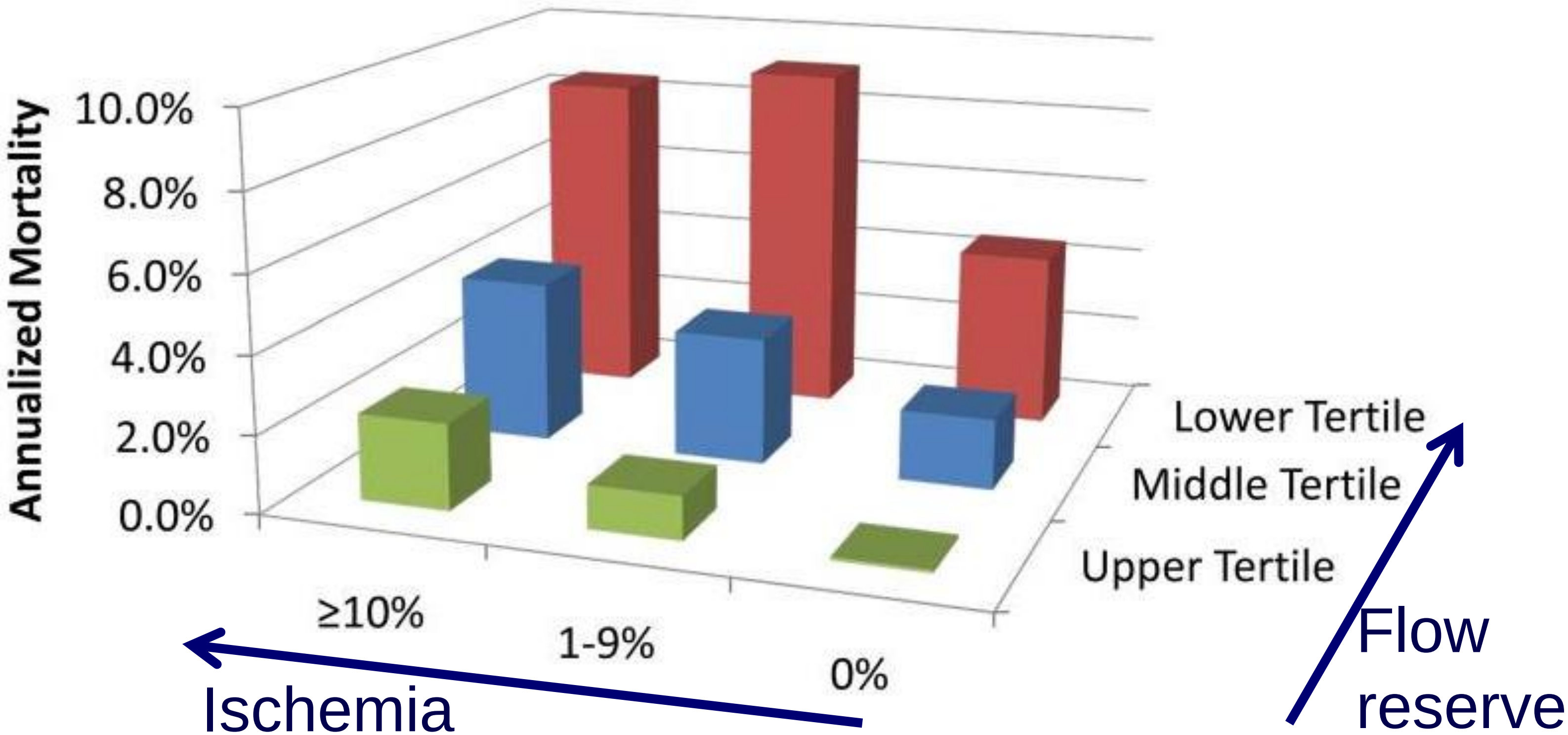




S-TPD: 4%
R-TPD: 0%

Cath 60 % LAD negative FFR
Multiple risk factors. Prob micro vascular

Added value of myocardial flow reserve mortality predicition



	≥10%	(n)	1-9%	(n)	0%	(n)
Upper Tertile	2.2%	(50)	1.1%	(197)	0.1%	(681)
Middle Tertile	4.2%	(119)	3.3%	(234)	1.8%	(575)
Lower Tertile	8.5%	(232)	9.1%	(298)	4.5%	(397)

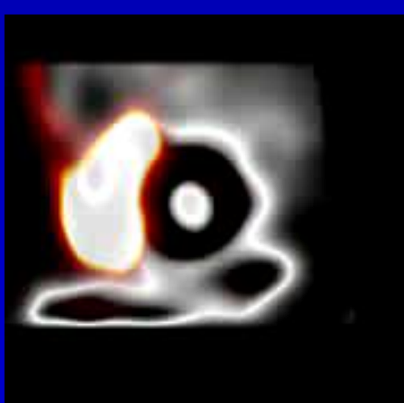
Murthy V, Circulation. 2011;124:2215-2

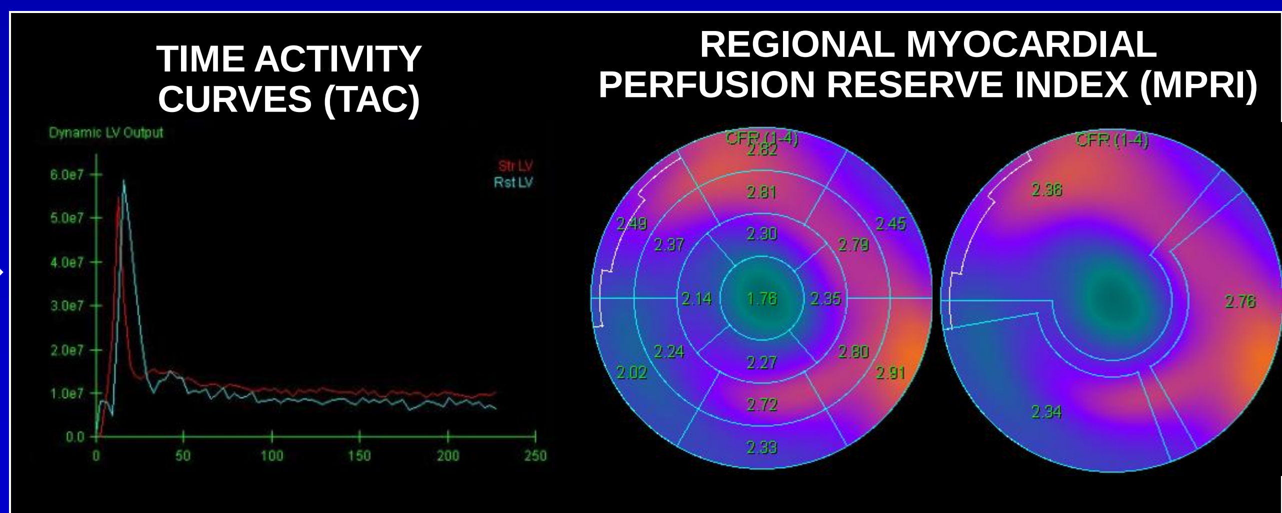
Dynamic SPECT Tc^{99m} imaging

Scanning method:

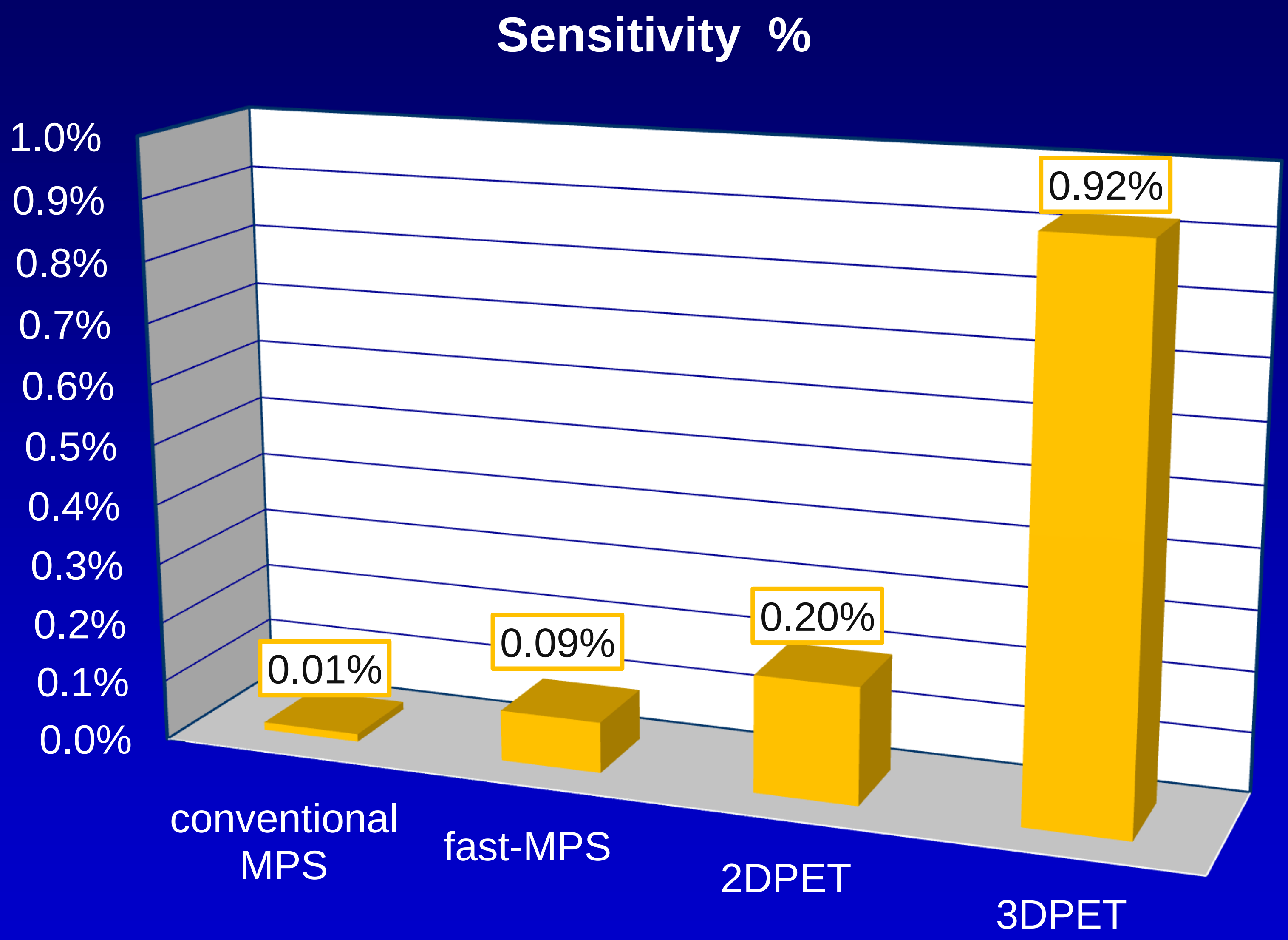
- 10 VIEWS / FRAME
- 3.5 SECONDS / FRAME
- 70 FRAMES
- 4 MIN SCAN

Dynamic FRAMES





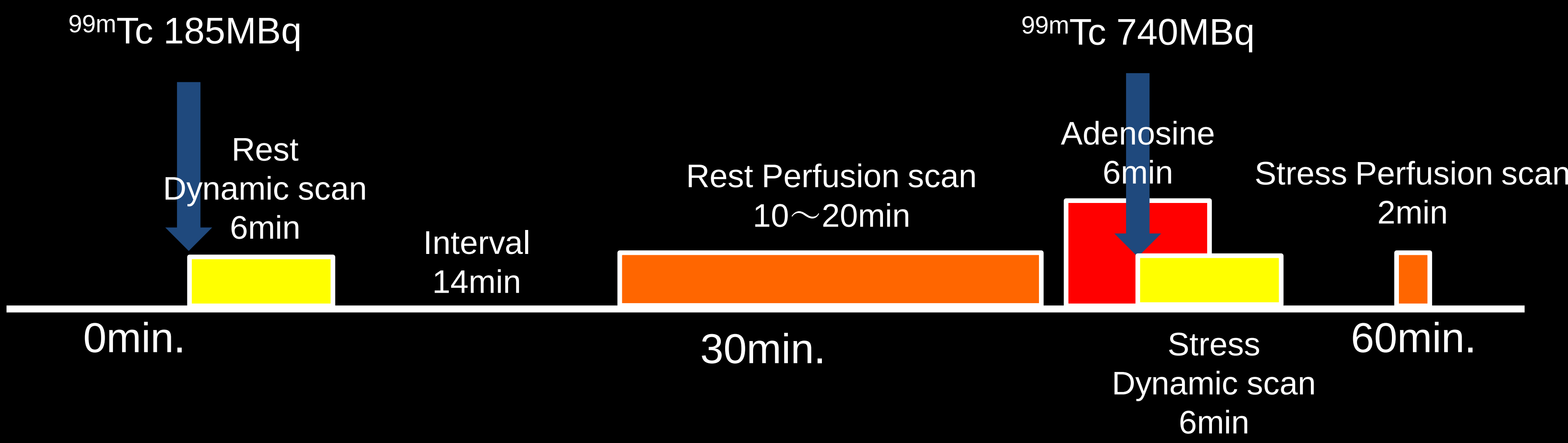
Fast-MPS sensitivity vs. PET



Slomka et al JNC 2014 based on Imbert et al J Nucl Med 2012, Mawlawi et al J Nucl 2004

Dynamic CZT SPECT Protocol

^{99m}Tc-sestaMIBI/tetrofosmin



Sakakibara
Heart Institute
Japan

Stress

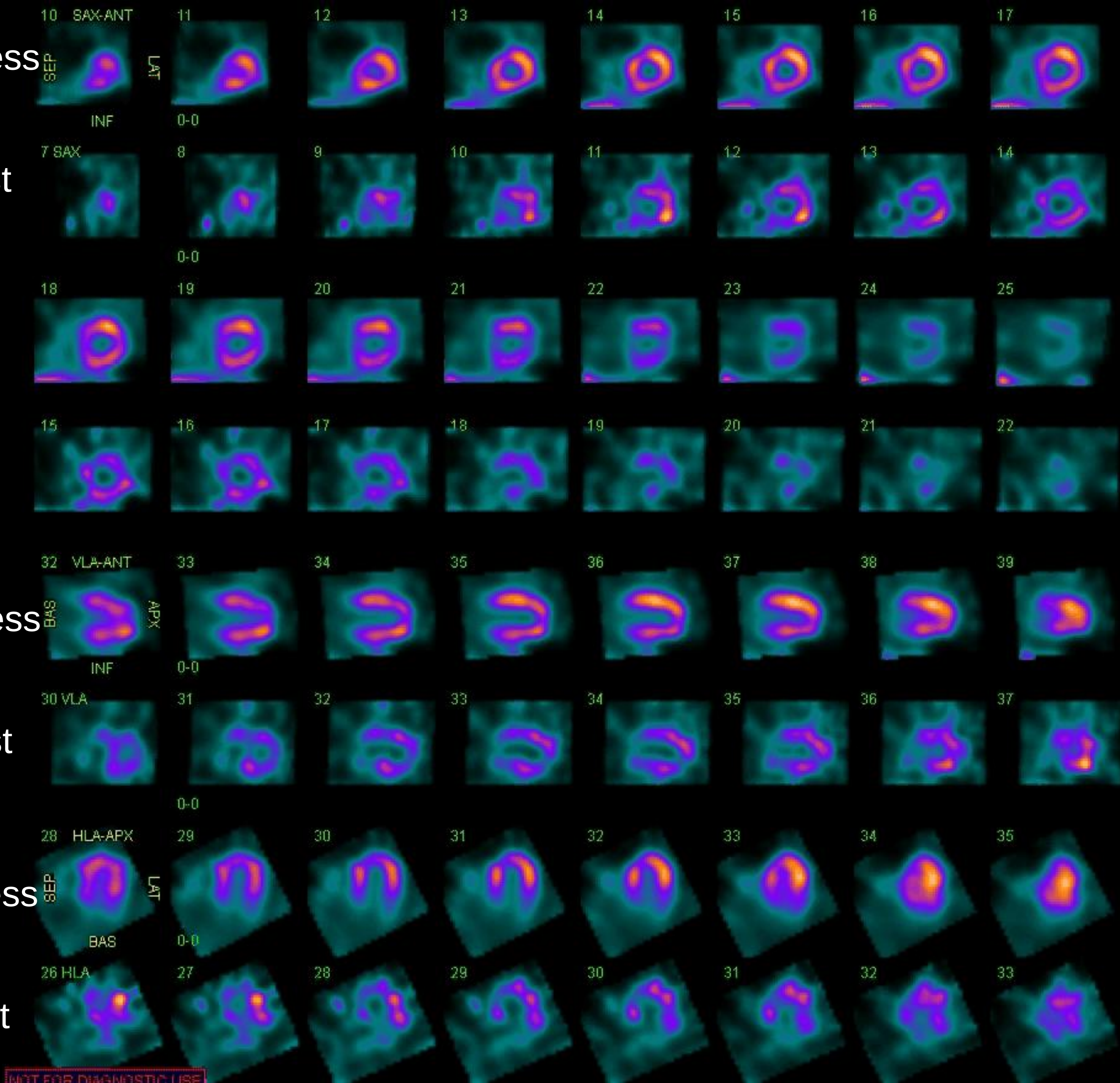
Rest

Stress

Rest

Stress

Rest



62 yr.
male

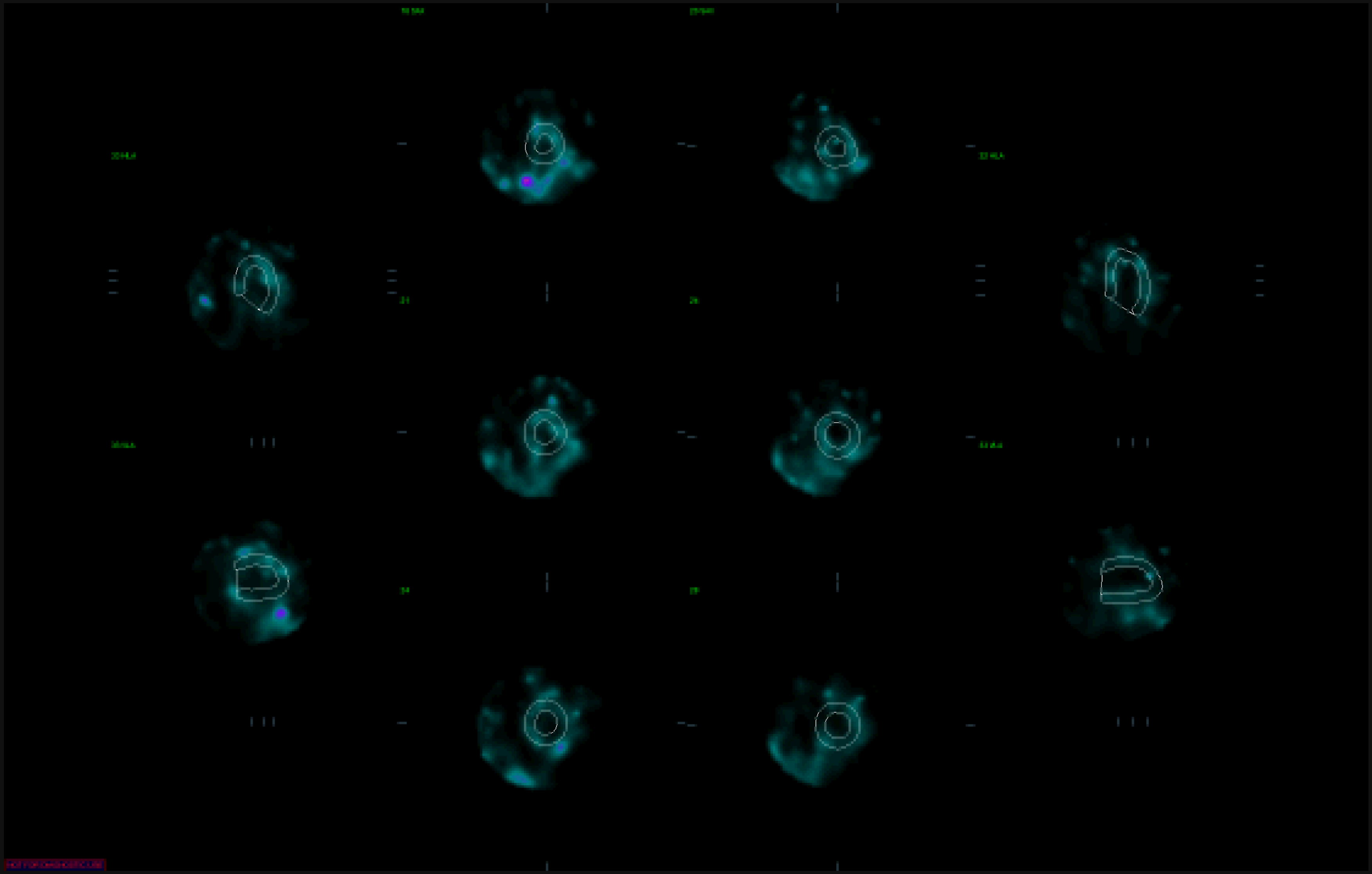
BMI:30.3
168cm
85.6kg

Scan time
Stress
6min
Rest
6min

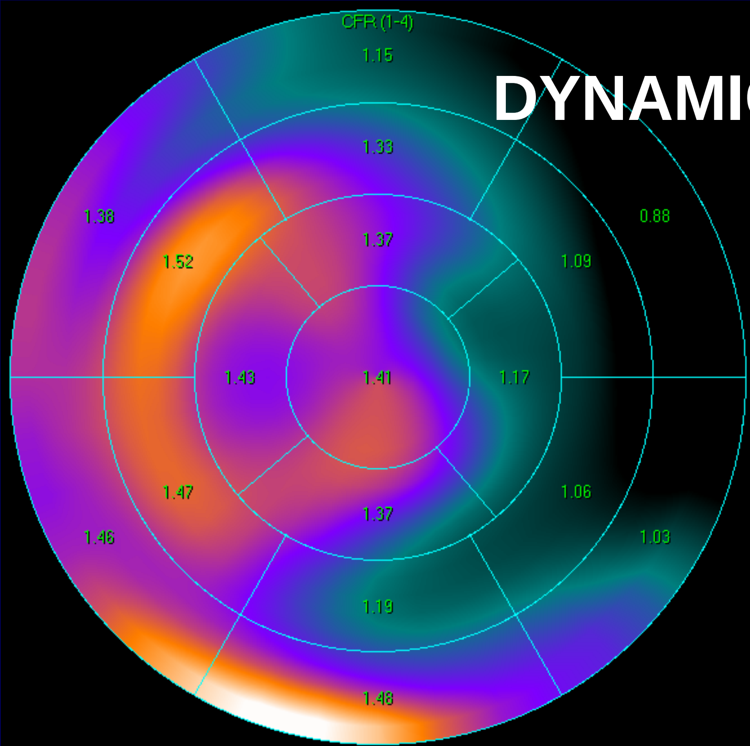
^{99m}Tc-MIBI
(Adenosine)

Stress
740MBq
Rest
185MBq
Effective dose
7.5mSv

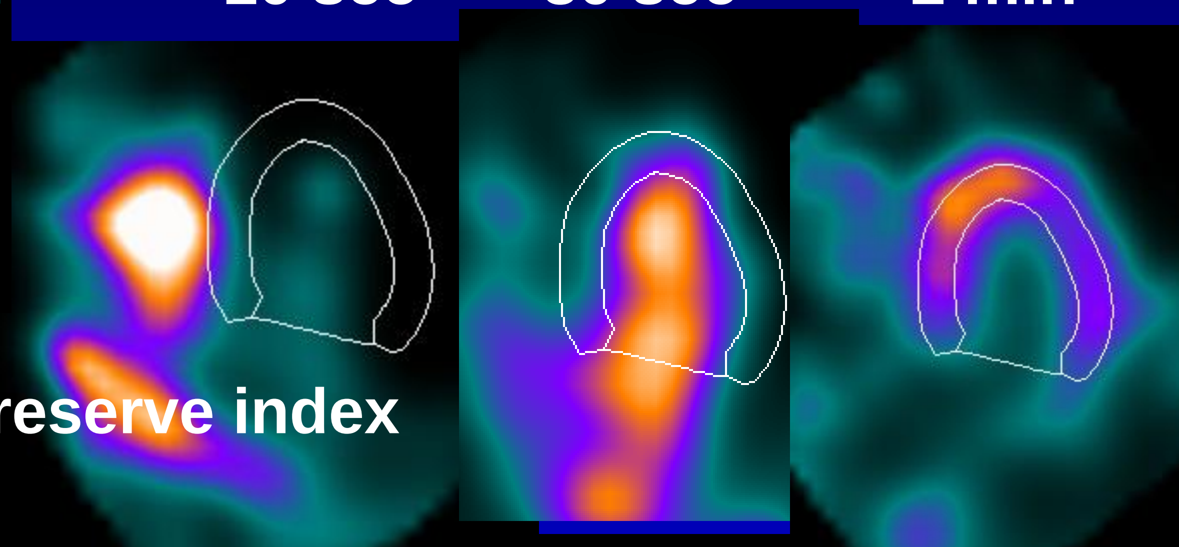
Dynamic SPECT: contour detection



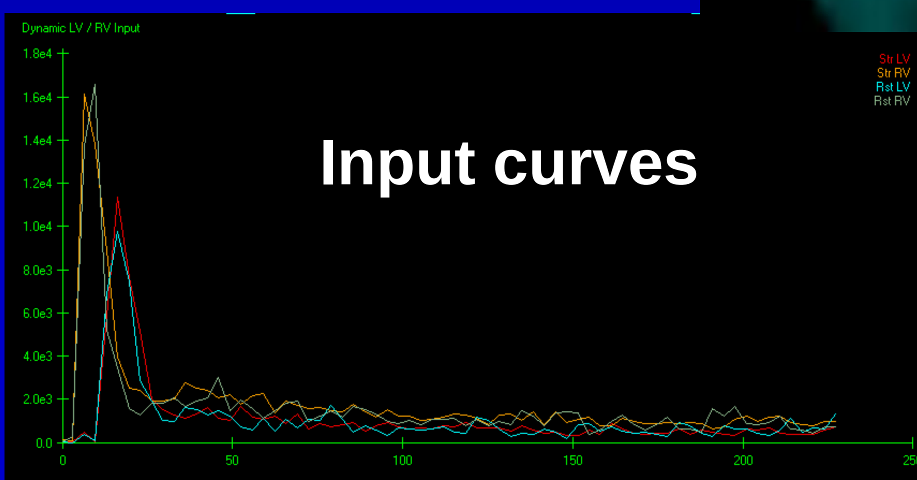
DYNAMIC SPECT with Fast SPECT Cameras ?



10 sec 30 sec 2 min



Myocardial perfusion reserve index



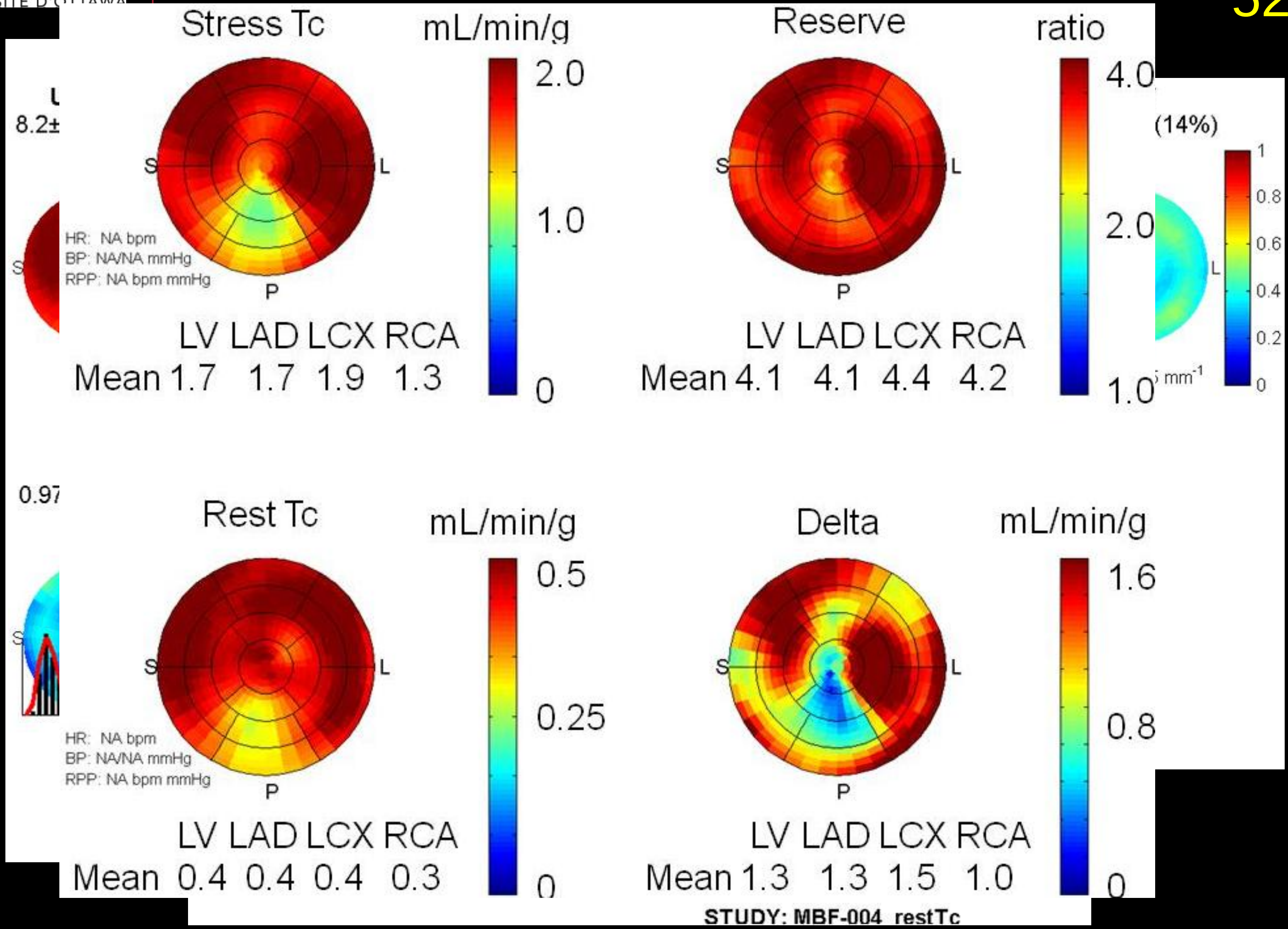
Input curves

Stress/rest tissue curve

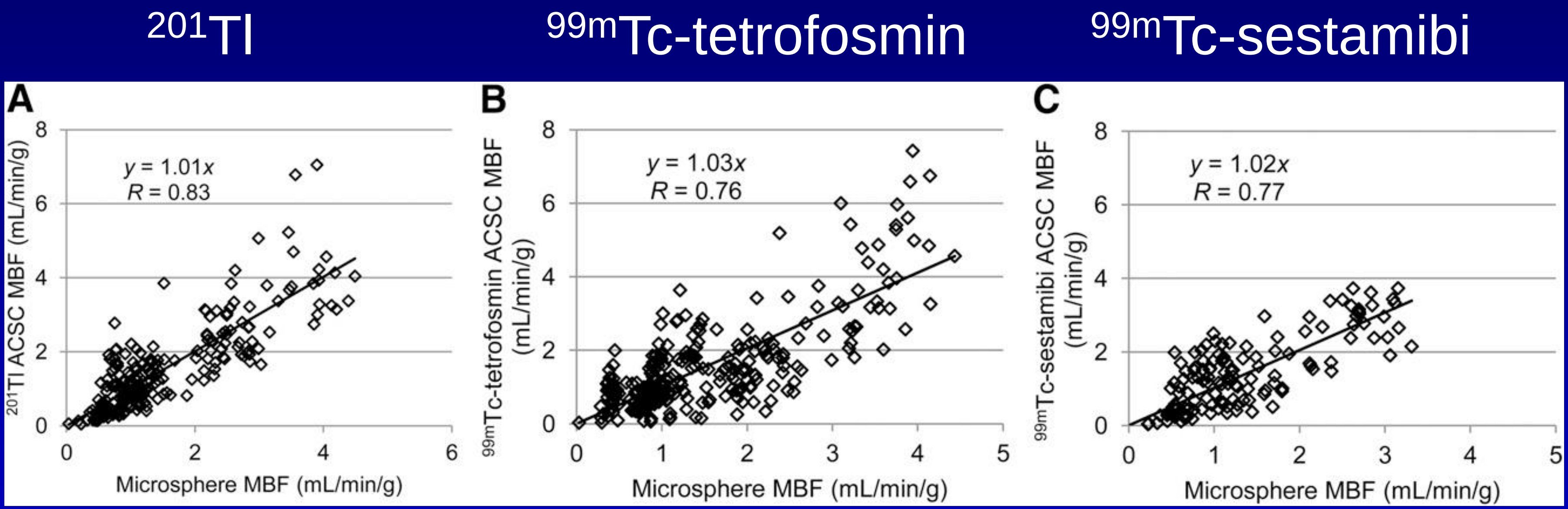
Breult et al ASNC 2010

Dynamic SPECT blood flow analysis

52Y M



^{99m}Tc-sestamibi CZT SPECT microspehere validation



17-segment comparison of microsphere MBF to MBF measured with attenuation- and scatter-corrected 201Tl (A), 99mTc-tetrofosmin (B), and 99mTc-sestamibi (C).

Wells et al JNM 2014

Question 5. Myocardial flow measurements in PET use the following units: _________ .

14%	a.	ml/sec
0%	b.	Bq/min
0%	c.	ml/cm^2
62%	d.	ml/g/min
24%	e.	Bq/ml/sec

Question 5. Myocardial flow measurements in PET use the following units: ________

(a) ml/sec ✗

(b) Bq/min ✗

(c) ml/g/min ✗

(d) ml/g/min ✓

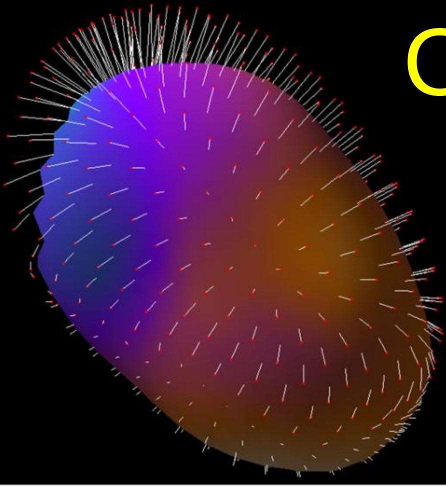
(e) Bq/ml/sec ✗

The correct answer is D, reference:
Quantification of myocardial blood flow and flow reserve: Technical aspects. Klein R, Beanlands RS, deKemp RAJ Nucl Cardiol. 2010;17:555-70.

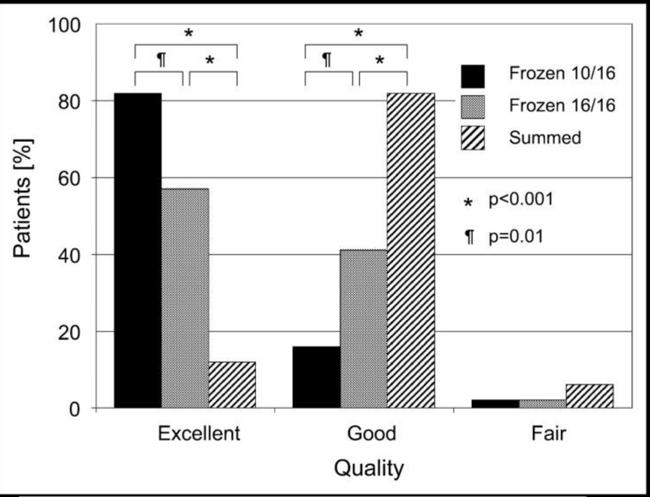
OUTLINE

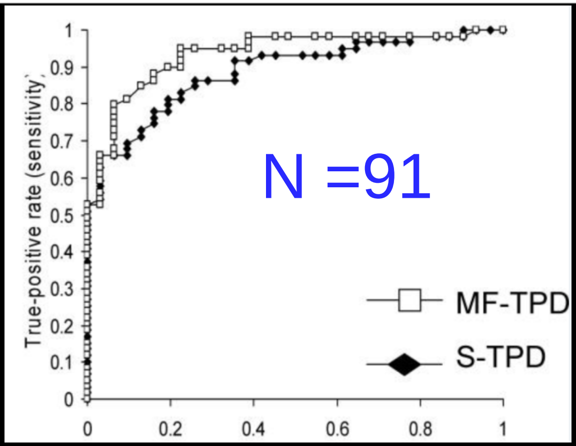
- Latest PET/CT hardware
- Latest SPECT hardware
- Low dose imaging
- Attenuation correction
- Perfusion quantification
- Kinetic modelling
- Motion
- Hybrid quantification

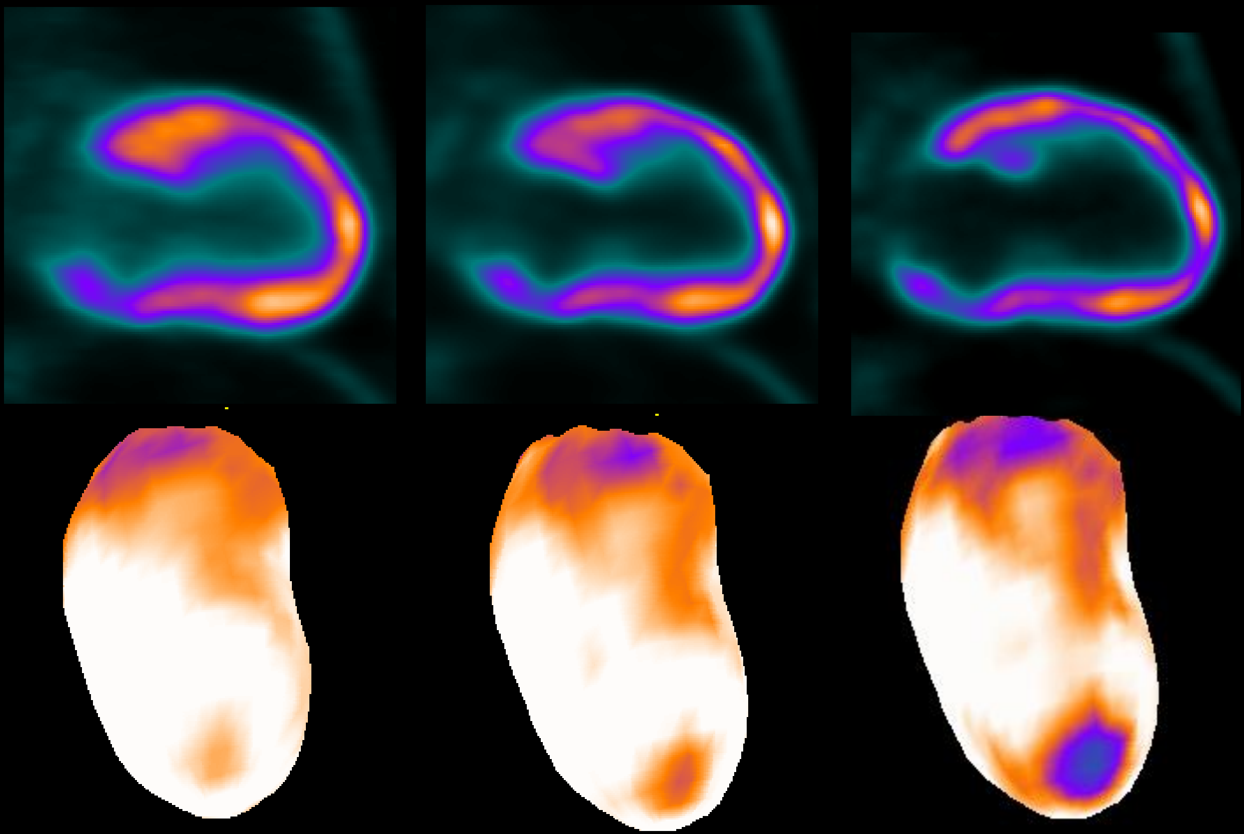
Cardiac motion-frozen perfusion



84 y/o patient BMI = 27 with a history of myocardial infarction







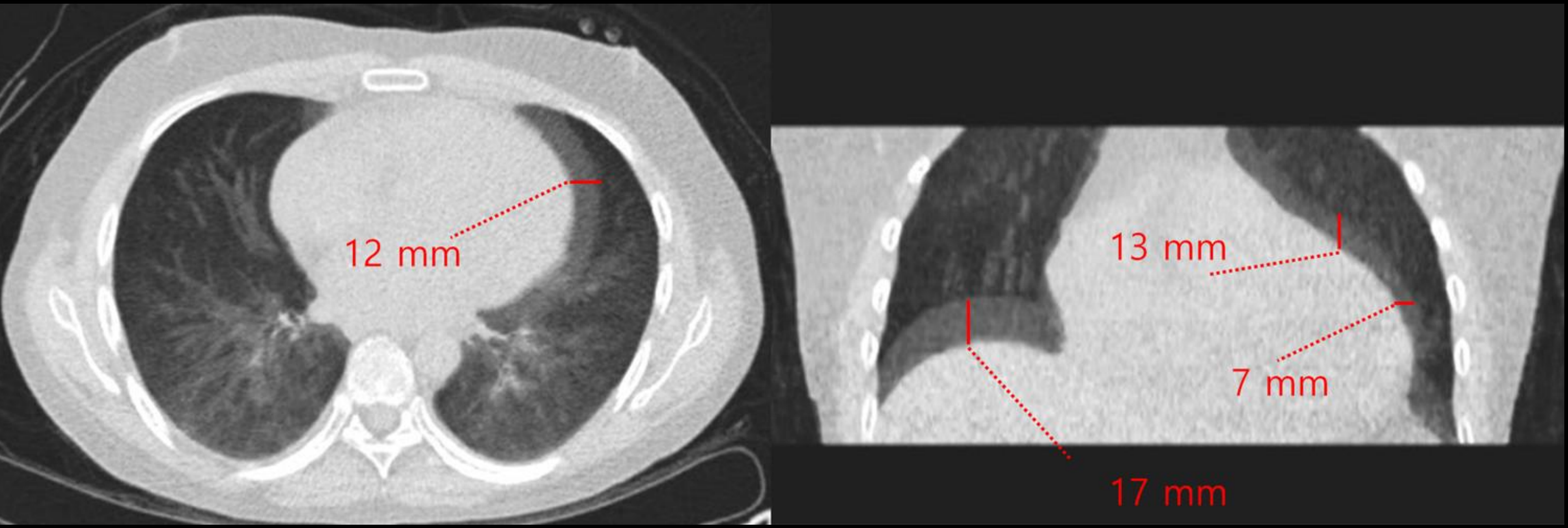
Standard Recon

High definition

Motion frozen

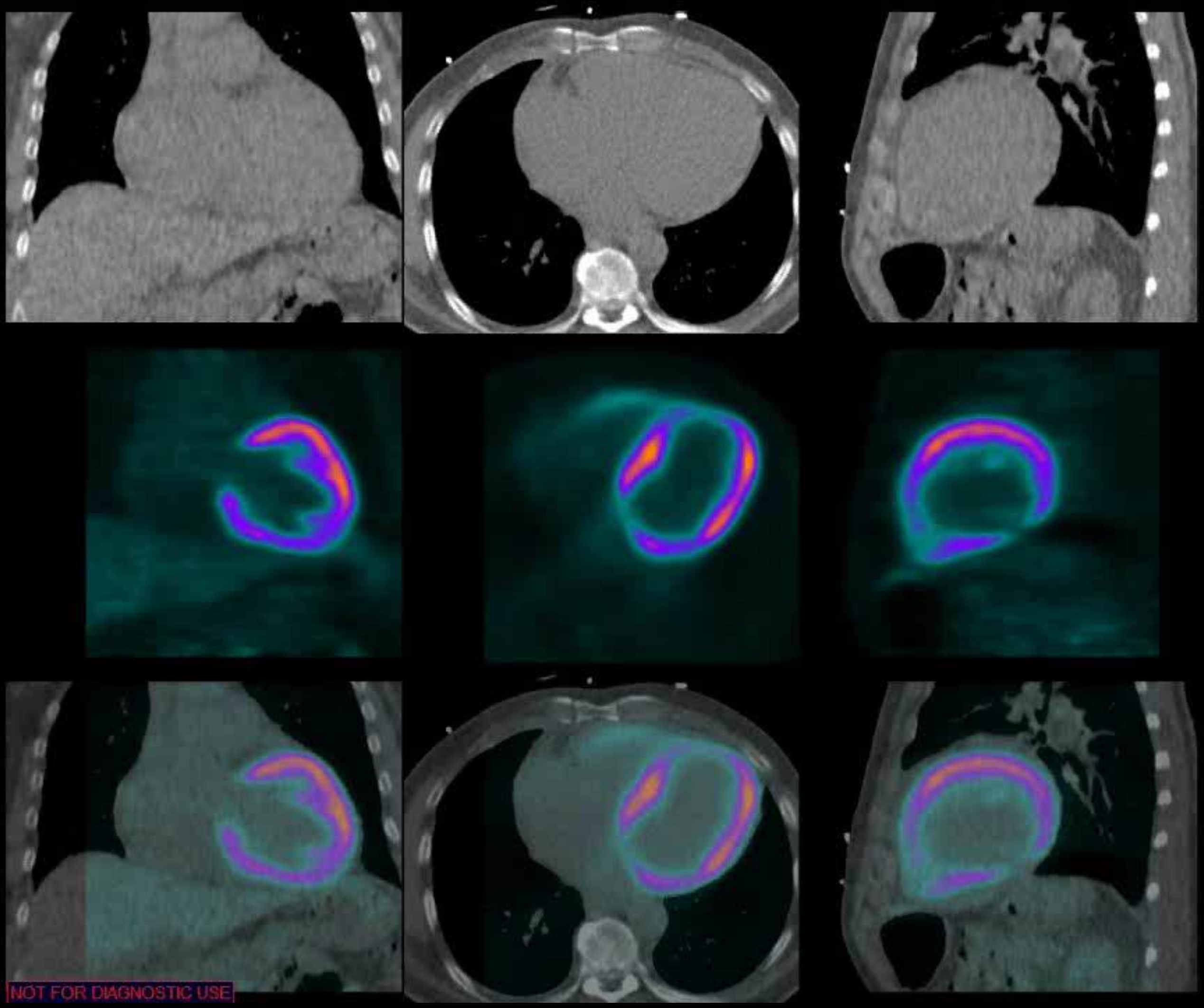
JNM 05, JNM 08, J Nucl Cardiol. 2011

Respiratory motion

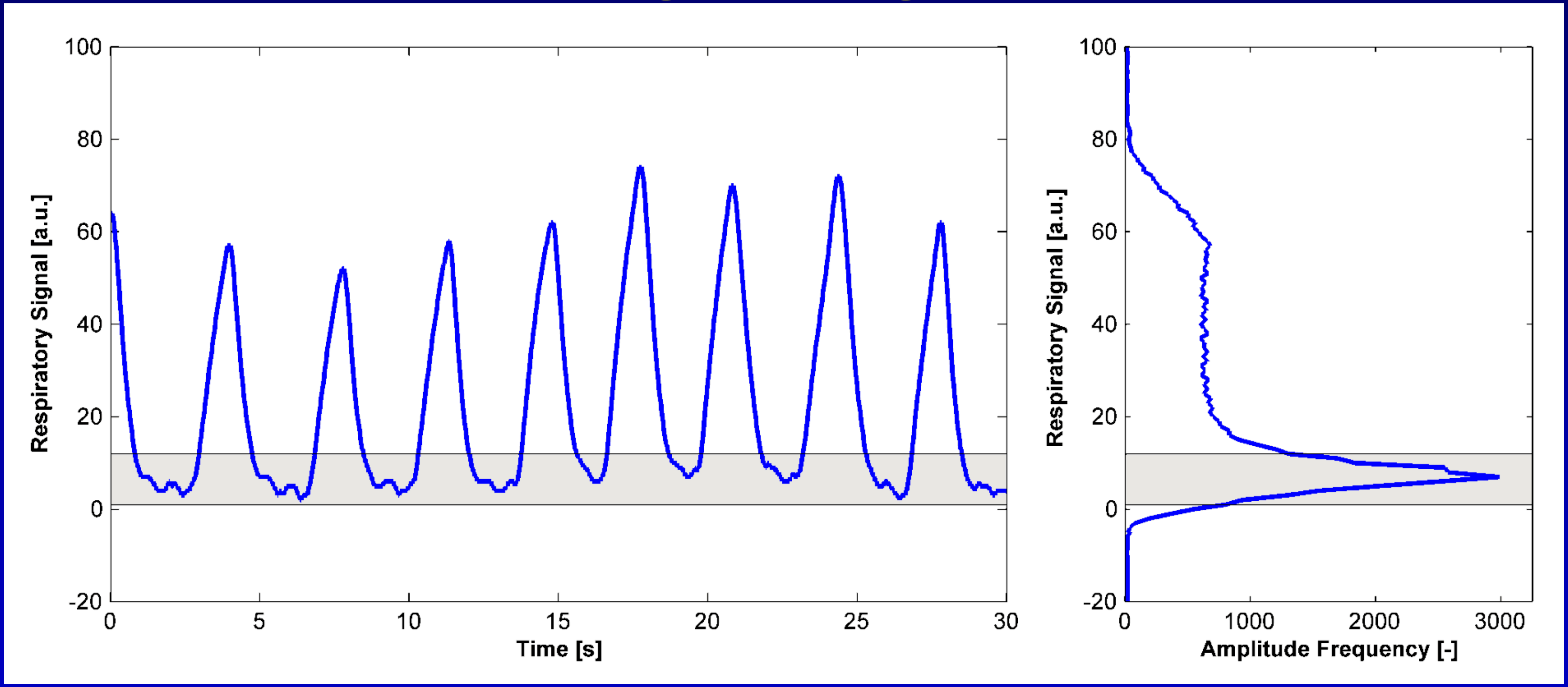


Normal patient breathing. low-dose cine no contrast CT scan
Average radiation dose ~ 1.7 mSv

Respiratory motion

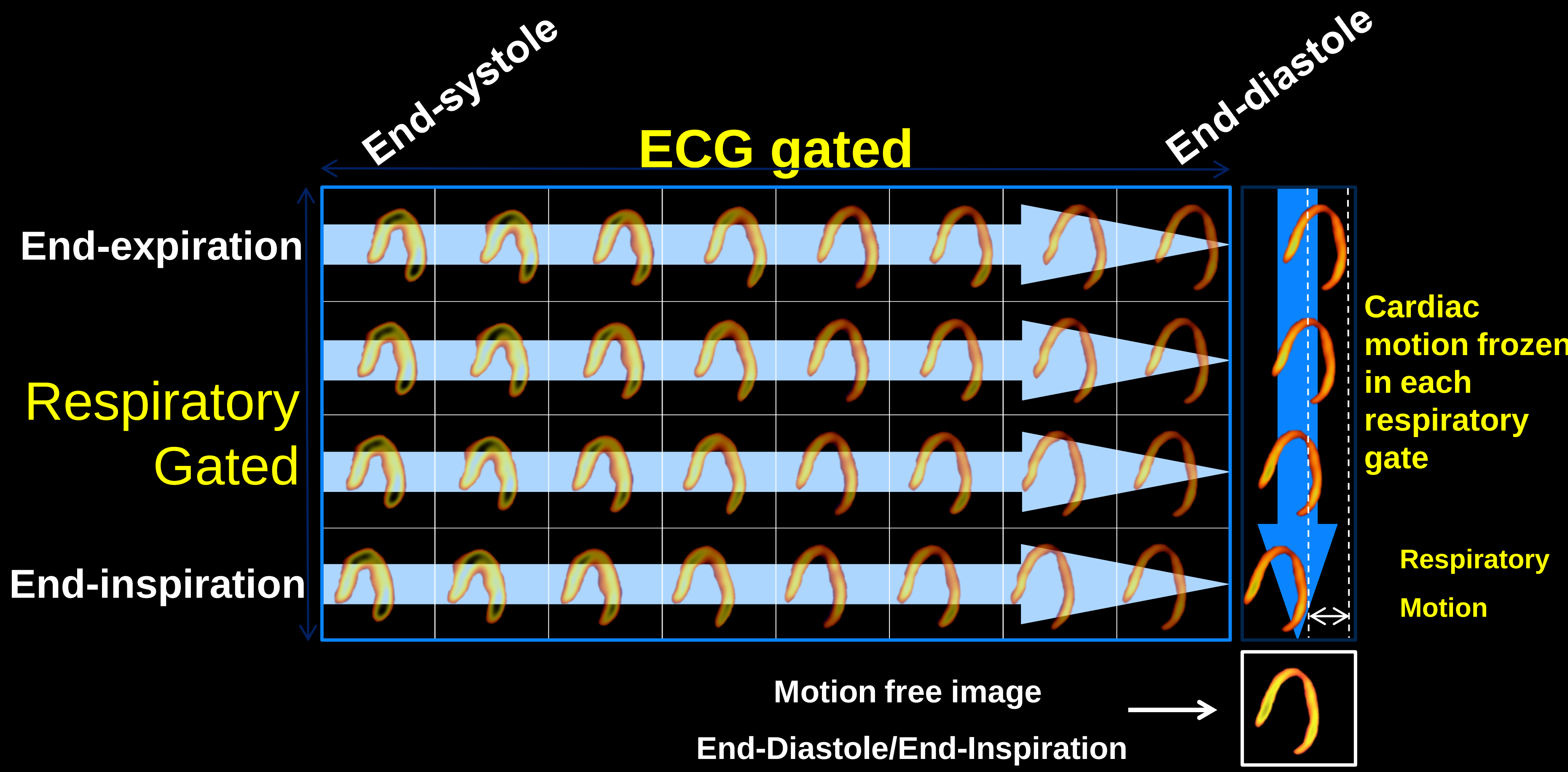


Cardiac PET/CT respiratory gating



- **The histogram (right) shows the amount of breathing amplitudes for the entire 24 min list-mode acquisition. The Optimal Gating method selects the narrowest bandwidth (shaded area) containing 35% of the respiratory signal**

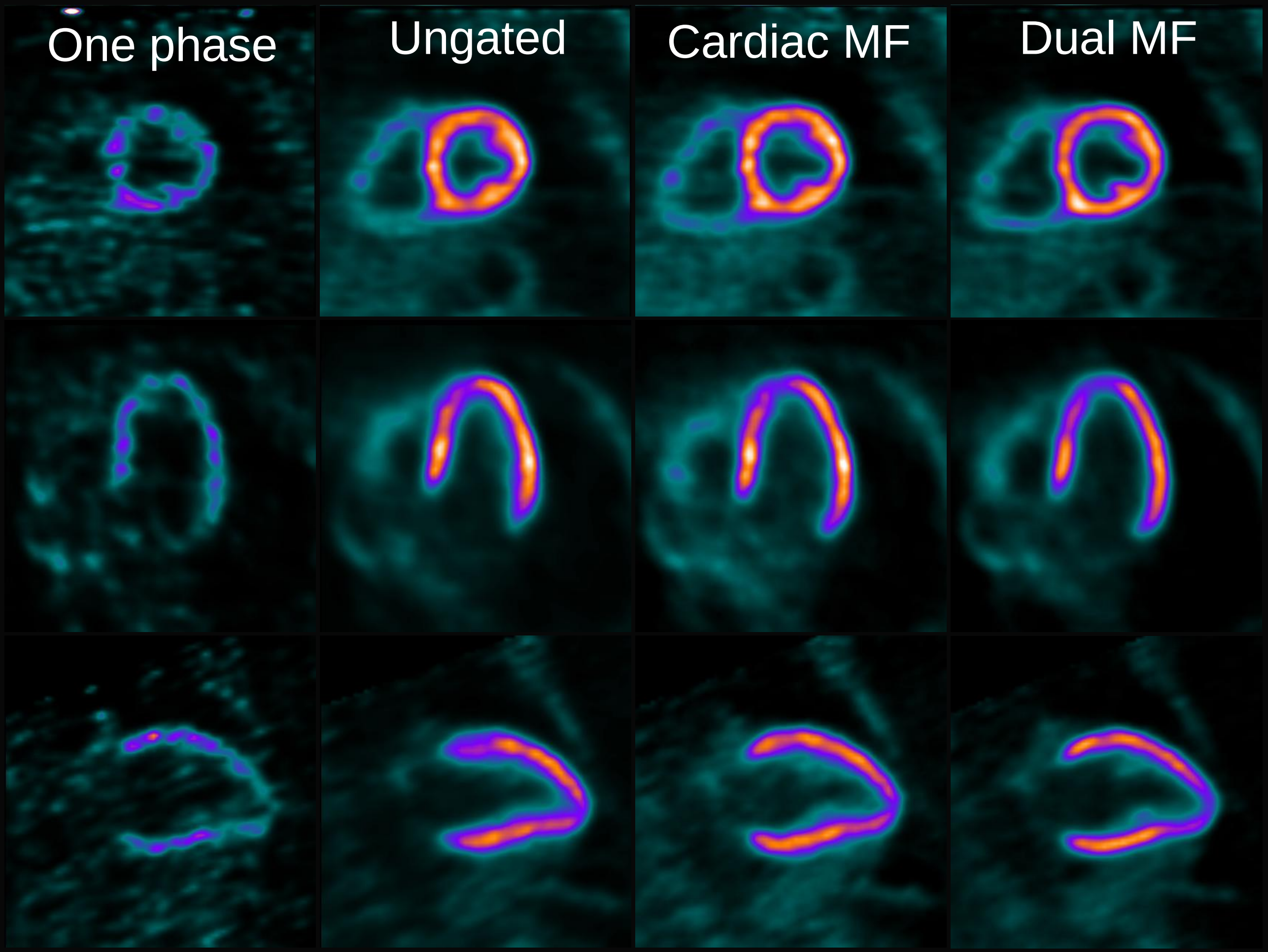
Dual motion-frozen PET



Cardiac motion frozen in each respiratory gate

Respiratory motion frozen

Dual-gated cardiac perfusion PET

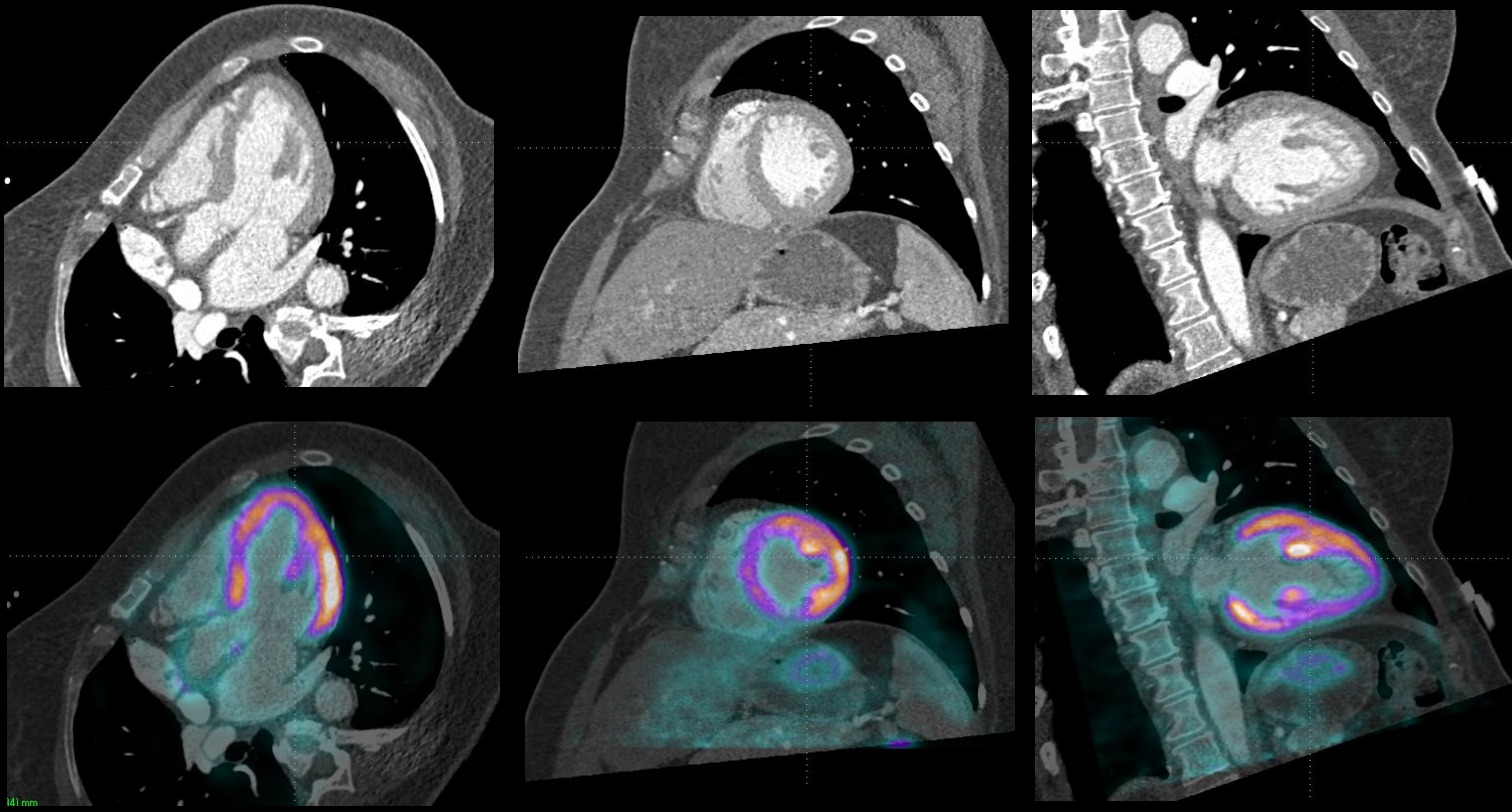


MF
motion
frozen

F, 42 y/o BMI:34.7, 7.7 mCi 18 F Flurpiridaz

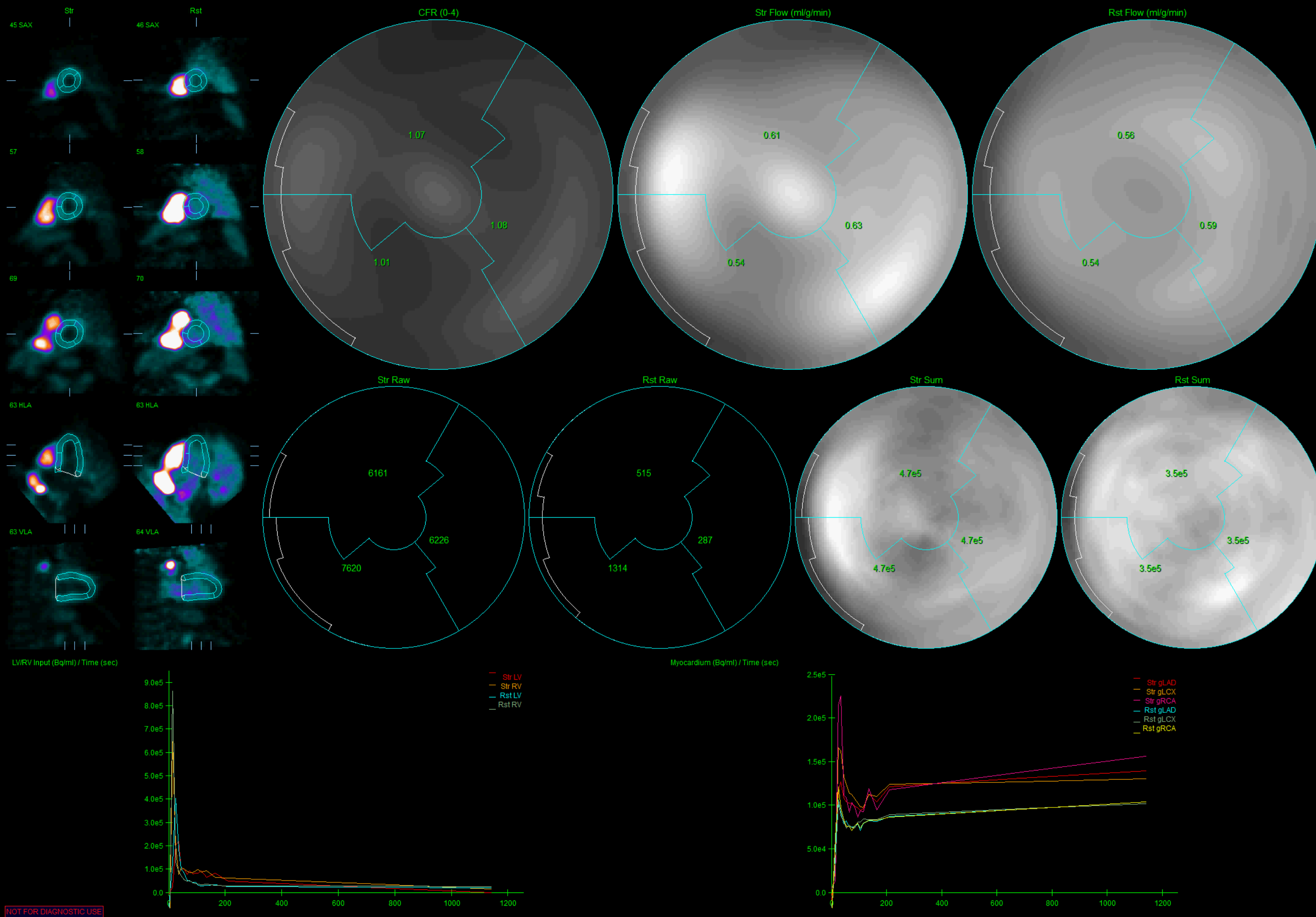
High resolution hybrid PET/CT

dual motion frozen PET

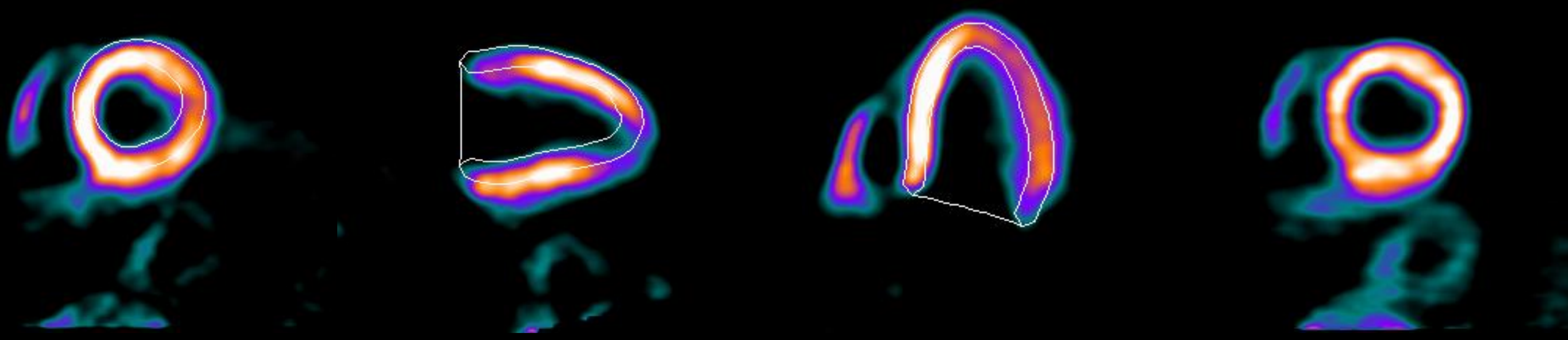


SNM 2010

PET/CT limitations: patient motion

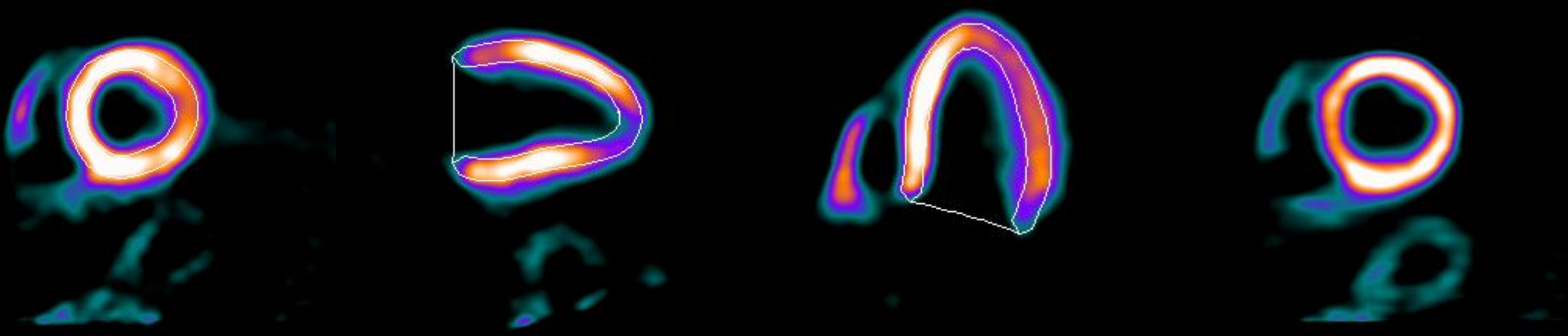


PET: patient motion correction



Before Motion Correction

Summed



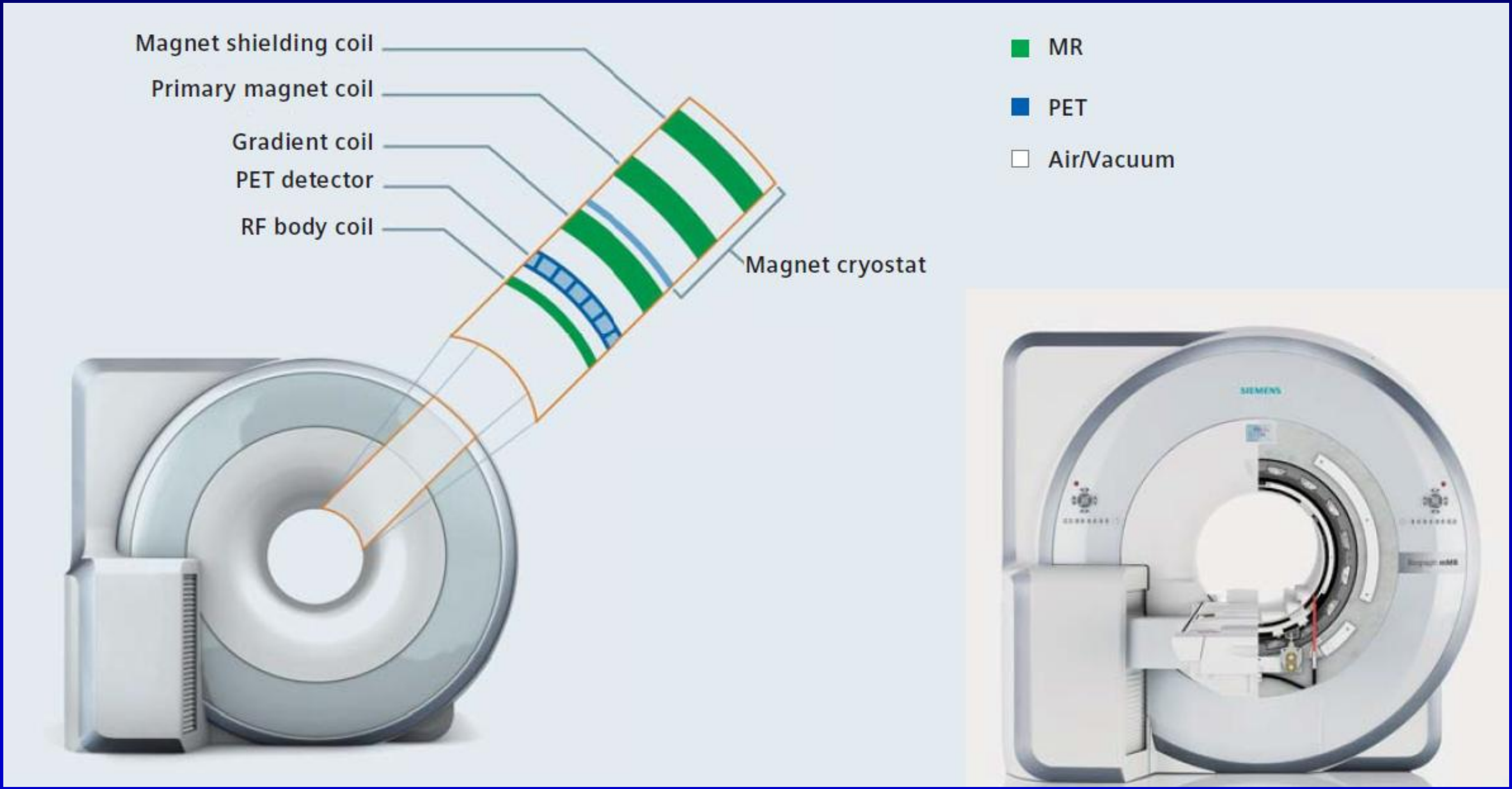
After Motion Correction

Summed

Woo Med Phys 2011

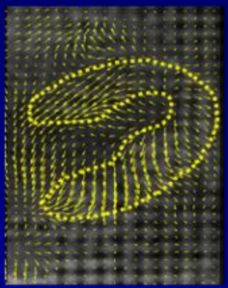
F18 Flurpiridaz

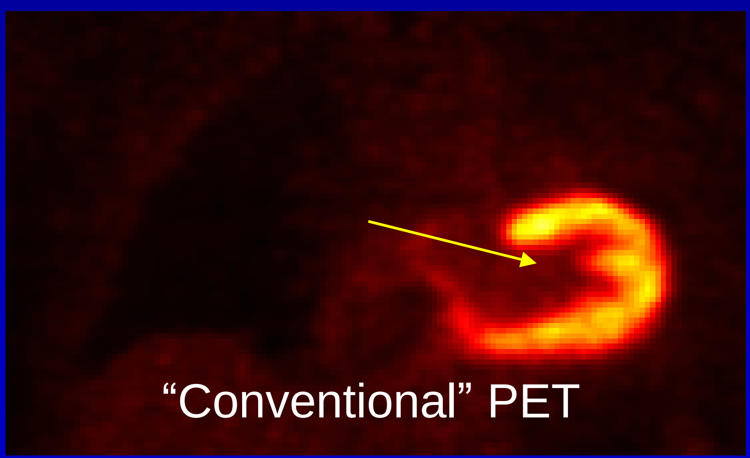
Simultaneous PET/MR systems

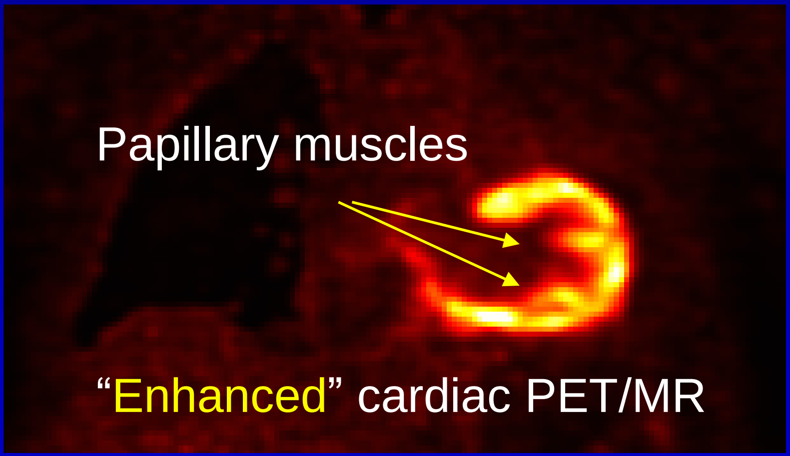


Motion compensation in Cardiac PET/MR

Estimation of heart motion using MRI







Dramatic Improvement in cardiac image quality as compared to conventional PET

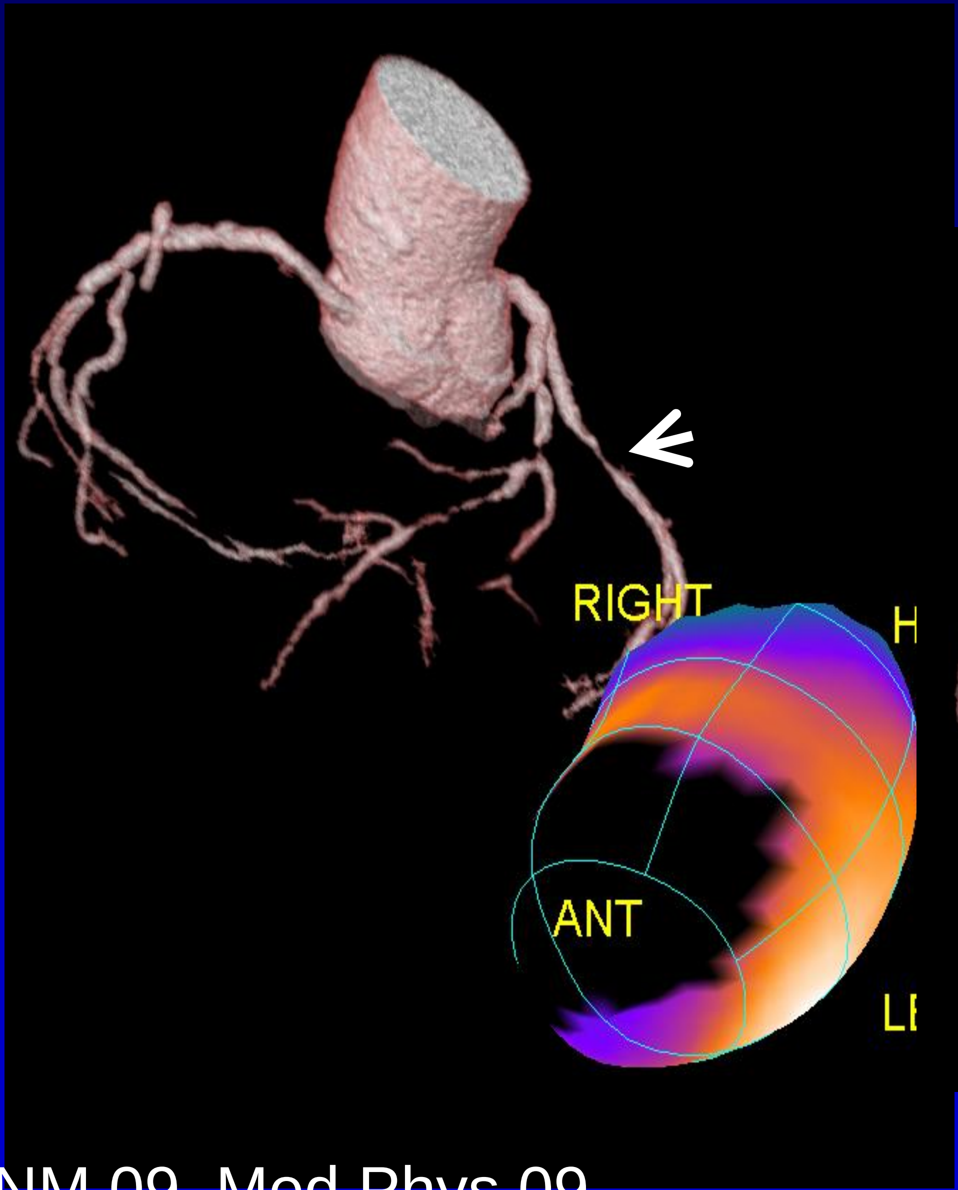
Courtesy Georges EL Fakhri, PhD, DABR

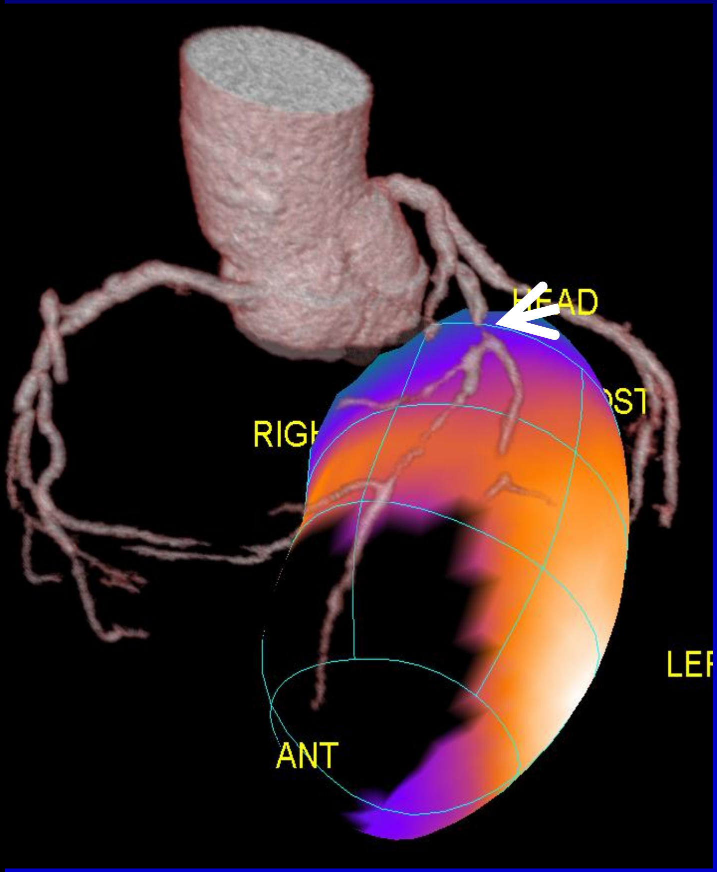
Center for Advanced Medical Imaging Sciences

OUTLINE

- Latest PET/CT hardware
- Latest SPECT hardware
- Low dose imaging
- Attenuation correction
- Perfusion quantification
- Kinetic modelling
- Motion
- Hybrid quantification

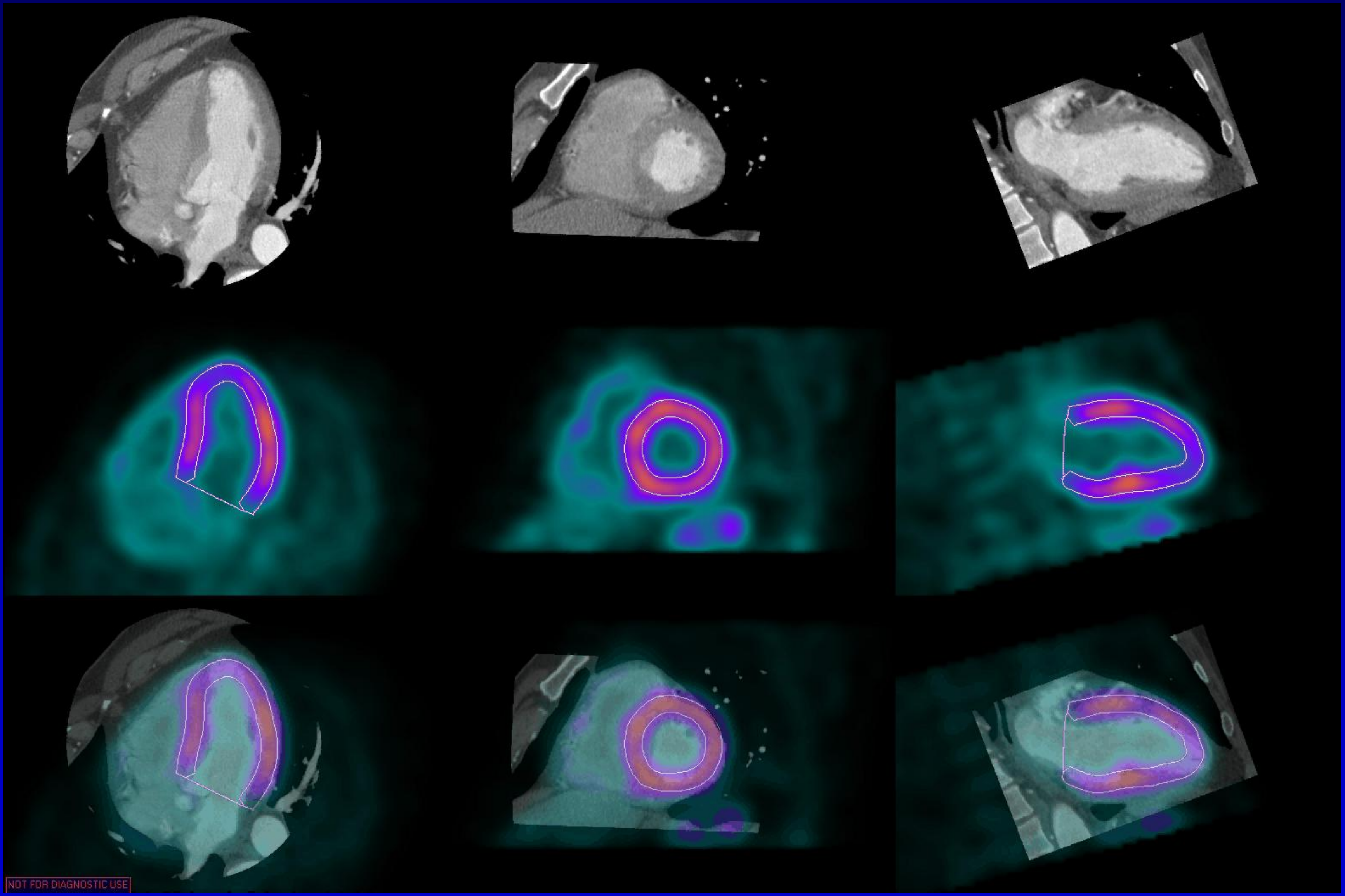
Automated PET/CTA fusion





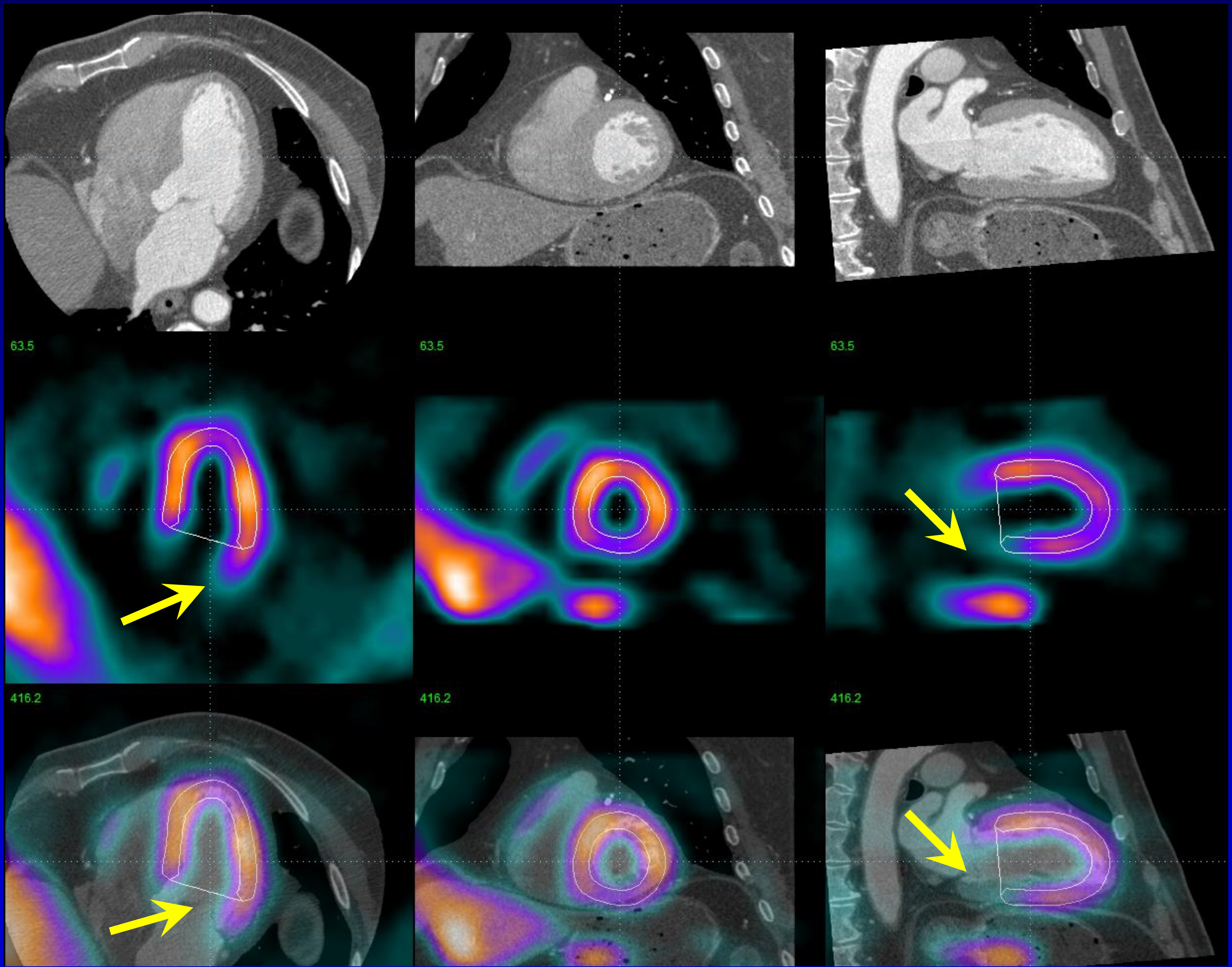
C JNM 09, Med Phys 09

Automated PET/CT fusion



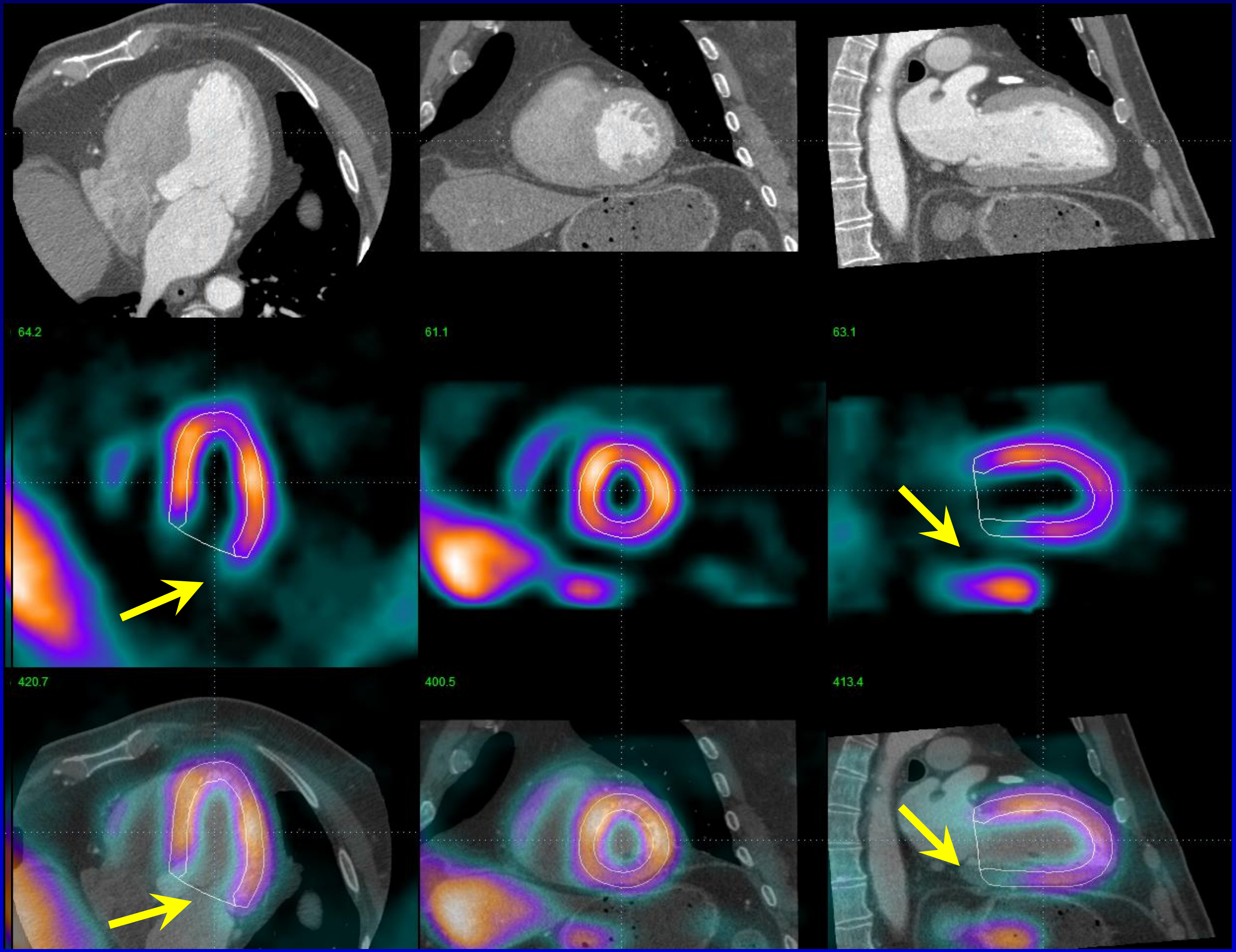
JNM 09, Med Phys 09

Example: Mitral Valve plane position adjustment



5A

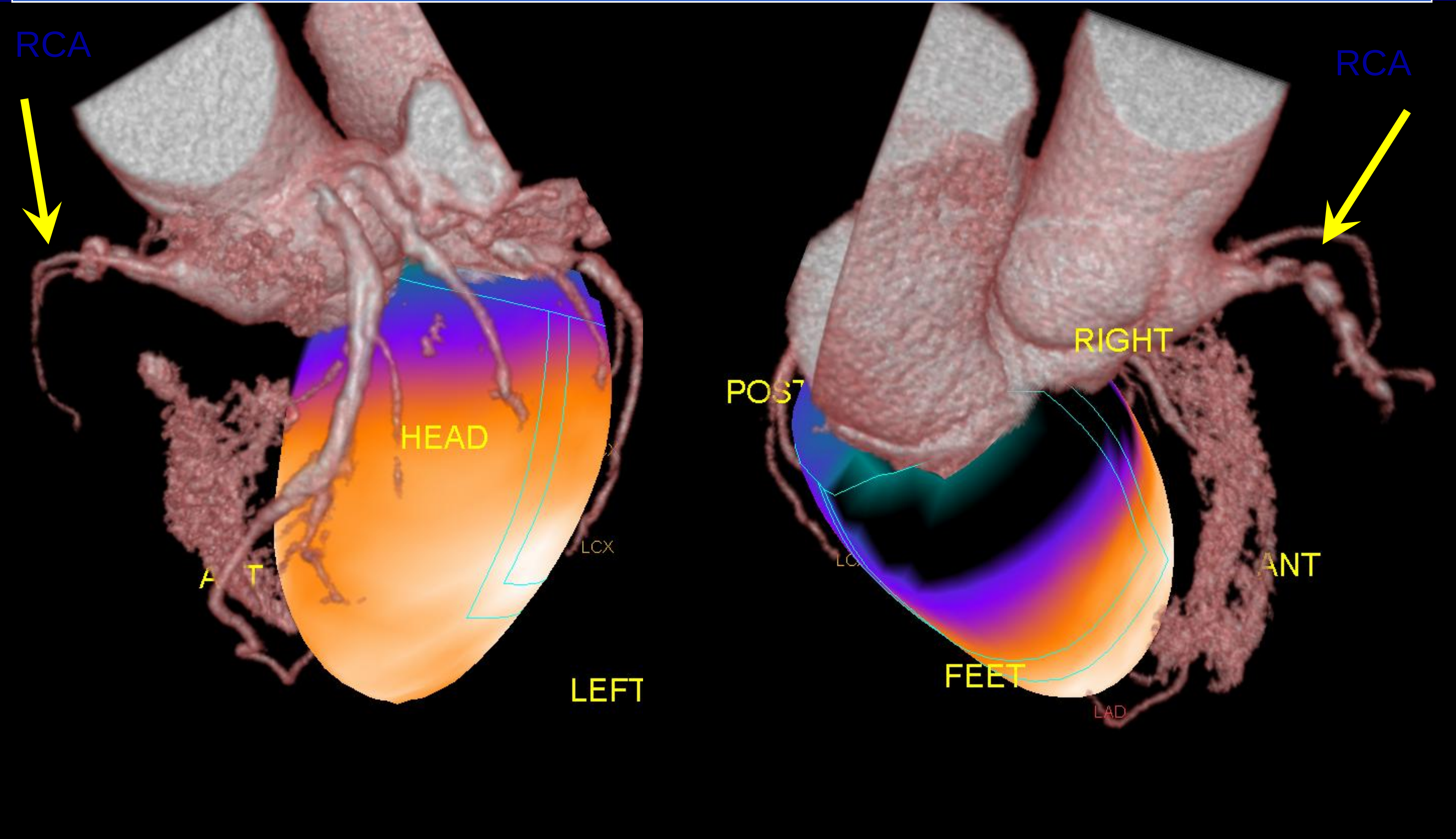
Example: Mitral Valve plane position adjustment



5B

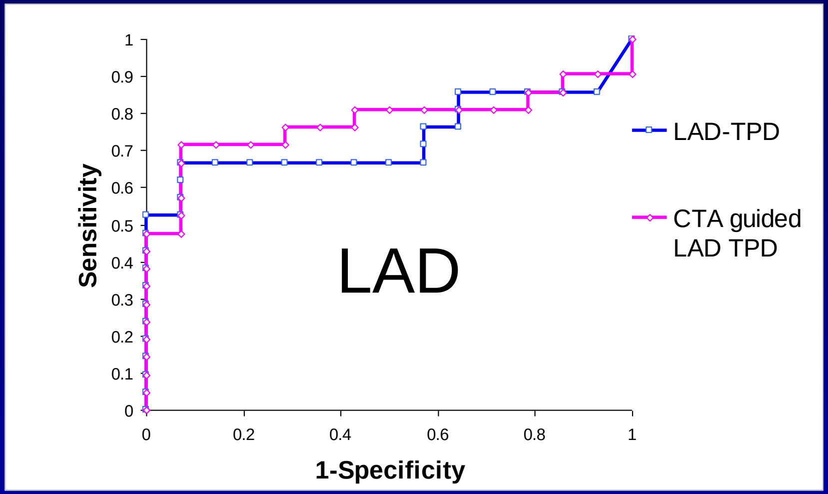
SPECT/CTA volume/surface fusion

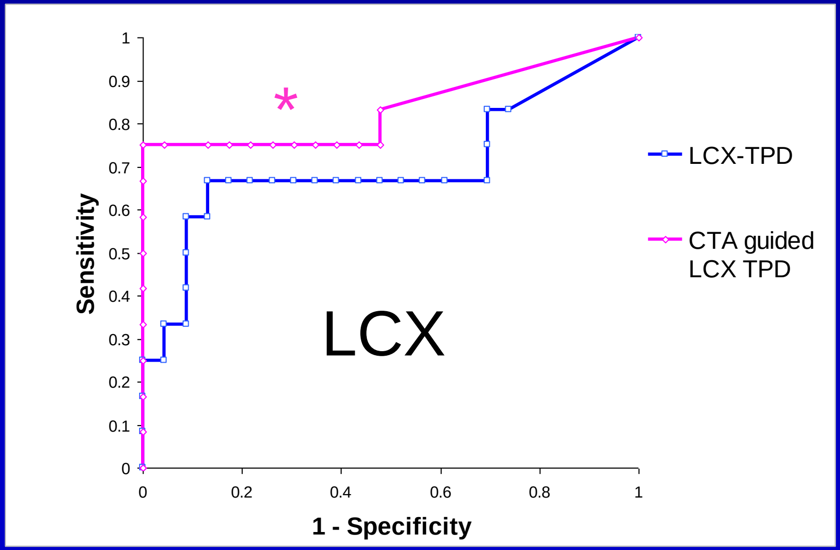
CATH: proximal RCA 100%, no significant LAD, LCX disease

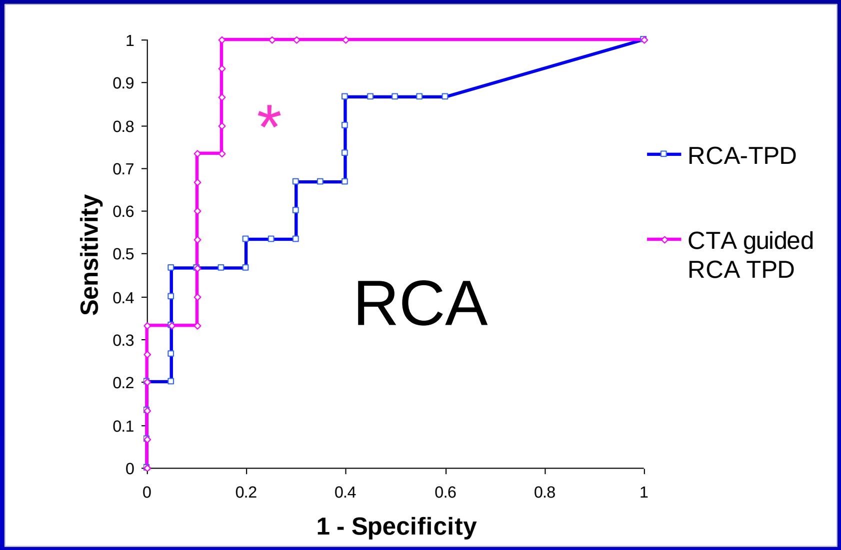


CTA-guided MPS quantification

N=35
patients



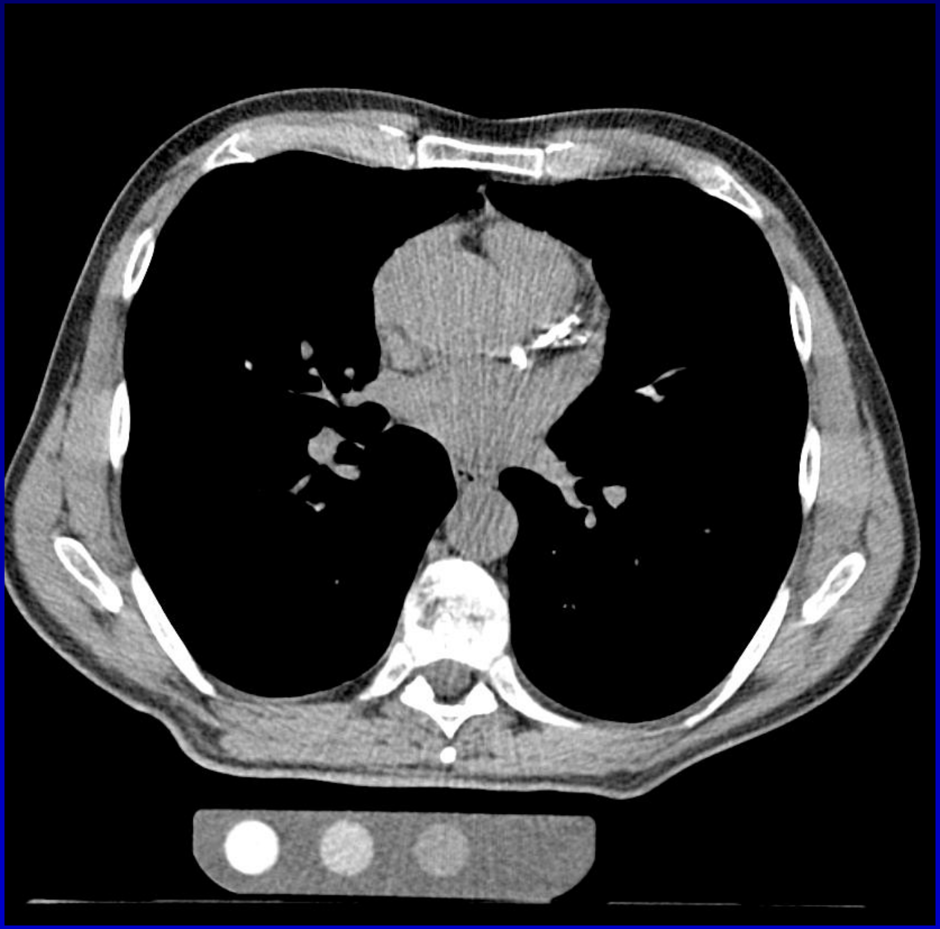




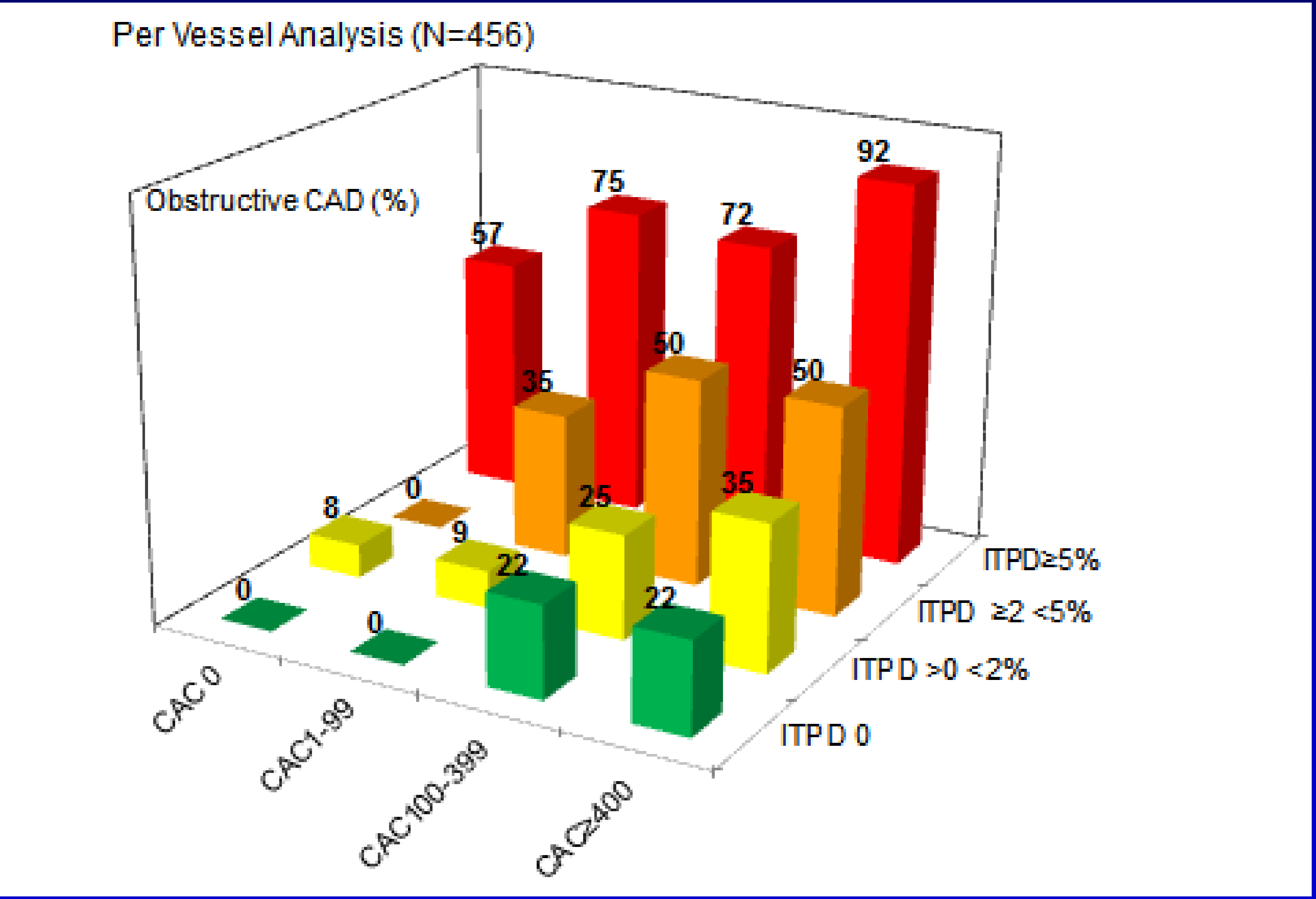
Slomka et al. J Nucl Med 2009

Coronary calcium scoring

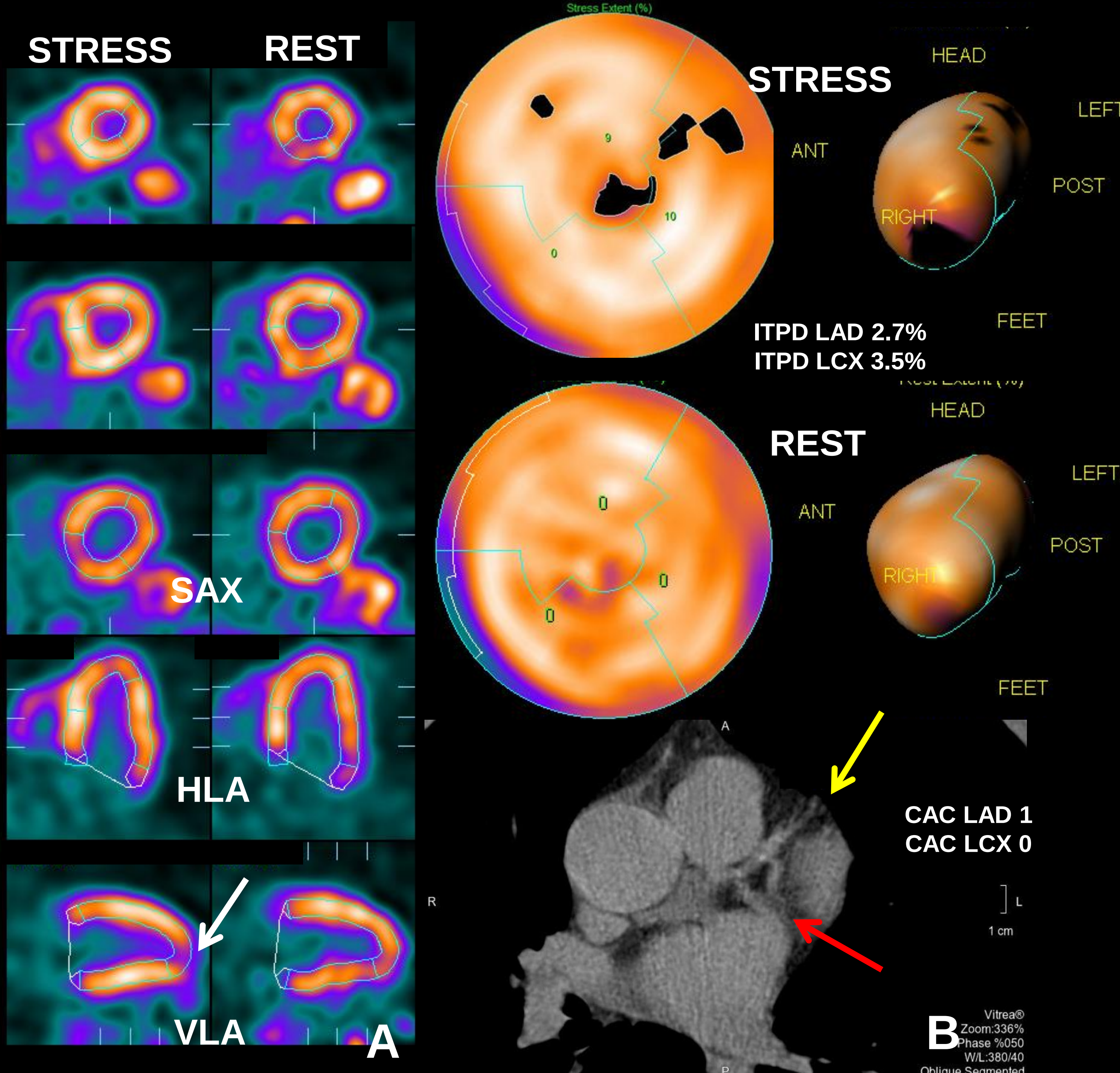
- ***Non-contrast*** *imaging of the heart*
- *Coronary Calcium Score predicts cardiovascular events*



Hybrid imaging: ischemia and calcium scans



Brodov et al JNM 2015 in press



False positive
By PET
LAD TPD 3%

Downgraded by quantitative PET/CT calcium score

Summary 1/2

- New PET/CT systems include Time of flight. Digital PET is introduced. Cardiac PET is growing
- High-sensitivity SPECT in clinical use (>300 systems) Sensitivity 7-9x, resolution 2x of Anger SPECT
- Most SPECT scanners <u>do not use</u> *AC.* 2-position is essential without AC. May correct other problems
- New tools for registration of CT maps with PET
- Ultra-low-dose stress-only SPECT imaging ≈1 mSv

Summary 2/2

- Flow quantification can be automated and reproducible
- dynamic SPECT enabled by high sensitivity
- Patient motion has a big effect on perfusion and flow: needs to be corrected
- Integration CT with PET and SPECT can improve accuracy