Starting, Optimizing, and Maintaining a Cardiac PET Program

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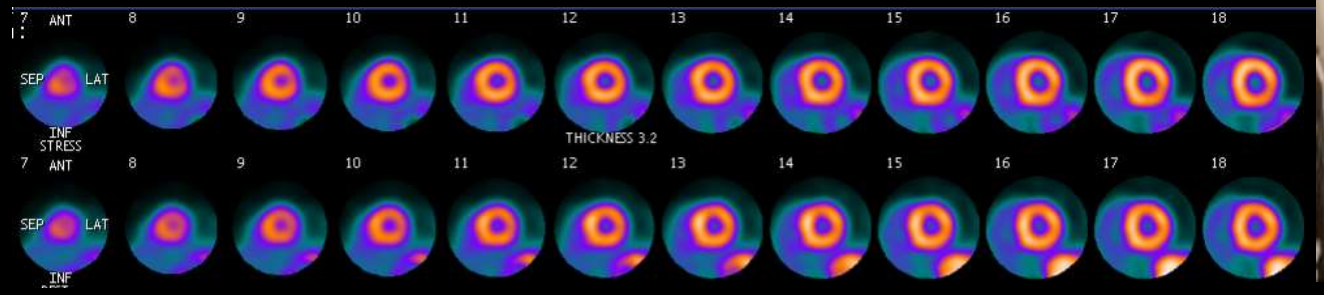


Objectives

- List steps required to build a Cardiac PET Program
- Formulate a plan for cardiac PET training and QA/QC
- Employ problem-solving strategies when cardiac PET images "don't look right“

Why start a cardiac PET program?

- Many benefits of PET over SPECT
- Why now?
  - *Evolving epidemiology of CV disease*
  - *Improvements in reimbursement for cardiac PET*
  - *Improved availability of PET tracers*
  - *Multiple FDA-approved software options*

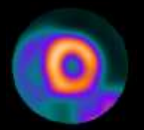
Epidemiology of cardiovascular disease

- CV disease remains #1 cause of death and disability
- Shifts in prevalence of CVD risk factors in the population (e.g., ↑ obesity, glucose intolerance, and older age)
- Changing clinical presentations
  - ↓ *incidence of atherothrombotic plaque rupture causing ST-segment elevation MI*
  - ↑ *rates of hospitalizations with a secondary MI diagnosis and heart failure with preserved ejection fraction (HFpEF)*

These shifts represent patient populations that may particularly benefit from cardiac PET

Heart disease and stroke statistics: Circulation. 2018; N Engl J Med 2010;362:2155-65; Am Heart J 2015;170:1211-9; N Engl J Med 2006;355:251-9

Benefits of PET over SPECT

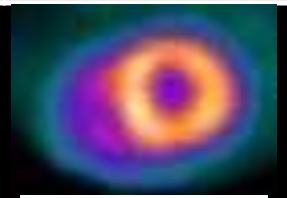


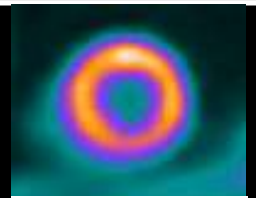
- Low radiation exposure (1-5 mSv)
- Short acquisition protocols (~30 min w/ Rb-82)
- High-quality images (particularly helpful to minimize artifacts from tissue attenuation and scatter)
- High diagnostic accuracy
- Ability to calculate myocardial blood flow, flow reserve, and LVEF reserve
- Strong prognostic power
- Improved ability to identify non-response to stress

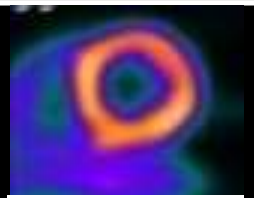
Bateman et al. J Nucl Cardiol 2016

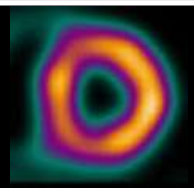
Cardiac PET Radiopharmaceuticals

	Rb-82	^{13}N-Ammonia	^{15}O-Water	^{18}F-Flurpiridaz	^{18}F-FDG
Half-Life	75 sec	~10 min	~2 min	~2 hours	~2 hours
Positron Range (mm)	5.9	1.5	2.5	0.6	0.6
Myocardial Extraction	Good	Very Good	Excellent	Excellent	
FDA Status	Approved	Approved	Not Approved	Soon????	Approved
Stress Type	Pharm	Pharm (or Exercise)	Pharm	Pharm or Exercise	
Per Dose Cost	$$$$ (more you do, cheaper per dose)	$$	$$	Unknown	$


Rb-82

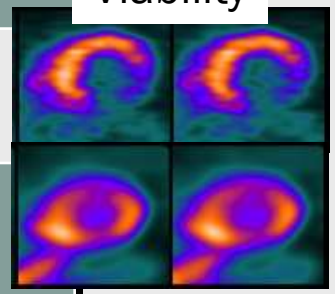

N-13 Ammonia


F-18 Flupiridaz

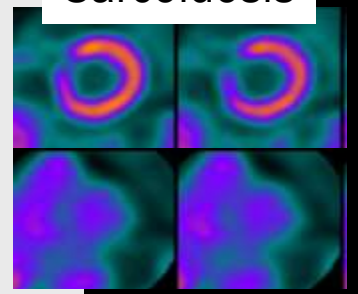

O-15 Water

Non-MPI Indications

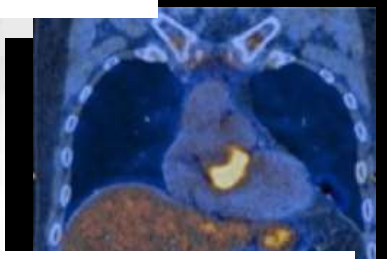
Viability



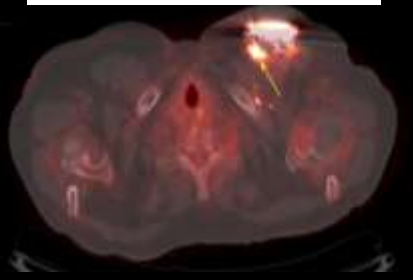
Cardiac Sarcoidosis



Endocarditis



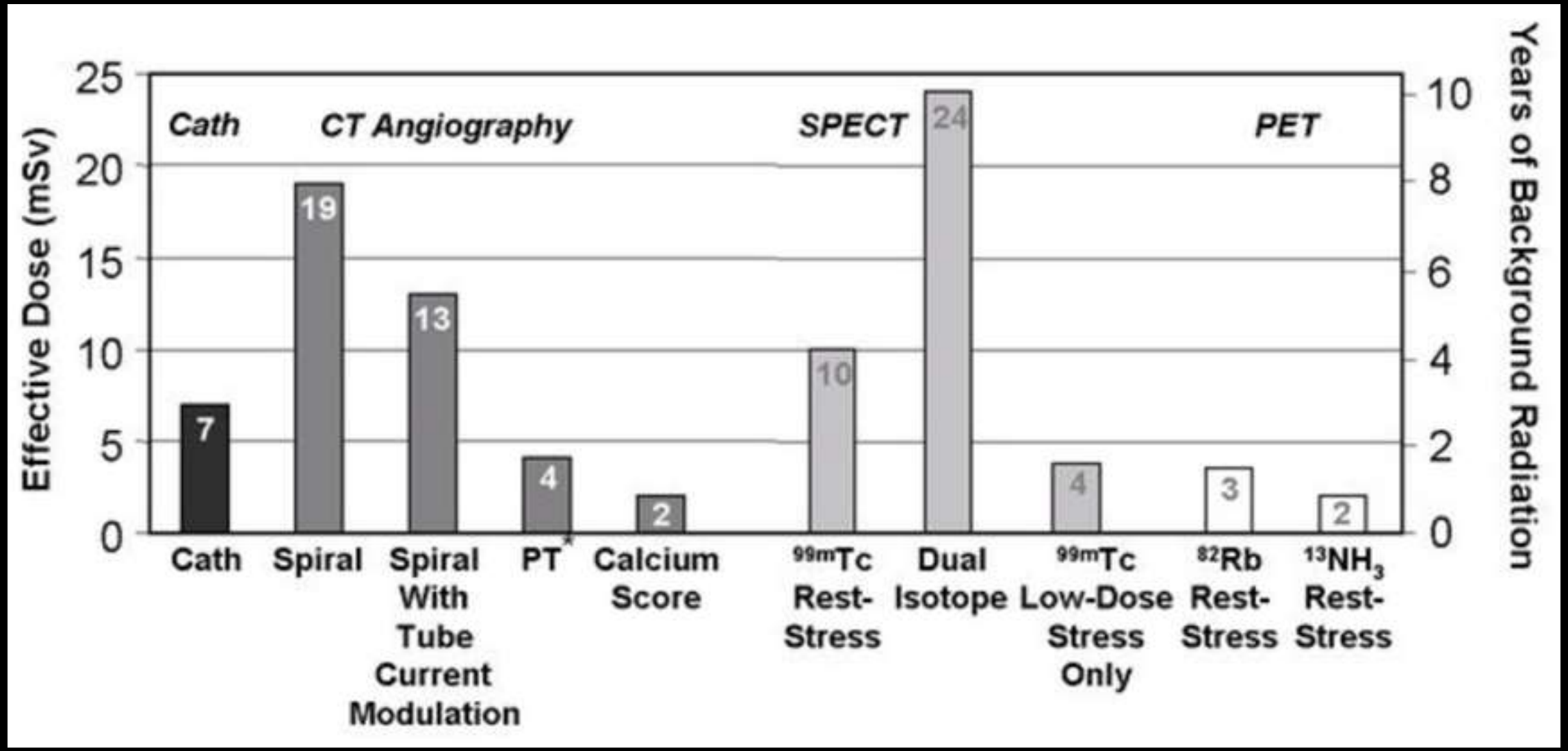
Cardiac Device Infection



Myocardial Perfusion Radiopharmaceuticals

Tracer	Mechanism	Production	Half - life	Scan duration (rest and stress)	Positron range (mm)	Intravenously administered activity (mCi)	Effective dose (mSv/MBq)	Total body radiation dose (mSv)
PET								
^{82}Rubidium	Na+/K+ pump	Generator	76 s	30-min	8.6	20-50	0.0048	1.1-3.5
^{13}N-ammonia	Metabolic trapping	Cyclotron	10 m	1.5-h	2.53	20-50	0.0022	~1.5
^{15}O-water	Free diffusion	Cyclotron	2 m	30-min	4.14	20-50	0.0011	
^{18}F-flurpiridaz	Binds to mitochondrial complex-1 inhibitor	Cyclotron	110 m	1.5-h or 2 d	1.5-h or 2 d	6-10	0.019	

Exposure from Common Cardiac Imaging Procedures



Myocardial Perfusion Radiopharmaceuticals

Tracer	Mechanism	Production	Half - life	Scan duration (rest and stress)	Positron range (mm)	Intravenously administered activity (mCi)	Effective dose (mSv/MBq)	Total body radiation dose (mSv)
SPECT								
^{201}Thalium	Na+/K+ pump	Cyclotron	73 h	4-h	–	2-4	0.23	~25
^{99m}Tc-sestamibi	Intact mitochondria	Generator	6 h	4-h or 2-days	–	10-25	0.0085	12
^{99m}Tc-tetrofosmin	Intact mitochondria	Generator	6 h	4-h or 2 days	–	10-25	0.0067	10.6
PET								
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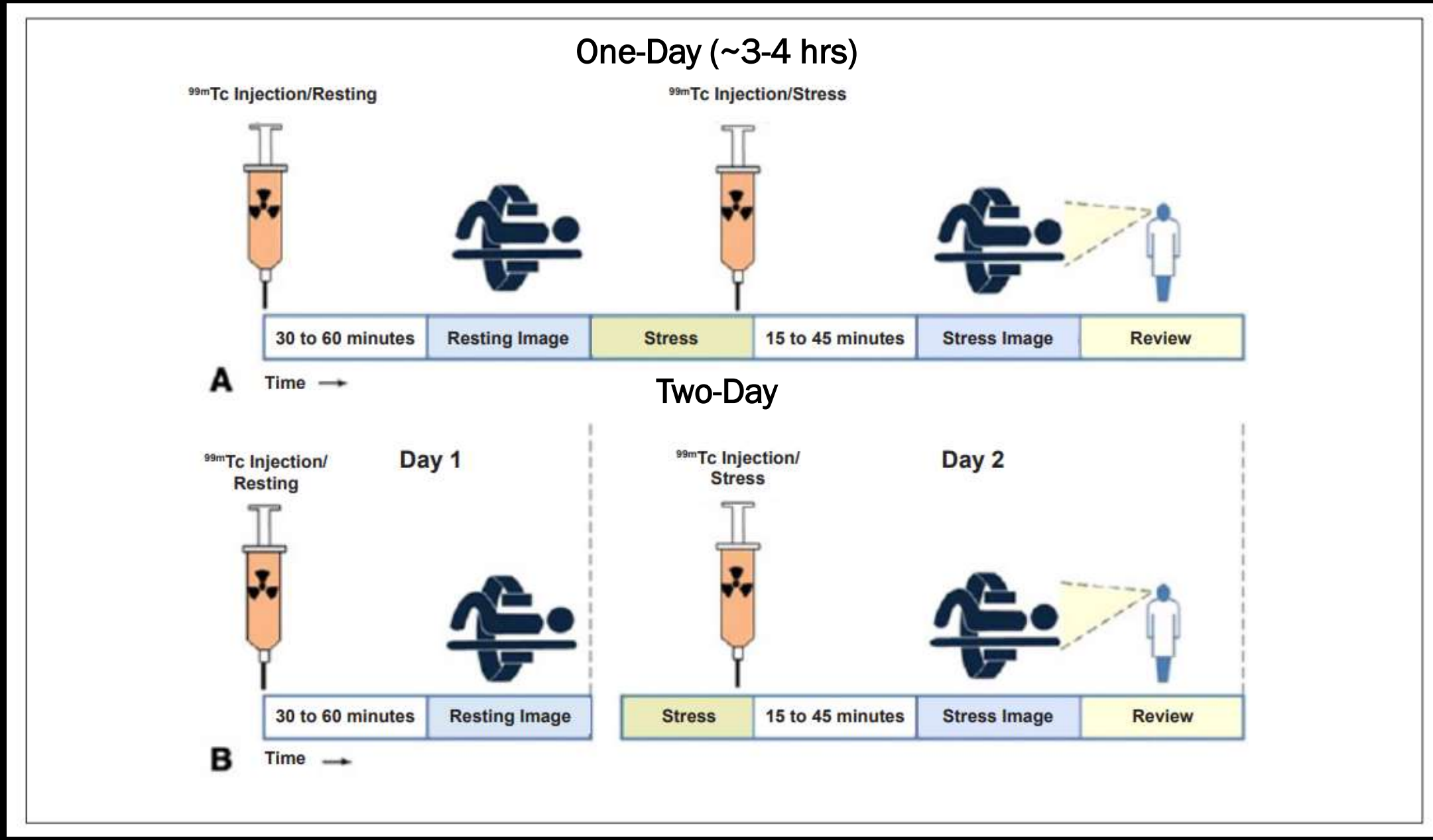
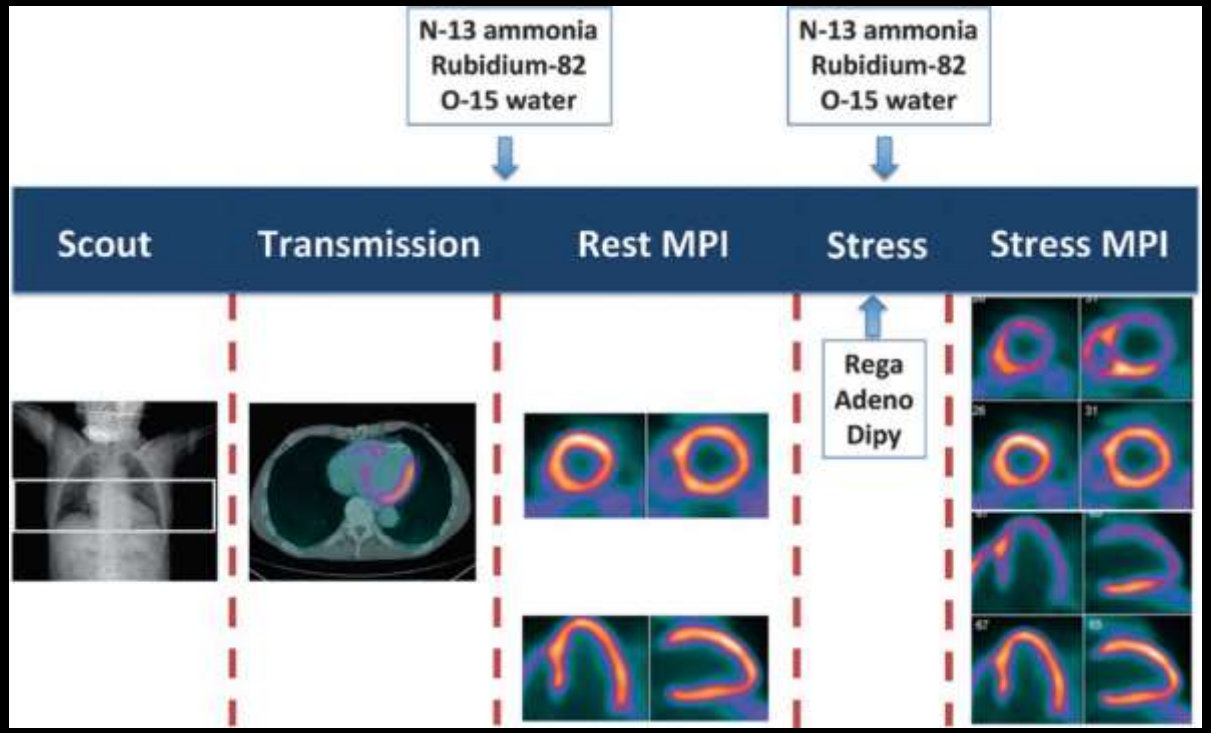
Myocardial Perfusion SPECT Protocol

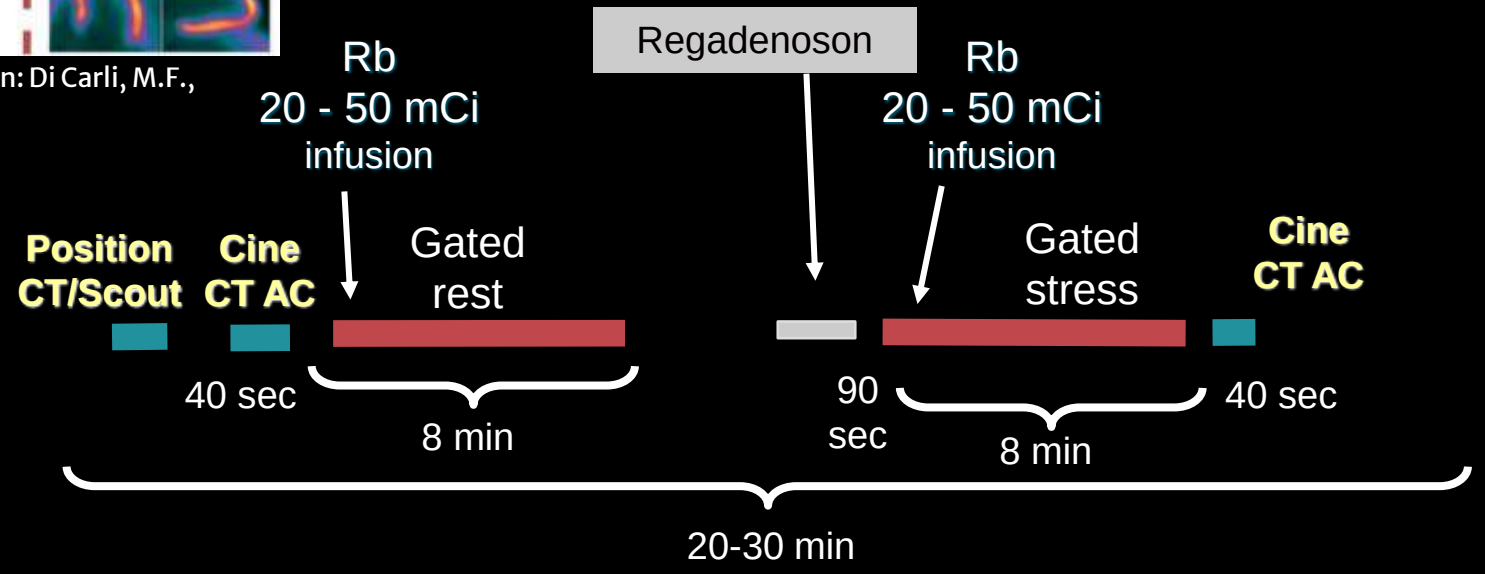


Mastrocola et al. Arq. Bras. Cardiol. 114 (2) • Feb 2020 https://doi.org/10.36660/abc.20200087

Myocardial Perfusion PET/CT Protocol



Di Carli, M.F. *et al.* (2022). Technical Considerations for Cardiac PET/CT. In: Di Carli, M.F., Dondi, M., Giubbini, R., Paez, D. (eds) IAEA Atlas of Cardiac PET/CT.



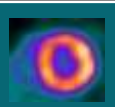
Cine CT Acquisition (120 kVp, 20mA, 2.5mm slice, 0.8 sec rot, ~4.8 sec cine duration)

Image Quality of PET over SPECT

- Improved myocardial extraction
- Improved spatial resolution (5-7 mm vs 6-11 mm)
- Improved attenuation correction
- Improved temporal resolution
- Higher counts rates (240% increase over SPECT)

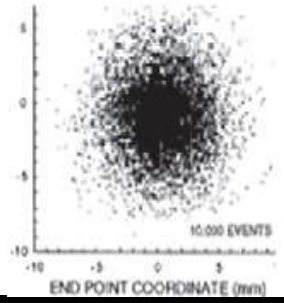
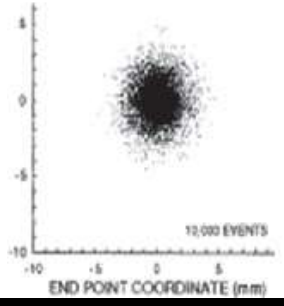
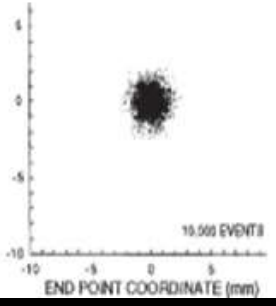
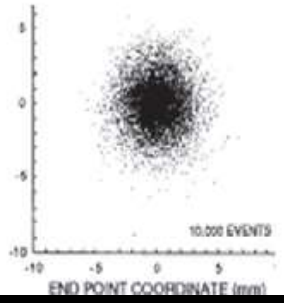
Leads to fewer false negatives and fewer false positives with increased diagnostic accuracy independent of gender or body habitus and improved identification of multivessel disease

Cardiac PET Radiopharmaceuticals

	 ^{82}Rb	 ^{13}N-Ammonia	 ^{18}F-Flurpiridaz	 ^{15}O-Water
Positron Range (mm)	5.9	1.5	0.6	2.5
Myocardial Extraction	Good	Very Good	Excellent	Excellent

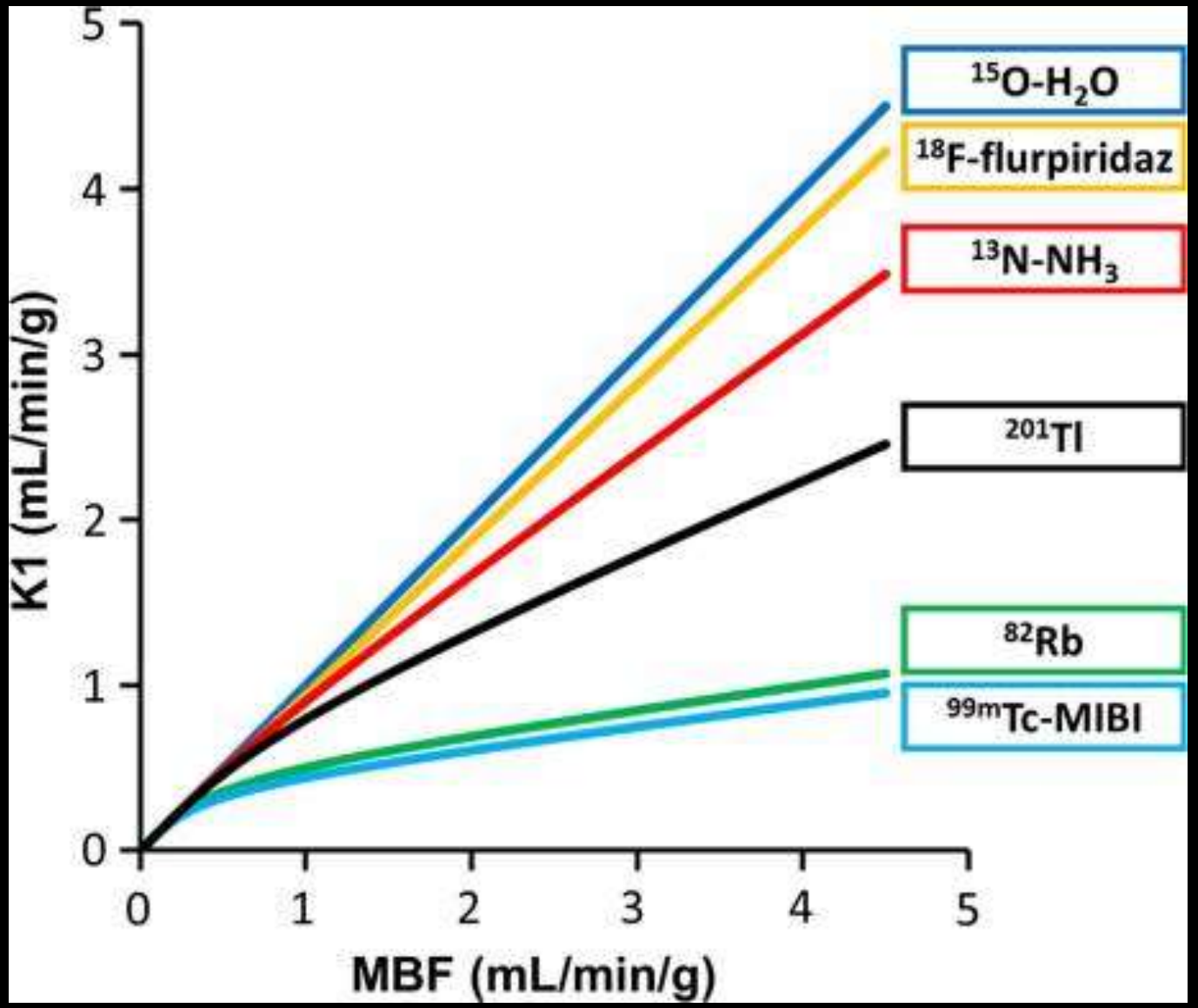
High-quality images

(particularly helpful to minimize artifacts from tissue attenuation and scatter)

	^{82}Rb	^{13}N ammonia	Flurpiridaz F 18	^{15}O water
Positron range (mm)	5.9	1.5	0.6	2.5
End point coordinate				

Maddahi, J., & Packard, R.R. (2014). Cardiac PET perfusion tracers: current status and future directions. *Seminars in nuclear medicine, 44 5*, 333-43 .

Extraction Fraction of MPI Tracers



Manabe et al.J Nucl Cardiol. *J Nucl Cardiol*. 2018;25(4):1204-1236.

Image Quality of PET over SPECT

PET

- 511KeV photons
- LIST mode (most)
- >3 Million(M) counts/sec
- ~35 M counts/study
- Sensitivity (detection of emitted photons) 2-15%
- Spatial resolution 5-7mm

SPECT

- Photon energies <140KeV
- Binned mode (most)
- 500-3000 counts/sec
- 7-10 M counts/study
- Sensitivity 2-3x less than PET→ longer acquisition
- Spatial resolution 6-11 mm

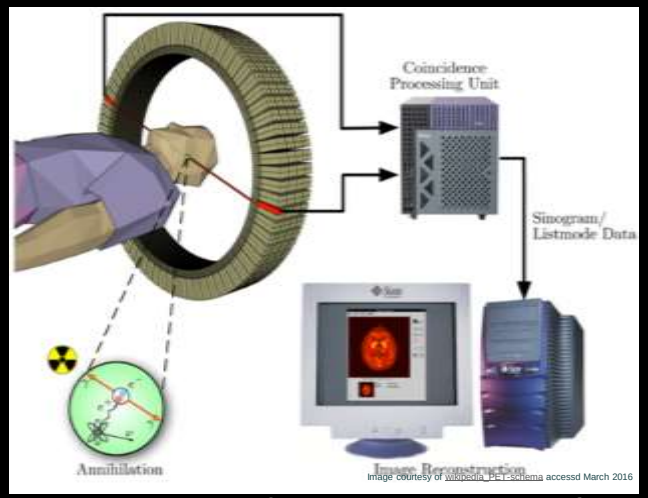


Image courtesy of wikipedia_PET-schema accessd March 2016

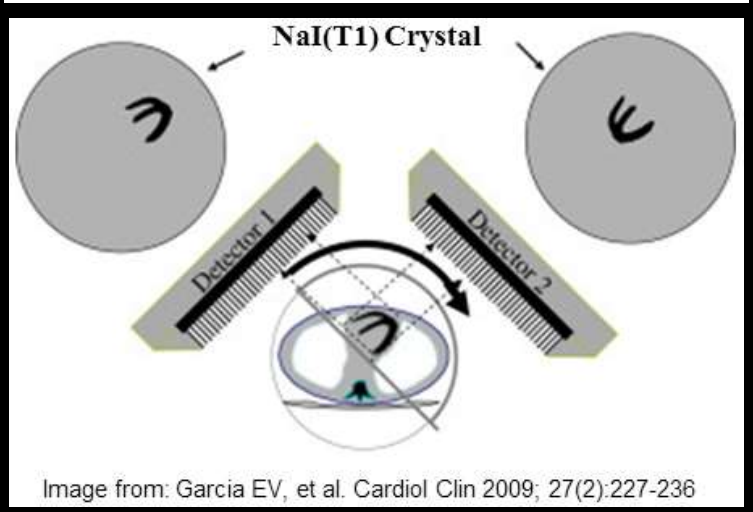


Image from: Garcia EV, et al. Cardiol Clin 2009; 27(2):227-236

Adapted from MITA PET Imaging in Cardiology: Advantages of PET Myocardial Imaging (https://www.petimagingresources.com/resources/cardiology/)

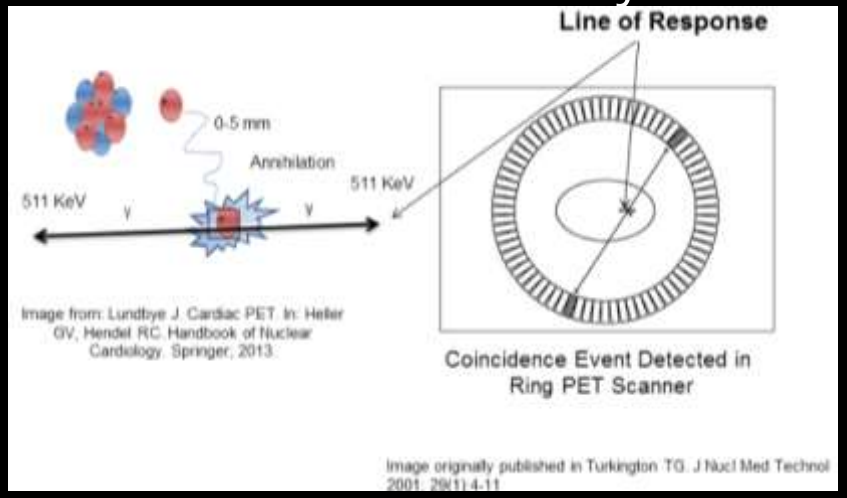
Improved Attenuation Correction

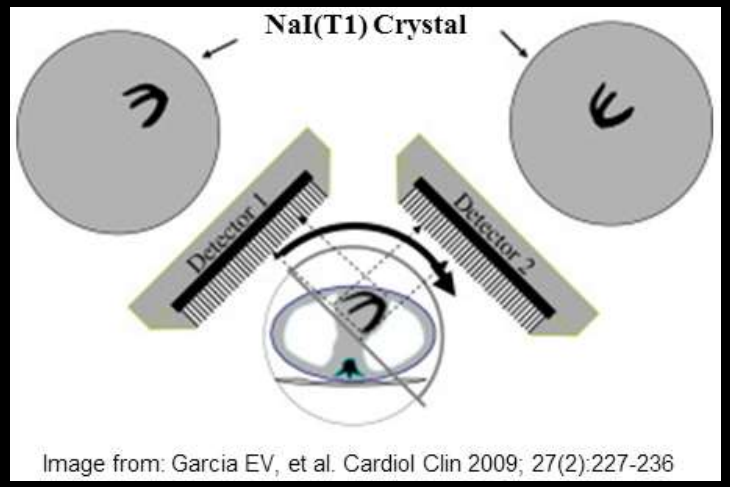
PET

- Built-in AC
- Attenuation is independent of point of origin along line of response, leading to accurate quantification of radiotracer activity

SPECT

- AC is optional
- Attenuation is dependent on the point of emission, so cannot accurately quantify radiotracer activity





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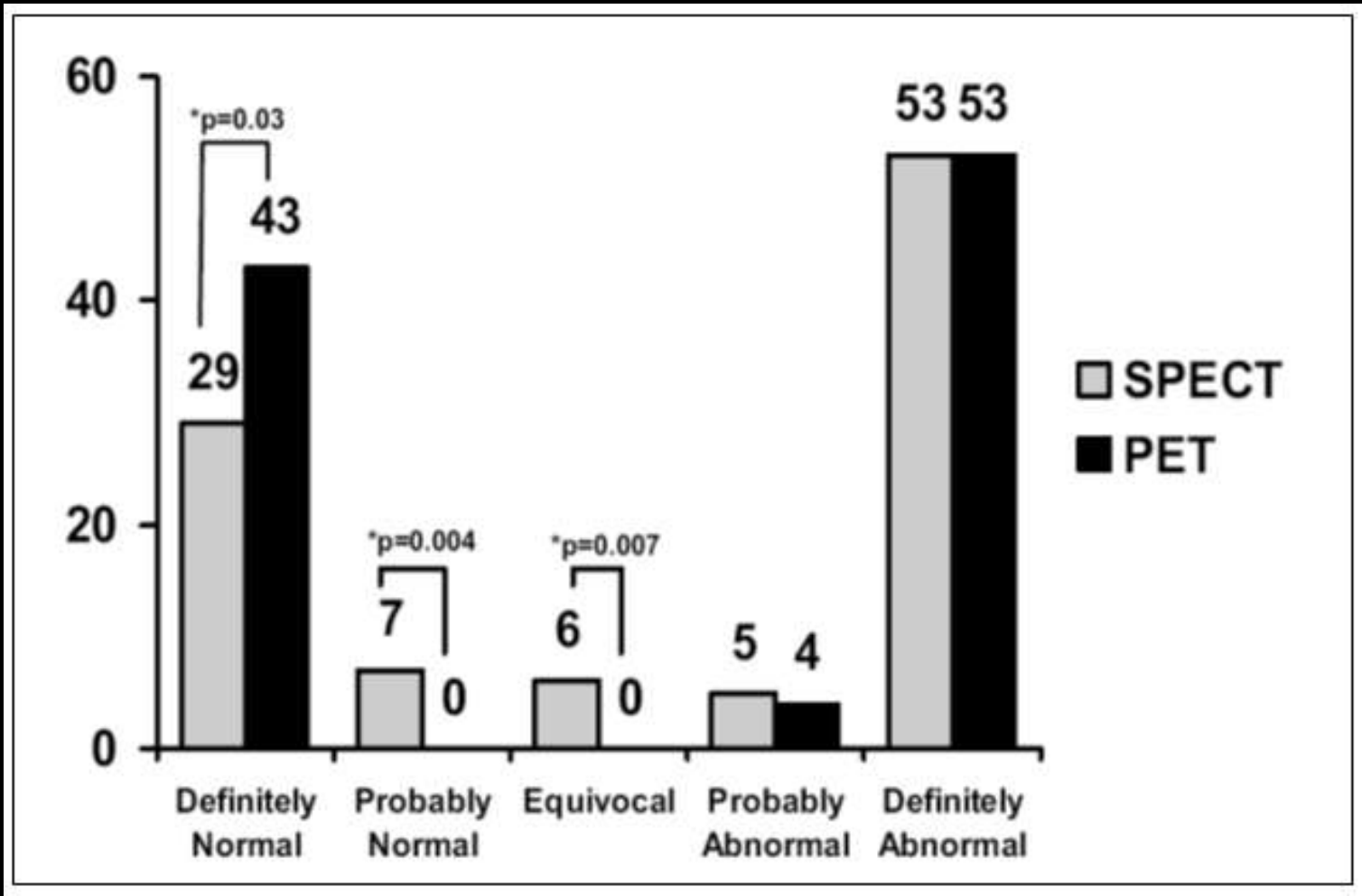
Improved Interpretative Certainty



"Equivocal" and "Probably Normal" cases are able to be moved to the "Definitely Normal" category

Improved Interpretative Certainty

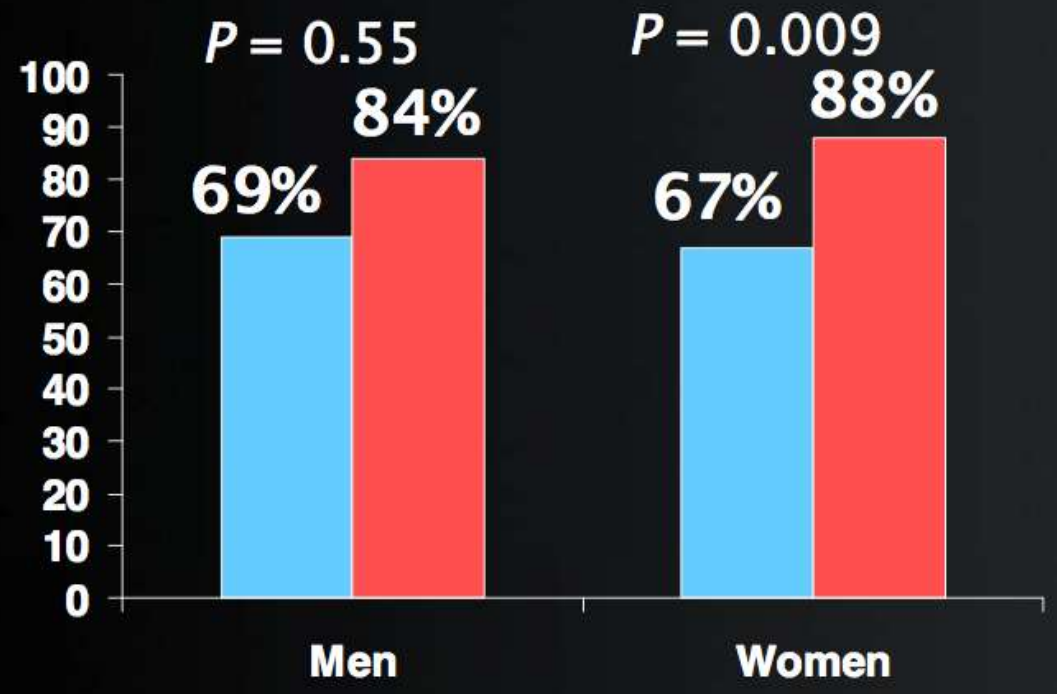
Does Cardiac PET Myocardial Perfusion Imaging In A Clinical Practice Change Referral For And Outcomes At Cardiac Catheterization?

Of patients taken to cath based on SPECT, 41% were found to have no or insignificant CAD vs. 16% with PET

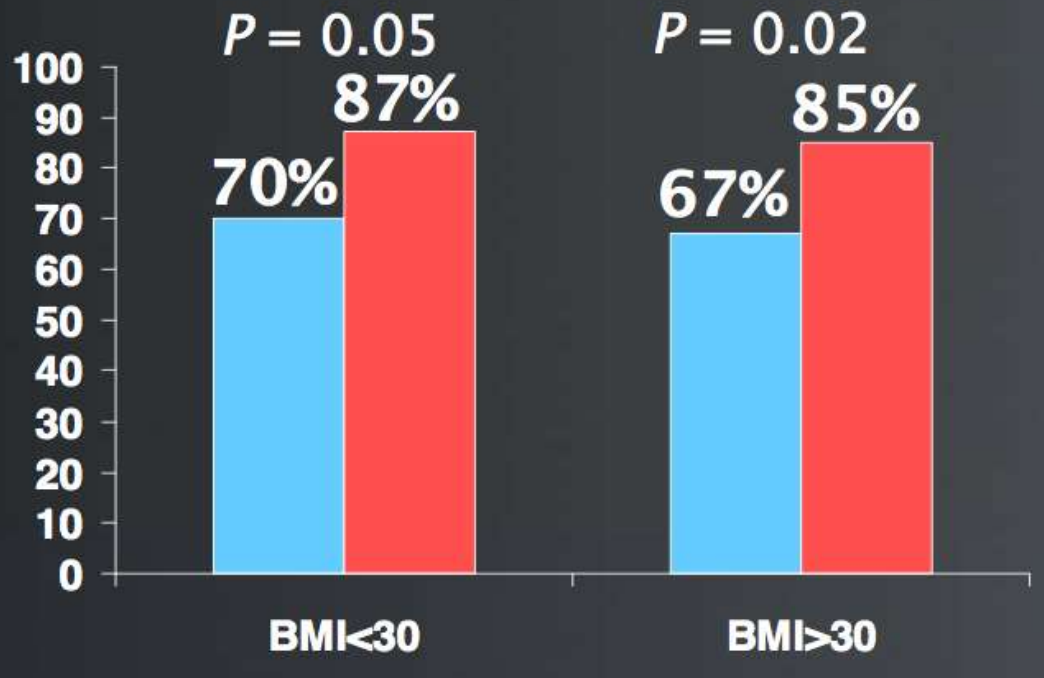
determined.

Results: 1328 SPECT patients in 9 months preceding the PET program were evaluated (mean age 76.5), and compared to 703 PET patients for 6 months after program initiation (mean age 75.7). Cardiac catheterization was performed in 6.9% of SPECT MPI and 6.1% of PET MPI (11.7% reduction, p=NS). For those patients who underwent catheterization, intervention (either PCI or CABG) was performed in 43.5% of SPECT patients and a higher percentage for PET MPI, 53.5% (p=NS). Of SPECT MPI patients, 41.3% were found to have no or insignificant CAD at catheterization compared with 16.3% of PET patients (p<0.001))

DIAGNOSTIC ACCURACY BY GENDER



DIAGNOSTIC ACCURACY BY BMI

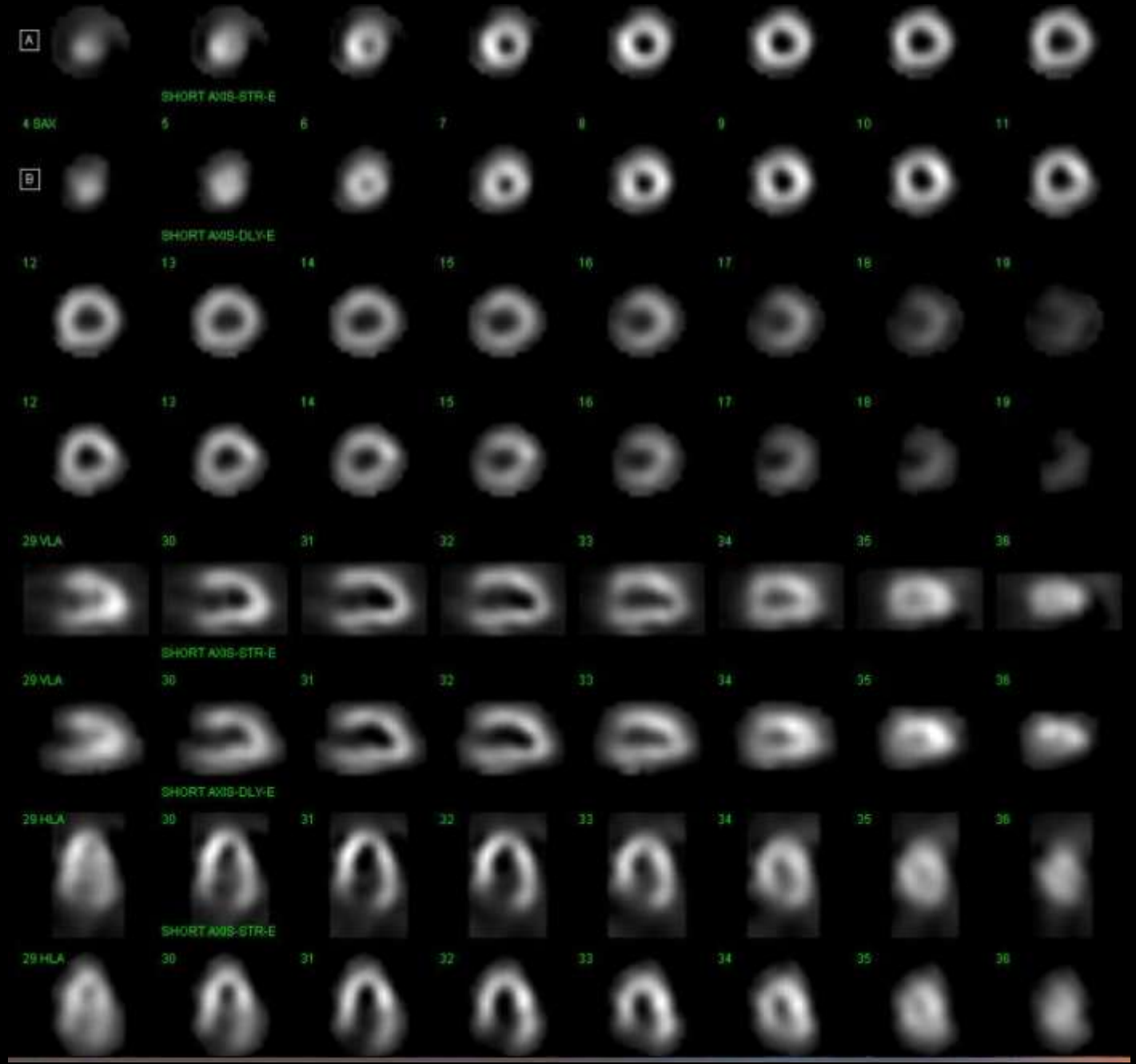


SPECT

PET

Bateman et al. J Nucl Cardiol. 2006; 13:24-33

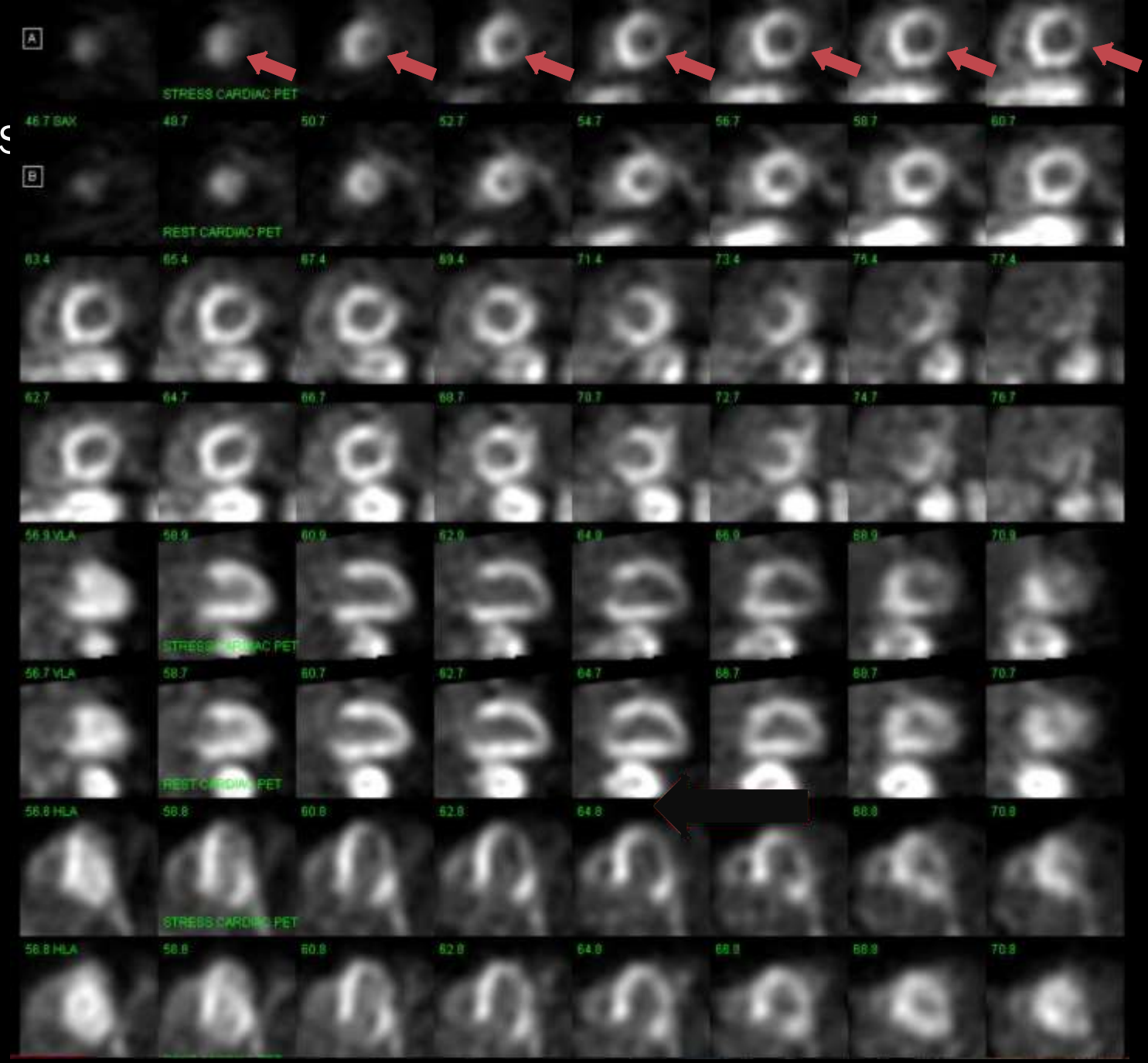
S



SPECT from 65-year-old man with anginal symptoms

Normal SPECT

No evidence of ischemia



PET from same

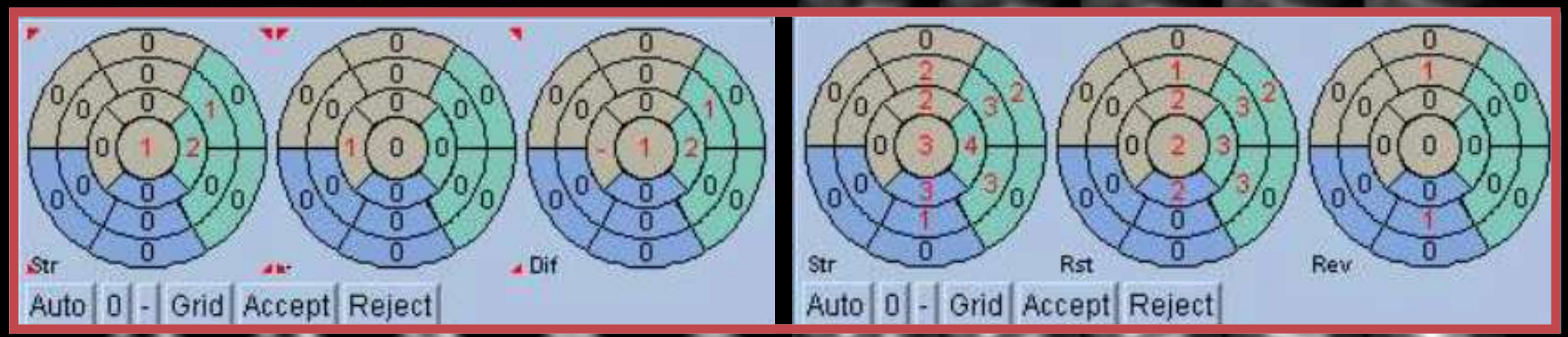
65-year-old man with anginal symptoms

Large area of moderate intensity lateral wall ischemia

SPECT

PET

S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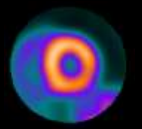
Benefits of PET over SPECT



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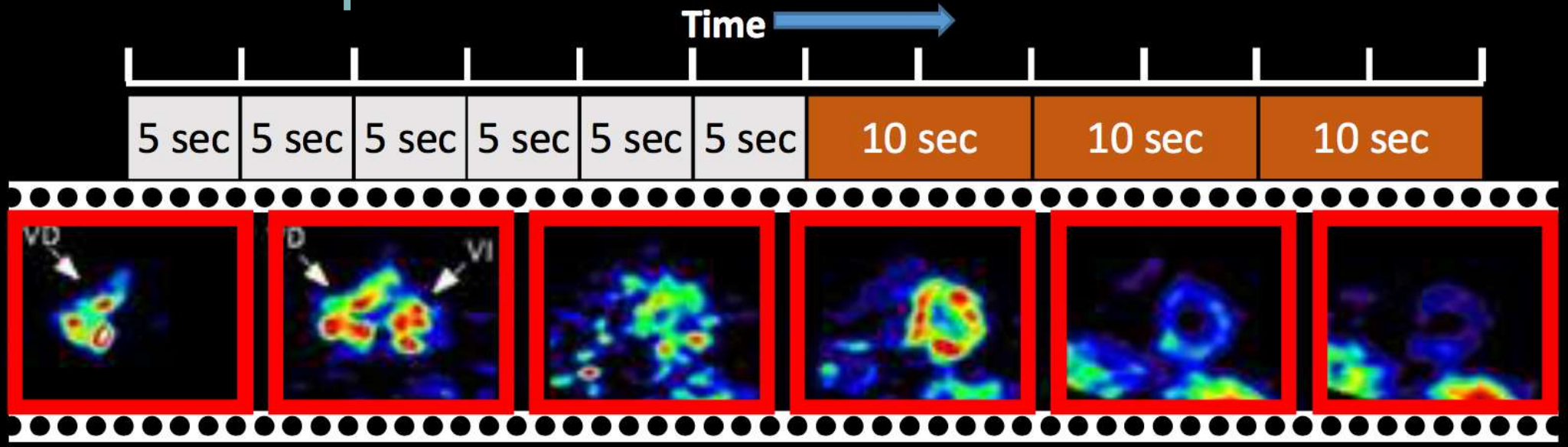
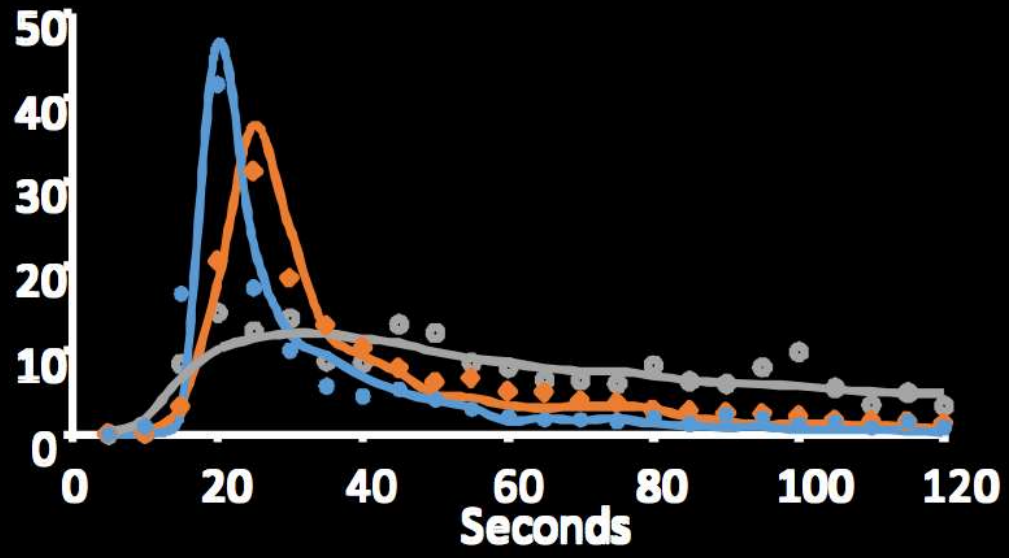
Bateman et al. J Nucl Cardiol 2016

Dynamic Acquisition

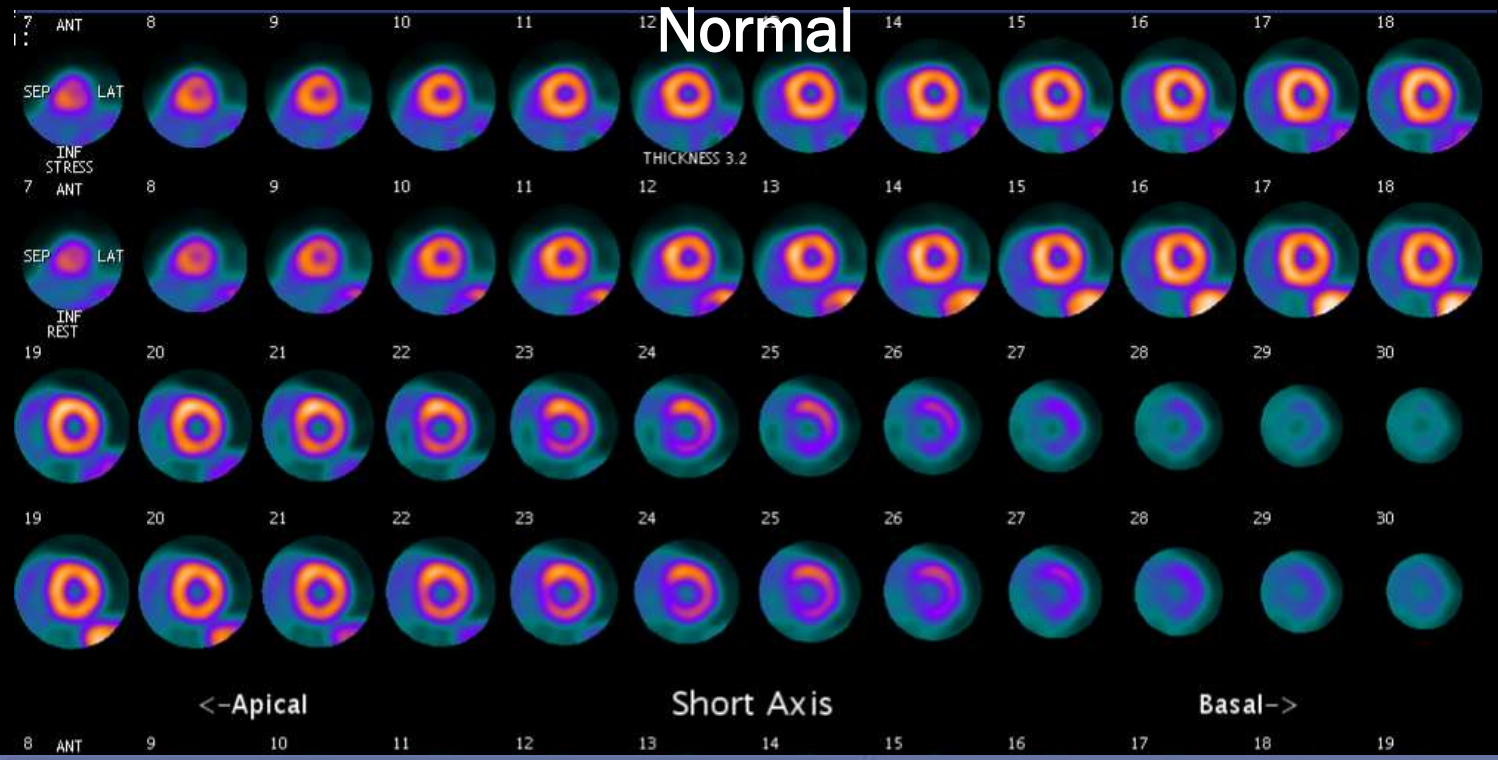


Number of Frames	Frame Duration
14	5 seconds
6	10 seconds
3	20 seconds
3	30 seconds
1	150 seconds



Murthy. Nuts & Bolts of Cardiac PET Perfusion Imaging ASNC Webinar: Clinical Quantification of Myocardial Blood Flow Using PET: Joint Position Paper of the SNMMI Cardiovascular Council and the ASNC

Normal


ANT
SEP
LAT
INF
STRESS
THICKNESS 3.2
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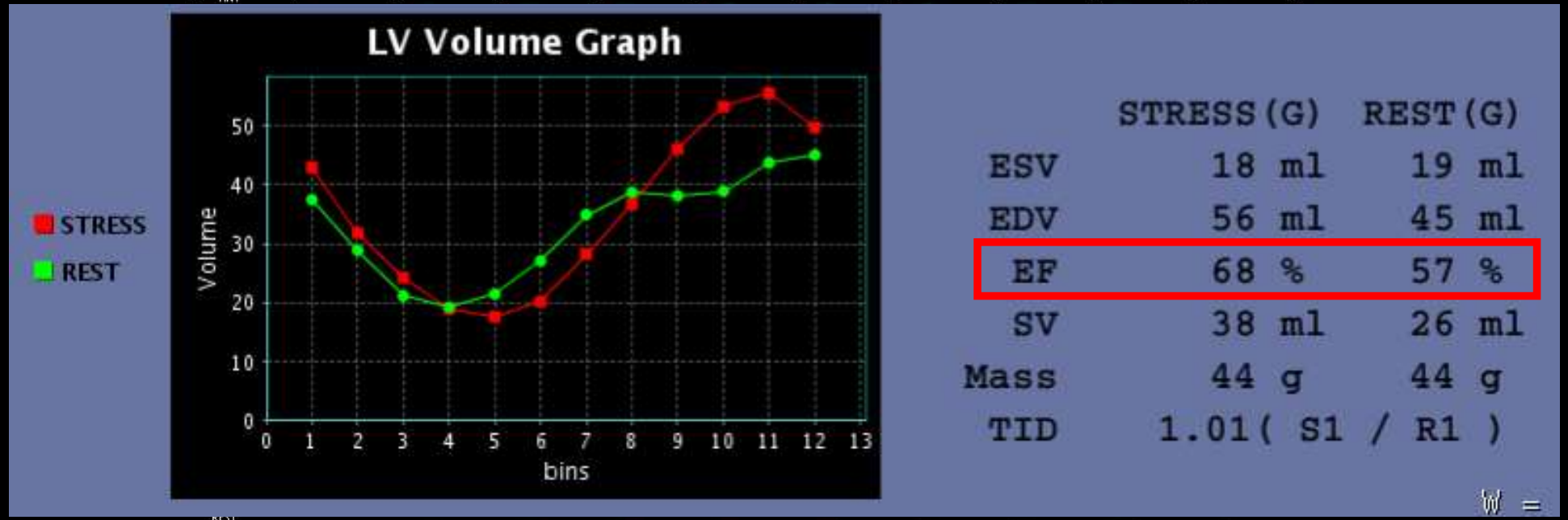
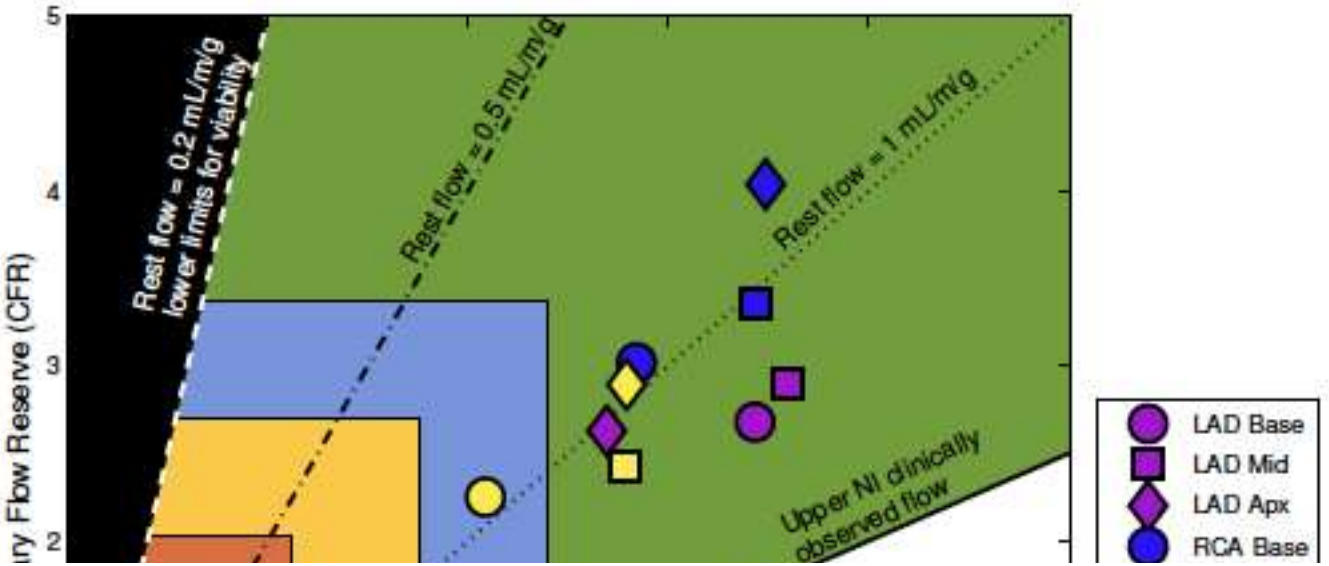
INF
REST
<-Apical
Short Axis
Basal->


LV Volume Graph
STRESS
REST
Volume
bins
STRESS(G) REST(G)
ESV 18 ml 19 ml
EDV 56 ml 45 ml
EF 68 % 57 %
SV 38 ml 26 ml
Mass 44 g 44 g
TID 1.01(S1 / R1)
<-Inferior
Horizontal Axis
Anterior->
1024 × 1024

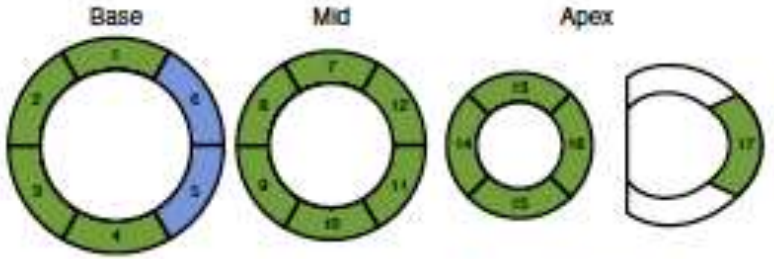
Interaction between Resting MBF, Stress MBF, and CFR



Myocardial Blood Flow (mL/min/g) & CFR (Stress/Rest) from Base to Apex

	LAD			RCA			Circumflex		
	Base	Mid	Apex	Base	Mid	Apex	Base	Mid	Apex
Rest	1.28	1.24	1.02	0.94	1.02	0.86	0.93	1.15	0.97
Stress	3.43	3.59	2.69	2.84	3.43	3.49	2.09	2.78	2.79
CFR	2.68	2.89	2.63	3.02	3.36	4.04	2.25	2.42	2.89
Interpret	*7	*7	*7	*7	*7	*7	*6	*7	*7

*Table 1: Interpretation based on [3]: *6: No ischemia, minimally reduced flow capacity; *7: Normal flow;*



Patient specific mapping of flow estimates to relationship plotted above.

Stress	3.43	3.59	2.69	2.84	3.43	3.49	2.09	2.78	2.79
CFR	2.68	2.89	2.63	3.02	3.36	4.04	2.25	2.42	2.89
Interpret	*7	*7	*7	*7	*7	*7	*6	*7	*7

*Table 1: Interpretation based on [3]: *6: No ischemia, minimally reduced flow capacity; *7: Normal flow;*

Patient specific mapping of flow estimates to relationship plotted above.

History

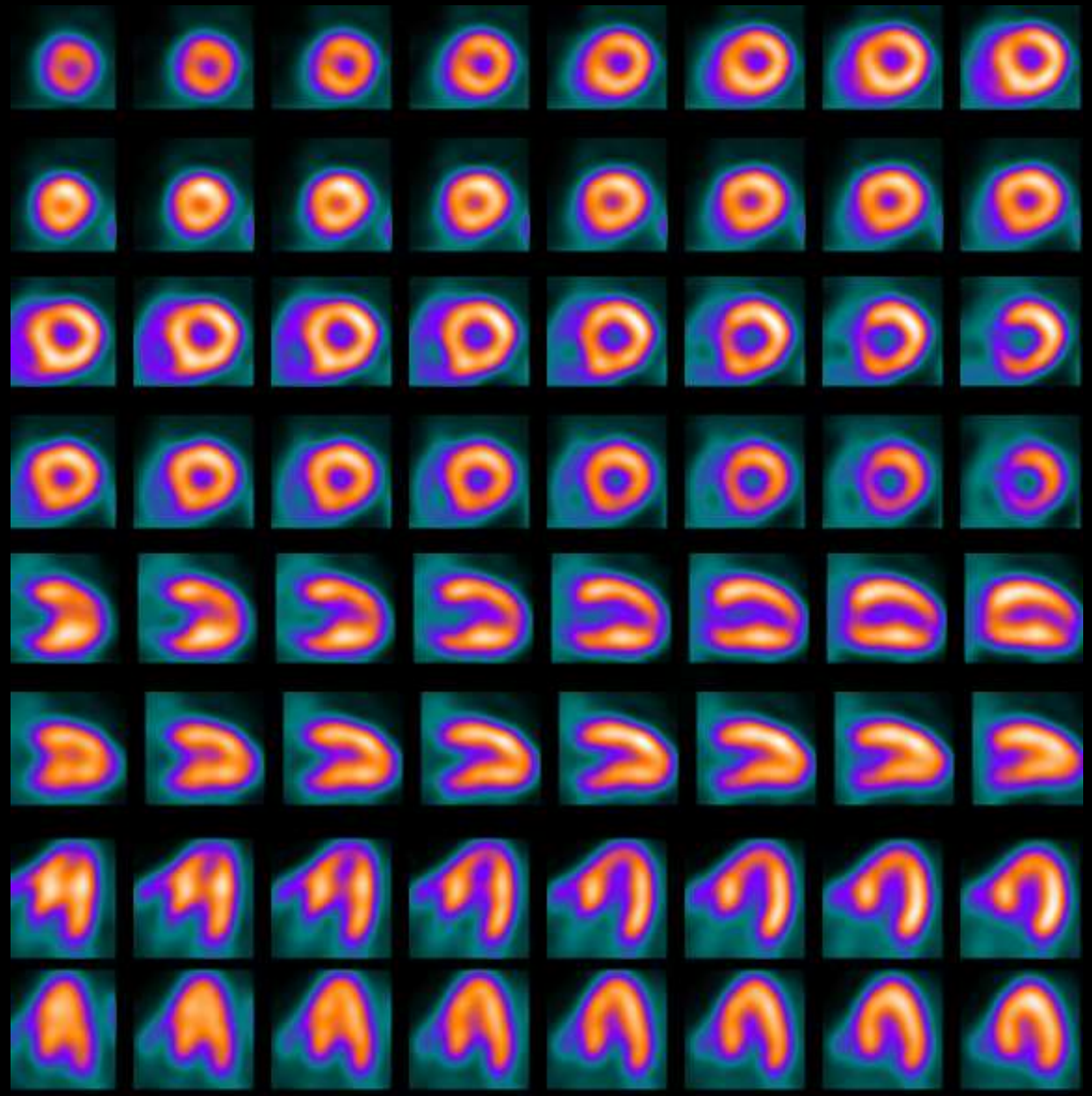
- 69 year-old female admitted to hospital after a cerebrovascular accident; found to be in atrial fibrillation; small increase in troponin i.
- PMH: Hypertension; Type II diabetes

Rest/dipyridamole stress Rubidium-82 myocardial perfusion PET study

Case courtesy of Tim Bateman, MD, Cardiovascular Consultants, Kansas City, MO

^{82}Rb PET Images

Near Balanced Flow Reduction



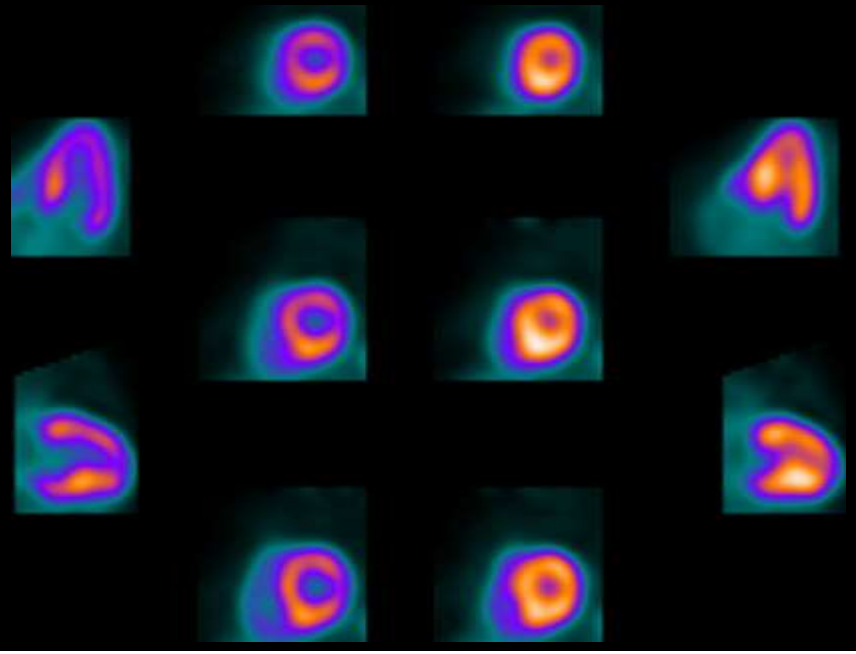
STRESS

REST

TID Ratio 1.63

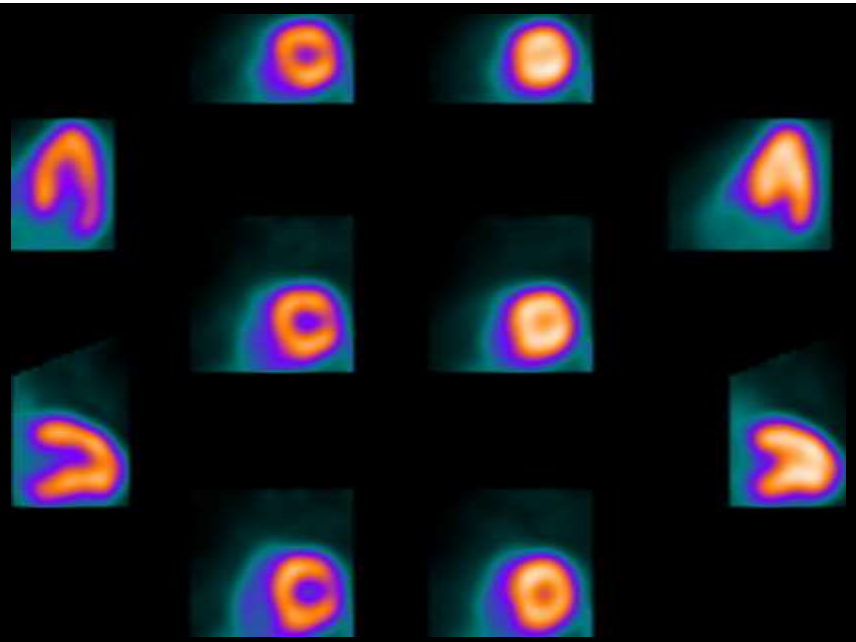
Case courtesy of Tim Bateman, MD, Cardiovascular Consultants, Kansas City, MO

^{82}Rb PET Gated Images



PEAK STRESS

LVEF 50%



REST

LVEF 61%

Case courtesy of Tim Bateman, MD, Cardiovascular Consultants, Kansas City, MO

PET Report

The combined test findings indicate the following:

1. Virtually diagnostic for the presence of CAD.
2. Apical ischemia probably in the distribution of the left anterior descending coronary artery.
3. Severe transient ventricular dilation, suggesting possible near-balanced flow reduction in multiple coronary territories.
4. Normal left ventricular function at rest (LVEF 61%).
5. Significant drop in LVEF in response to pharmacologic stress.
6. Prognostically concerning scan, with numerous markers of high-risk for major adverse coronary events.

Case courtesy of Tim Bateman, MD, Cardiovascular Consultants, Kansas City, MO

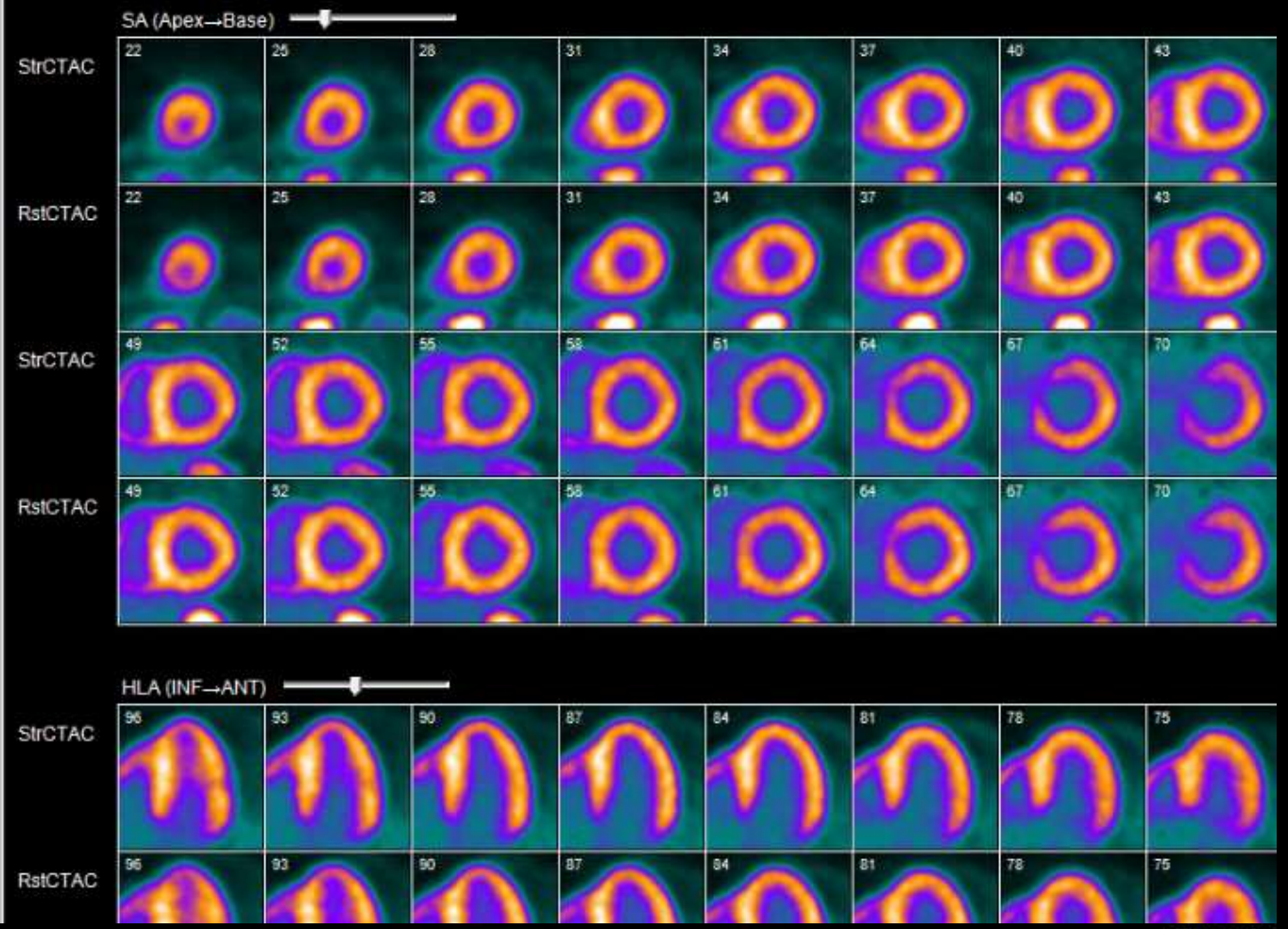
Cath Correlation

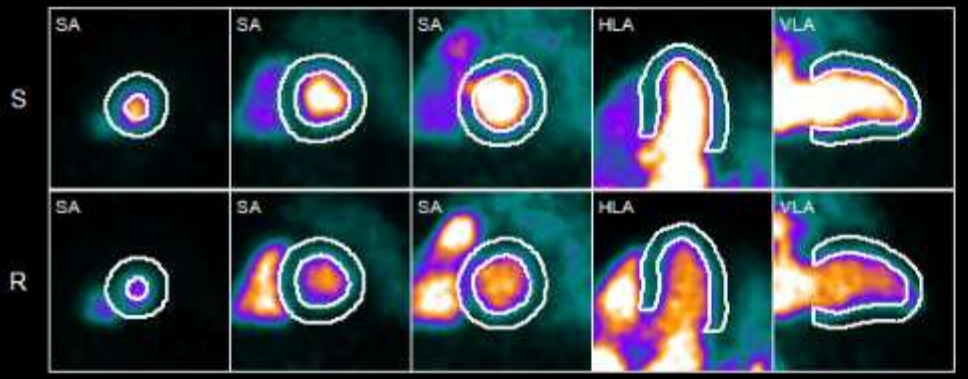
- Coronary angiography showed a 75% left main stenosis, a 90% stenosis of the mid LAD, and a 70% right coronary artery stenosis.
- CABG surgery was performed after recovery from the CVA.

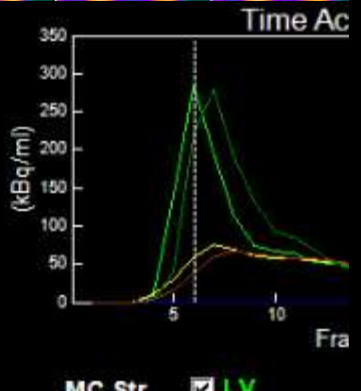
Case courtesy of Tim Bateman, MD, Cardiovascular Consultants, Kansas City, MO

Non-responsiveness to pharmacological stress

- Patient does not demonstrate features expected with severe multivessel CAD.
- Global and regional flows are at or near 1.0, with homogeneous rather than heterogeneous MFR
- Uptake similar to rest and no new defects
- Little or no hemodynamic changes
- No high-risk response features (e.g., ECG changes, stress-induced perfusion defects, wall motion abnormalities, TID, RV uptake)





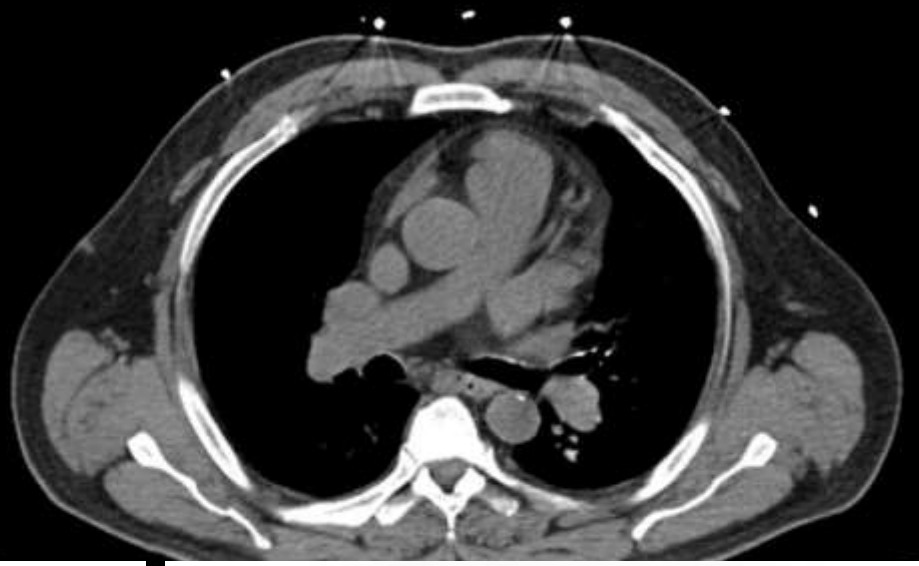


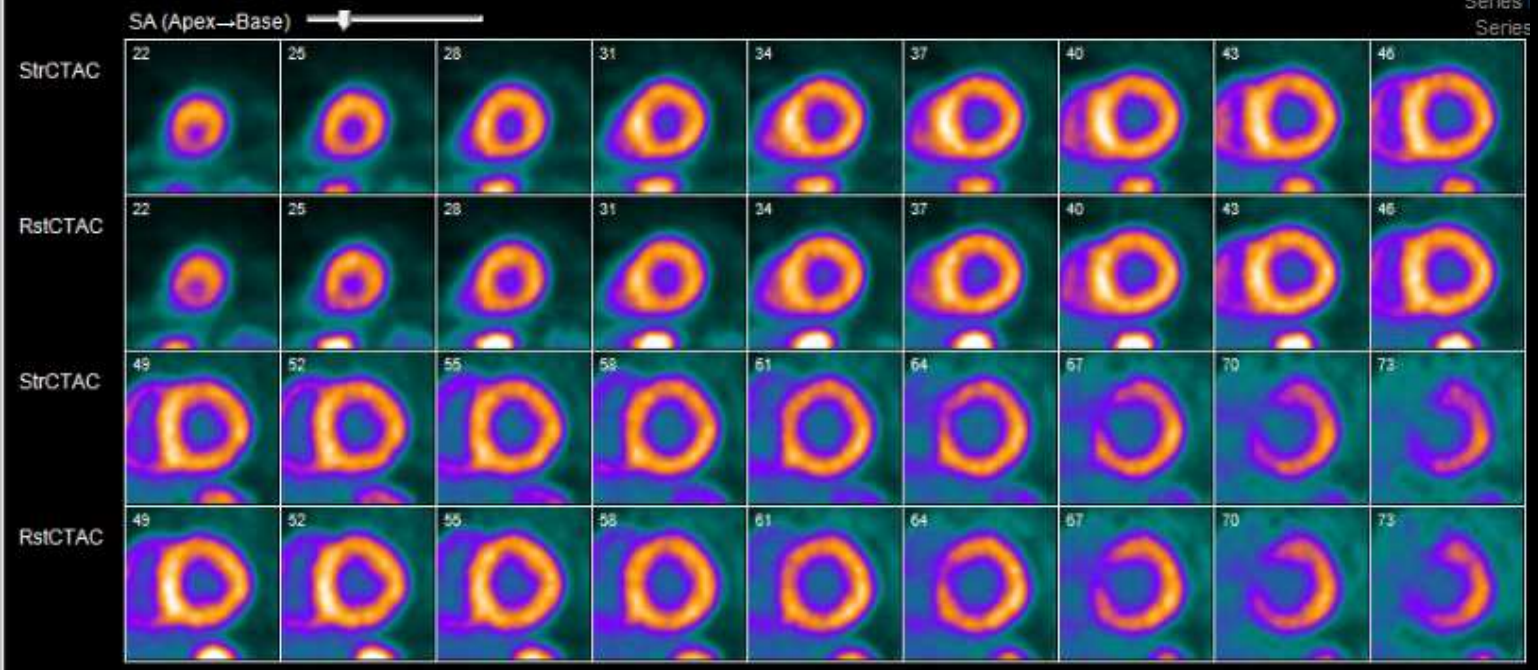
Global Results

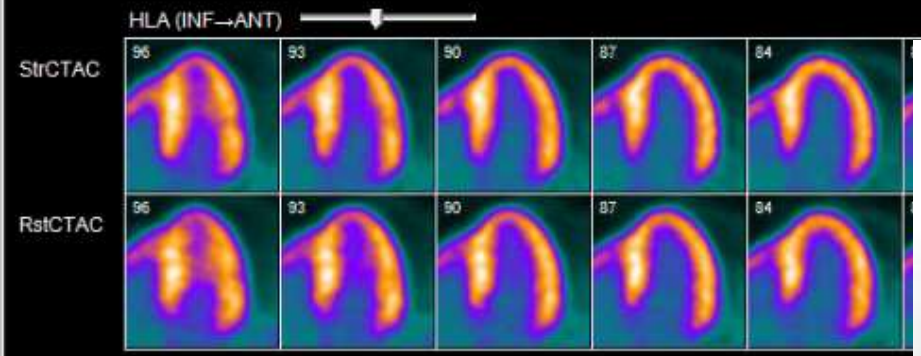
Region	Mean Flow (ml/min/g) MC Str	MC Rst	MC Str	MC Rst	Reserve
LAD	86%	86%	1.02	0.72	1.42
LCX	88%	89%	1.01	0.75	1.35
RCA	88%	87%	1.13	0.72	1.57
TOT	87%	87%	1.04	0.72	1.45

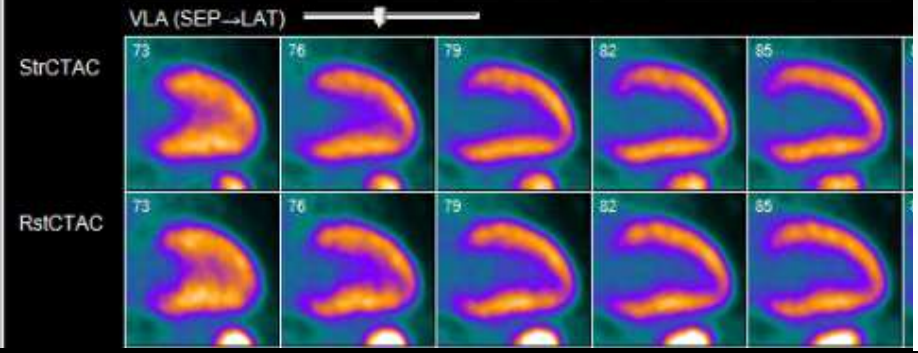
Region	Normal	N Perf/ A Flow	A Perf/ N Flow
LAD	25 % (1.56)	75 % (1.38)	0 % (--)
LCX	23 % (1.53)	78 % (1.31)	0 % (--)
RCA	40 % (1.62)	51 % (1.52)	0 % (--)
TOT	31 % (1.58)	69 % (1.39)	0 % (--)

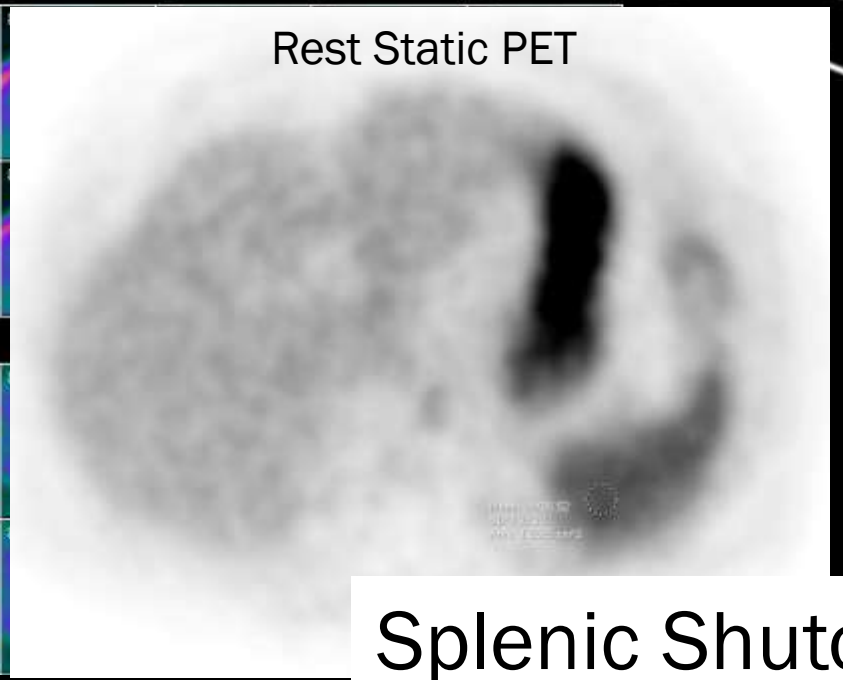
50-year-old man w ESRD secondary to diabetes & HTN





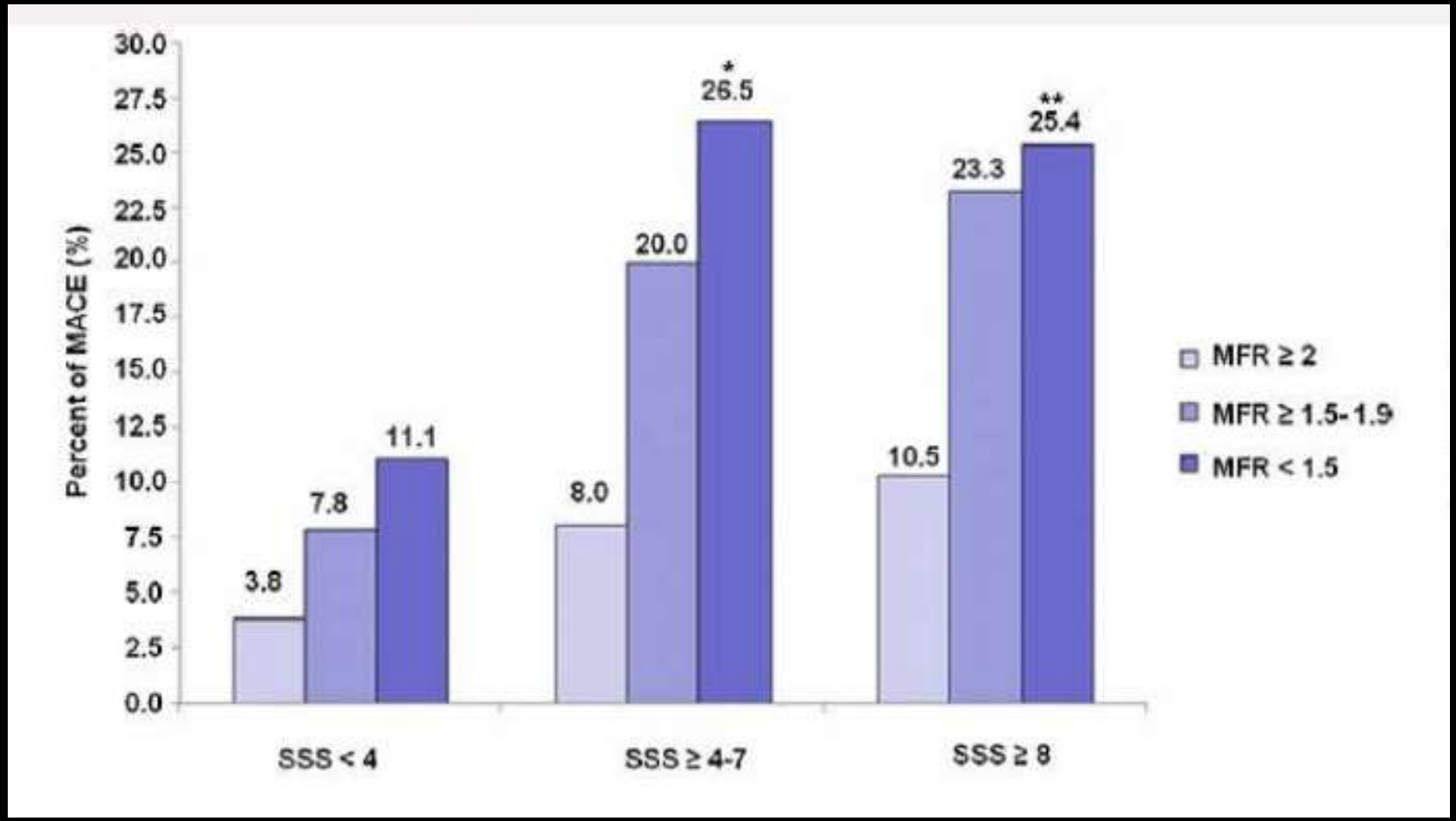






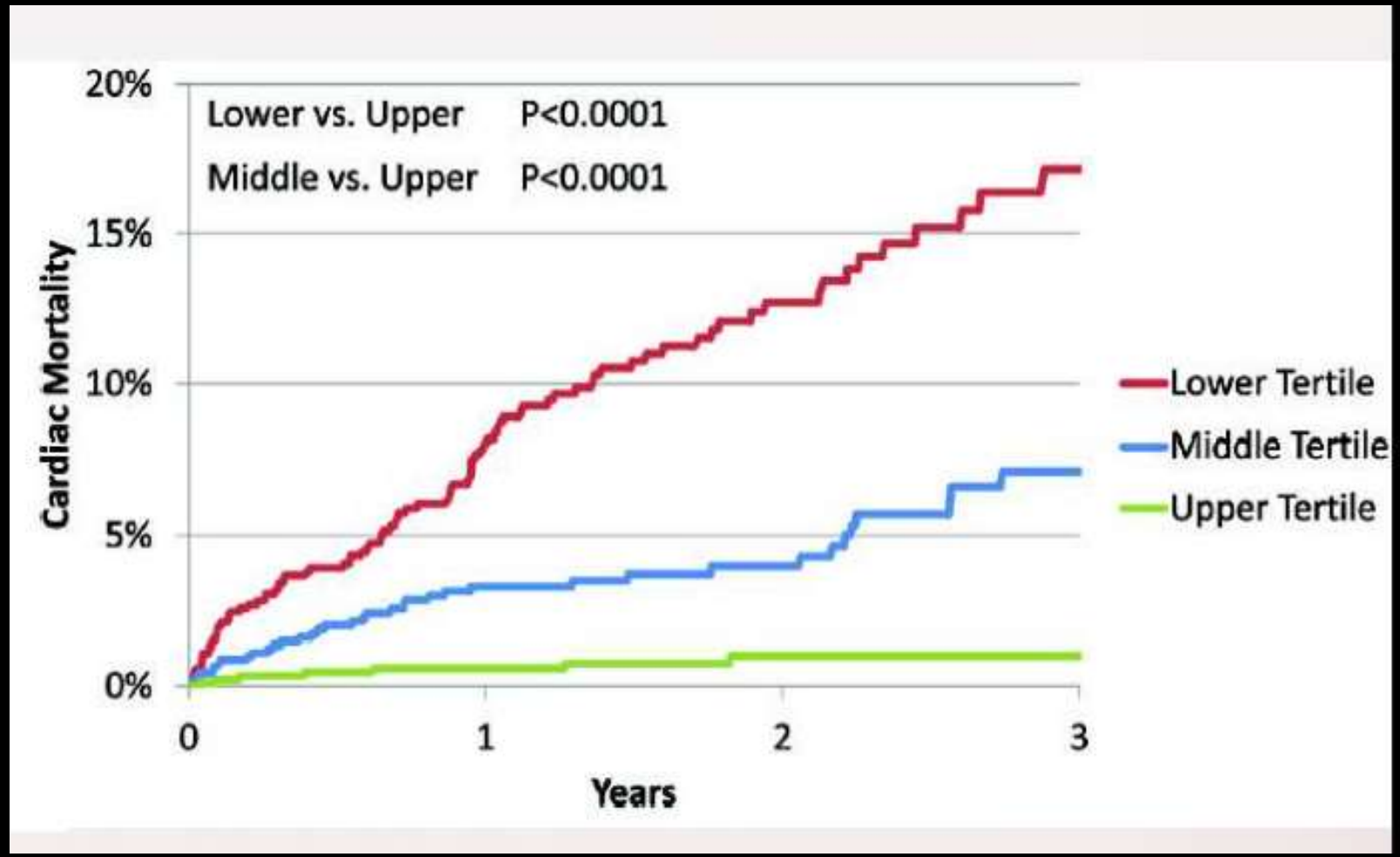
Splenic Shutoff Response

Myocardial Flow Reserve and Prognosis



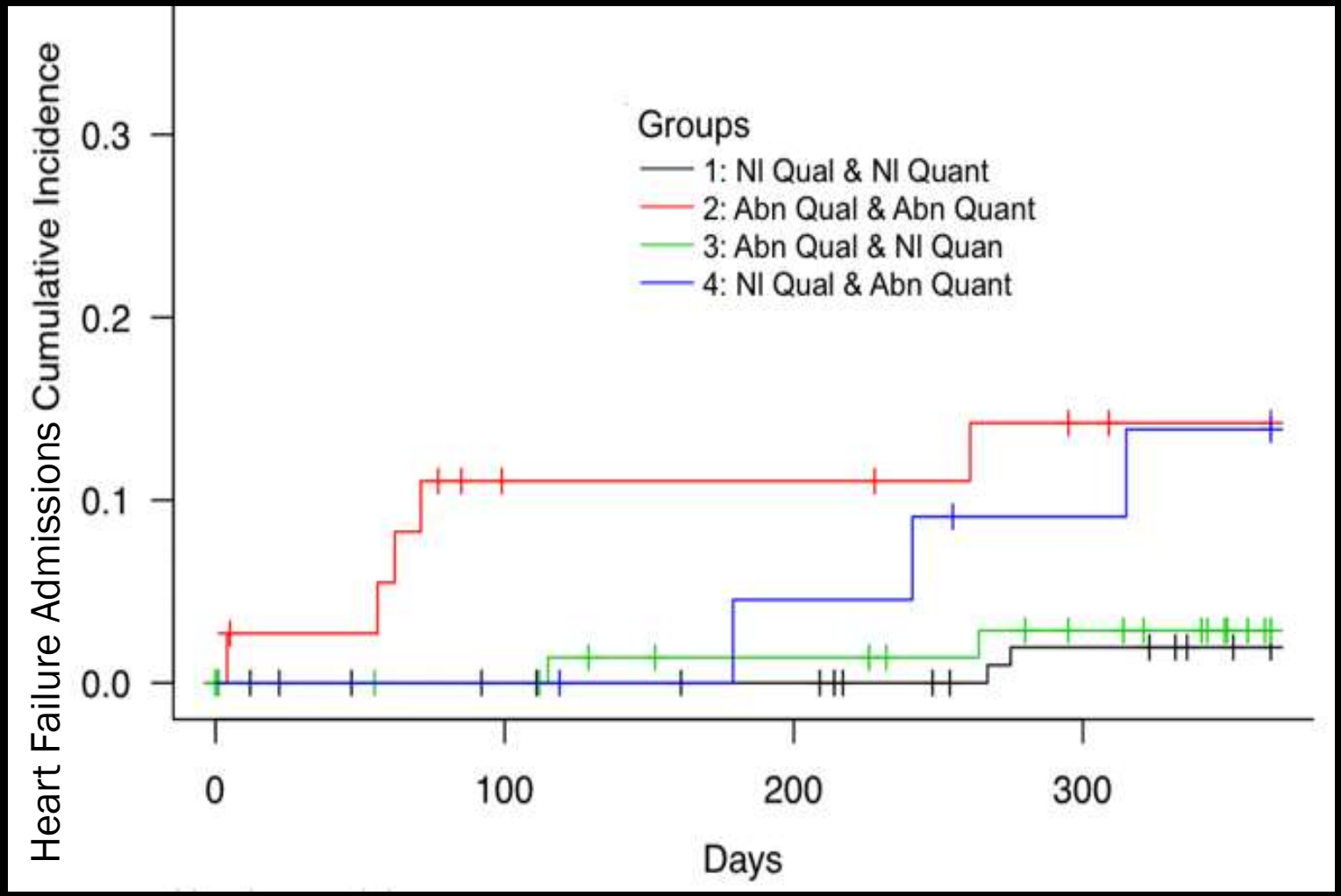
Ziadi et al. J Nucl Cardiol 2012

Myocardial Flow Reserve and Prognosis

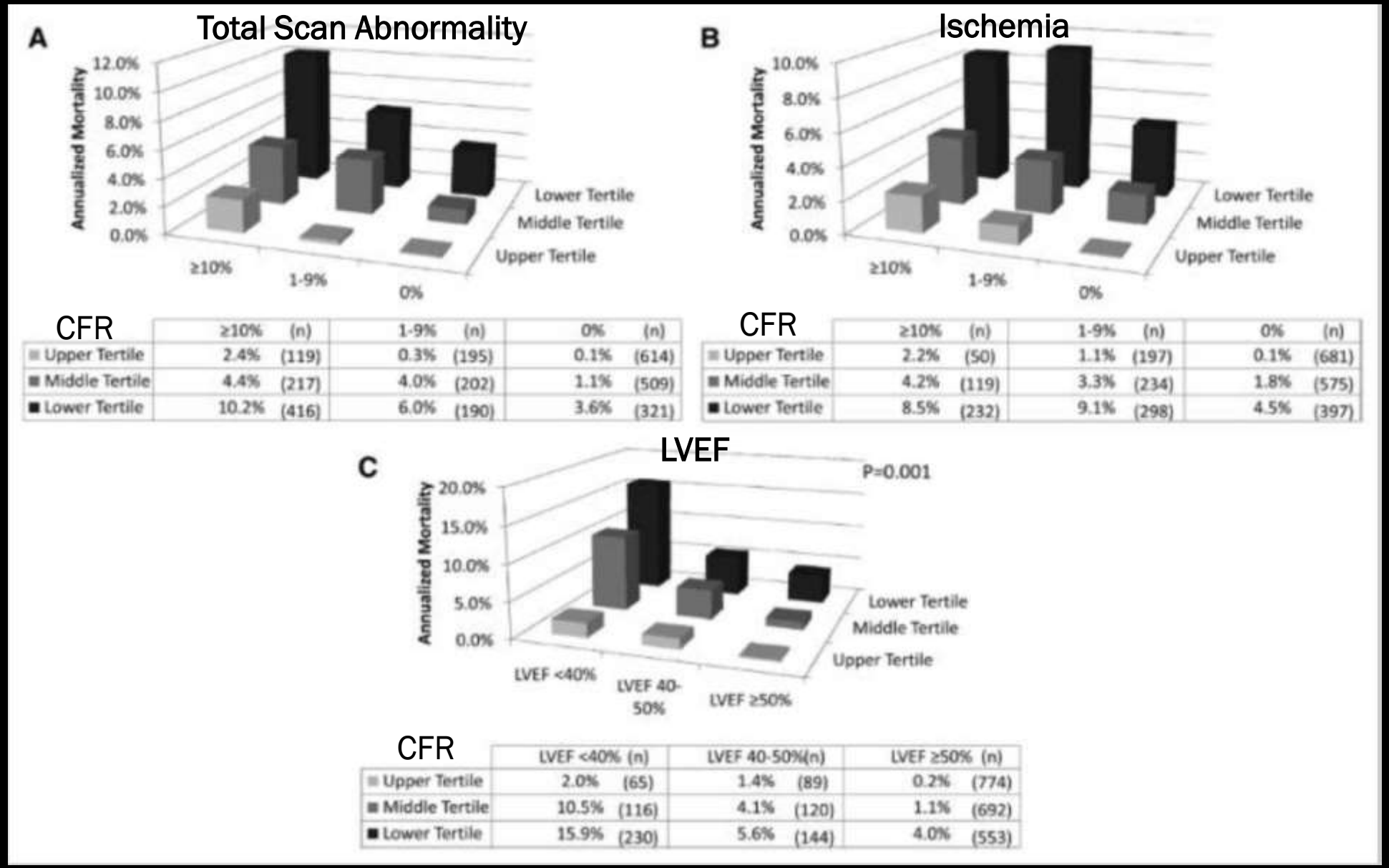


Murthy et al. Circulation 2011

Myocardial Flow Reserve and Prognosis



Elman et al. ASNC 2018



CFR	≥10%	(n)	1-9%	(n)	0%	(n)
Upper Tertile	2.4%	(119)	0.3%	(195)	0.1%	(614)
Middle Tertile	4.4%	(217)	4.0%	(202)	1.1%	(509)
Lower Tertile	10.2%	(416)	6.0%	(190)	3.6%	(321)

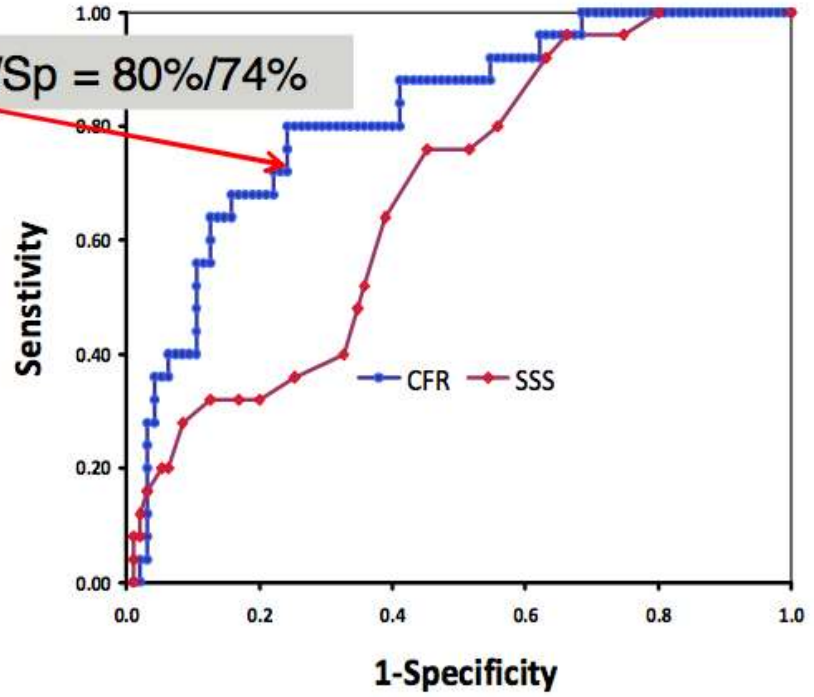
CFR	≥10%	(n)	1-9%	(n)	0%	(n)
Upper Tertile	2.2%	(50)	1.1%	(197)	0.1%	(681)
Middle Tertile	4.2%	(119)	3.3%	(234)	1.8%	(575)
Lower Tertile	8.5%	(232)	9.1%	(298)	4.5%	(397)

CFR	LVEF <40%	(n)	LVEF 40-50%	(n)	LVEF ≥50%	(n)
Upper Tertile	2.0%	(65)	1.4%	(89)	0.2%	(774)
Middle Tertile	10.5%	(116)	4.1%	(120)	1.1%	(692)
Lower Tertile	15.9%	(230)	5.6%	(144)	4.0%	(553)

Murthy VL et al. Circulation. 2011;124:2215–24

^{82}Rb PET Global MFR in 3-vessel disease detection

MFR < 1.5: Sn/Sp = 80%/74%



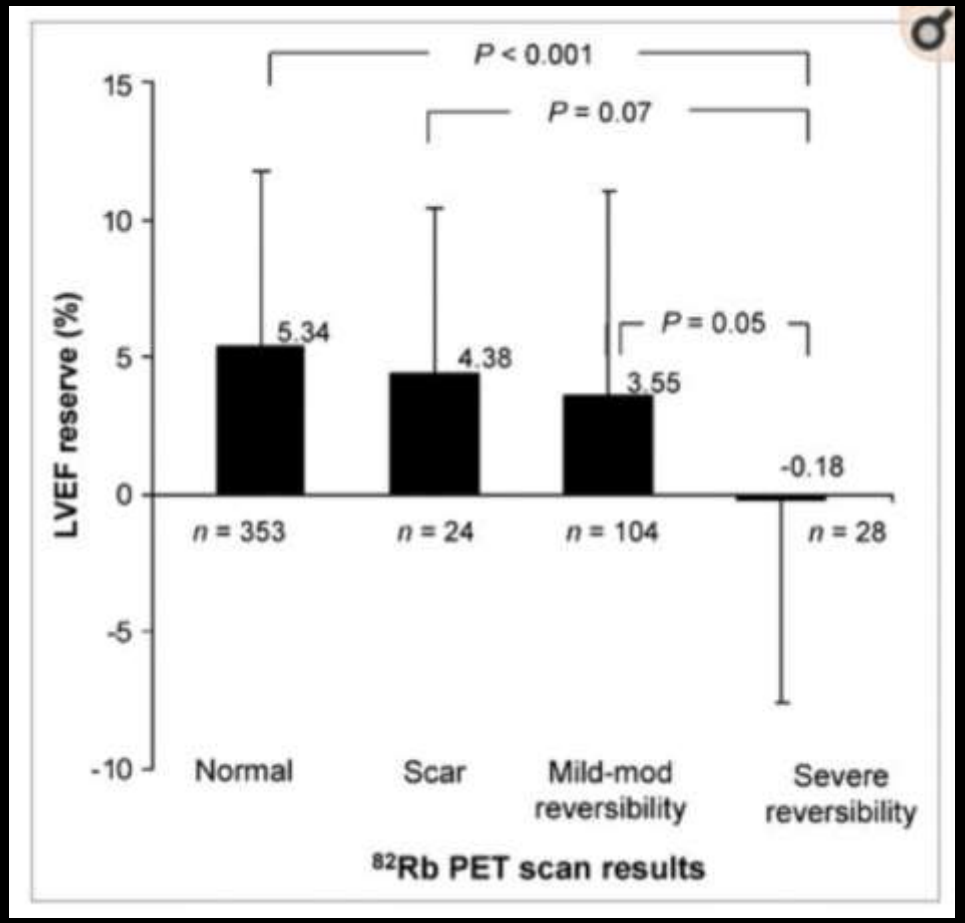
C-statistics

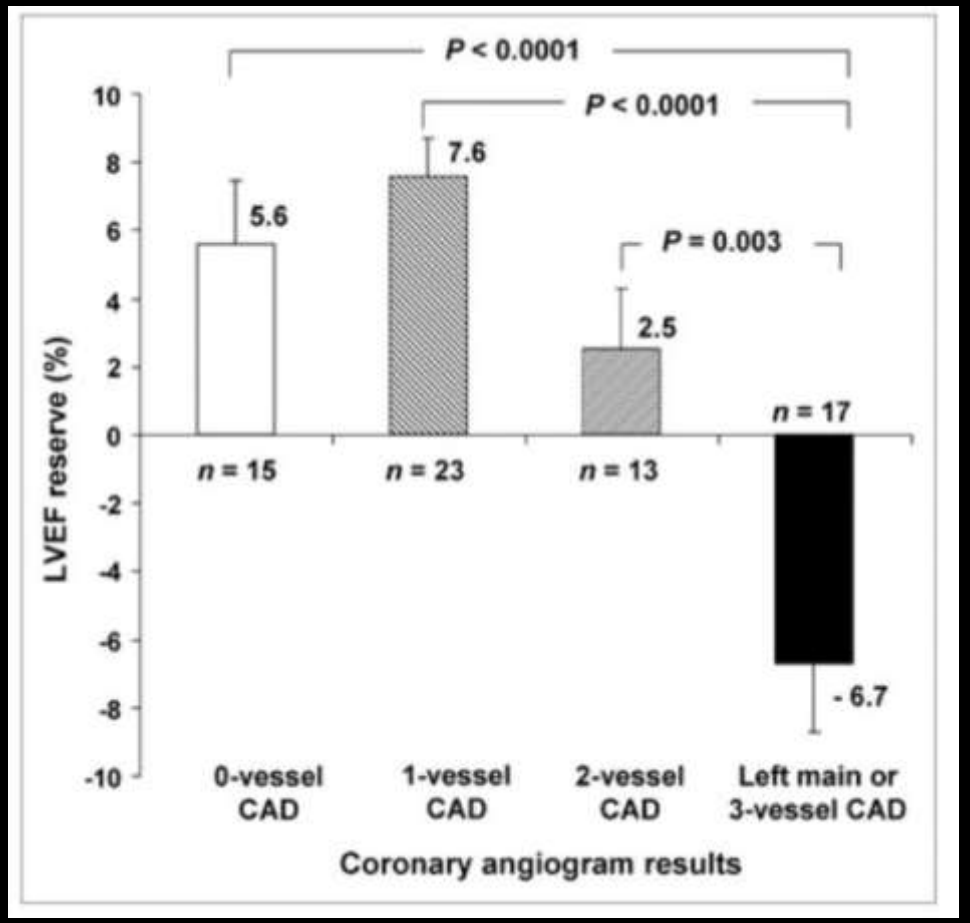
MFR = 0.817

SSS = 0.679

p = 0.018

Ziadi et al. J Nucl Cardiol 2012





Dorbala et al.. J Nucl Med. 2007;48:349–58.

ASNC

ASNC/SNMMI POSITION STATEMENT

AMERICAN SOCIETY OF NUCLEAR CARDIOLOGY AND SOCIETY OF NUCLEAR MEDICINE AND MOLECULAR IMAGING JOINT POSITION STATEMENT ON THE CLINICAL INDICATIONS FOR MYOCARDIAL PERFUSION PET

Writing Group:

Timothy M. Bateman MD (Co-Chair), Vasken Dilsizian MD (Co-Chair), Rob S. Beanlands MD, E. Gordon DePuey MD, Gary V. Heller MD, PhD, David A. Wolinsky MD

provided by a noninvasive cardiac imaging test. Cardiac imaging tests can provide information regarding the presence, extent, and severity of CAD, estimate risk for early and late major adverse cardiac events, and assist in determining the most appropriate treatment, including medical therapy and/or coronary revascularization. Valuable information can also be provided from a normal scan result that can obviate the need for further cardiac tests, reduce unnecessary medication expenses, lead to expeditious referrals for assessment of other causes of symptoms, and relieve anxiety over potential life-threatening etiologies for symptoms.

Bateman et al. J Nucl Cardiol 2016

Clinical Indications

- Prior stress imaging study was of poor quality, equivocal or inconclusive, affected by attenuation artifact, or discordant with clinical impressions or other diagnostic test results including findings at coronary angiography.
- Body characteristics that commonly affect image quality [large breasts, breast implants, obesity (BMI greater than 30), protuberant abdomen, chest wall deformities, pleural effusions, and inability for proper body positioning such as inability to position arms outside of a SPECT scanner's field of view].

Bateman et al. J Nucl Cardiol 2016

Clinical Indications

- High-risk patients in whom diagnostic errors carry even greater clinical implications.
  - *Chronic kidney disease stage 3, 4 or 5*
  - *Diabetes mellitus*
  - *Known or suspected potentially high-risk CAD such as left main, multivessel, or proximal LAD disease*
  - *Known extensive coronary disease following CABG or PCI*
  - *Suspected transplant coronary vasculopathy*
  - *When ischemia is suspected in patients with LV dysfunction*
  - *Patients for whom revascularization carries increased morbidity and mortality risk.*

Bateman et al. J Nucl Cardiol 2016

Clinical Indications

- Young patients with established CAD who are anticipated to need repeated exposures to radiation-associated cardiac imaging procedures, in order to minimize accumulated life-time exposure.
- Patients in whom myocardial blood flow quantification is identified by clinicians to be a needed adjunct to the image findings, to better identify or exclude multivessel CAD, for improved risk stratification, and when assessment of microcirculatory function is needed for clinical decision making.
- NO clinical scenarios where PET should not be considered a preferred test for patients who meet appropriate criteria for a stress imaging test and who require pharmacologic stress.

Bateman et al. J Nucl Cardiol 2016

Considerations for starting a cardiac PET program

- PET Tracers
- Equipment & Software
- Space
- Scheduling
- Training of techs, physicians, other staff
- Referring provider education & marketing

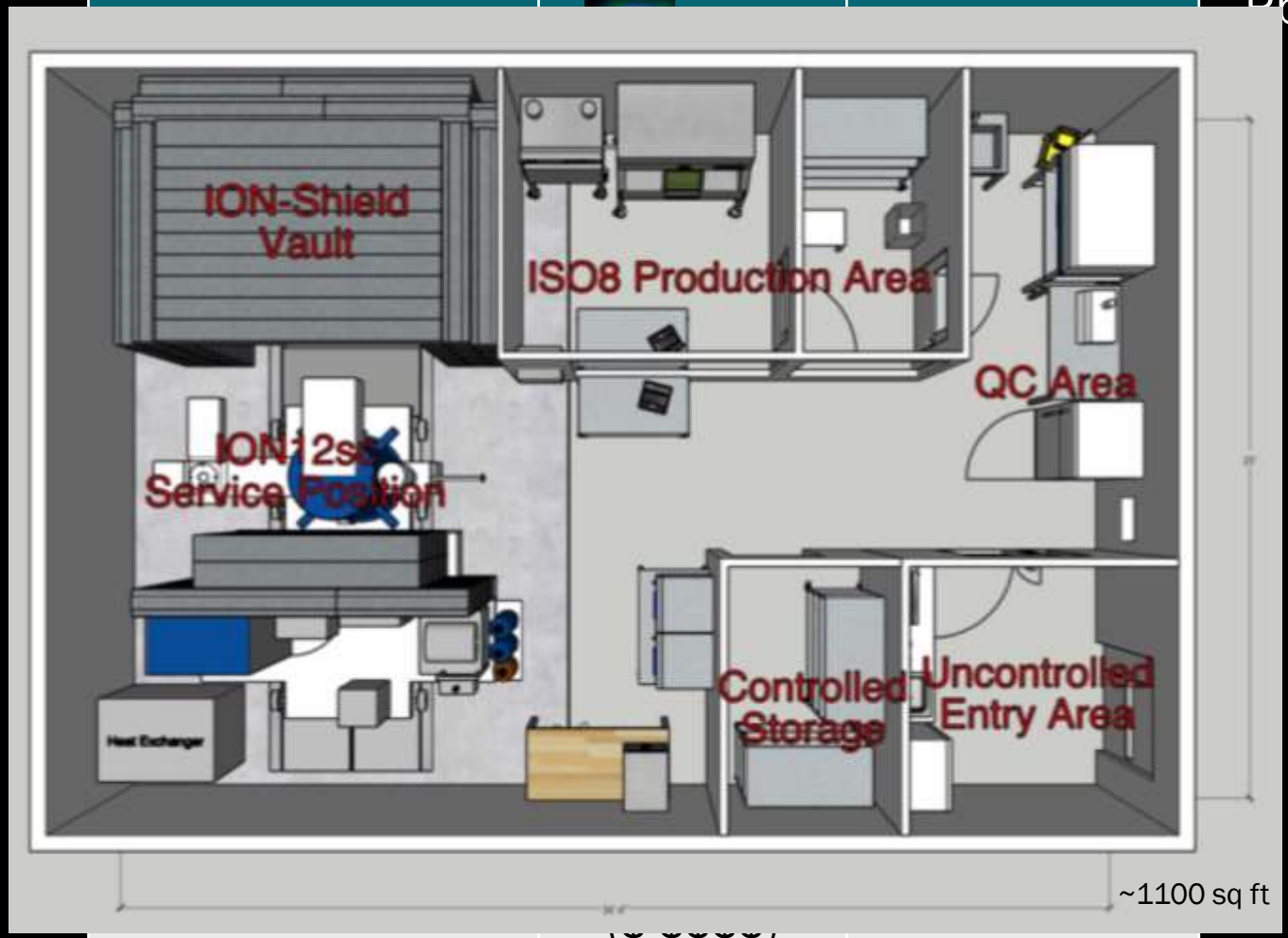
Decision Analysis

Occasional Imaging	*and*	On-site cyclotron	N-13 ammonia
Daily Imaging	*and*	PET/CT capacity	Rb-82 chloride

Improved Availability of PET Tracers & FDA-approved Software

Cardiac PET Radiopharmaceuticals

Rb-82

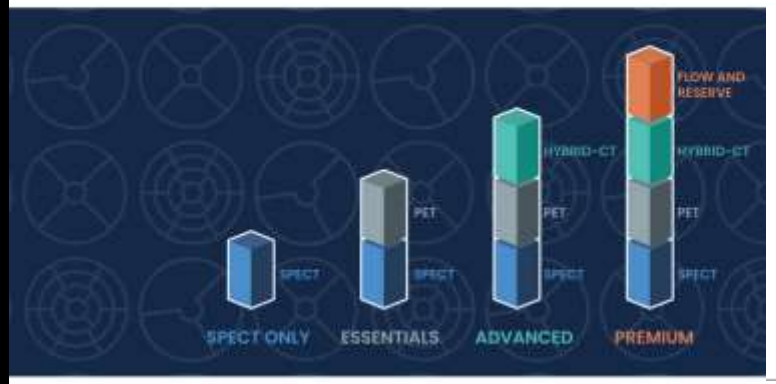


Per Dose Cost	($ $$$$) Depends on how many you do per day/month	$$

CLINICAL RELEVANCE 4DM SOFTWARE CUSTOMER SUPPORT ABOUT INVIA MEMBER LOGIN INV

PACKAGES

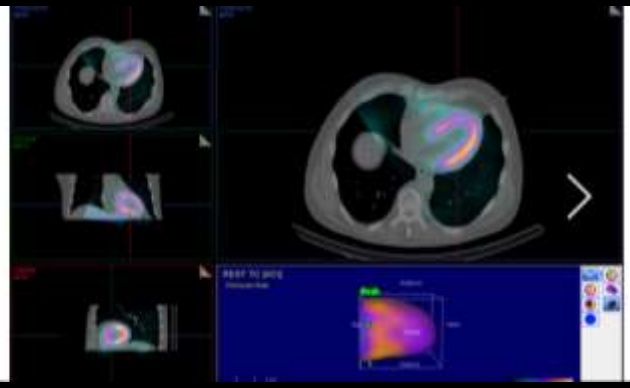
4-DM



ADVANCED

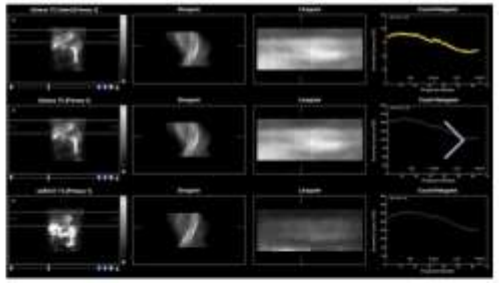
Everything in Essentials Package +

- Add Hybrid-CT to nuclear images
- Calcium agatston quantification
- Calcium percentile comparison to normals database
- Dedicated CT displays: MPR, MIP, Thin MIP
- ROI and anatomic measurement tools
- Full body viewing

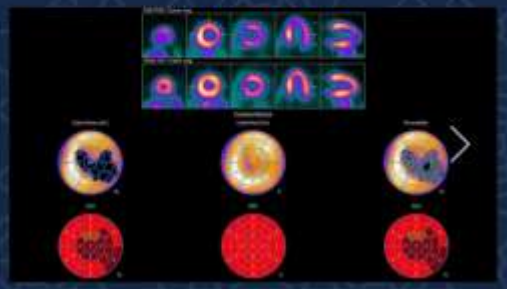


SPECT ONLY

- Tomo Quality Assurance
- Integrated Myocardial Perfusion with Function
- Planar and SPECT Blood Pool Quantification
- Multiple image formats
- Segmental Scoring Overlays
- Multi-monitor support



*Click images to expand



ESSENTIALS

Everything in SPECT Only Package +

- Attenuation map review
- PET perfusion, function, viability in a single application
- Viability quantification and displays
- Inflammatory workflow
- PET Standard Uptake Value (SUV) calculations

*Click images to expand

https://www.inviasolutions.com/packages

CARDIOVASCULAR
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ImagenPRO 2.2 Cardiac PET Software Environment

The Industry Standard ImagenPRO®: Don't settle for promises, get the proof!

- 30 minute rest stress acquisition times
- Compatibility with most dedicated cardiac systems
- Support for PET/CT
- Patented transmission reconstruction algorithm
- Validated, FDA approved 3D imaging
- Support for most interpretive software
- INCLUDES CVIT's "Real Time, Real Answers™" support

Request Information

ImagenPRO®, offers a complete, state of the art cardiac PET software environment for processing and interpreting cardiac PET studies. Used by almost 100 sites across the United States, ImagenPRO® is the largest 3rd party reconstruction and post-processing environment in cardiac PET today.

ImagenPRO® offers:

- Complete, intuitive and interactive misregistration correction
- Iterative OSEM Reconstruction for non-gated and ECG gated datasets
- 3D Fourier based, "Butterworth" noise suppression
- Our patented Bayesian iterative transmission reconstruction algorithm for maximizing transmission quality and allows transmission scanning times to be reduced from 5 minutes to as short as 60–90 seconds.
- Dicom export to most image review environments
- Click for additional information on ImagenPRO®

ImagenPRO® supports:

- Siemens ECAT ACCEL
- Siemens HR+
- Siemens EXACT-47
- Dedicated GE PET systems, i.e. Advance NXI
- GE Pre-Dimension Console PET/CT systems, i.e. Discovery LS and DST

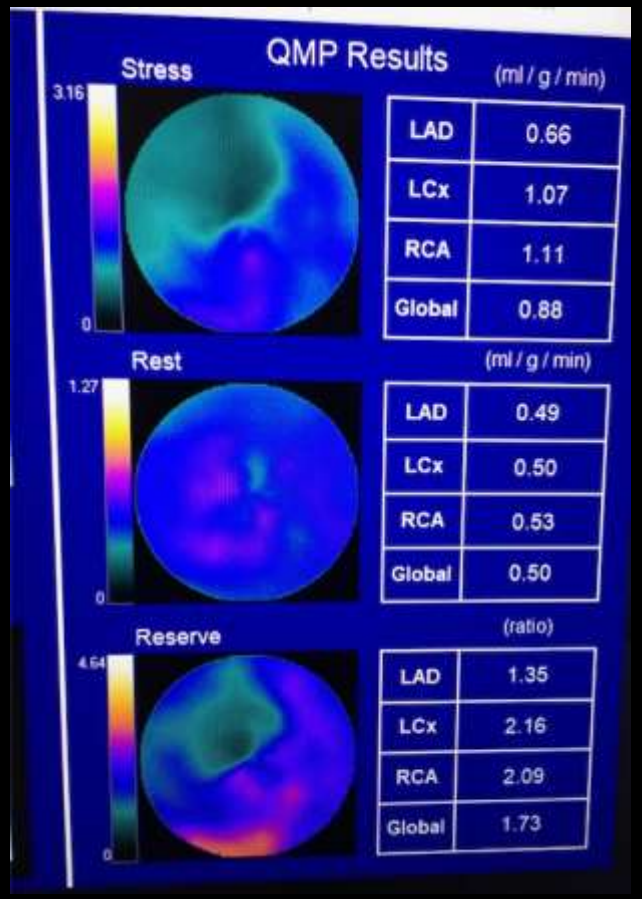
*WARNING: Federal law restricts this device to sale, distribution and use by or on the order of a physician and other practitioners licensed by the law of the State in which the device is used. Specific training in the use of this device is required. For Support, go to http://www.gotoassist.com/sb/cvit

https://www.cvit.com/products/imagenpro/

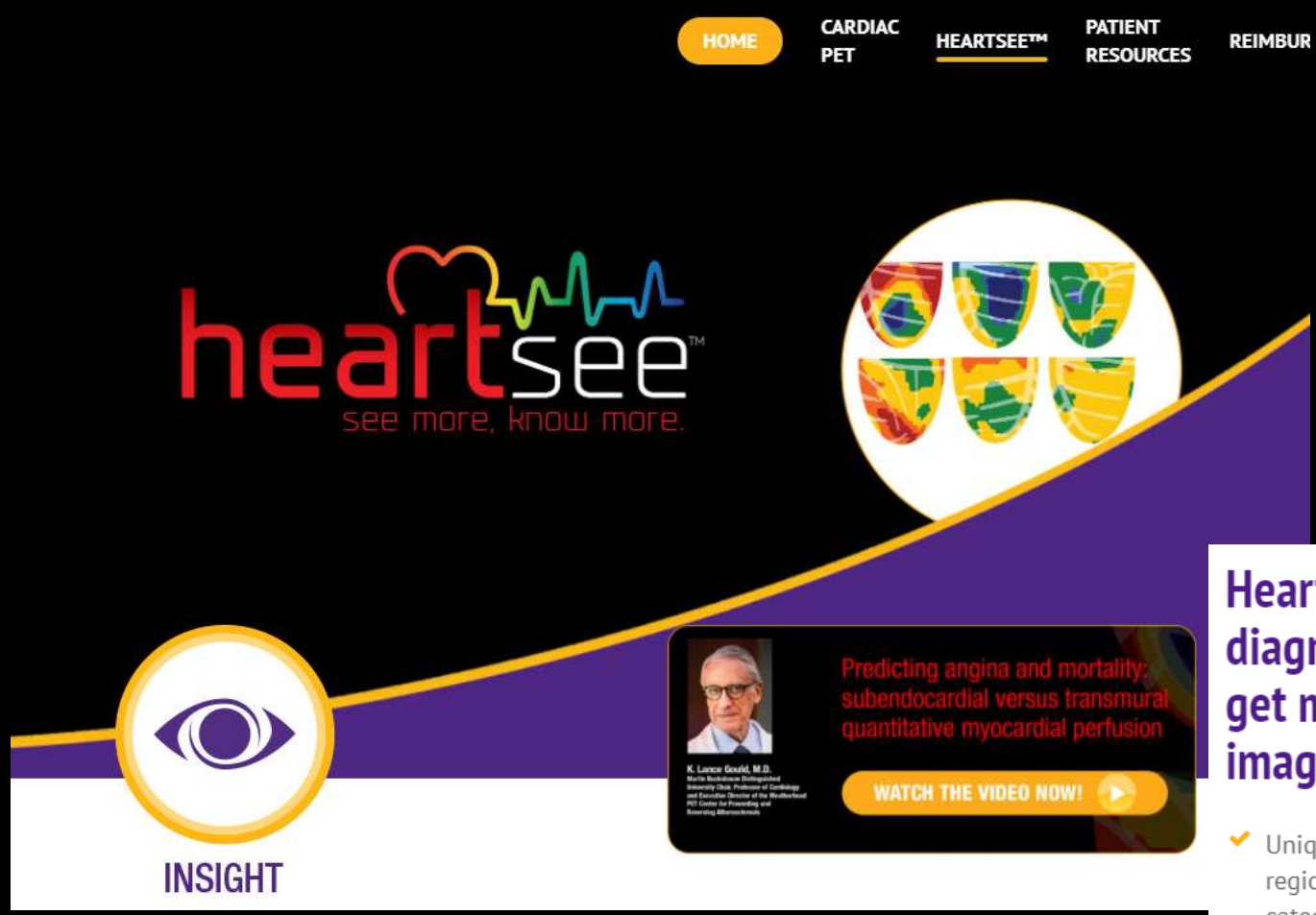
How to Start a Cardiac PET-CT Imaging Program

Many centers are looking at PET imaging as they plan replacements for older SPECT systems

Rupa Sanghani, M.D., FASNC, director of Rush's nuclear cardiology and stress laboratory, explaining to ASNC 2019 attendees how Rush implemented its program during a tour of its PET-CT suite.



https://www.dicardiology.com/article/how-start-cardiac-pet-ct-imaging-program



HeartSee is the innovative diagnostic tool that helps you get more from your cardiac PET imaging

- Unique coronary flow capacity (CFC) map shows regional and global coronary defects and helps categorize severity of disease.
- HeartSee delivers the new CFC map in easy to interpret reports along with traditional diagnostic data.
- Invasive coronary intervention within 90 days after the PET scan is associated with a **54%** reduced risk of death, myocardial infarction or stroke over five years for patients who show severely reduced blood flow capacity on HeartSee's CFC maps.[3]

https://cardiogen.com/heartsee/

Equipment & Space issues

- Can you use your current PET/CT camera ?
  - *Adequate camera for cardiac PET? (e.g., cardiac gating package)*
  - *How will addition of cardiac PET affect your oncologic PET practice?*
- New PET/CT or refurbished PET camera?
  - *Cost:*
    - >$1.5million for new PET/CT plus add'l 10-12% of equipment cost for maintenance per year
    - ~$350,000-$450,000 for refurbished system, plus ~$85,000/yr for maintenance
      - *Risk for parts needed for servicing to become unavailable*
  - *Size: Will require ~14x24-ft room for PET/CT, generator with storage cart, infusion system, control area*
  - *Shielding*
    - For Rb-82 or N-13 Ammonia
    - For F-18 agents
      - *Viability PET*
      - *Cardiac sarcoidosis*
      - *Plan ahead for anticipated FDA-approval of F-18 Flupiridaz or other cardiac agents under investigation*

Estimating Start-up Costs

- How many cardiac PETs do you plan to do per day?
- How will the addition of cardiac PET affect revenue from cardiac SPECT? Or other cardiac imaging modalities?
  - *How many treadmill MPIs vs pharmacologic MPIs?*
- Radiopharmaceutical
  - *Rb-82 generator costs ~$20,000-$30,000 ($120,000-$432,000/yr depending on exact price per generator and frequency of replacement)*
  - *N-13 Ammonia require cyclotron on site.*
    - Increased availability with Ionetix mini-cyclotron
  - *F-18 Flupiridaz: ???*
- Personnel?
  - *Who performs stress portion of the exam? Do you have adequate staffing to perform cardiac PET and cardiac SPECT simultaneously or will you need 2 separate people?*

Prep for Rb82 go-live

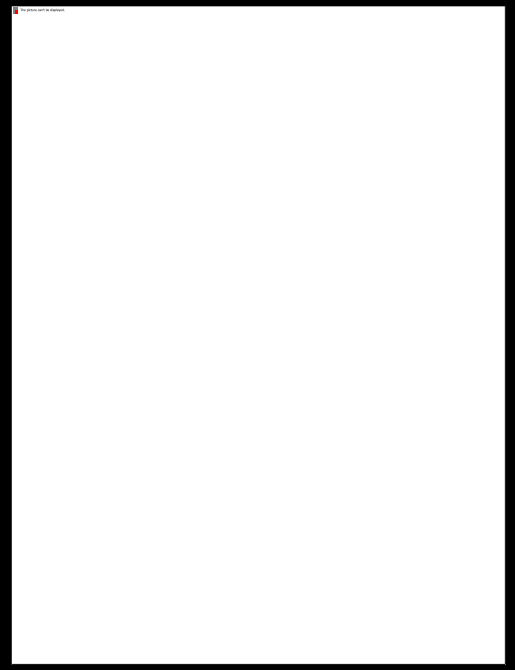
- Staffing considerations
- Supplies and associated costs
  - *Generator*
  - *Admin tubing*
  - *QC vials*
  - *Install kits*
  - *Saline bags*
  - *10µCi Na-22 constancy source*
  - *Waste bottles/lids (for generator and long term storage)*
  - *Printer paper for generator*
  - *ECG leads, caps for tubing, sharp container for waste*

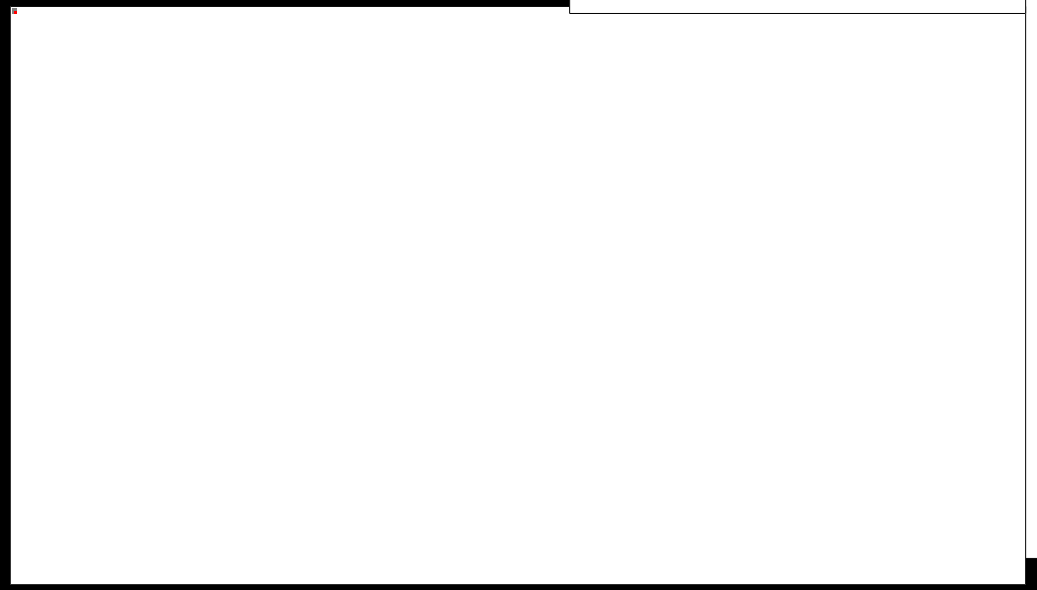
Prep for Rb82 go-live

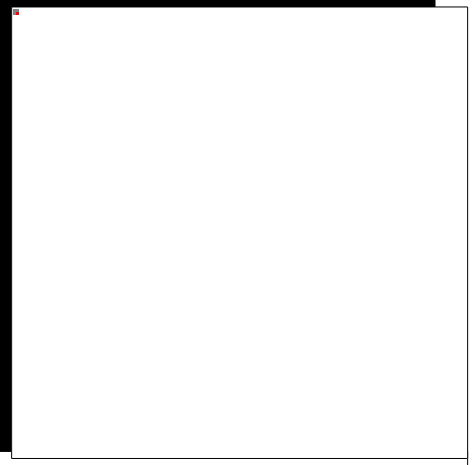
- Radiation safety review, update RAM license, storage for waste, State concerns?
- Infection control, bio-shop/clinical engineering sign off?
- Coordination with post-processing software company
- Workflow discussions
  - *Days of service*
  - *Tech responsibilities*
  - *SOP and protocol development*

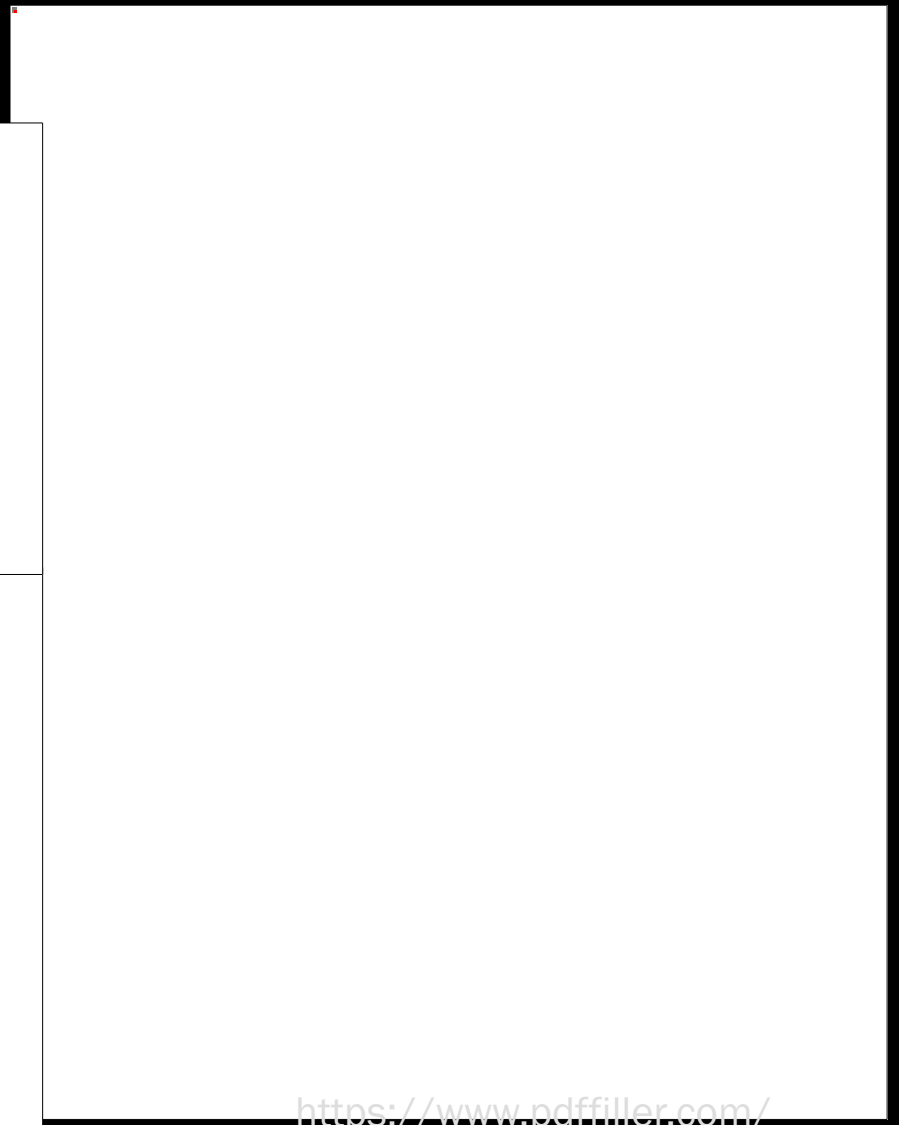
Prep for Rb82 go-live

- Delivery logistics
- Return shipping
  - *Who's responsible*
  - *DOT training*



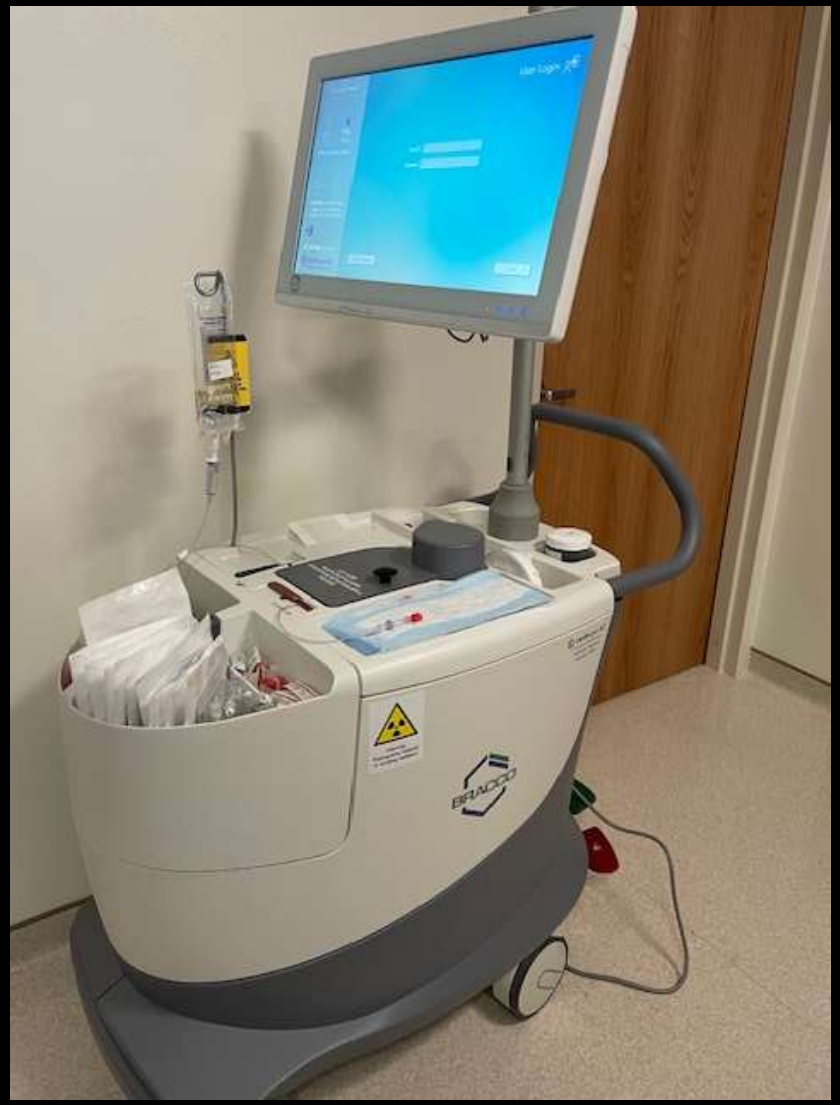






Prep for Rb82 go-live

- Training
  - *Pre-training (online)*
  - *New Start training*
  - *Return Shipment training*
  - *Annual Recertification (online)*
  - *Consider limiting number of techs trained to do removal/install of the generator*



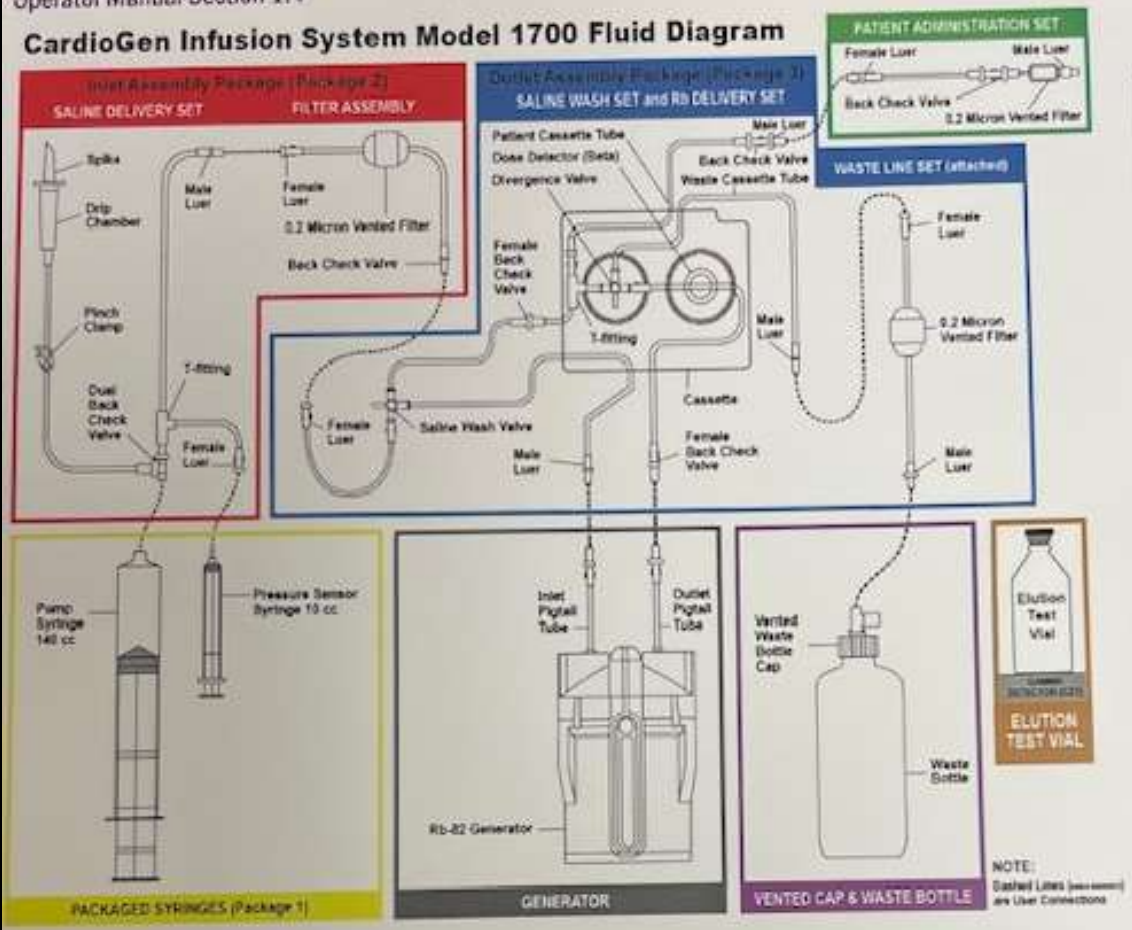
https://www.bracco.com/sites/default/files/2023-05/cardiogen-82-and-the-model-1701-infusion-system.pdf

Quick reference for CardioGen-82® Infusion System component connections and fluid path.

Operator Manual Section 1.4

CardioGen-82®
Infusion System
Fluid Diagram

CardioGen Infusion System Model 1700 Fluid Diagram



Color Key

- Packaged Syringes
- Inlet Assembly Package
- Outlet Assembly Package
- Patient Administration Set
- Waste Bottle and Waste Bottle Cap
- Generator
- Elution Test Vial

Prep for Rb82 go-live

- Planning for required QC
  - *Daily QC (≈60min)*
  - *Calibration (≈30-45min)m performed at install and at least every 14 days*

- Planning for generator removal/install (every 4, 5 or 6 weeks)
  - *Receipt of new generator (wipes, surveys, complete required paperwork, input into NM tracking system (NMIS, Syntrac, etc) (10min)*
  - *Removal – purge old system and remove tubing (20min)*
  - *Install new generator, followed by calibration and daily QC (≈2-2.5hrs)*
  - *Return shipment of old generator (wipes, surveys, complete required paperwork, document in NM tracking system, call FedEx (20min)*
  - *Run Back-Up (USB only option)*

- Annual maintenance, system verification – provided by Bracco engineer (1-2 days)

UNM Scanner Info

- Siemens Biograph Vision PET/CT scanner
  - *3.2-mm LSO crystals*
  - *51-*mm^3volumetric resolution
  - *Timing resolution = 214 picoseconds*
  - *64 slice CT*
  - *78-cm bore, 500lb weight capacity*
  - *Large FOV*

Dosing for Rb infusions

- Dosing:
  - *Cardiogen® Package insert (Rb82): "The recommended adult (70 kg) single dose of rubidium Rb 82 chloride injection is 1,480 MBq (40 mCi), with a range of 1,110 MBq to 2,220 MBq (30 mCi to 60 mCi). Do not exceed a single dose of 2,220 MBq (60 mCi) per rest or stress component of a procedure.*
  - *Consider weight based dosing, adjusting for body habitus as needed.*

Patient weight (lbs)	Rb82 Rest (mCi)	Rb82 Stress (mCi)
<250	20	20
250-299	25	25
300-349	30	30
≥ 350	35	35

  - *More sensitive cameras and/or crystals with slower decay time may require lower Rb82 doses.*
  - *Keep an eye on injection peak count rate to ensure dead time saturation won't be an issue.*

Protocol – Rest/Stress Rb82

- Patient prep
  - *same a rest/stress nuc med study*
  - *20g IV ideal (22g doable)*
  - *Access for claustrophobia*
  - *Able to lie flat, arms up, for ≈ 20min*
    - May rest arms down for 4min between imaging sessions.
    - If arms down, move generator to front of scanner, inj in hand IV if possible.

Protocol – Rest/Stress Rb82

- Imaging specs may vary depending on camera used
    1. Rest CTAC
    2. Rest Rb82 admin, immediately start rest dynamic scan (≈ 6min)
    3. ≈ 4min pause (to allow for rest dose decay, and for generator regeneration)
    4. Stress agent admin
    5. Stress Rb82 admin, immediately start stress dynamic scan (≈ 6min)
    6. Optional Stress CTAC
    7. Start reconstructions (dyn, gated, static, NAC)*
    8. Patient may leave

- Images will need to be shifted to include the PET and applied CTAC match. This allows for appropriate attenuation correction.

Protocol – Rest/Stress Rb82

UNM sample protocol:

Rest/Stress CTAC: 150mAs, 120 kV

Rest/Stress (NAC) Static – for CT/PET registration: 90s delay, 120s duration

Rest/Stress Dyn (AC): (**USE LIST MODE**) 24 frames x 5sec each, 4 frames x 60sec each

RGATE/SGATE (AC): 120s delay, 240s duration, Trigger – 8 gates

Rest/Stress Static (AC): 120s delay, 240s duration

Rest/Stress (NAC) Delay Static: Rest STATIC NAC DELAY: 120s delay, 240s duration

Reconstructions:

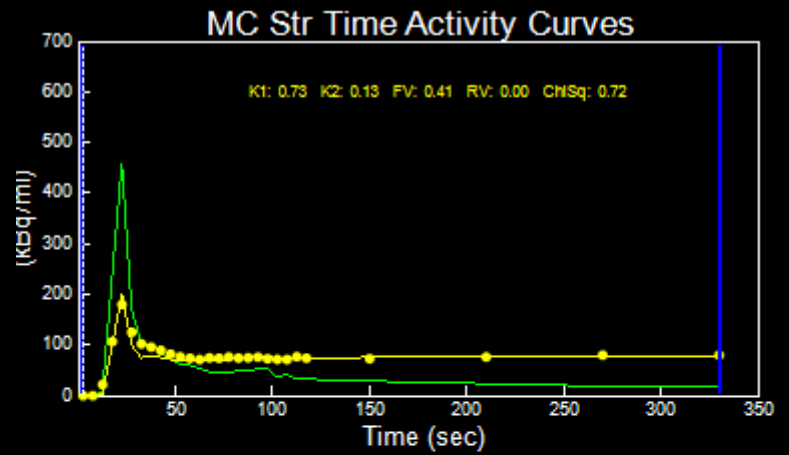
NAC STATIC	AC DYN	AC GATED	AC STATIC	NAC STATIC DELAY
Recon Method: Iterative +TOF Iterations: 4, Subsets: 5 Image Size: 220 Zoom: 2.0 Filter: Gaussian, FWHM:6.0mm Scatter Correction: None	Recon Method: Iterative +TOF Iterations: 4, Subsets: 5 Image Size: 220 Zoom: 2.0 Filter: Gaussian, FWHM:6.0mm Scatter Correction: Absolute	Recon Method: Iterative +TOF Iterations: 4, Subsets: 5 Image Size: 220 Zoom: 2.0 Filter: Gaussian, FWHM:6.0mm Scatter Correction: Absolute	Recon Method: Iterative +TOF Iterations: 4, Subsets: 5 Image Size: 220 Zoom: 2.0 Filter: Gaussian, FWHM:6.0mm Scatter Correction: Absolute	Recon Method: Iterative +TOF Iterations: 4, Subsets: 5 Image Size: 220 Zoom: 2.0 Filter: Gaussian, FWHM:6.0mm Scatter Correction: None

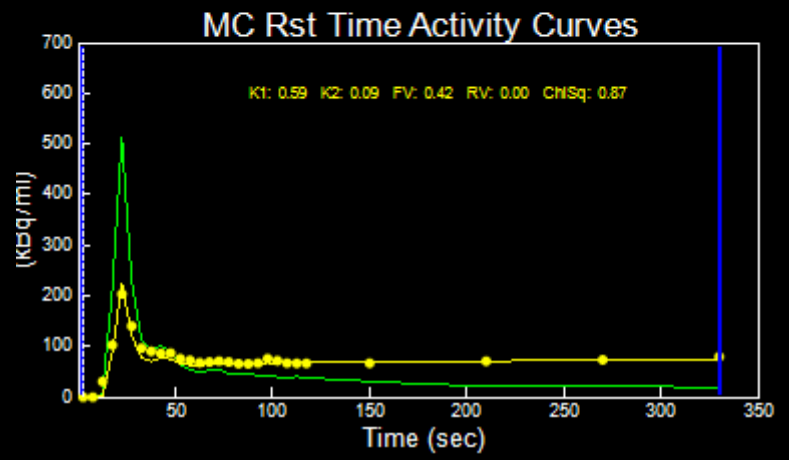
Protocol – Rest/Stress Rb82

- **Bolus infusion of Rb82** – quality of peak will affect Coronary Flow and CFR calculations
- Test IV in position arm will be in for Rb82 infusion.

Normal Values for Coronary Flow and CFR:

Rest Flow	**0.7-1.2**
Stress Flow	**≥ 2.0**
Total CFR	**≥ 2.0**





Protocol – Rest/Stress Rb8

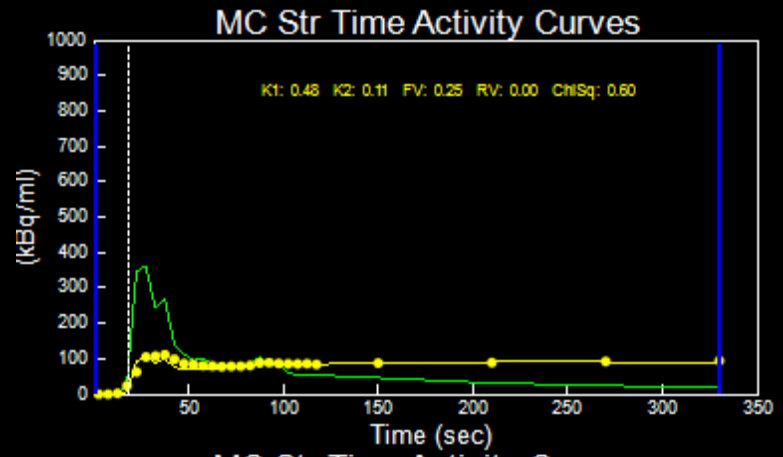
- MIP generated from AC static:
  - *Allows visualization of the quality of the radiotracer infusion.*

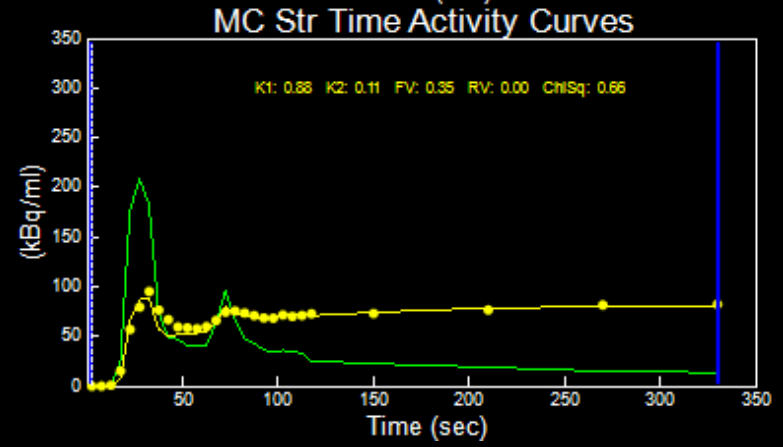
Ex: Radiotracer in right subclavian, corresponds with blunted and/or double peak on bolus. Affects coronary flow mesurements.

Similar results if BP measurement performed on arm of injection site during infusion.

Fixes:

- Raise arm against camera during Rb82 infusions.
- RN to place BP cuff on opposite arm, or at least ensure BP measurement not taken during infusion.



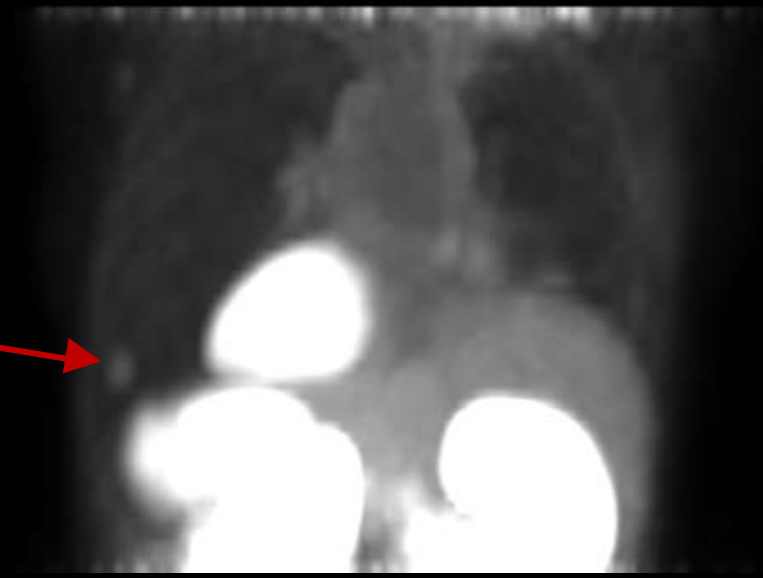


Protocol – Rest/Stress Rb82

- MIP generated from AC static:
  - *Allows visualization of abnormal radiotracer uptake*

Uptake in LUL. Later biopsy proven to be adenocarcinoma.

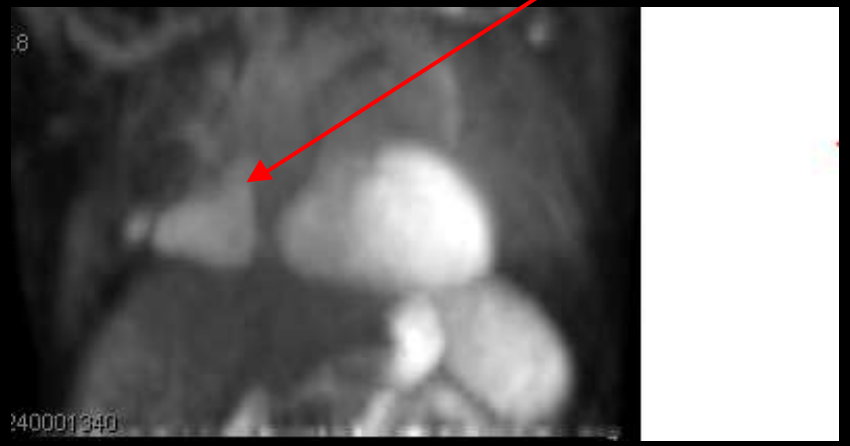
Healing rib fracture

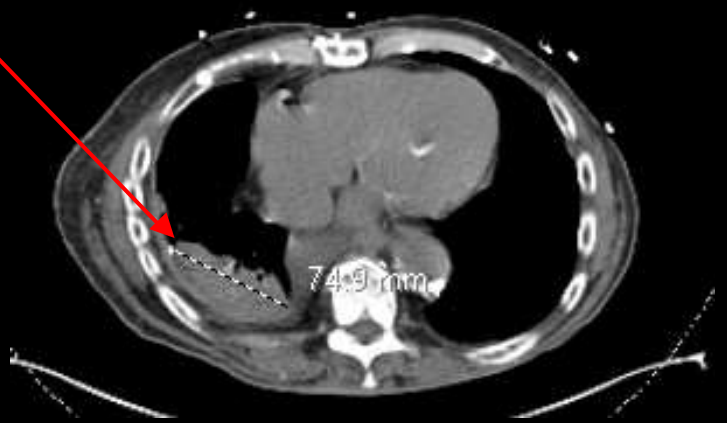


Protocol – Rest/Stress Rb82

- <u>MIP generated from AC static:</u>
  - *Allows visualization of abnormal radiotracer uptake*

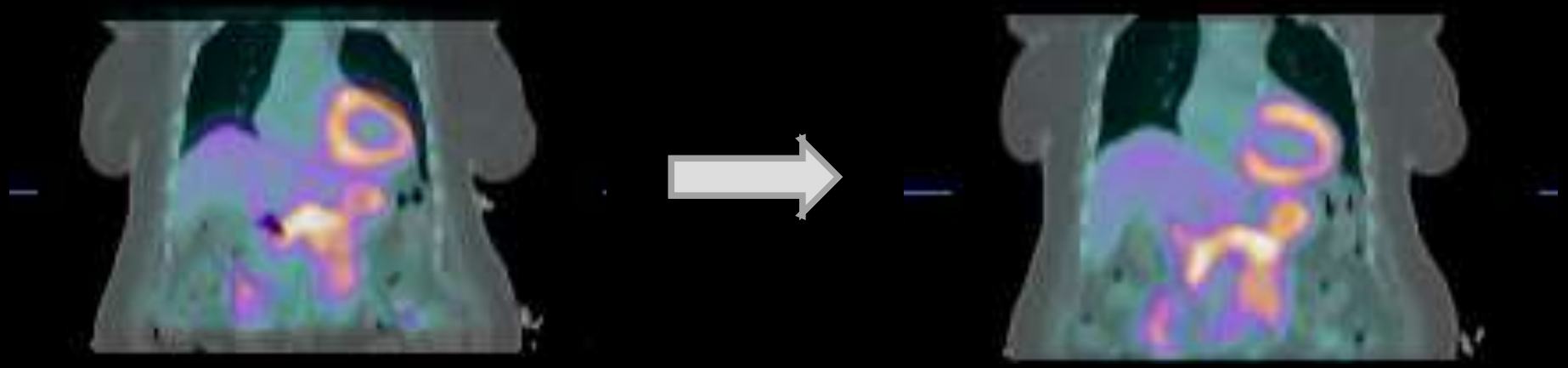
Right-sided pleural thickening and effusion and adjacent RLL pulmonary opacities. Radiotracer activity involving RLL pulmonary opacities.





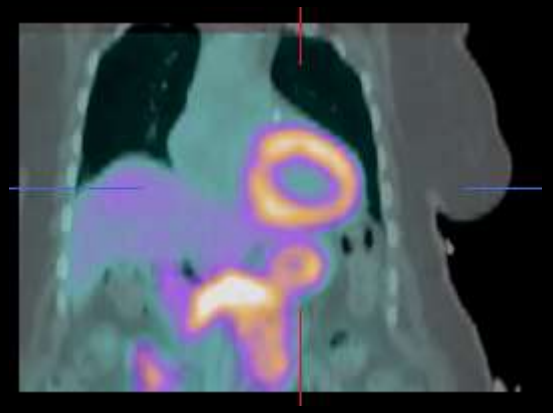
Protocol – Rest/Stress Rb82

- Shifting PET to match CTAC

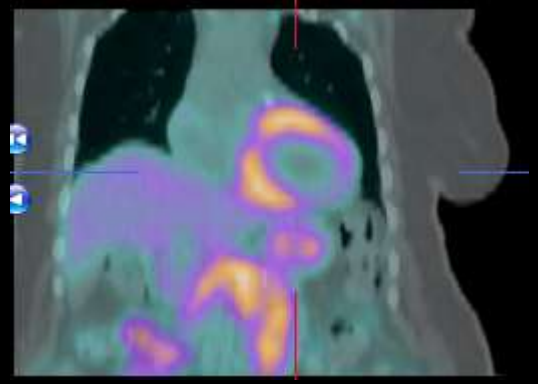


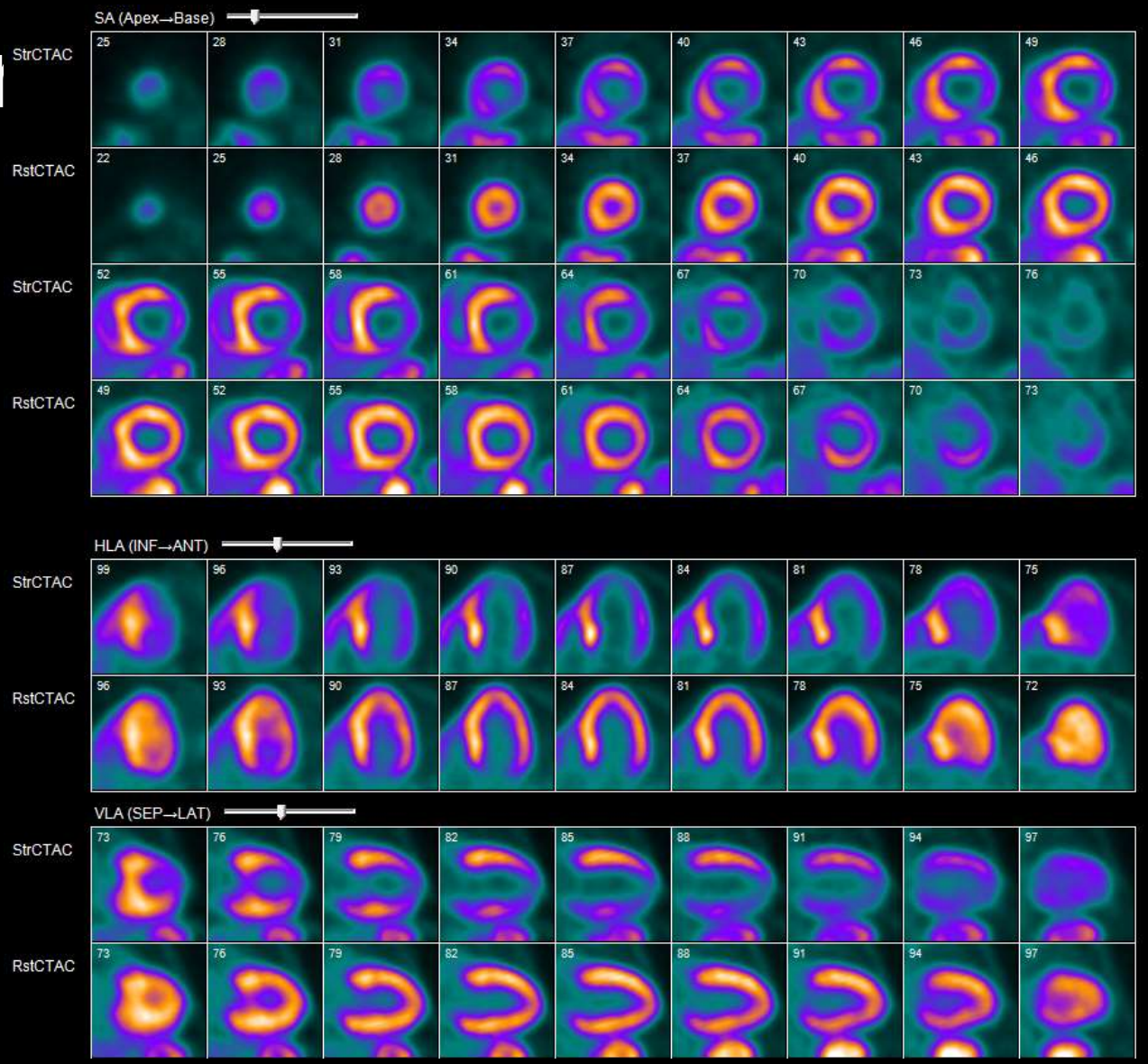
Protocol – Rest/Sti

Rest Static Fused image



Stress Static Fused image

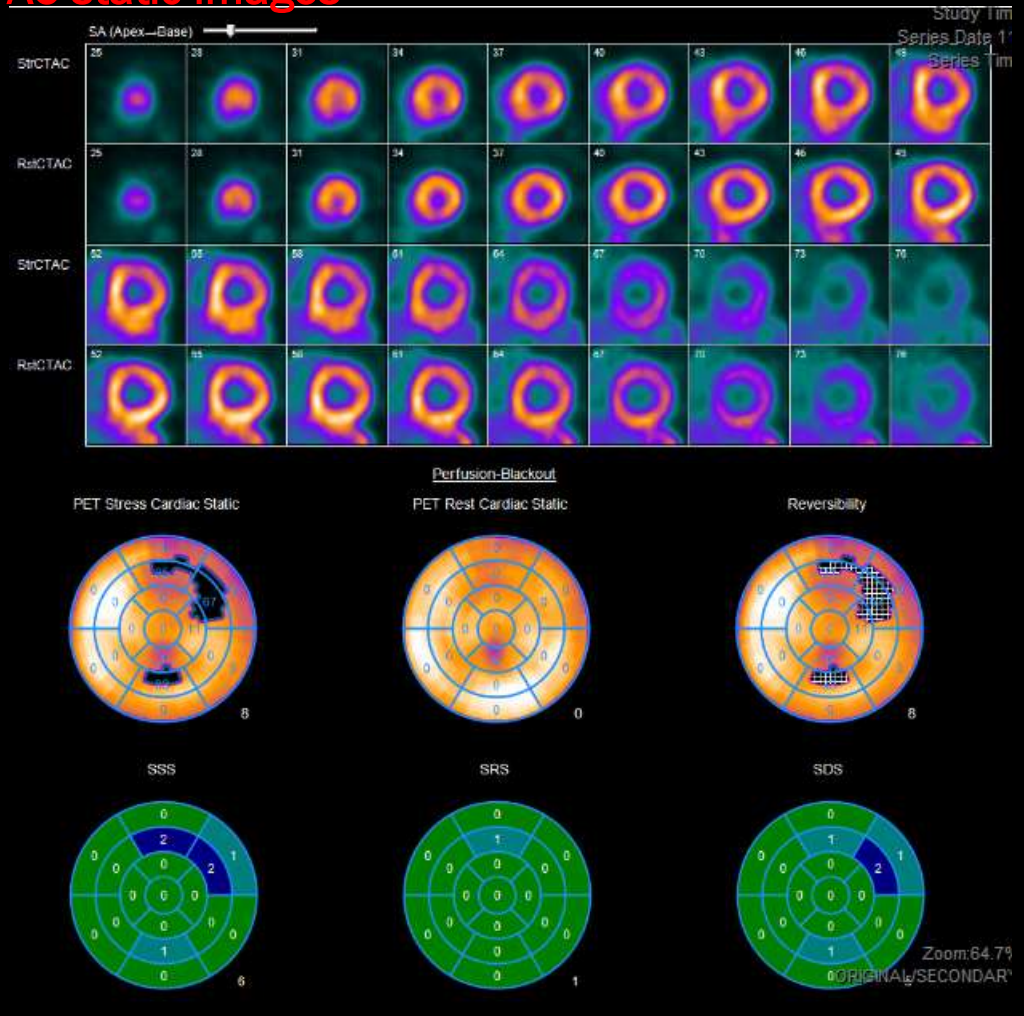




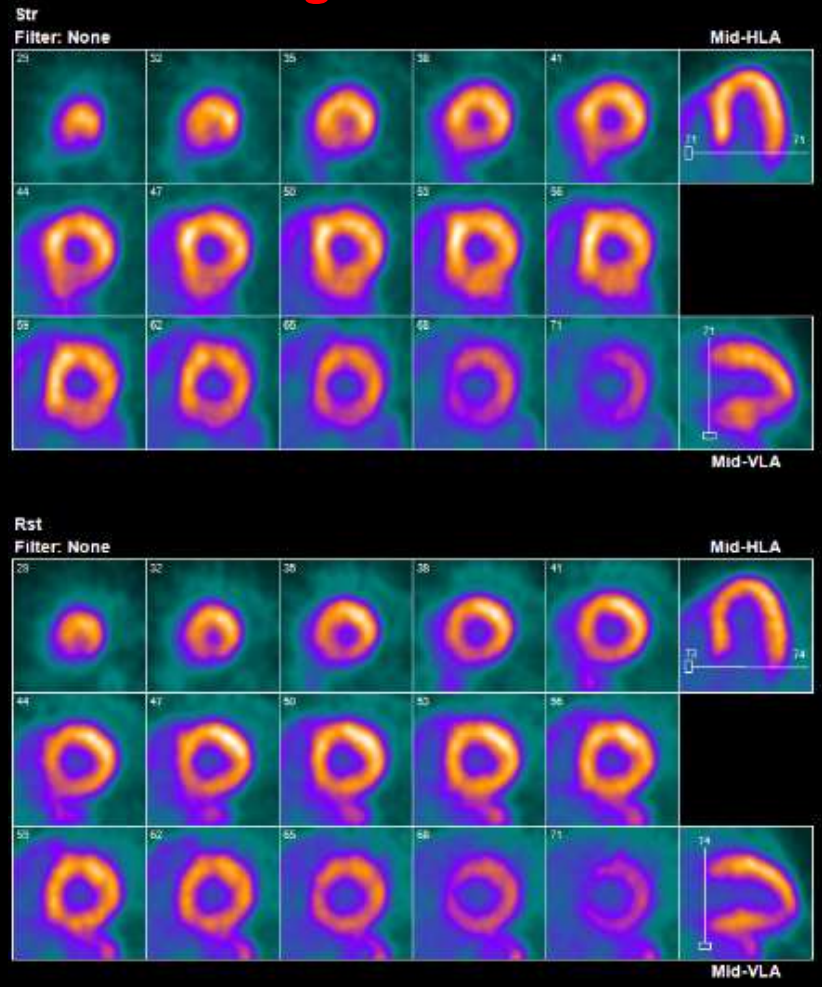
Protocol – Rest/Stress Rb82

- Importance of looking at NAC images

AC static images

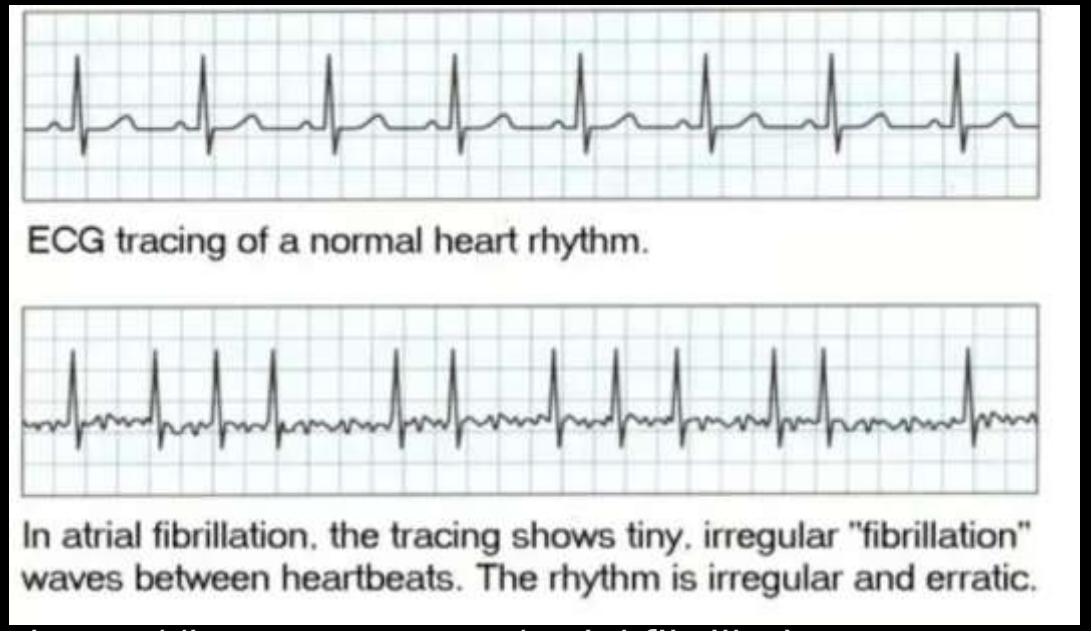


NAC static images



Protocol – Rest/Stress Rb82

- Gating/Trigger problems will likely affect EF calculations
  - *Let MD know if patient is in A-fib during scan*
  - *Let MD know of any trigger problems during the scan (ex: lead comes off during middle of scan)*



https://heart-sense.org/atrial-fibrillation

Questions?
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Join our UNM team as
Nuc Med Tech Program
Director (1.0 FTE) or
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