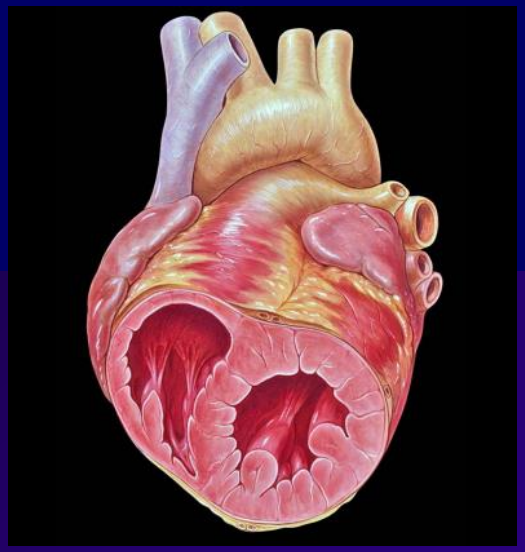
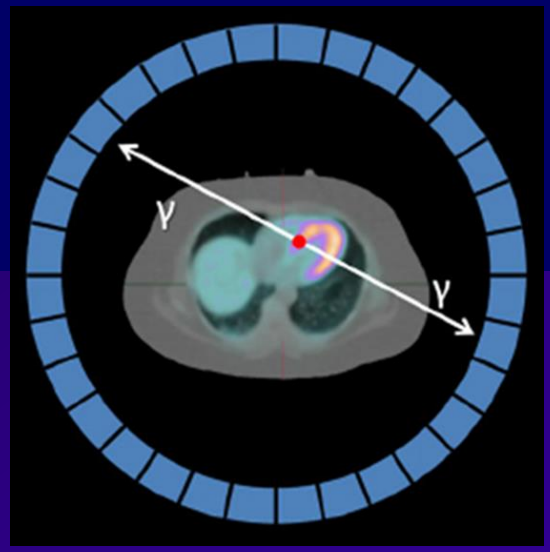
Imaging Symposium
February 23, 2019

KAISER PERMANENTE

The Basics of Cardiac Rb PET/CT





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CEDARS-SINAI
LEADING THE QUEST™

Introduction

- Patients with suspected or known CAD benefit from the information provided by a noninvasive cardiac imaging test, regarding the presence, extent, and severity of CAD.
- An important goal of imaging is to provide a high quality appropriate test for the right patient at the right time.
- These goal include effective, safe, efficient, patient-centered, equitable, and timely care.

J Nucl Cardiol 2016

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

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Clinical Indications

- ***Preferred:***

  - Patients with known or suspected CAD who meet AUC and are unable to complete a diagnostic level exercise stress imaging study

Clinical Indications

✓ ***Recommended:***

- Prior stress imaging study was poor quality, equivocal or inconclusive – attenuation artifact, or discordant with clinical impressions of other diagnostic test results
- Body characteristics (BMI >30, unusual shape, dextrocardia, pleural effusions)
- High-risk patients (kidney dz, DM, known or suspected potentially high-risk CAD)
- Young patients with established CAD
- Myocardial blood flow quantification benefits to exclude multivessel CAD, to improve risk stratification, assessment of microcirculatory function

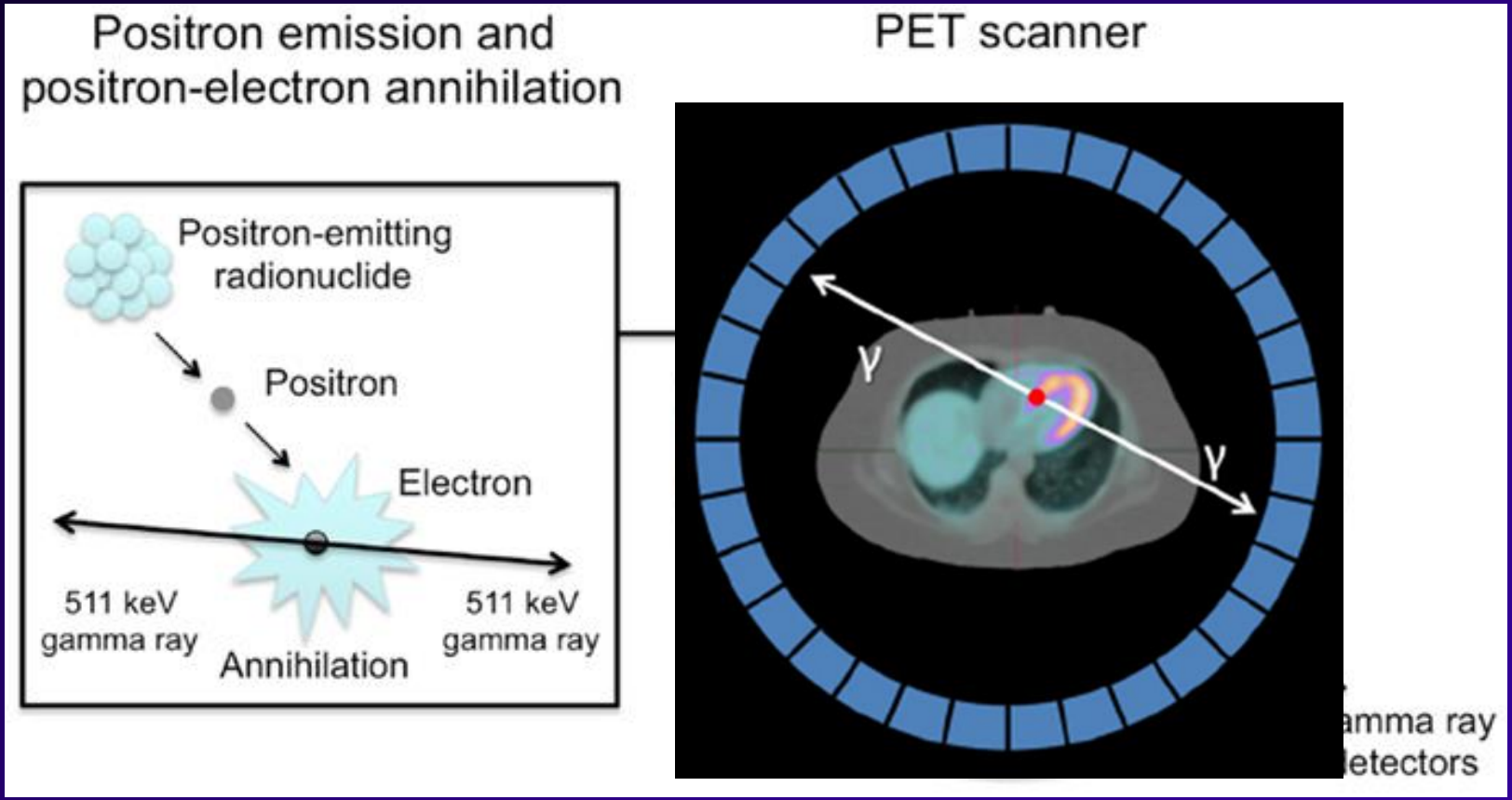
Important Properties of Myocardial Perfusion PET

1. High Diagnostic Accuracy
2. Consistent High-Quality Images
3. Low Radiation Exposure
4. Short Acquisition Protocols
5. Quantification of myocardial Blood Flow
6. Strong Prognostic Power

Course Outlines

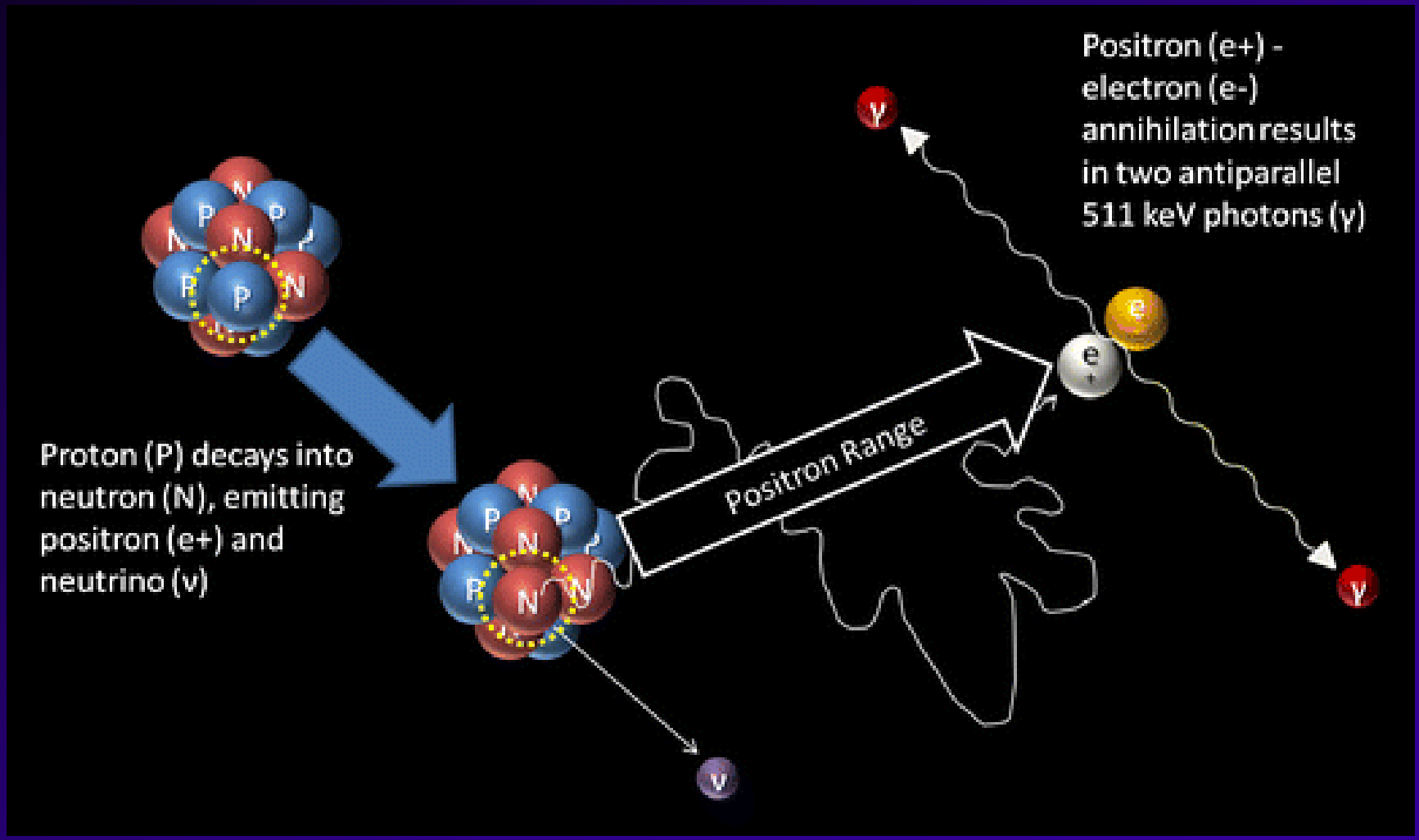
- Compare Cardiac PET Radiopharmaceutical
- Quality Control
  - Rubidium Generator
  - PET/CT Scanner
- Imaging Protocol and Artifacts

The Basics of PET Imaging



Front. Oncol., 13 August 2013

The Basics of PET Imaging

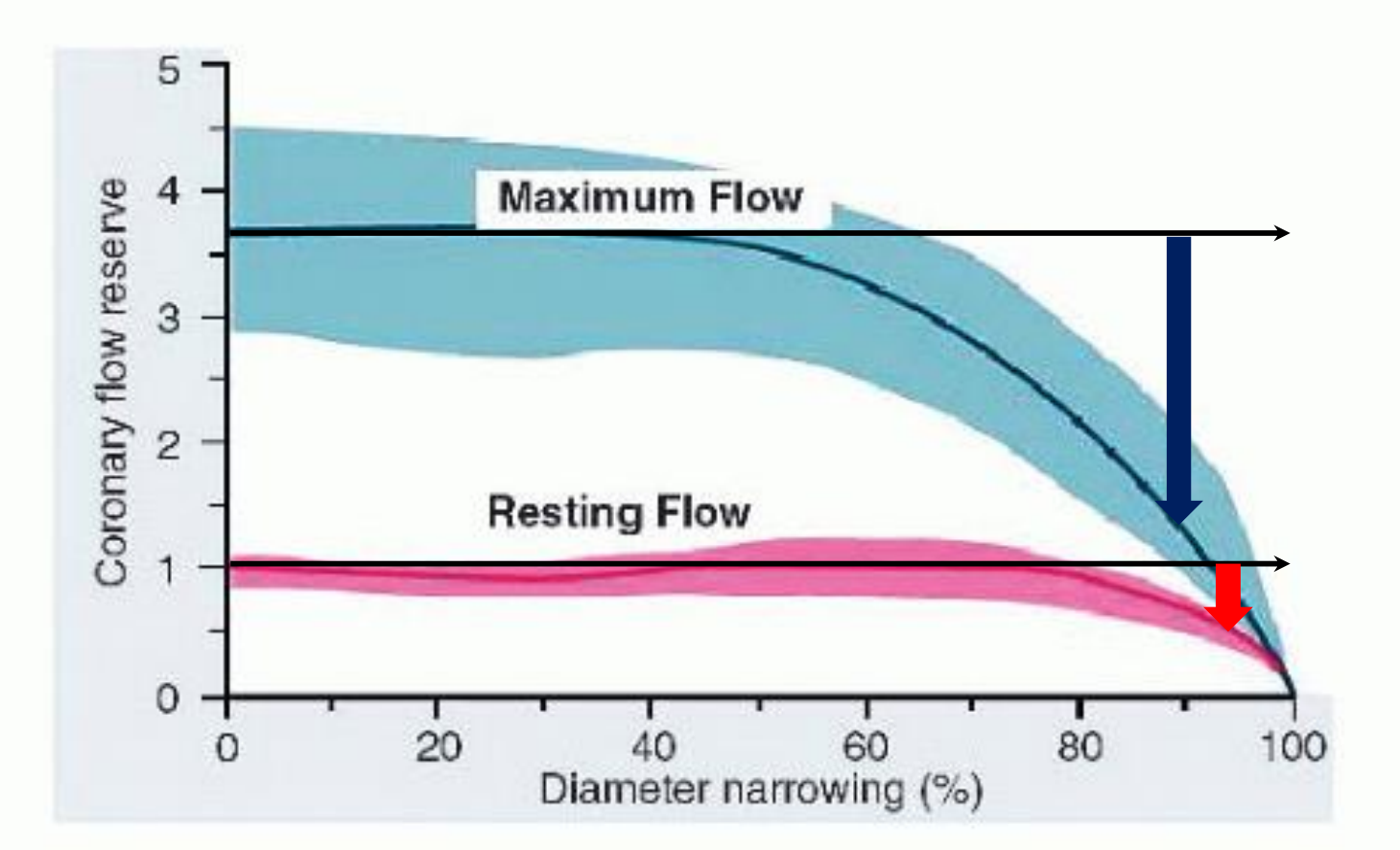


PET MPI Tracers

Property	^{82}Rb-chloride	^{13}N-ammonia	^{15}O-water	^{18}F-flurpiridaz
Isotope production method	Generator	Cyclotron	Cyclotron	Cyclotron
Isotope half-life (min)	1.27	10	2.0	110
Positron range (mm) RMS	2.6	0.57	1.0	0.23
Image resolution (mm) FWHM	8	5	6	5
Effective dose (mSv/GBq)	1	2	1	20
Peak stress/rest* extraction (%)	35/70	95/100	100	95/100
Peak stress/rest* retention (%)	25/70	50/90	0	55/90
Spillover from adjacent organs	Stomach wall	Liver and lung	Liver	Early liver
Regulatory status	FDA-approved; 2 suppliers	FDA-approved; ANDA required for onsite production	Not FDA-approved	Phase 3 trials partially completed
Typical rest dose for 3D/2D (mCi†)	30/45	10/15	20/30	2/3
Typical stress dose for 3D/2D (mCi†)	30/45	10/15	20/30	6/7
Protocol features	Rapid protocol	Permits exercise‡; delay of 4–5 half-lives between rest and stress unless different doses used	Rapid protocol; no tracer retention for routine MPI	Permits exercise‡; different doses for rest and stress required

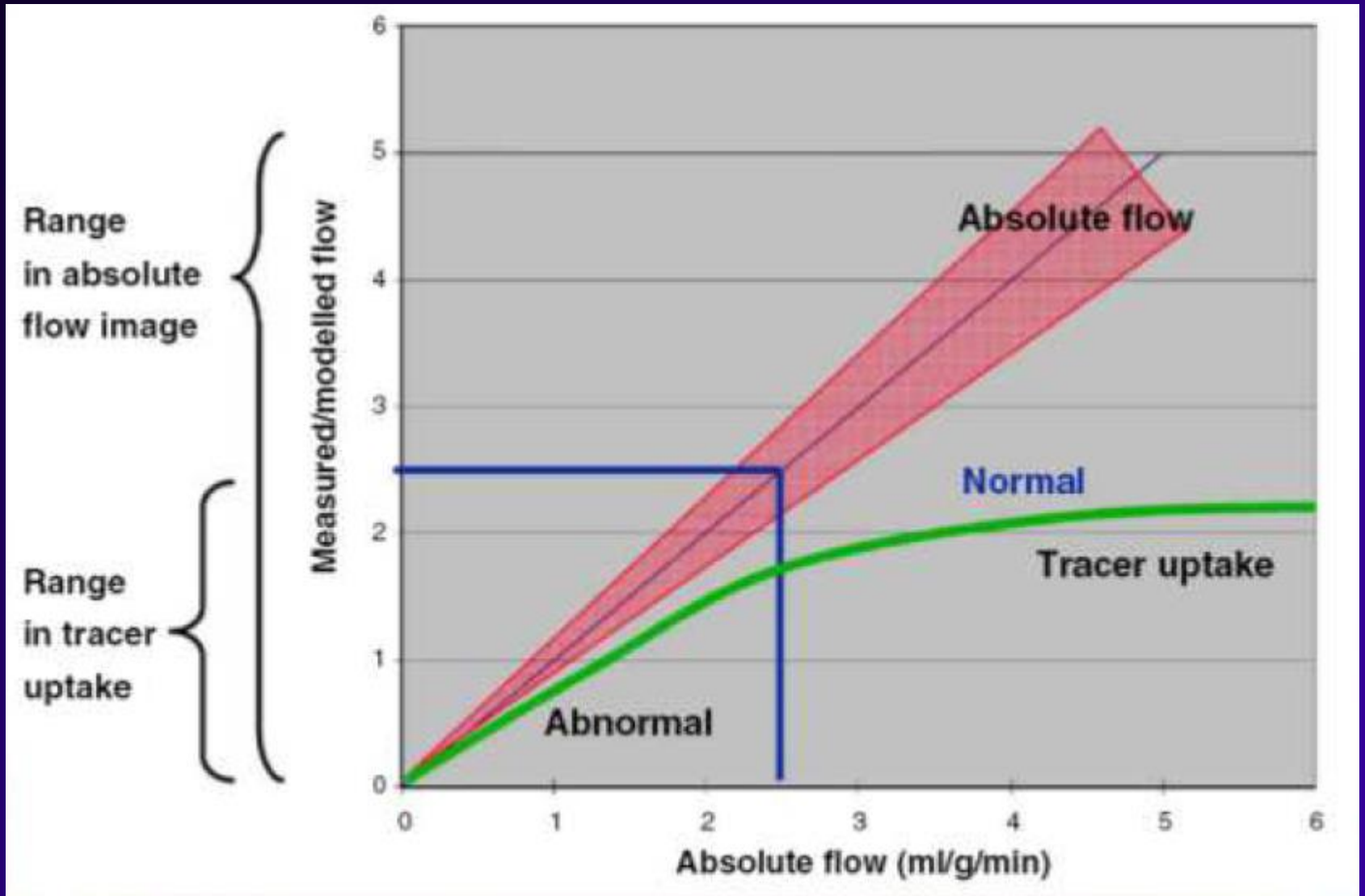
J Nucl Cardiol 2018;25:269–97.

Myocardial Blood Flow



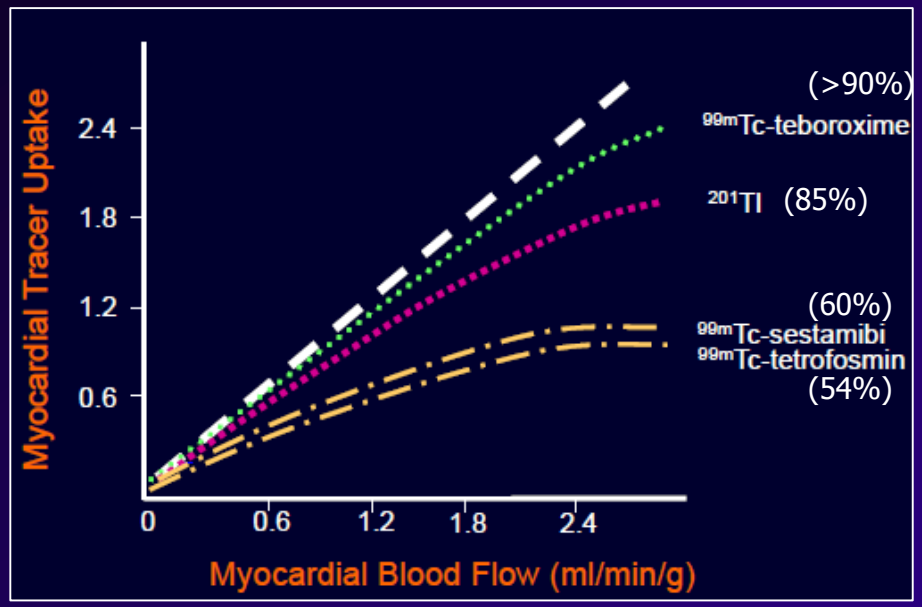
(Gould KL, *Am J Cardiol* 1974;33:87-94.)

Myocardial Flow Quantification

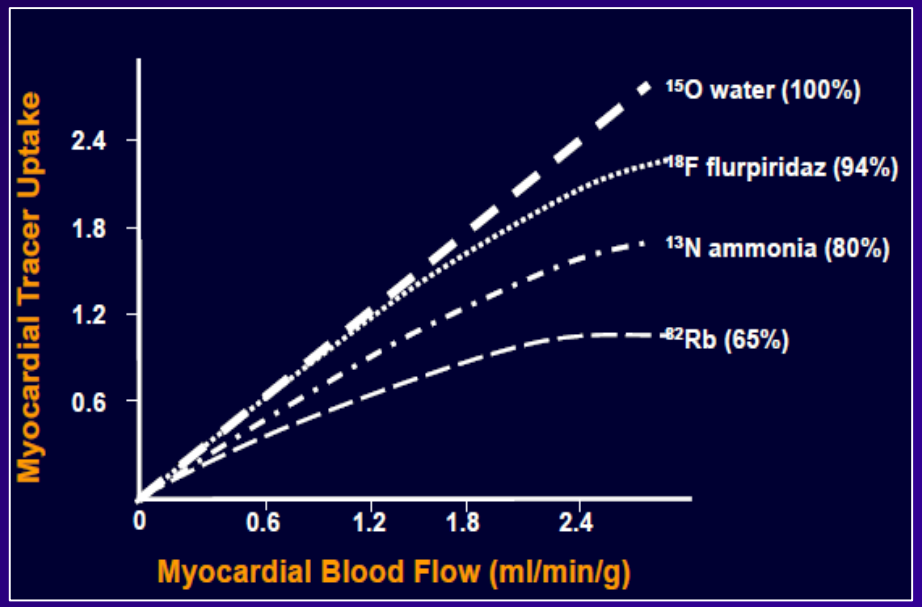


Extraction Fraction of Tracers

SPECT Tracer



PET Tracer



Higher extraction fractions:

- More accurate stress myocardial blood flow
- Greater defect resolution
- Increased cardiac counts at stress
- Decreased dose to other organs

PET Radiopharmceuticals

Radiopharm	Year of FDA Approval	Clinical Indication
F-18 Fluoride	1972	Bone imaging
Rb-82	1992	Myocardial perfusion imaging
F-18 FDG	1994	Epileptic foci
F-18 Fluoride	2000	Bone imaging
N-13 NH3	2000	Myocardial perfusion imaging
F-18 FDG	2000	Epileptic foci in brain Myocardial glucose metabolism Tumor glucose metabolism
F-18 FDG	2005	Alzheimer's disease and Fronto-temporal dementia

^{82}Rb-chloride

- Potassium analog
- Actively transported across the cell membrane by Na-K pump
- Produced from a Sr-82/Rb-82 generator and IV administered using an infusion pump
- Contains Sr-82 and Sr-85 in a hydrous stannic oxide column
  - Sr-82 T ½ =25 days (parent isotope)
  - Sr-85 T ½ = 65 days (unintended byproduct)
- The "daughter" is Rb-82 chloride (T ½ ≈ 75 sec)
- Same dose for rest and stress imaging
- On-demand availability

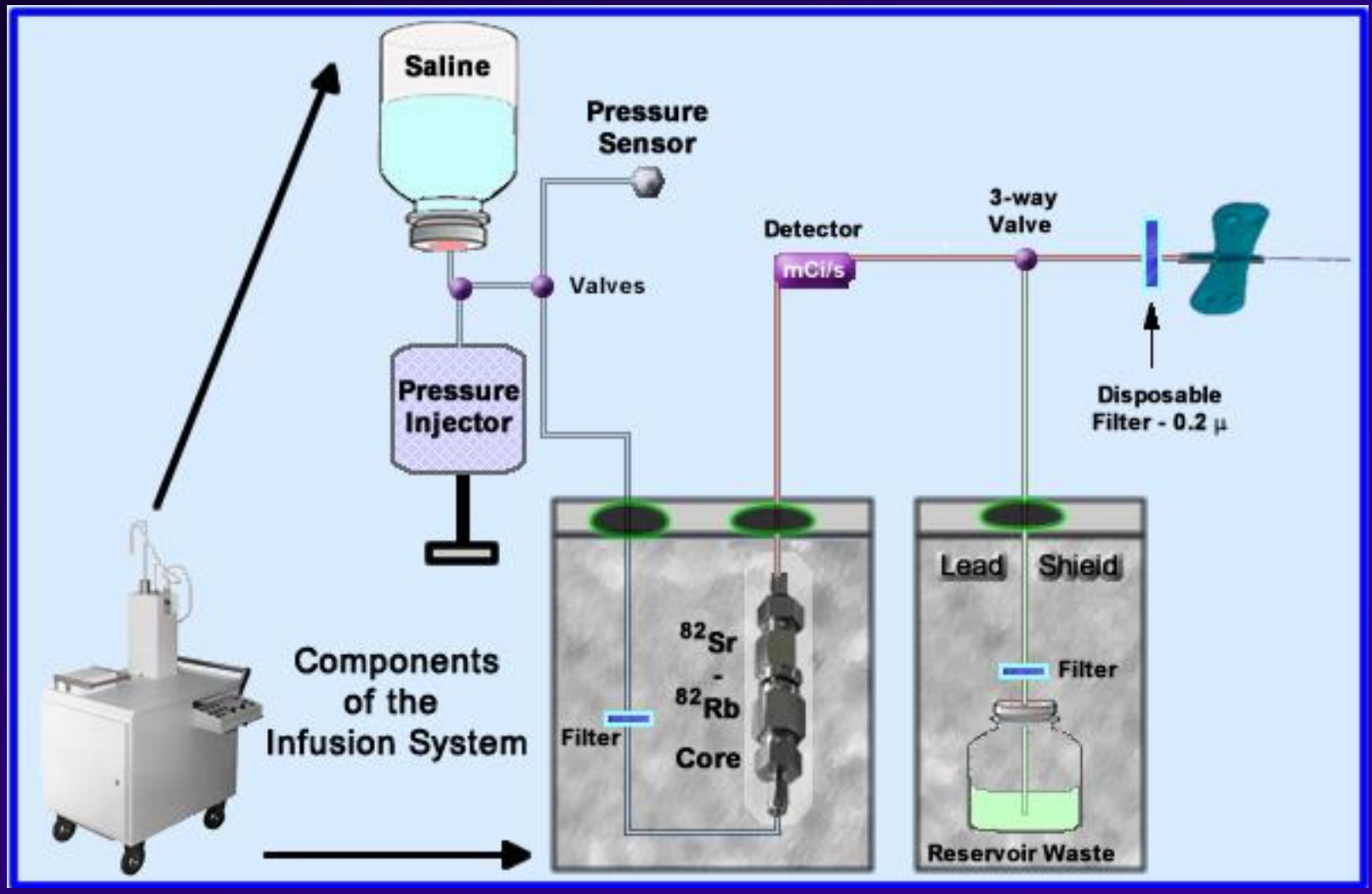
Course Outlines

- Compare Cardiac PET Radiopharmaceutical
- Quality Control
  - Rubidium Generator
  - PET/CT Scanner
- Imaging Protocol and Artifacts

CardioGen-82 Generator

- Generator sits inside a shielded container in the cart
- Automatic infusion system
- Positron detector (Dose calibrator)
- Control Panel

CardioGen-82 Infusion System

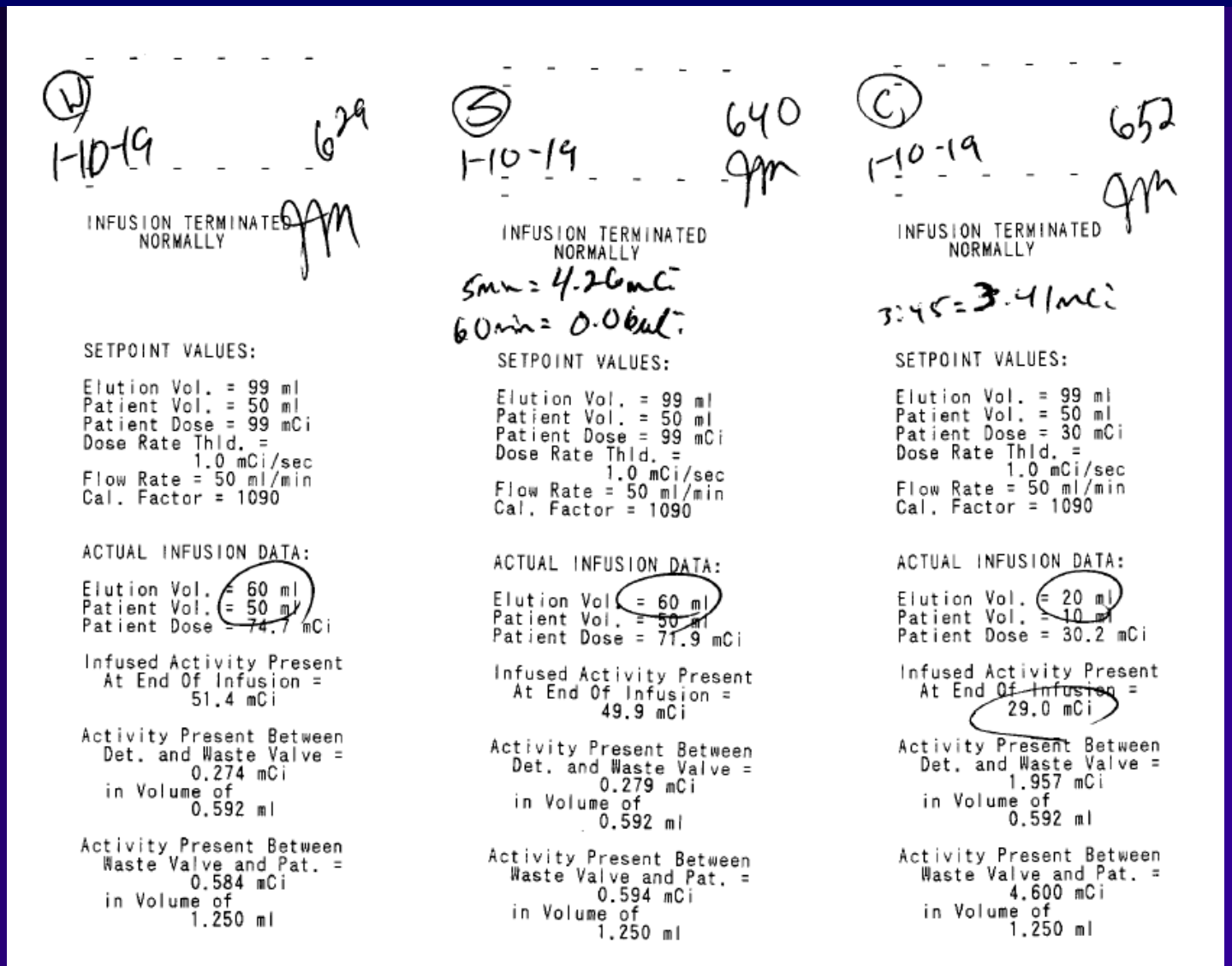


CardioGen-82 Infusion System

- *Quality Control*

1. Daily column wash
2. Rb-82, Sr-82 and Sr-85 level testing daily prior to patient administration
3. Daily Calibration

CardioGen-82 QC Records



W
1-10-19 629

INFUSION TERMINATED NORMALLY 9pm

SETPOINT VALUES:

Elution Vol. = 99 ml
Patient Vol. = 50 ml
Patient Dose = 99 mCi
Dose Rate Thld. =
1.0 mCi/sec
Flow Rate = 50 ml/min
Cal. Factor = 1090

ACTUAL INFUSION DATA:

Elution Vol. = 60 ml
Patient Vol. = 50 ml
Patient Dose = ~~74.7~~ mCi

Infused Activity Present
At End Of Infusion =
51.4 mCi

Activity Present Between
Det. and Waste Valve =
0.274 mCi
in Volume of
0.592 ml

Activity Present Between
Waste Valve and Pat. =
0.584 mCi
in Volume of
1.250 ml

S
1-10-19 640 9pm

INFUSION TERMINATED NORMALLY
5min = 4.26mCi
60min = 0.06mCi

SETPOINT VALUES:

Elution Vol. = 99 ml
Patient Vol. = 50 ml
Patient Dose = 99 mCi
Dose Rate Thld. =
1.0 mCi/sec
Flow Rate = 50 ml/min
Cal. Factor = 1090

ACTUAL INFUSION DATA:

Elution Vol. = 60 ml
Patient Vol. = 50 ml
Patient Dose = 71.9 mCi

Infused Activity Present
At End Of Infusion =
49.9 mCi

Activity Present Between
Det. and Waste Valve =
0.279 mCi
in Volume of
0.592 ml

Activity Present Between
Waste Valve and Pat. =
0.594 mCi
in Volume of
1.250 ml

C
1-10-19 652 9pm

INFUSION TERMINATED NORMALLY
3:45 = 3.41mCi

SETPOINT VALUES:

Elution Vol. = 99 ml
Patient Vol. = 50 ml
Patient Dose = 30 mCi
Dose Rate Thld. =
1.0 mCi/sec
Flow Rate = 50 ml/min
Cal. Factor = 1090

ACTUAL INFUSION DATA:

Elution Vol. = 20 ml
Patient Vol. = 10 ml
Patient Dose = 30.2 mCi

Infused Activity Present
At End Of Infusion =
29.0 mCi

Activity Present Between
Det. and Waste Valve =
1.957 mCi
in Volume of
0.592 ml

Activity Present Between
Waste Valve and Pat. =
4.600 mCi
in Volume of
1.250 ml

CardioGen-82 Label

- *Alert Limits*
  - Sr-82 level exceeds 0.002 µCi Sr-82/mCi Rb-82, or
  - Sr-85 level exceeds 0.02 µCi Sr-85/mCi Rb-82, or
  - A total elution volume of 14 L has passed through the generator column

- *Expiration Limits*
  - Sr-82 level exceeds 0.01 µCi Sr-82/mCi Rb-82, or
  - Sr-85 level exceeds 0.1 µCi Sr-85/mCi Rb-82, or
  - A total elution volume of 17 L has passed through the generator column, or
  - 42 days post calibration date

Worksheets

Generator Data	
Generator Lot #:	09101-181381
Generator Calibration Date:	5/20/2018

Previous Day Cumulative Generator Elution Volume (mL) 3899
(Enter information from the previous day's worksheet)
(If first day of use, Enter 0)

Note: Please record the "Elution Volume" value taken from the "Actual Infusion Data" section of the Infusion System Report Print Out for every entry

Daily Quality Control (QC) Elution Volume Readings from Infusion Print-Out (mL)

BRACCO

Cardiogen-82®

Cardiogen-82®
(Rubidium Rb 82 Generator)

Site Name CSMC **Reviewed by site signature:** _____

Calibration Worksheet

BRACCO
LIFE FROM INSIDE

Decay Factors		
Decay Time		Factor
2 min 30 Sec	2:30	4
3 min 45 sec	3:45	8
5 min	5:00	16

Generator Data	
Generator Lot #	09101-190041
Calibration Date	1/4/2019

CALIBRATION SHOULD ALWAYS BE DONE AT THE SAME PATIENT DOSE SETTINGS AS WILL BE USED FOR PATIENT INFUSIONS.
The first elution of the day must be discarded in accordance with site specific procedures before starting quality control procedures. Calibration is performed using the standard patient dose parameters. Refer to Rb-82 Infusion System-Calibration Data Sheet in the Infusion System User Guide for instructions

A	B	C*	D	E	F	G*	H**	I	J	K	L	M
Calibration Infusion Date and Time	Dose Reading from Dose Calibrator (mCi)	Decay Time	Decay Corrected Dose(mCi) (B x Decay Factor)	Printed Activity at End of Infusion (mCi)	Ratio D to E (D / E)	Calib +/- 5%? F= 0.95 - 1.05	Calib +/- 10%? F= 0.90 - 1.10	Is this the first calibration of the new generator?	Current Calib Factor	New Calib Factor (F x J) or (J)	Comments	Operator Initials
Ex: 9/28/05: 8:00am	6.07	3:45	48.56	57.2	0.85	NO	NO	Yes	1000	850		KM
Ex: 9/28/05: 8:15am	6.86	3:45	54.88	55.7	0.985	YES	YES	Yes	850	850		KM
1/16/19 0630am	3.56	3:45	28.48	28.9	0.985	YES	YES	No	1090	1090		JSF
1/17/19 0640am	3.63	3:45	29.04	28.7	1.012	YES	YES	No	1090	1090		JSF
									1090	Complete I, G, H		
									Complete I, G, H	Complete I, G, H		

On-Line Data Trak

End of Day

End of Day

Total Elution Volume from Patient Doses (mL):	124
Total Number of Patients Dosed on this Day:	3
Cumulative Daily Volume (mL):	269
Cumulative Volume for this Generator (L):	5.061
Was this the last usage of generator?	☐ Yes ☑ **No**
If Yes, Date of Last Use (DD/MMM/YYYY):	

When any of the Threshold criteria are met, additional Sr-82/Sr-85 levels must be performed after every 750 mL of eluate volume that passe

- **The ratio of Sr-82 reaches 0.002 µCi / mCi Rb-82**
- **The ratio of Sr-85 reaches 0.02 µCi / mCi Rb-82**
- **Cumulative volume of the generator reaches 14 Liters**

When any of the Expiry criteria are met, the generator has expired and use of the generator should stop immediately. Expiry criteria are me

- **The ratio of Sr-82 reaches 0.01 µCi / mCi Rb-82**
- **The ratio of Sr-85 reaches 0.1 µCi / mCi Rb-82**
- **Cumulative volume of the generator reaches 17 Liters**
- **43 days of use post generator calibration date has occurred**

RUBY-FILL Generator

Advancing cardiac PET imaging to be:

Precise	Constant-activity infusion option Maintains consistent activity rate profiles throughout the life cycle of the generator[1-3]
Flexible	Accurate patient-specific dosing Long shelf life—60 days
Efficient	Automated daily quality control Built-in safety controls

RUBY-FILL PI

Determine Rb 82, Sr 82, Sr 85 in the generator eluate:

- Once a day, prior to any drug administration, and
- At additional daily tests after detection of an Alert Limit.
  - 20 L for the generator's cumulative eluate volume, or
  - An eluate Sr 82 level of 0.004 µCi/ mCi (kBq/MBq) Rb 82, or
  - An eluate Sr 85 level of 0.04 µCi/ mCi (kBq/MBq) Rb 82.
- Perform additional daily tests every 4 patients after detection of an alert limit

Stop use of a generator at any of the following Expiration Limits.

- 30 L for the generator's cumulative eluate volume, or
- Expiration date of the generator (60 days post-manufacturing)
- An eluate Sr 82 level of 0.01 µCi /mCi (kBq/MBq) Rb 82, or
- An eluate Sr 85 level of 0.1 µCi /mCi (kBq/MBq) Rb 82

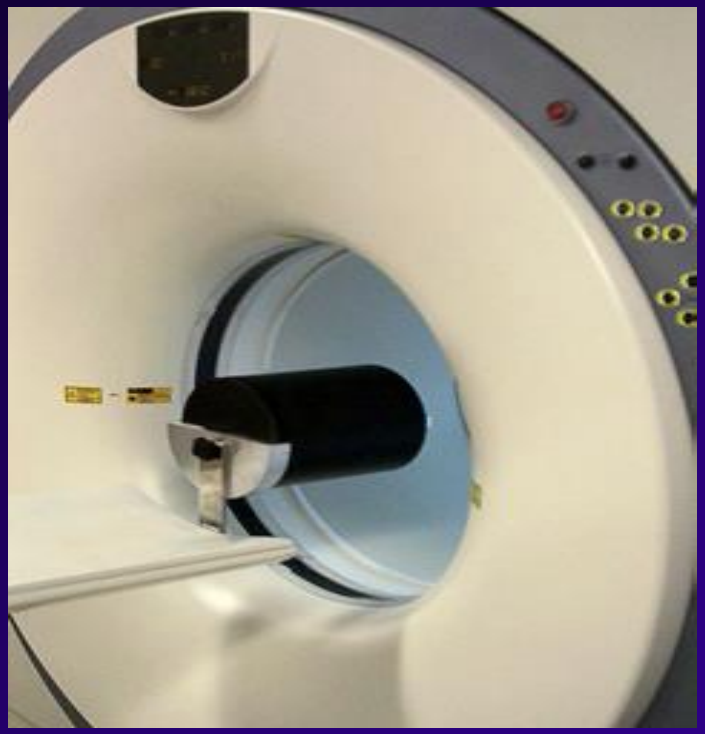
Comparison of Limits: CardioGen-82® vs RUBY-FILL®

Limit	Volume (liters)	^{82}Sr Breakthrough (mCi/mCi ^{82}Rb)	^{85}Sr Breakthrough (mCi/mCi ^{82}Rb)	Time (days)
RUBY-FILL				
Alert	20	0.004	0.04	
Expiratory	30	0.01	0.1	60
CardioGen-82				
Alert	14	0.002	0.02	
Expiratory	17	0.01	0.1	42

Course Outlines

- Compare Cardiac PET Radiopharmaceutical
- Quality Control
  - Rubidium Generator
  - PET/CT Scanner
- Imaging Protocol and Artifacts

PET/CT QC



Ge-68 Source

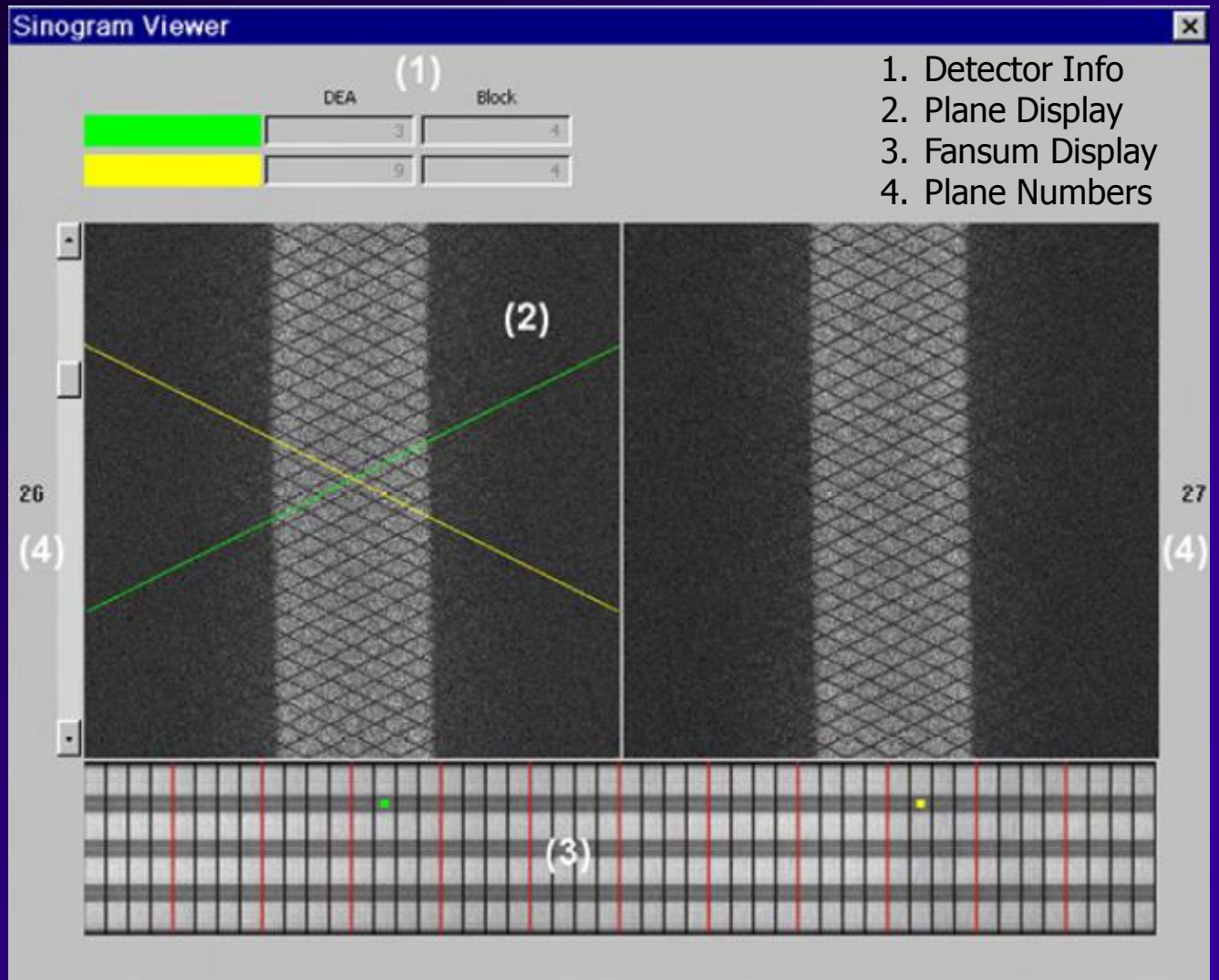
CT Phantom

Dedicated PET QC Procedures

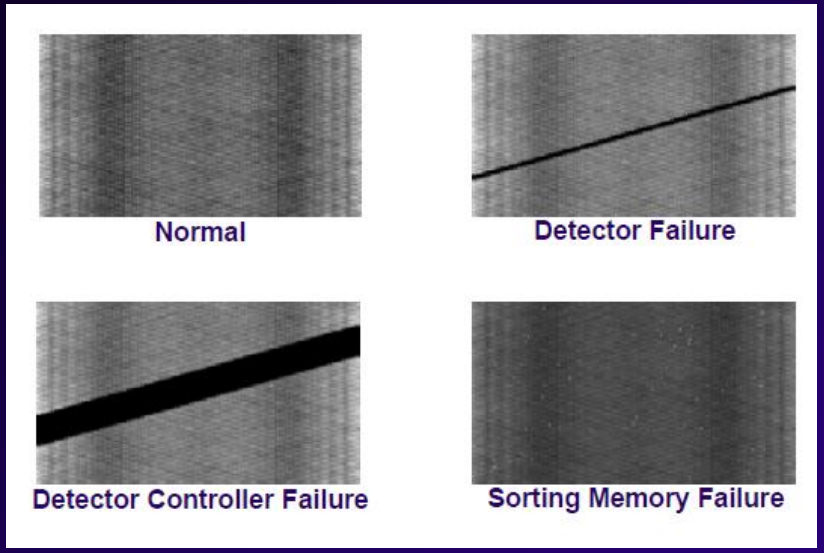
Procedure	Frequency
Acceptance testing (NU 2-2012)[5]	Once upon delivery and upon major hardware upgrades
Daily QC, as recommended by vendor (attenuation blank scan, phantom scan, etc.)	Daily
Sensitivity and overall system performance	Weekly preferred (or at least monthly)
Accuracy (corrections for count losses and randoms)	At least annually
Scatter fraction	At least annually
Accuracy of attenuation correction	At least annually
Image quality	At least annually
Measurements specified by the manufacturer	As per the manufacturer

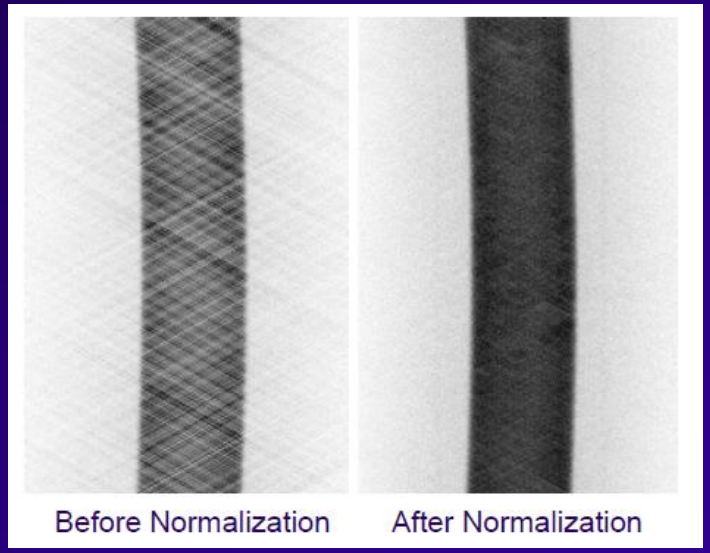
ASNC Imaging Guidelines

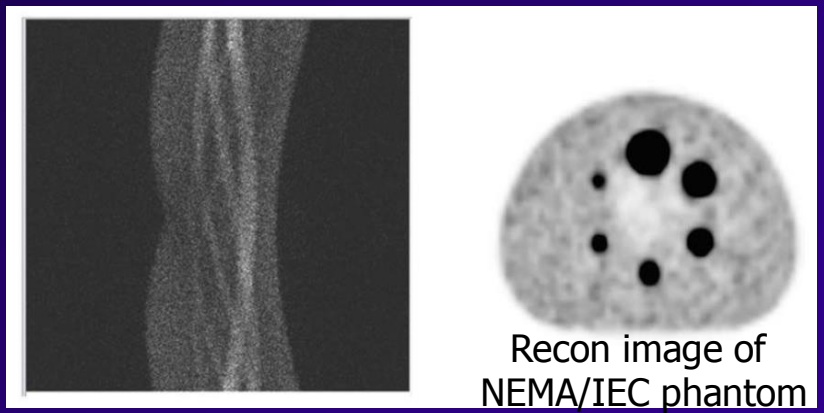
PET QC: Sinogram



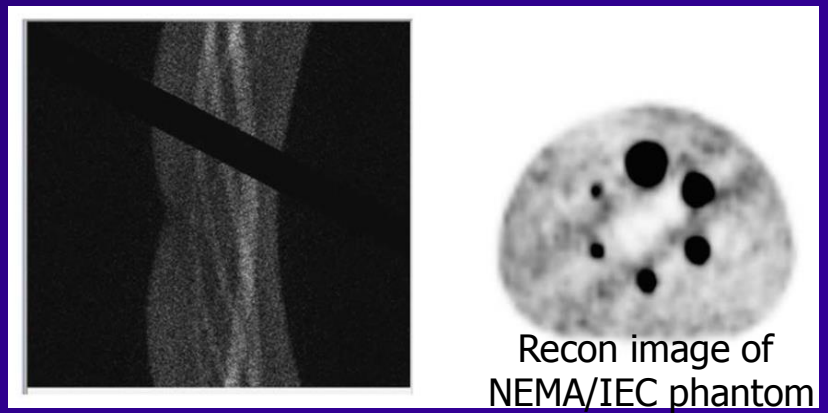
PET QC: Normalization







Normal Sinogram



Non-operational Detector Blocks

PET QC Report

Phantom Parameters	
Isotope	Ge-68
Assay Activity	2.305382 [mCi]
Assay Date and Time	Thursday, September 17, 2015; 7:37:00
Volume	8407 [cc]
Calibration Factor	1.030000

Input for Computation	
Daily Sinogram location	\\PETACS\sinograms\CTIEMSINO_2_1_4.0.251570314.s
Proposed ECF Value	3.173e+007 [Bq*s/ECAT counts]
Last Partial Setup	Monday, August 01, 2016; 7:54:32
Last Partial Setup Completion State	setup succeeded
Last Full Setup	Monday, July 11, 2016; 7:55:21
Last Full Setup Completion State	setup succeeded
Partial setup enabled	true
Full setup enabled	false
Time Alignment enabled	false
ICS Name	CT58031
SW Version	PETsyngo_6.7.2 0381.02
Gantry Type	1094

Results	
System Quality Results	Passed
QC Phantom Activity	Passed
QC succesfully completed. All values are within valid ranges.	
QC Phantom has remaining activity greater than 0.5 mCi.	

Detailed System Quality Report

Item	Upper Bound	Lower Bound	Value	Decision
Block Noise	3 [crystal]	0 [crystal]	0 [Block_Outside_Range]	Passed
Block Efficiency	120 [%]	80 [%]	0 [Block_Outside_Range]	Passed
Measured Randoms	115 [%]	85 [%]	103.1 [%]	Passed
Scanner Efficiency	42.38 [cps/Bq/cc]	22.82 [cps/Bq/cc]	33.9 [cps/Bq/cc]	Passed
Scatter Ratio	36.3 [%]	29.7 [%]	32.8 [%]	Passed
Scanner efficiency correction factor (ECF)	4e+007 [Bq*s/ECAT counts]	2e+007 [Bq*s/ECAT counts]	3.173e+007 [Bq*s/ECAT counts]	Passed
Image Plane Efficiency	5 [%]	-5 [%]	0 Planes out of range	Passed

Combined PET/CT QC Procedures

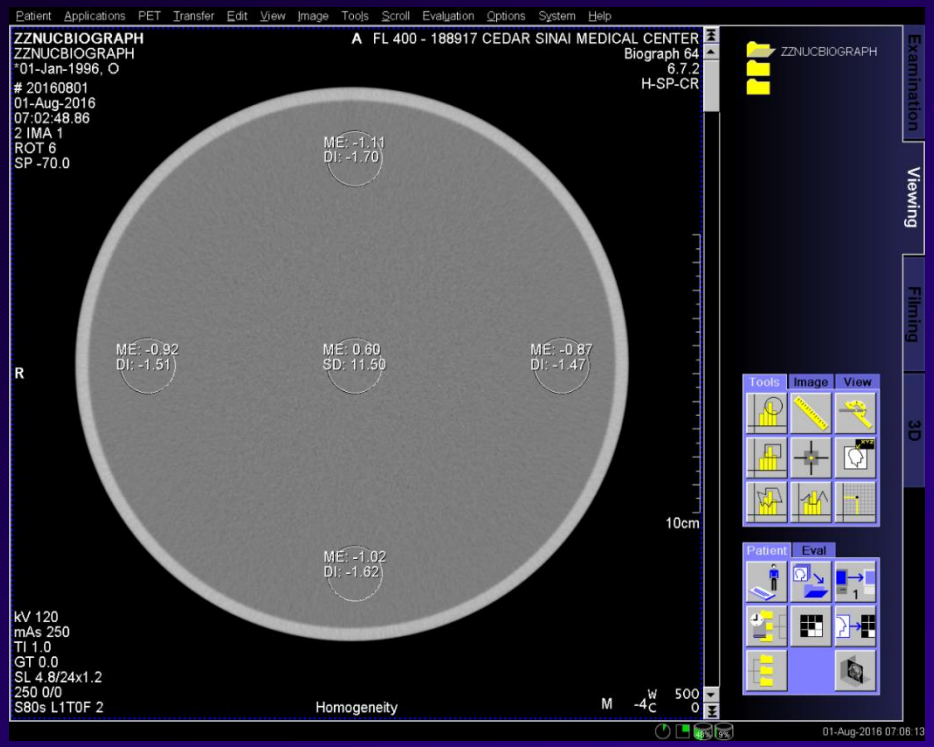
Test	Requirement	Frequency
Calibration	Mandatory	Monthly*
Field uniformity	Mandatory	Monthly*
*or as recommended by the manufacturer		

Test	Frequency
Water phantom QA	Daily
Tube warm-up	Daily
Air calibration ("fast QA)	Daily
Water phantom checks: slice thickness, accuracy, positioning	Monthly

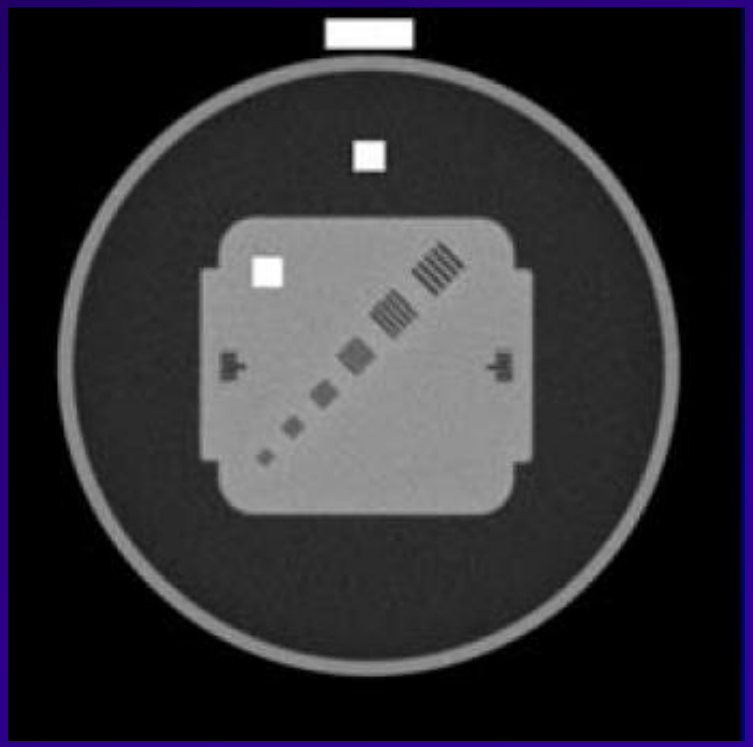
Test	Requirement
Registration	Mandatory
Attenuation correction accuracy	Mandatory

ASNC Imaging Guidelines

CT QC



Noise & Uniformity



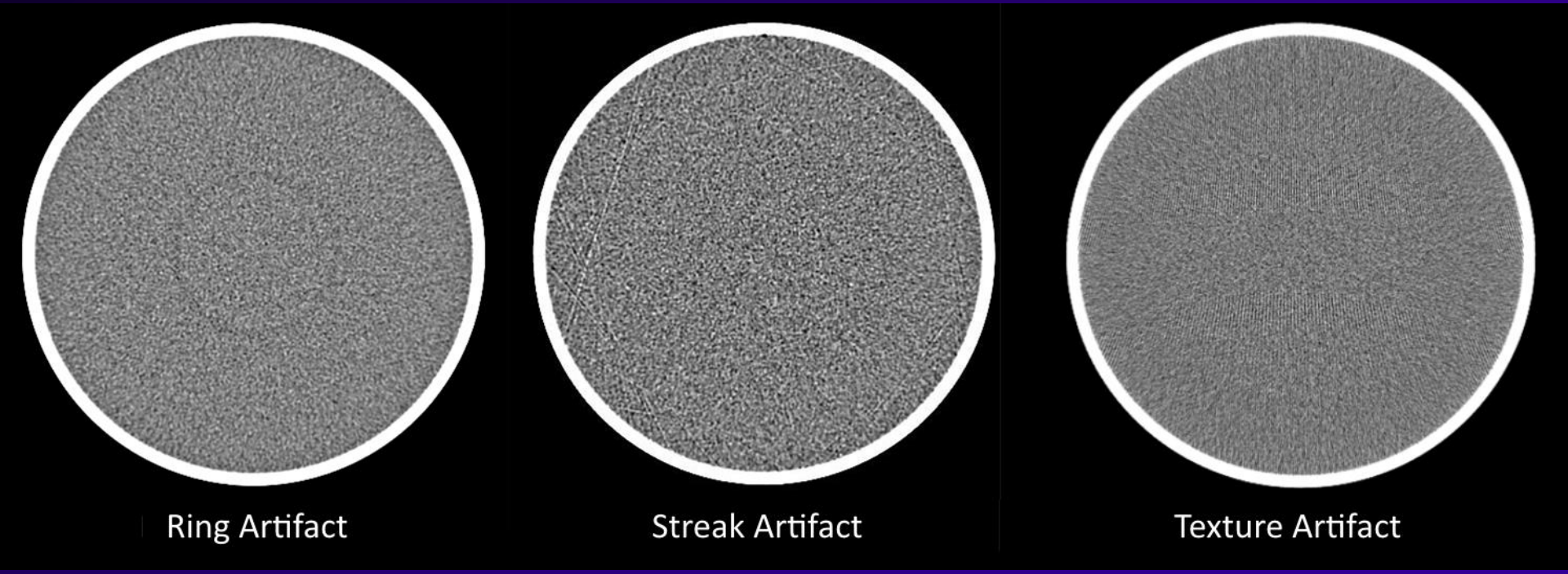
Linearity

CT QC Record

Taper Biograph Quality Assurance Record - Technologist Daily, Weekly and Monthly Checks

DATE	UNIT STATUS	ARTIFACTS			DAILY CT # CHECK								WEEKLY SMPTE CHECK				TECH INITIALS
6/1/2018	(select)	Free of Artifacts	PASS / FAIL	If OK, proceed	Scan Type	Center CT#	Center StdDev	Top CT#	Right CT#	Bottom CT#	Left CT#	Water CT # Uniformity	PASS / FAIL	5% Visible	95% Visible	No Aliasing	PASS / FAIL	
6/1/2018	OPEN	Y	PASS		Axial	-1.40	5.31	-1.77	-1.39	-1.45	-1.87	0.47	PASS					JB
6/2/2018	CLOSED																	
6/3/2018	CLOSED																	
6/4/2018	OPEN	Y	PASS		Axial	-1.43	5.39	-1.39	-1.33	-1.37	-1.50	-0.10	PASS	Y	Y	Y	PASS	JB
6/5/2018	OPEN	Y	PASS		Axial	-1.01	5.44	-1.83	-1.79	-1.90	-2.02	1.01	PASS					JB
6/6/2018	OPEN	Y	PASS		Axial	-1.46	5.33	-1.47	-1.27	-1.52	-1.54	-0.19	PASS					JB
6/7/2018	OPEN	Y	PASS		Axial	-1.66	5.38	-1.15	-1.05	-1.26	-1.71	-0.61	PASS					JN
6/8/2018	OPEN				Axial													
6/9/2018	CLOSED																	
6/10/2018	CLOSED																	
6/11/2018	OPEN				Axial													
6/12/2018	OPEN				Axial													
6/13/2018	OPEN				Axial													
6/14/2018	OPEN				Axial													
6/15/2018	OPEN				Axial													
6/16/2018	CLOSED																	
6/17/2018	CLOSED																	
6/18/2018	OPEN				Axial													
6/19/2018	OPEN				Axial													
6/20/2018	OPEN				Axial													
6/21/2018	OPEN				Axial													
6/22/2018	OPEN				Axial													
6/23/2018	CLOSED																	
6/24/2018	CLOSED																	
6/25/2018	OPEN				Axial													
6/26/2018	OPEN				Axial													
6/27/2018	OPEN				Axial													
6/28/2018	OPEN				Axial													
6/29/2018	OPEN				Axial													
6/30/2018	CLOSED																	

CT QC Artifacts



Course Outlines

- Compare Cardiac PET Radiopharmaceutical
- Quality Control
  - Rubidium Generator
  - PET/CT Scanner
- Imaging Protocol and Artifacts

Technical Advantages of Rb PET

- High spatial & temporal resolution
- High count density
- Reliable attenuation & scatter correction
- Short half-life radionuclides
- Short image acquisition protocols
- Tracers with superior kinetics
- Validated models for quantifying myocardial blood flow (MBF)

PET 2D vs 3D Imaging

Recommendation:

Validated 3D imaging should be used whenever possible for both dose reduction & high-quality images

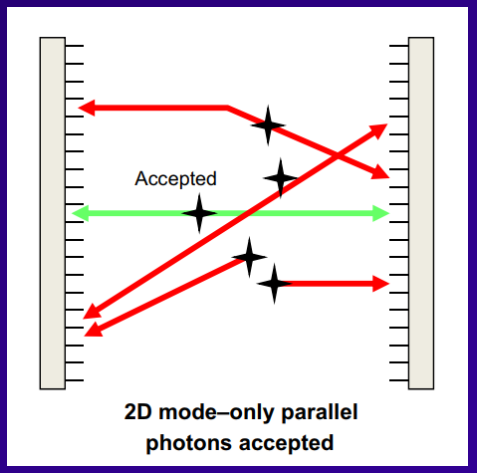
INFORMATION STATEMENT

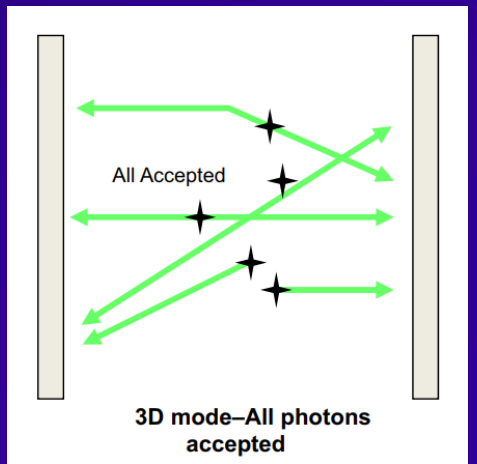
CrossMark

Status of cardiovascular PET radiation exposure and strategies for reduction: An Information Statement from the Cardiovascular PET Task Force

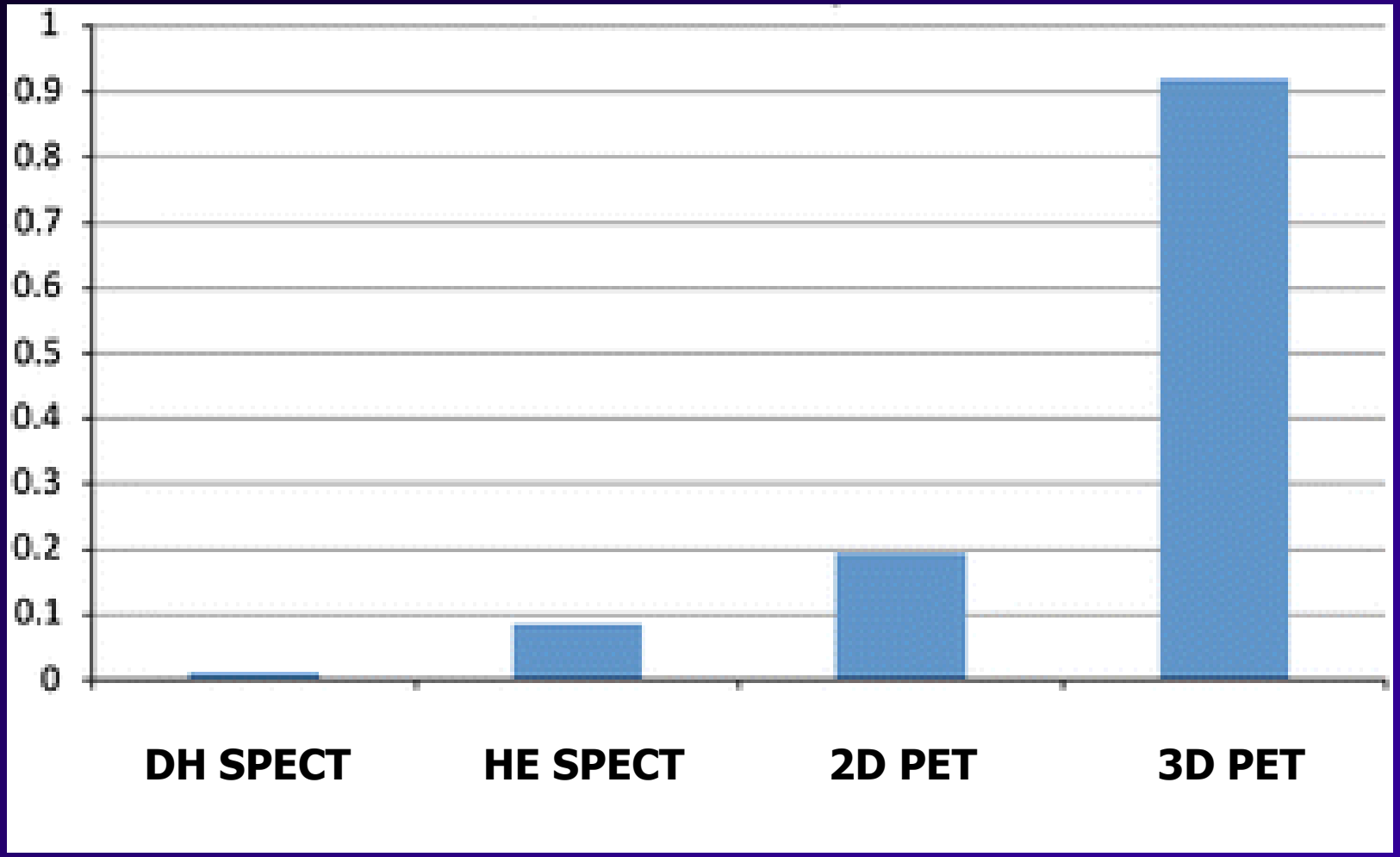
James A. Case, PhD,[a] Robert A. deKemp, PhD,[b] Piotr J. Slomka, PhD,[c] Mark F. Smith, PhD,[d] Gary V. Heller, MD, PhD,[e] and Manuel D. Cerqueira, MD[f]

J Nucl Cardio. May 2017





Count Sensitivity (%)



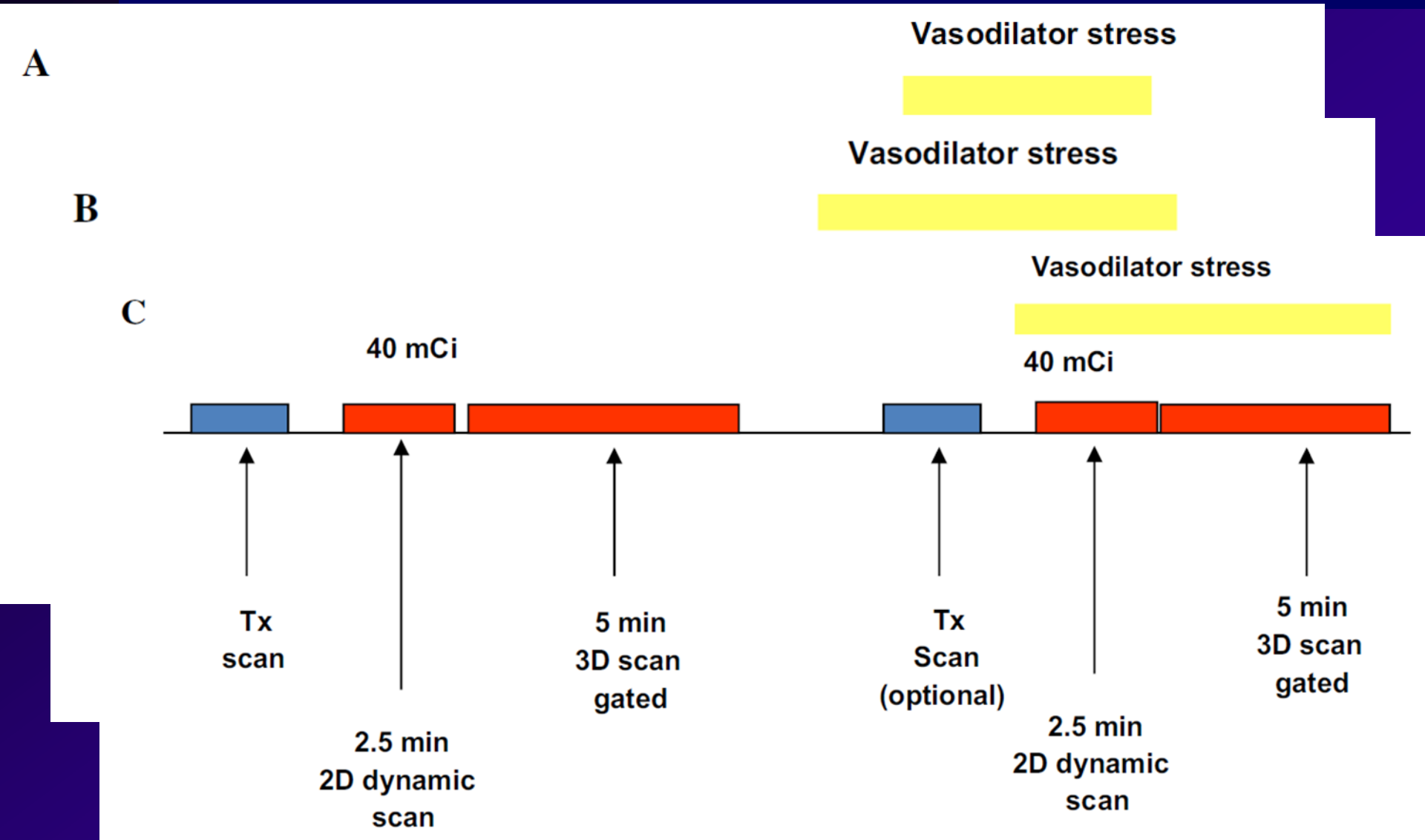
Slomka, J Nucl Cardiol 2014;21:1092–5

Radiation Effective Doses (mSv)

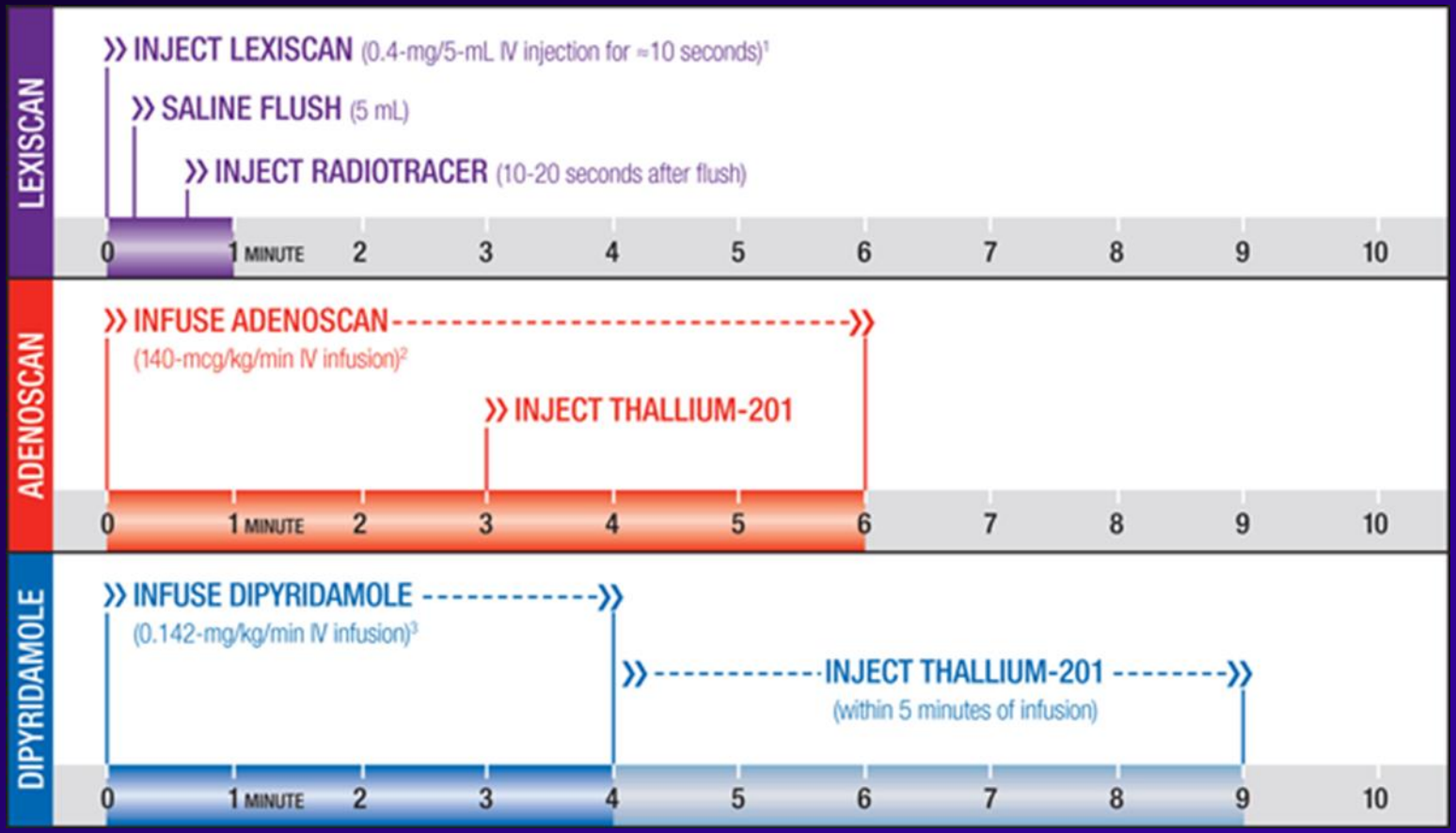
Study protocol	Isotope	Modality	Activity (mCi)[a]	E (mSv)[b]
Rest + stress perfusion	^{82}Rb-chloride	3D PET	25 + 25	2
		2D PET	50 + 50	4
Rest + stress perfusion	^{13}N-ammonia	3D PET	10 + 10	2
		2D PET	20 + 20	4
Rest viability, sarcoid, or inflammation (+ perfusion)	^{18}F-FDG (+$^{13}NH_3$ or ^{82}Rb)	3D PET	5 (+10 or 25)	3.5 (+ 1)
		2D PET	10 (+20 or 50)	7 (+ 2)
Stress-only perfusion (ultra-low-dose)	^{99m}Tc-sestamibi	CZT-SPECT	3.5	1
Stress-only perfusion (full-dose)	^{99m}Tc-sestamibi	GC-SPECT	30	10
Rest + stress perfusion one-day (half-dose)	^{99m}Tc-sestamibi	CZT-SPECT	5 + 15	6.4
	^{99m}Tc-tetrofosmin			5.6
Rest + stress perfusion one-day (full-dose)	^{99m}Tc-sestamibi	GC-SPECT	10 + 30	13
	^{99m}Tc-tetrofosmin			11

J Nucl Cardiol, May 2017; 1071-3581

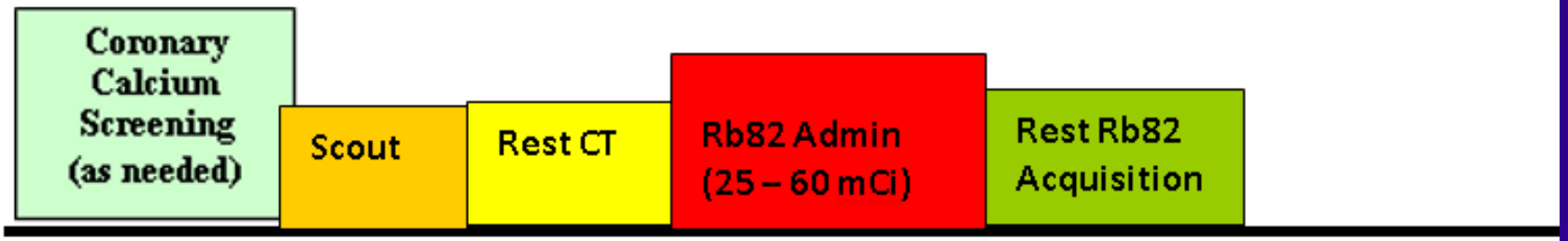
Rb-PET MPI Protocol



Pharmacologic Stress Comparison

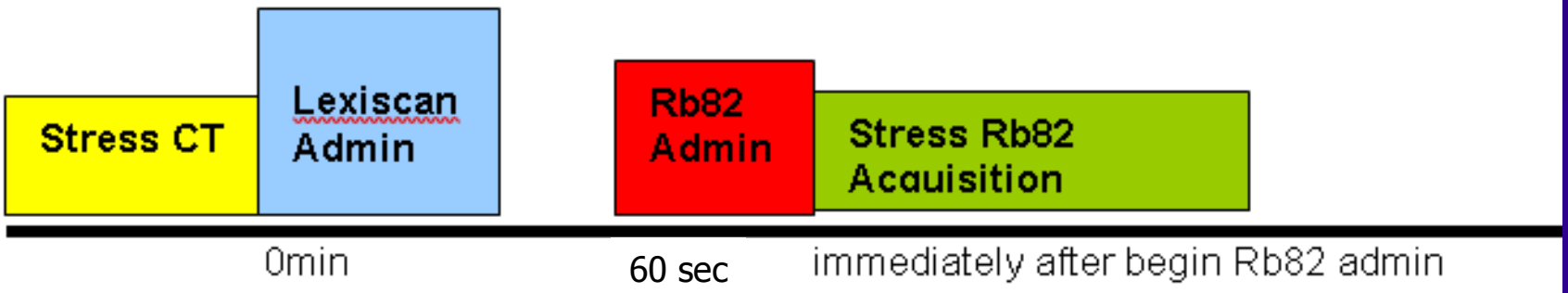


Rest Rb Study



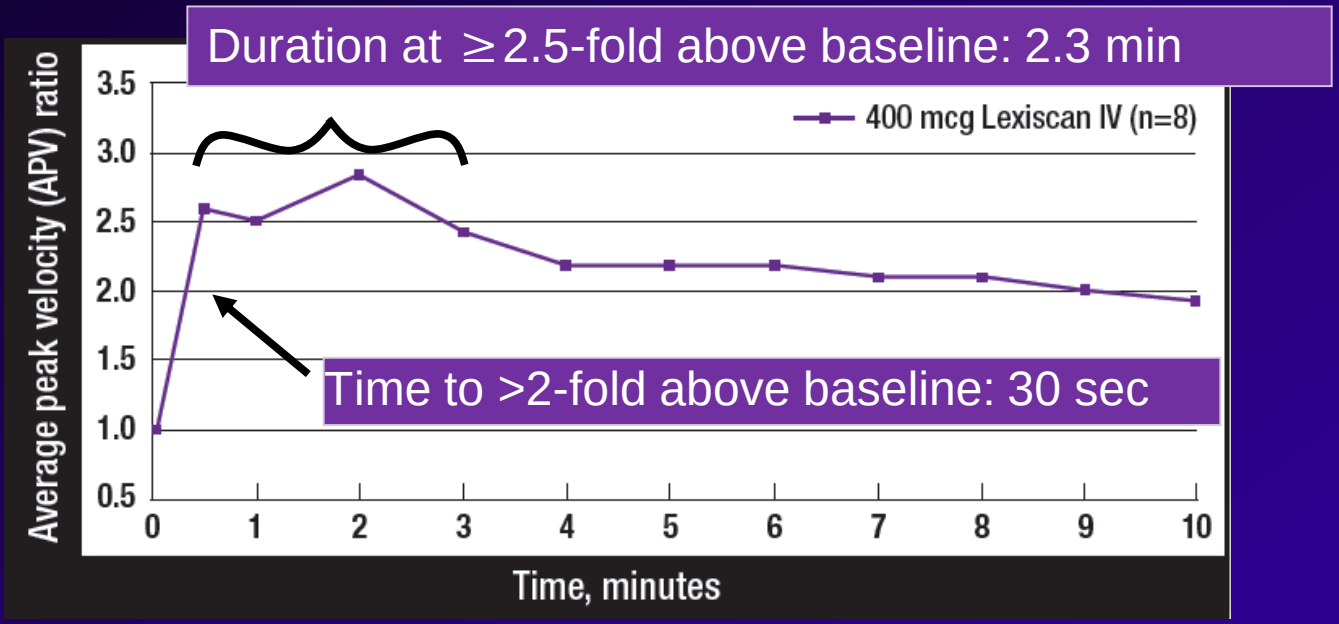
a. Coronary Calcium Screening (as needed)
b. Scout (Topogram)
c. Rest CT
d. Rb82 administration
e. Rest Rb 6 min list mode (begin acquisition at the beginning of Rb administration)

Lexiscan Pharm Rb Stress



a. Acquire Stress CT
b. Administer Lexiscan
c. Wait 60 seconds, injection Rb82 (25 -60 mCi)
d. Immediately begin 6 minute list mode stress acquisition.

Lexiscan-Induced Coronary Blood Flow[1]

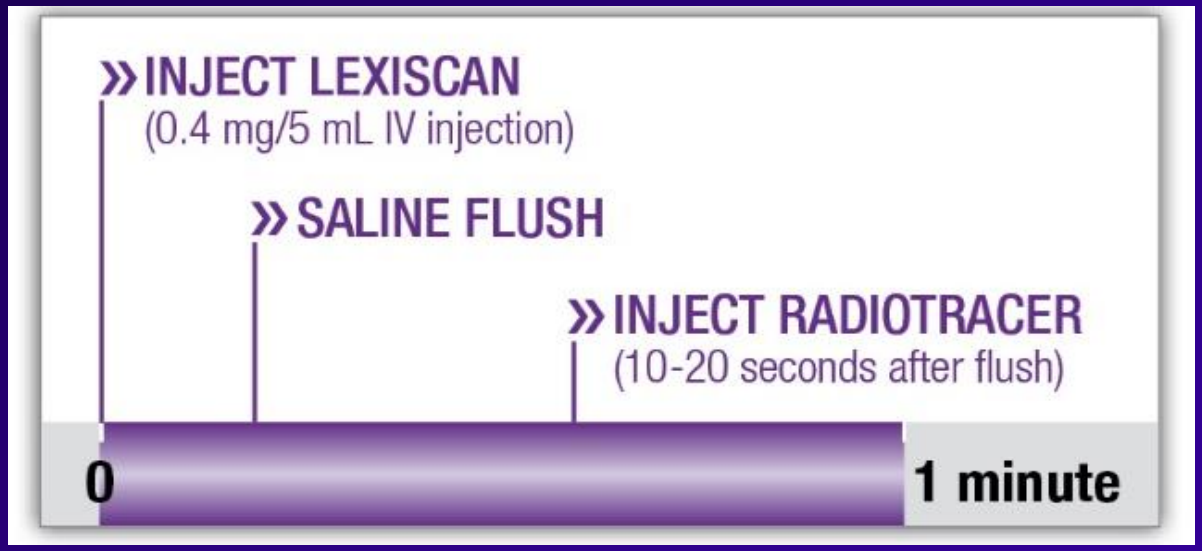


- Activation of the A_{2A} adenosine receptor by Lexiscan produces coronary vasodilation and increases coronary blood flow (CBF)[2]
- Lexiscan causes a rapid increase in CBF that is sustained for a short duration[2]

1. Lieu HD, et al. *J Nucl Cardiol*. 2007;14:514-520.
2. Lexiscan (regadenoson) injection [package insert]. Deerfield, IL: Astellas Pharma US, Inc.; 2008.

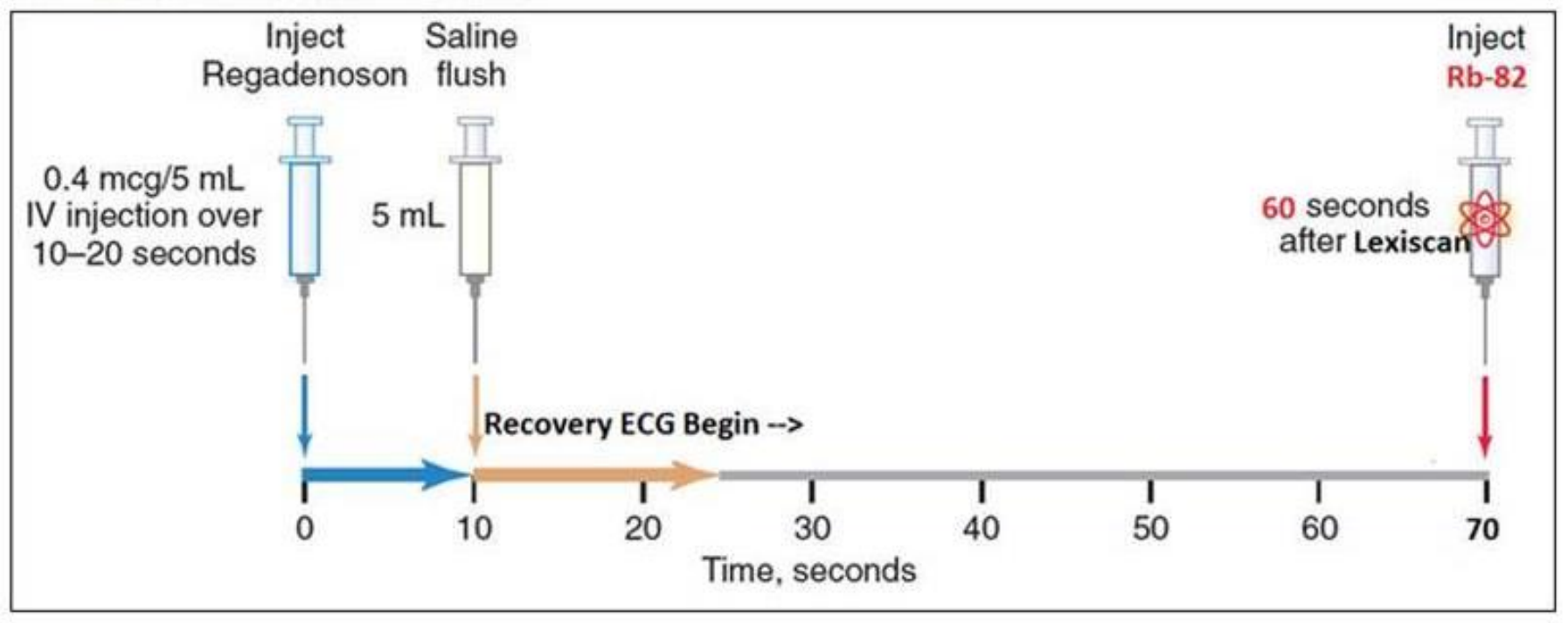
Dosing and Administration

- ✓ Recommended dose of 0.4 mg/5 mL for all patients, regardless of body weight
- ✓ Rapid (approximately 10 seconds) IV injection administration
  - No pump required
- ✓ Administration of stress and tracer complete in less than 1 minute



*Flush after radionuclide administration per your lab protocol.

The New Lexi/Rb-82 Injection Protocol



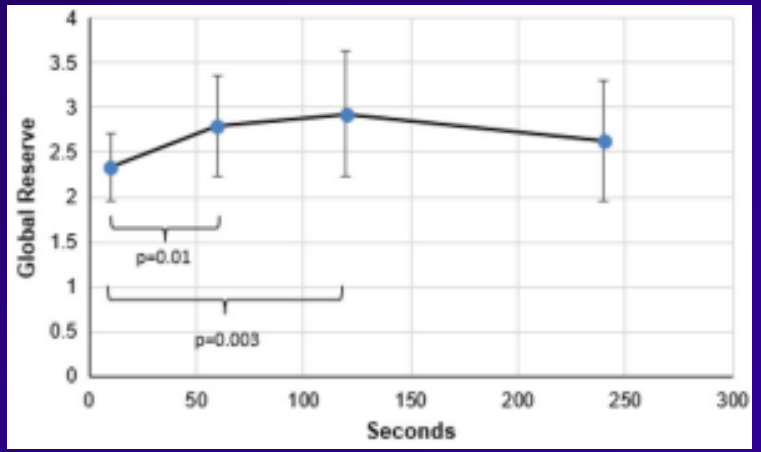
When to Inject Radiotracer for MBF after Regadenoson

TIME DEPENDENCE OF MYOCARDIAL BLOOD FLOW RESERVE MEASUREMENTS FOLLOWING REGADENOSON RUBIDIUM-82 MYOCARDIAL PERFUSION PET: NEW DATA SUPPORTING A LONGER INFUSION DELAY

T M Bateman*,[1] J A Case,[1] S A Courter,[1] J Jensen,[1] E V Burgett,[2] S Van Vickle[2]

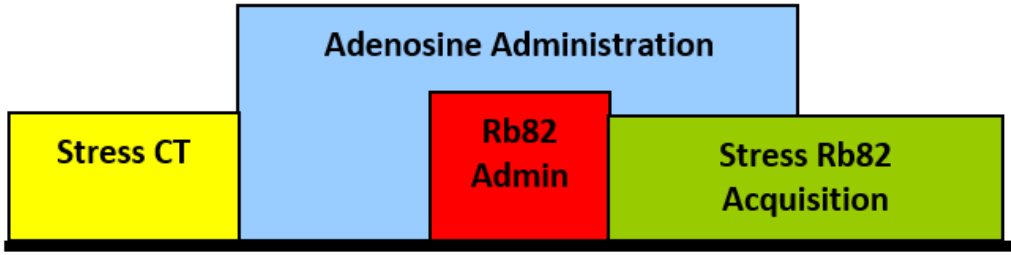
[1]Cardiovascular Imaging Technologies, Kansas City, MO, [2]Saint Luke's Health System, Kansas City, MO

Background: Rb-82 infusion is commonly begun 10 seconds following regadenoson (Reg) injection, similar to SPECT protocols. However,



Conclusion: This study indicates that peak vasodilation after regadenoson injection occurs considerably later than 10 seconds after beginning of Rb-82 infusion. Specifically, delaying the start of the Rb-82 infusion for 60 to 120 seconds following regadenoson injection provides higher peak MBFR measurements. Further studies are needed to determine if a longer delay also improves image accuracy.

Adenosine Pharm Rb Stress



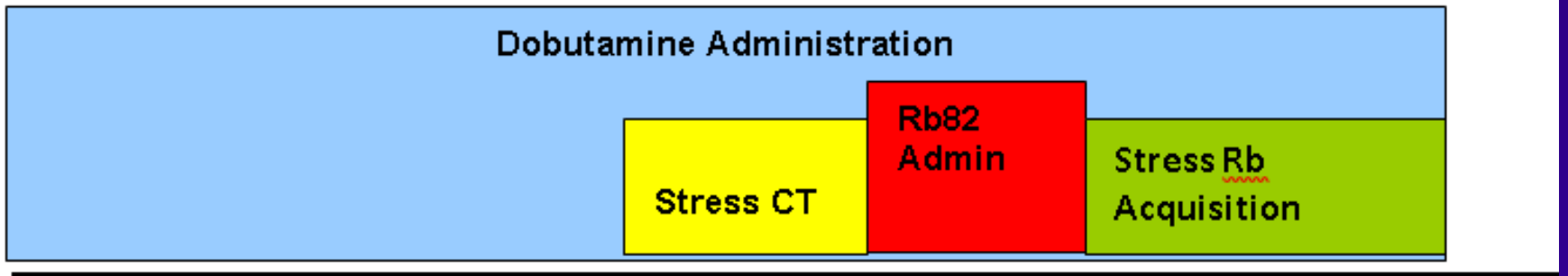
7min Adeno admin 6 min Stress Rb-82 Acquisition
3sec Rb admin
Administer 25 -60 mCi Rb @ 1.5min or @ 2.5 min
Acquire stress images for 6 min

a. Acquire Stress CT
b. Begin adenosine administration for 7 or 8 minutes (depending on rate selection by NP)
c. Injection Rb82 (25 - 60 mCi) at 1.5 min of Adenosine administration or at 2.5 min
d. Begin a 6 minute list mode stress acquisition at 1.5 min of Adenosine administration or at 2.5 min
e. Adenosine administration completes at 7 or 8 minutes
f. Stress Rb acquisition completes at 8.5 or 9.5 minutes

Dipyridamole Pharm Rb Stress

a. Administer Dipyridamole over 4 minutes
b. Wait 3 - 5 minutes, injection Rb82 (25 –60 mCi)
c. Immediately begin 6 minute list mode stress acquisition.
d. At end of imaging, begin recovery and administer aminophylline as needed

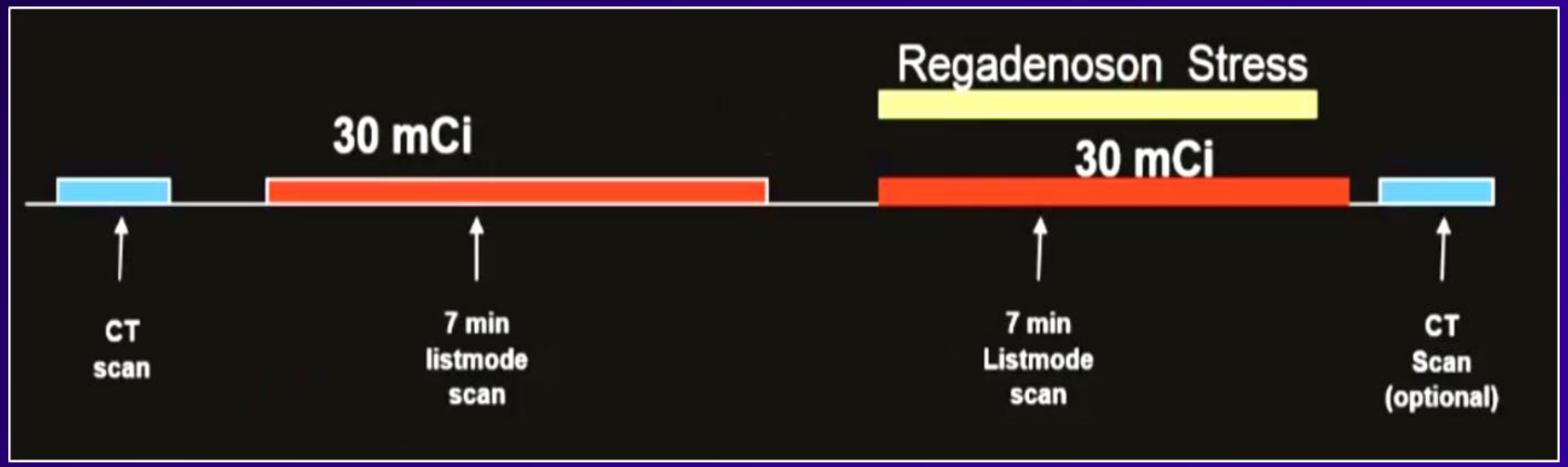
Dobutamine Pharm Rb Stress



a. Begin Dobutamine administration
b. As patient nears 85% of peak heart rate, acquire Stress CT
c. At peak heart rate administer Rb82 (25 -60 mCi) begin 6 minutes stress acquisition
d. Maintain Dobutamine administration rate for 2 minutes post peak heart rate
e. At 2 minutes reduce rate to previous administration rate until end of stress acquisition

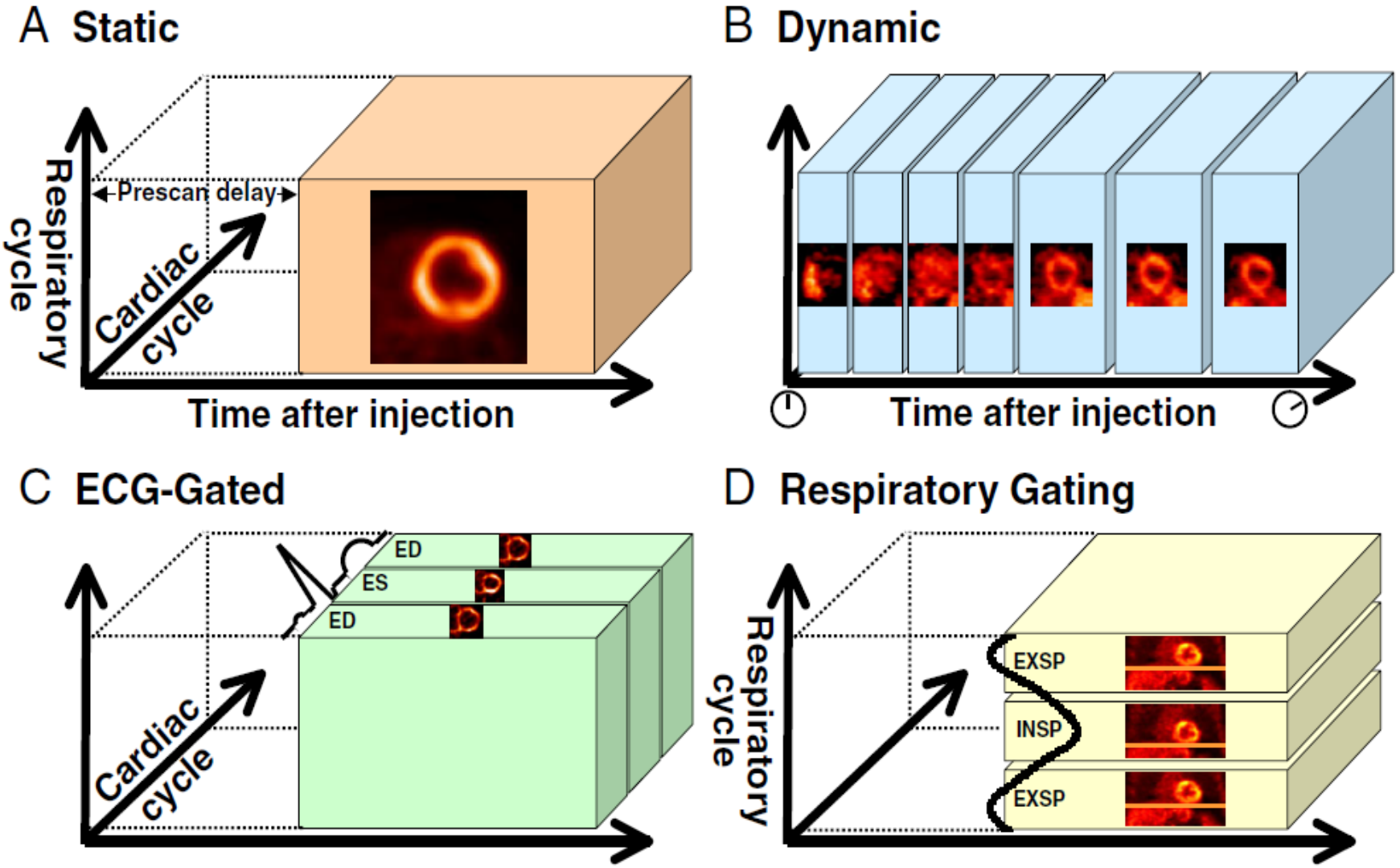
Diagnostic Accuracy of Rb-PET MPI

- Spatially-relative image interpretation (visual & quantitative)
- Rest & peak stress LVEF, EDV, ESV
- Rest & peak stress global & regional WM & WT
- Myocardial blood flow (MBF) & coronary flow reserve (CFR)

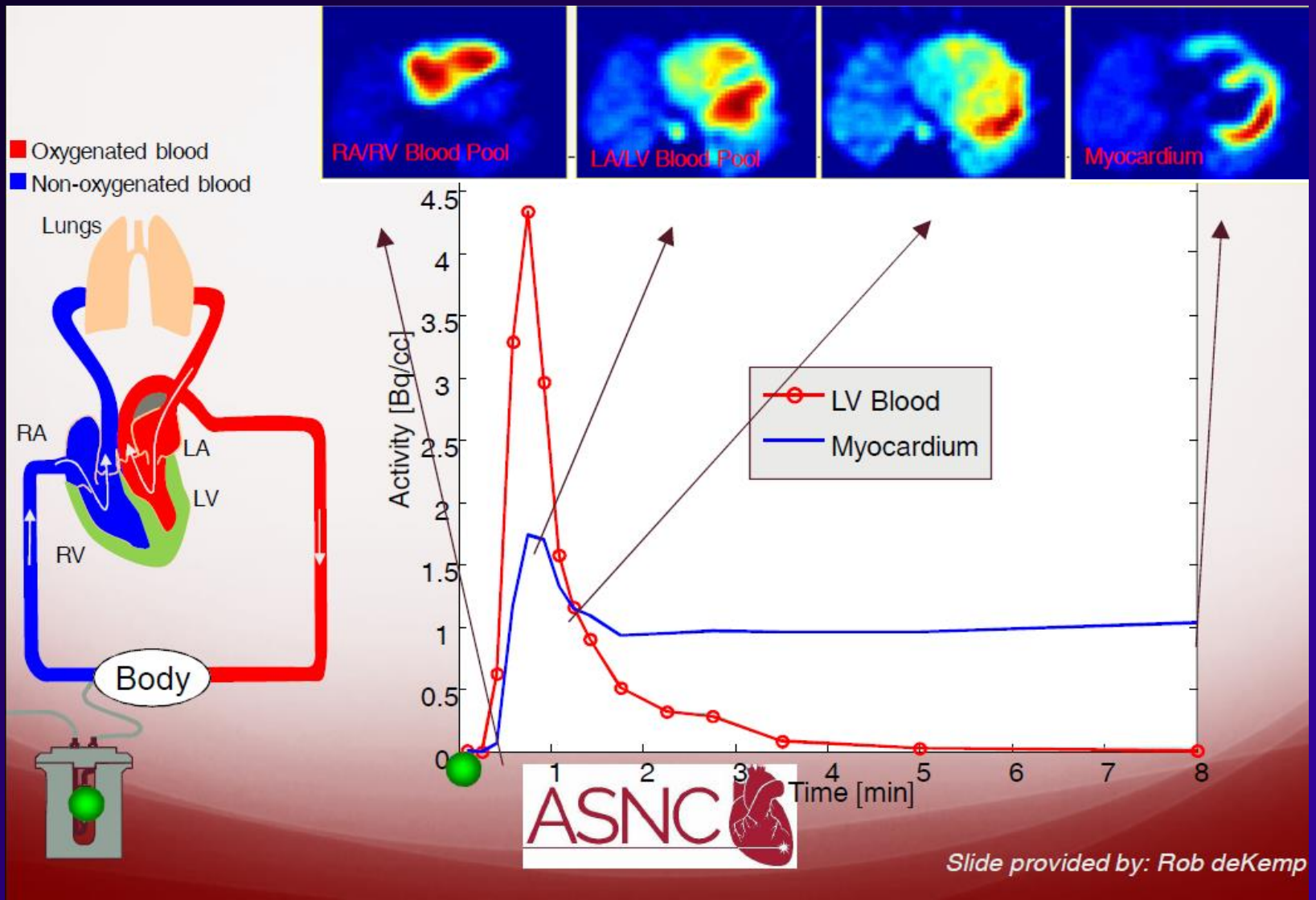


Cardiac PET MPI

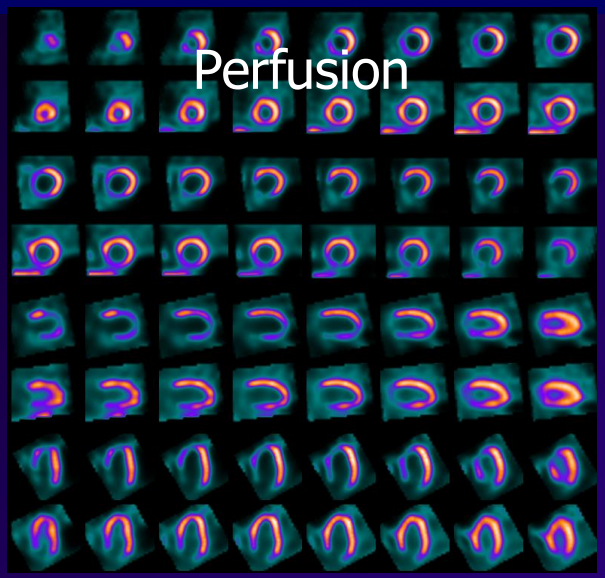
Multi-demensional List-Mode Acquisition

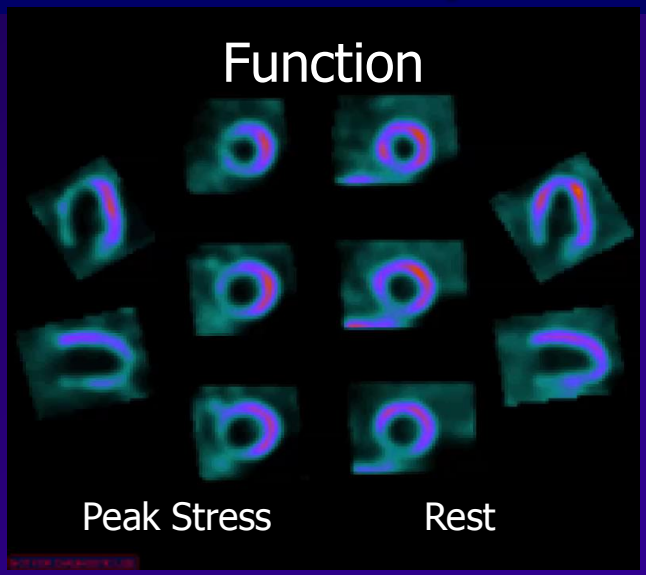


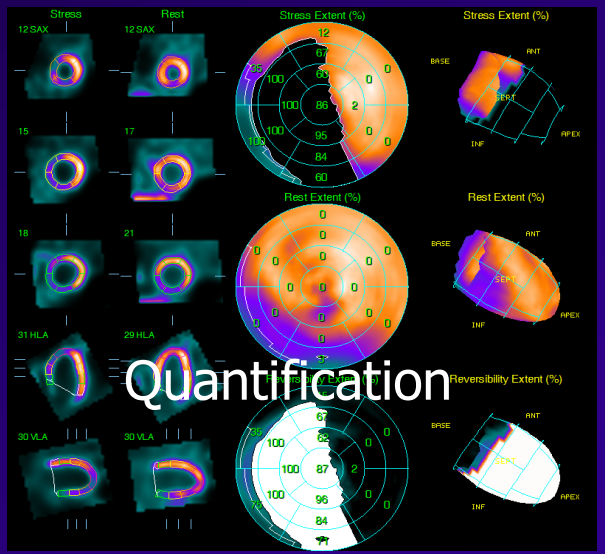
Dynamic Cardiac PET

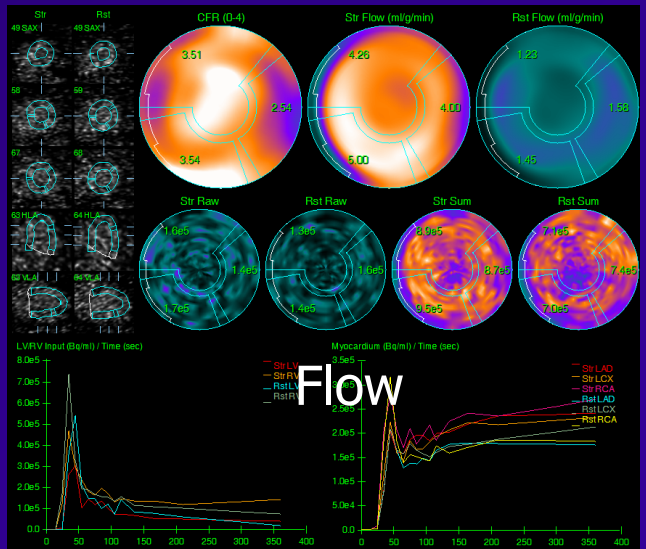


Myocardial Perfusion SPECT/PET

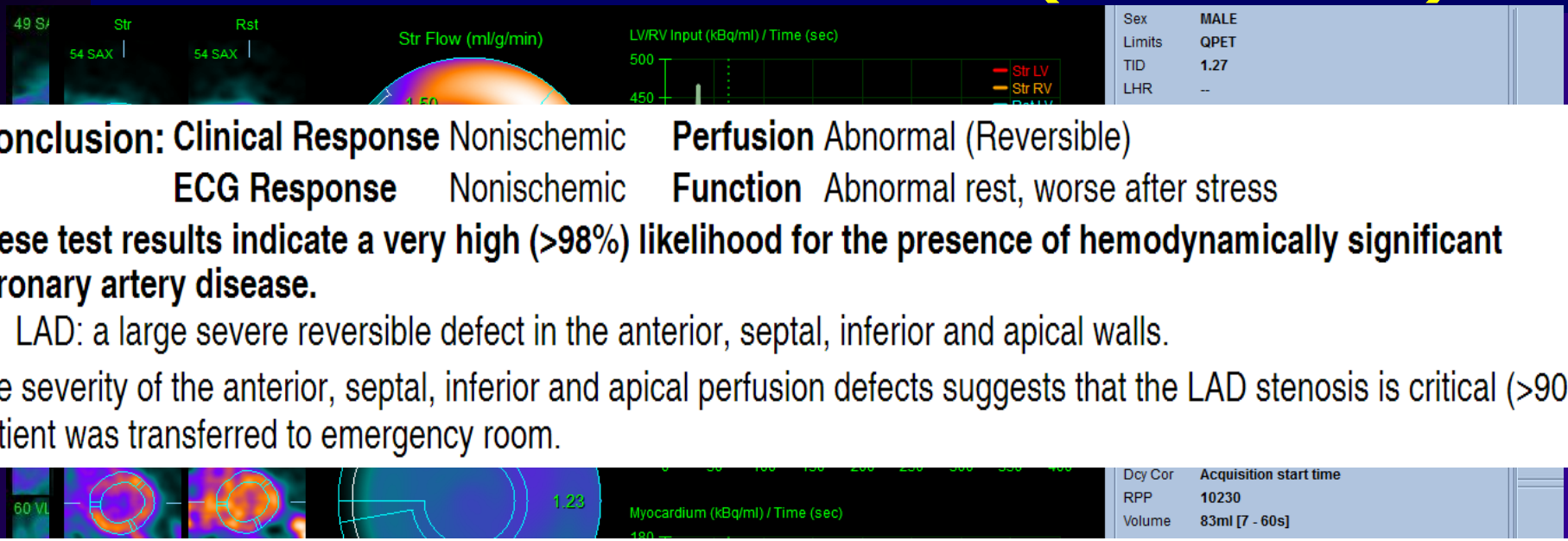








Rb-PET MPI w/Flow (case #1)



Conclusion: **Clinical Response** Nonischemic **Perfusion** Abnormal (Reversible)
ECG Response Nonischemic **Function** Abnormal rest, worse after stress

These test results indicate a very high (>98%) likelihood for the presence of hemodynamically significant coronary artery disease.

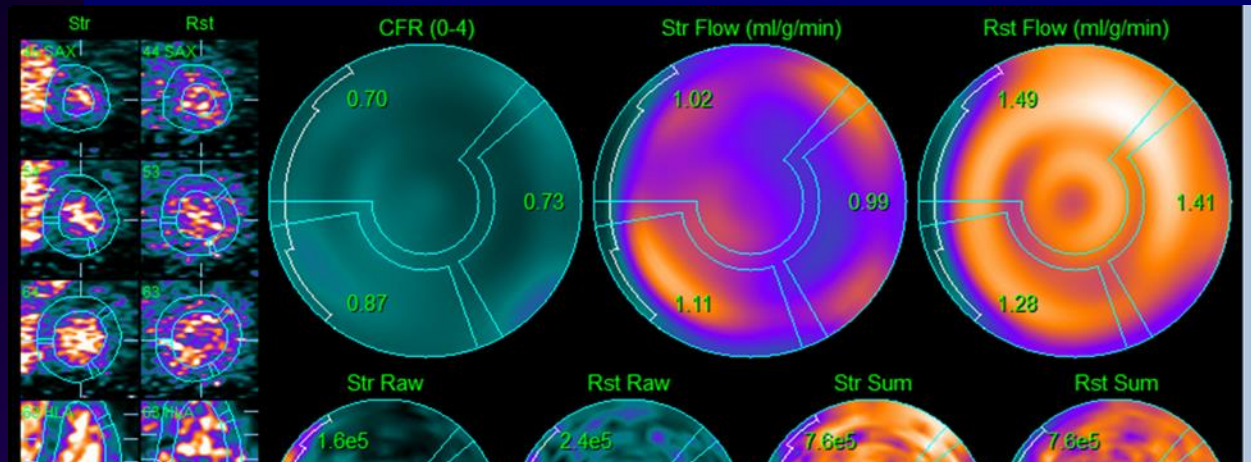
- LAD: a large severe reversible defect in the anterior, septal, inferior and apical walls.

The severity of the anterior, septal, inferior and apical perfusion defects suggests that the LAD stenosis is critical (>90%). Patient was transferred to emergency room.

IMPRESSION:
1. Severe native coronary artery disease as described above.
2. Status post successful percutaneous coronary intervention to the left anterior descending and first diagonal branch.

RECOMMENDATIONS:
Initiate dual antiplatelet therapy as well as statin therapy.
The patient is to be observed under the hospital service overnight for postprocedure care.

Rb-PET MPI w/Flow (case #2)



Sex	MALE				
Limits	QPET				
TID	0.94				
LHR	--				
SSS	0	SRS	0	SDS	0
SS%	0	SR%	0	SD%	0

Study	PET^1_2_Large_Rest_Stress_w_CCS (Adult)
Dataset	DYN16frames_STRESS_2D_ap (AC)
Date	2018-01-19 10:21:16
Status	QC=1.34, IR=0.28 (saved)
Dcy Cor	Acquisition start time
Volume	54ml [4 - 30s]
Shape	0.68 [SI], 0.86 [Ecc]
Counts	--

Conclusion: **Clinical Response** Nonischemic **Perfusion** Normal

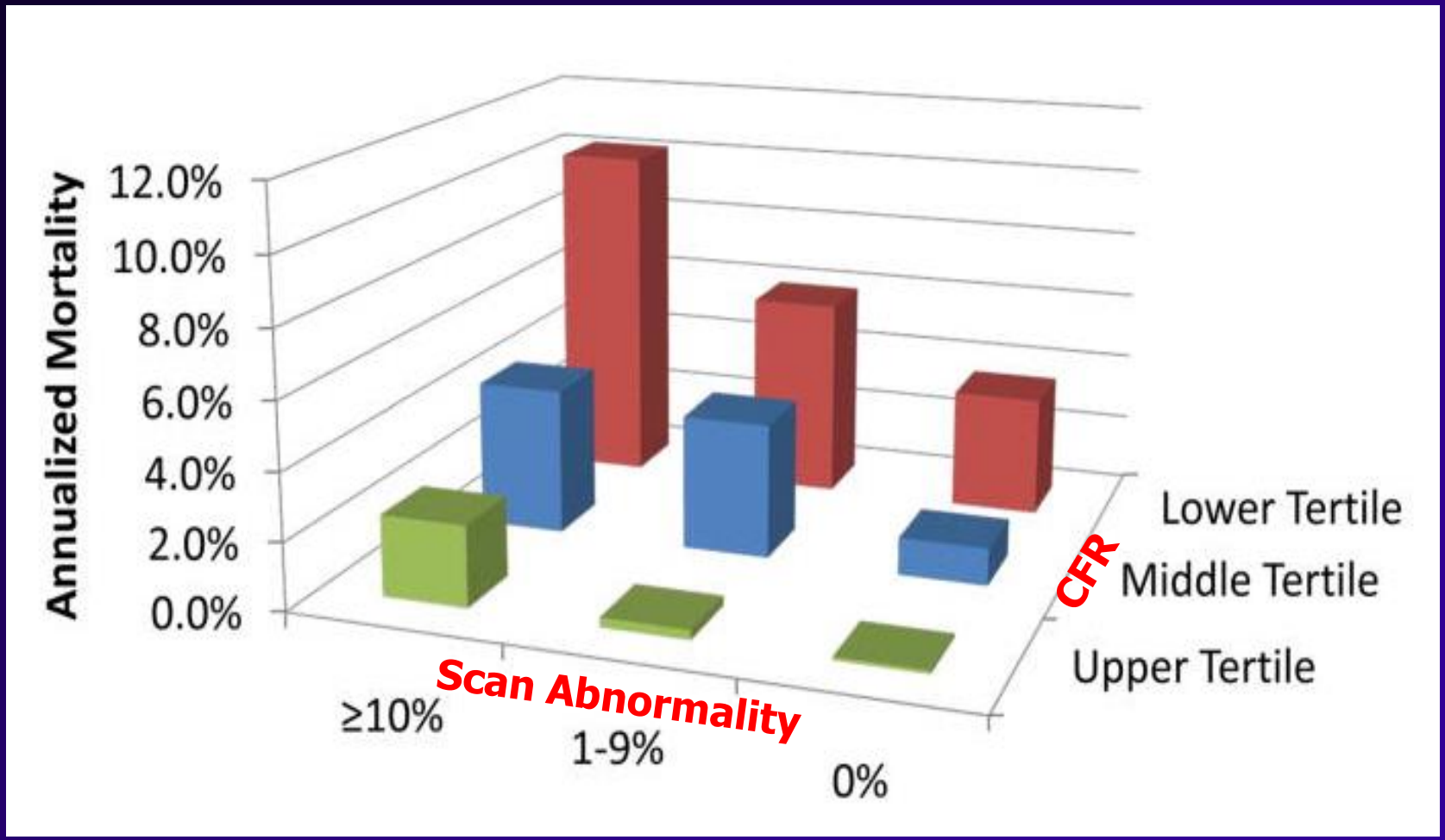
ECG Response Nondiagnostic (RBBB) **Function** Normal

These test results indicate an intermediate (30-69%) likelihood for the presence of jeopardized myocardium.

- The right ventricle is enlarged and hypertrophied
- Stress flow 1.04 ml/gm/min. Rest flow 1.42 ml/gm/min. The markedly decreased myocardial flow reserve of 0.75 (normal > 2.0) suggests increased risk of cardiac hard events. Cannot rule out triple vessel disease with balanced flow reduction

TOT	0	0.0	0	0.0	0

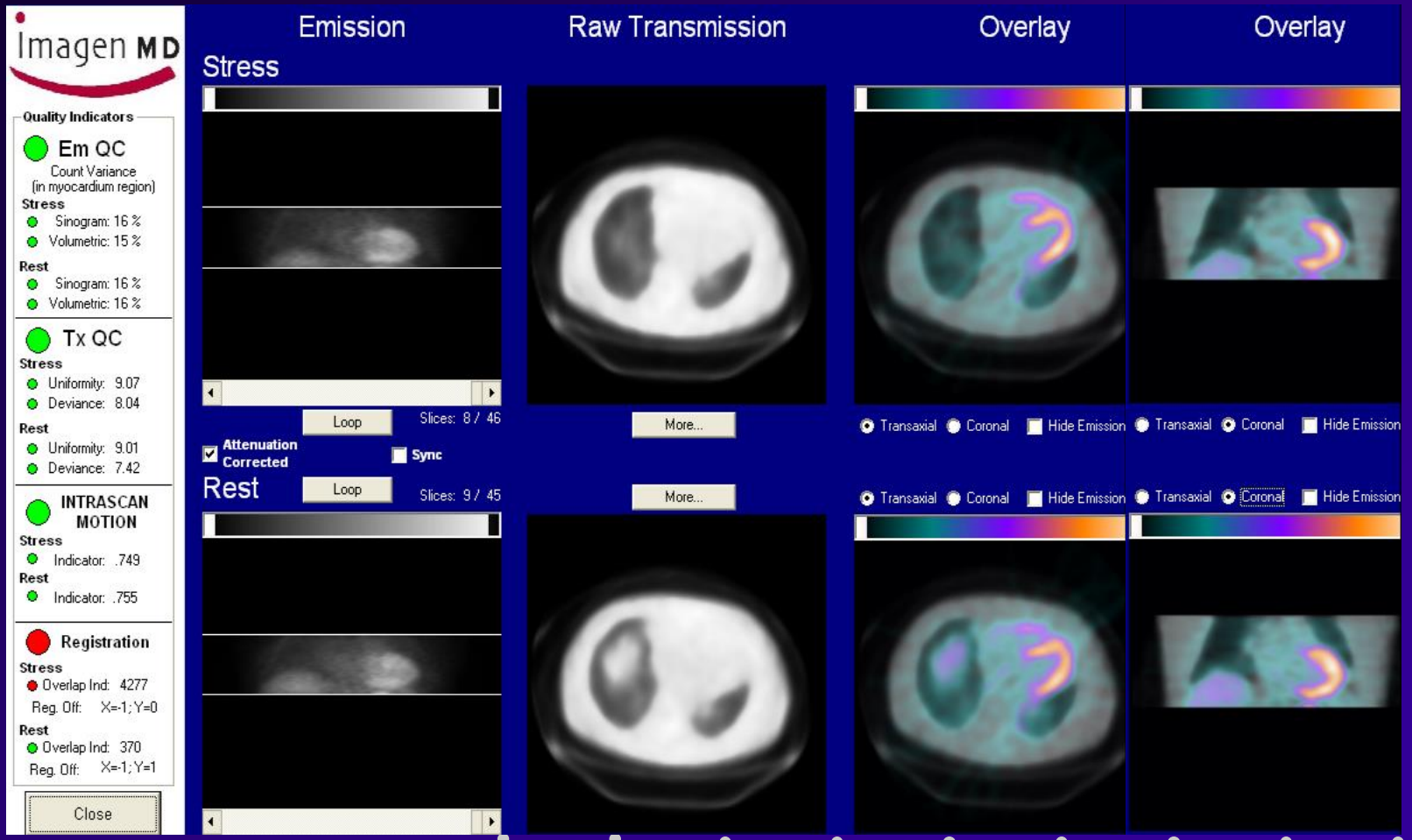
Cardiac Mortality by CFR & Scan Abnl



Murthy: Circ, 2011

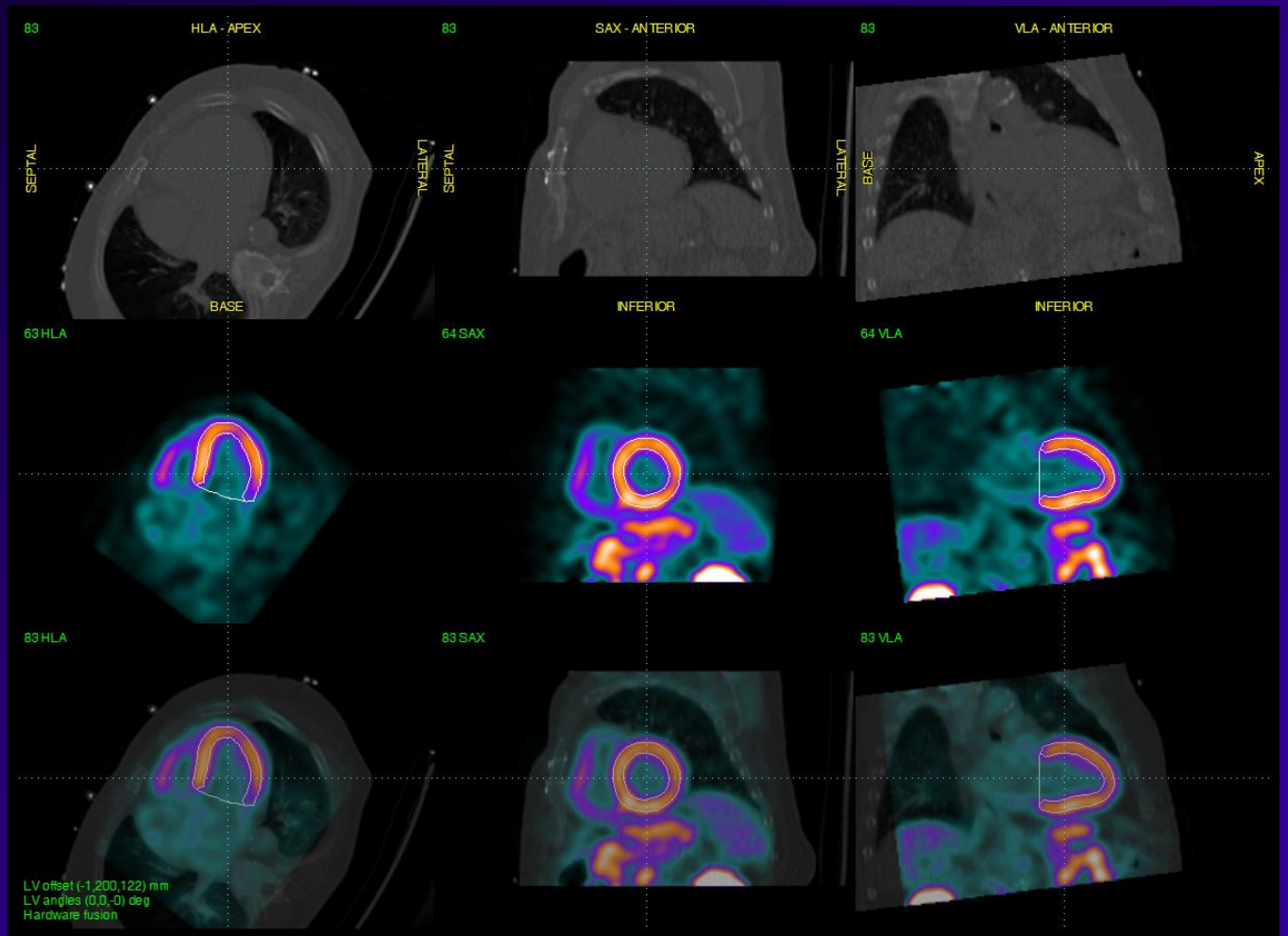
Tx/Em Registration QC

Dedicated PET System



Tx/Em Registration QC

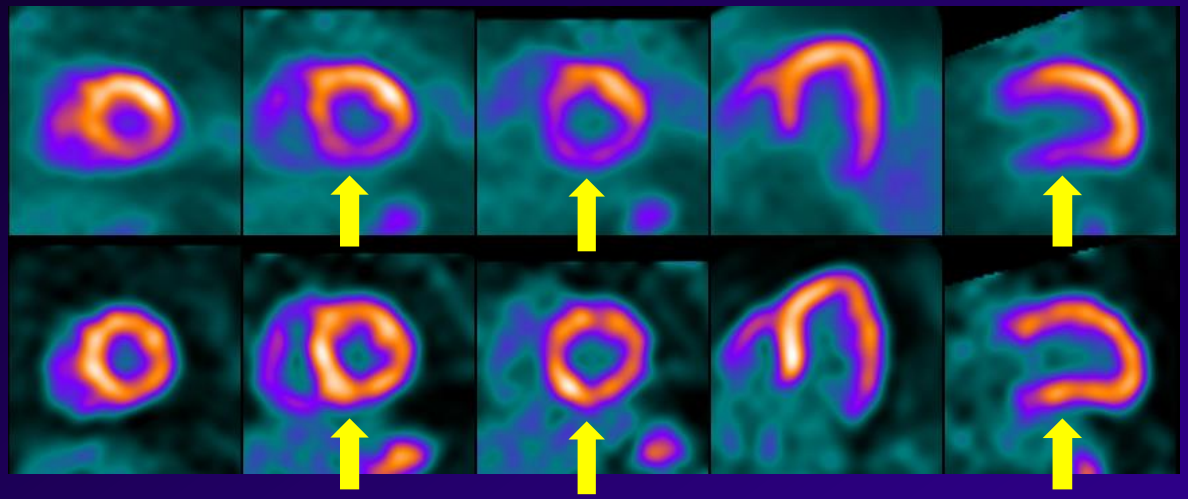
PET/CT System

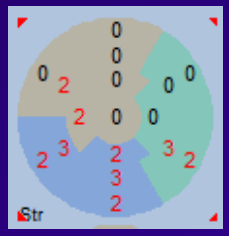


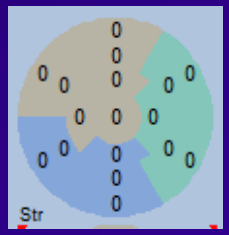
Attenuation Correction

NAC

AC

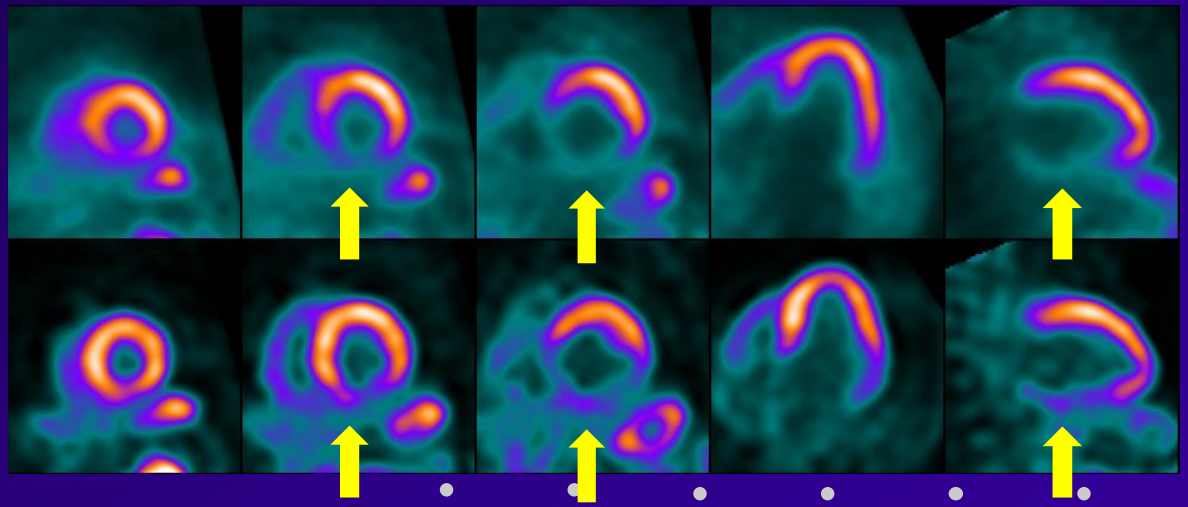


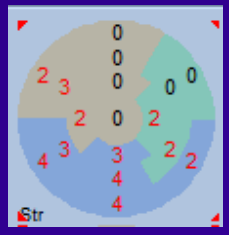


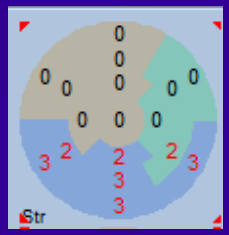


NAC

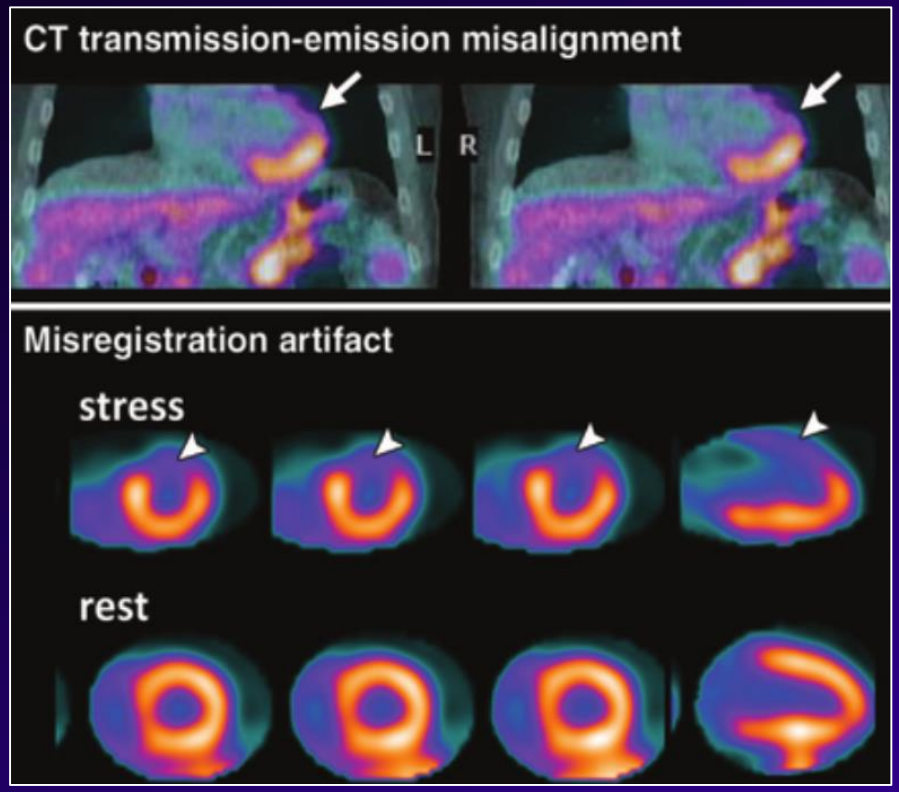
AC

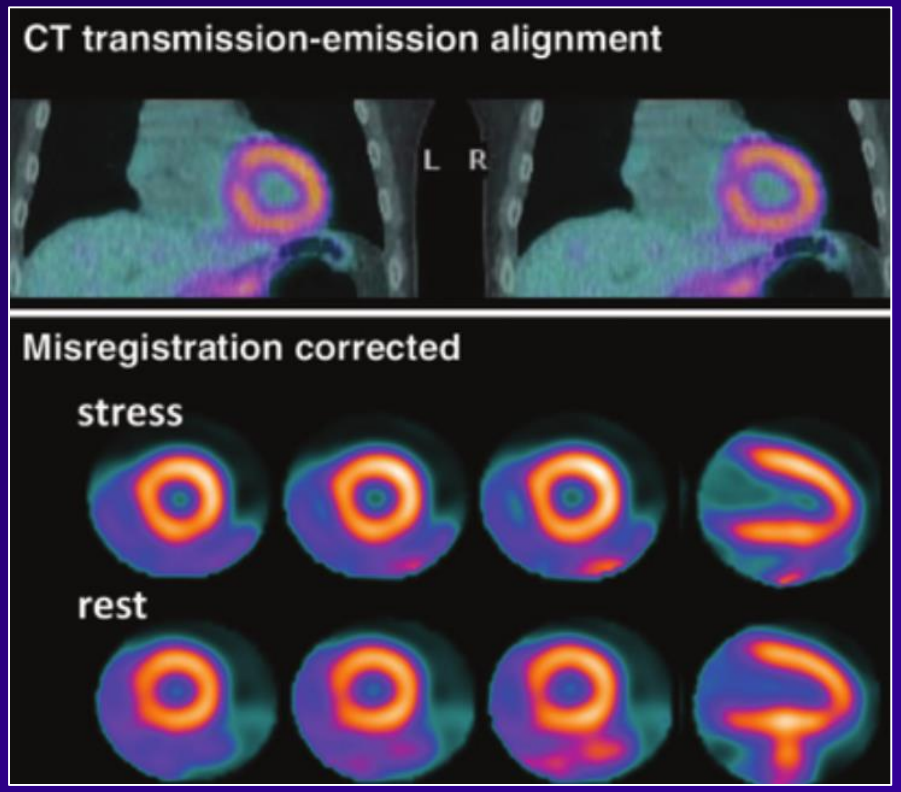




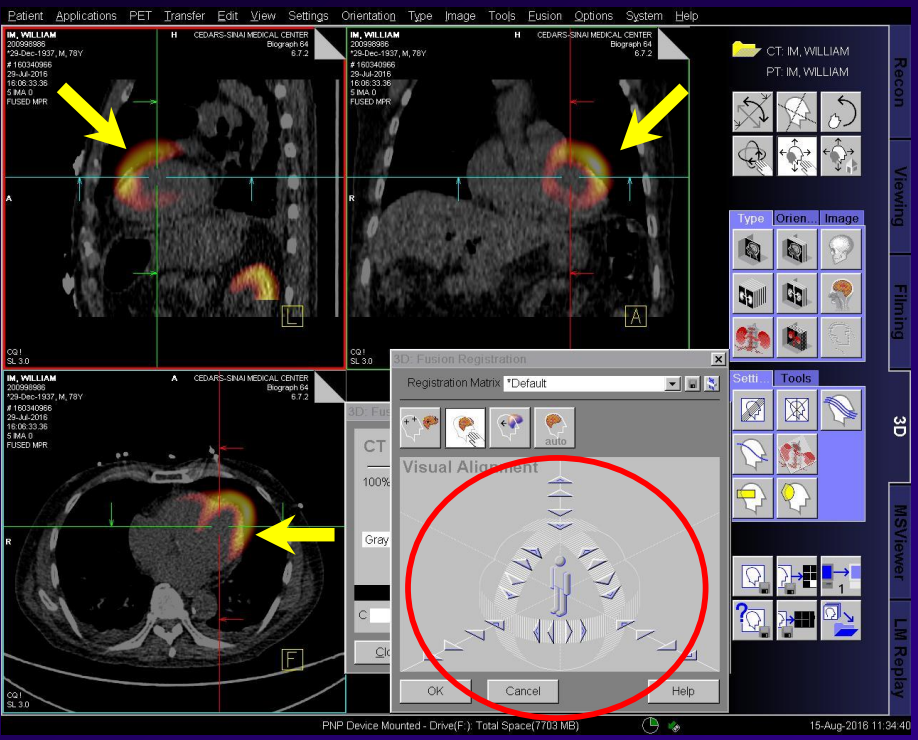


Mis-registration Artifacts

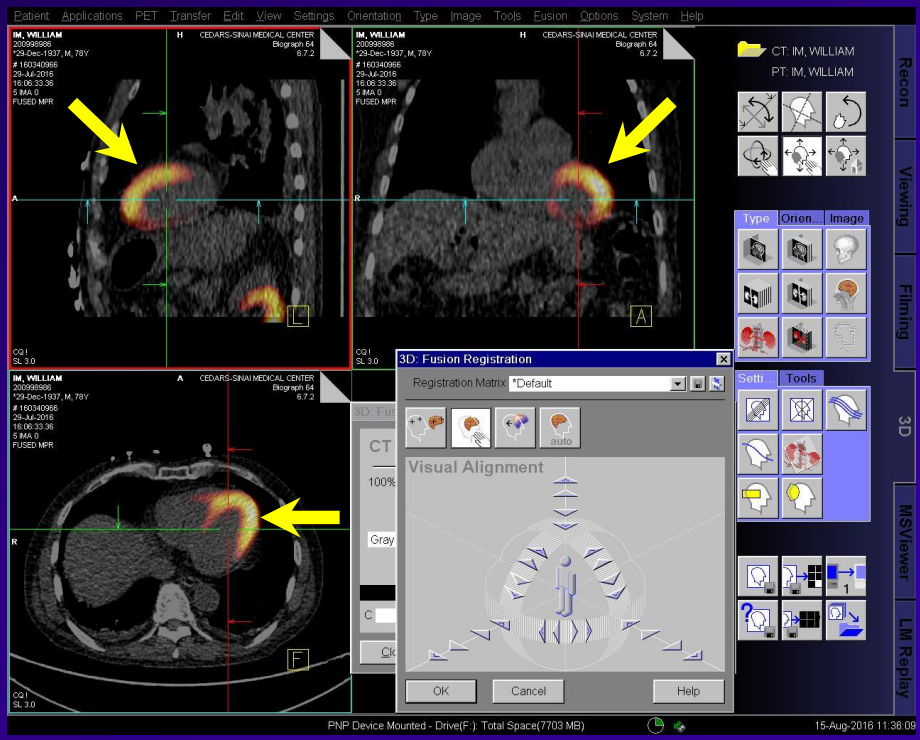




3D Fusion Registration

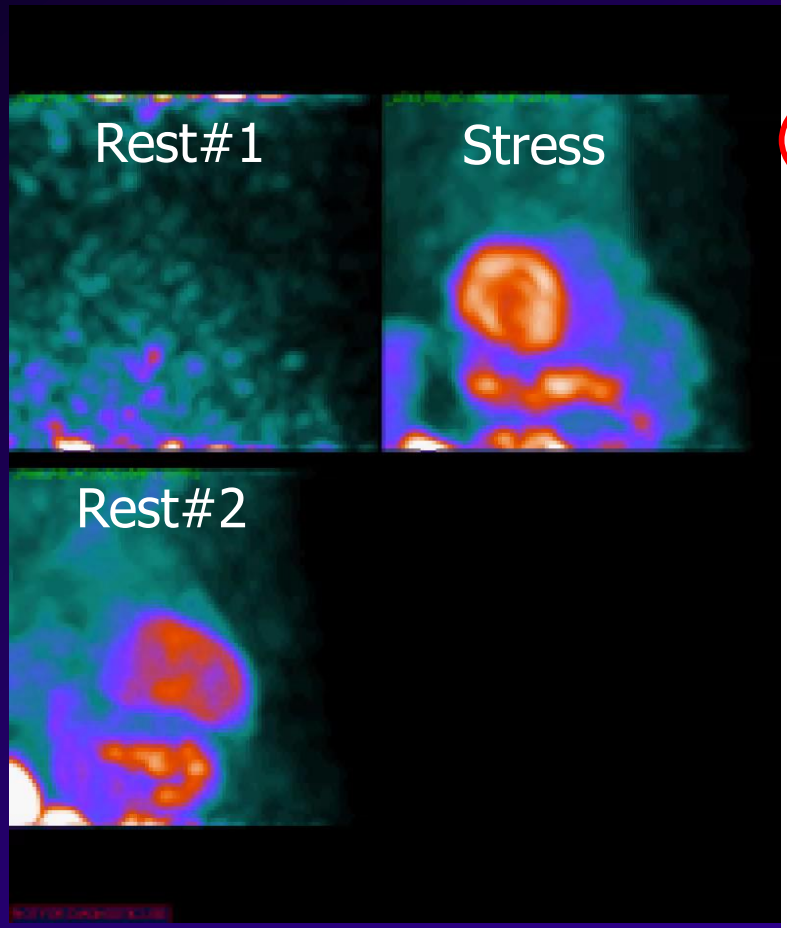


Before



After

Infusion System Errors



Rest #1

10:50

3/1/16

INFUSION ABORTED
BY ERROR

High Pressure Error

SETPOINT VALUES:

Elution Vol. = 99 ml
Patient Vol. = 50 ml
Patient Dose = 35 mCi
Dose Rate Thld. =
1.0 mCi/sec
Flow Rate = 50 ml/min
Cal. Factor = 1232

ACTUAL INFUSION DATA:

Elution Vol. = 17 ml
Patient Vol. = 6 ml
Patient Dose = 8.2 mCi

Infused Activity Present
At End Of Infusion =
8.0 mCi

Activity Present Between
Det. and Waste Valve =
1.172 mCi
in Volume of
0.592 ml

Activity Present Between
Waste Valve and Pat. =
2.439 mCi
in Volume of
1.250 ml

ACTIVITY PROFILE

Time Detector Patient

Rest #2

11:05

3/1/16

INFUSION TERMINATED
NORMALLY

SETPOINT VALUES:

Elution Vol. = 99 ml
Patient Vol. = 50 ml
Patient Dose = 35 mCi
Dose Rate Thld. =
1.0 mCi/sec
Flow Rate = 50 ml/min
Cal. Factor = 1232

ACTUAL INFUSION DATA:

Elution Vol. = 25 ml
Patient Vol. = 14 ml
Patient Dose = 35.2 mCi

Infused Activity Present
At End Of Infusion =
33.0 mCi

Activity Present Between
Det. and Waste Valve =
1.104 mCi
in Volume of
0.592 ml

Activity Present Between
Waste Valve and Pat. =
2.570 mCi
in Volume of
1.250 ml

ACTIVITY PROFILE

Time sec | Detector mCi/sec | Patient mCi/sec

1 0.000

Slow - 1

3/1/16

INFUSION TERMINATED
NORMALLY

1115

SETPOINT VALUES:

Elution Vol. = 99 ml
Patient Vol. = 50 ml
Patient Dose = 35 mCi
Dose Rate Thld. =
1.0 mCi/sec
Flow Rate = 50 ml/min
Cal. Factor = 1232

ACTUAL INFUSION DATA:

Elution Vol. = 25 ml
Patient Vol. = 14 ml
Patient Dose = 35.0 mCi

Infused Activity Present
At End Of Infusion =
32.8 mCi

Activity Present Between
Det. and Waste Valve =
1.153 mCi
in Volume of
0.592 ml

Activity Present Between
Waste Valve and Pat. =
2.685 mCi
in Volume of
1.250 ml

ACTIVITY PROFILE

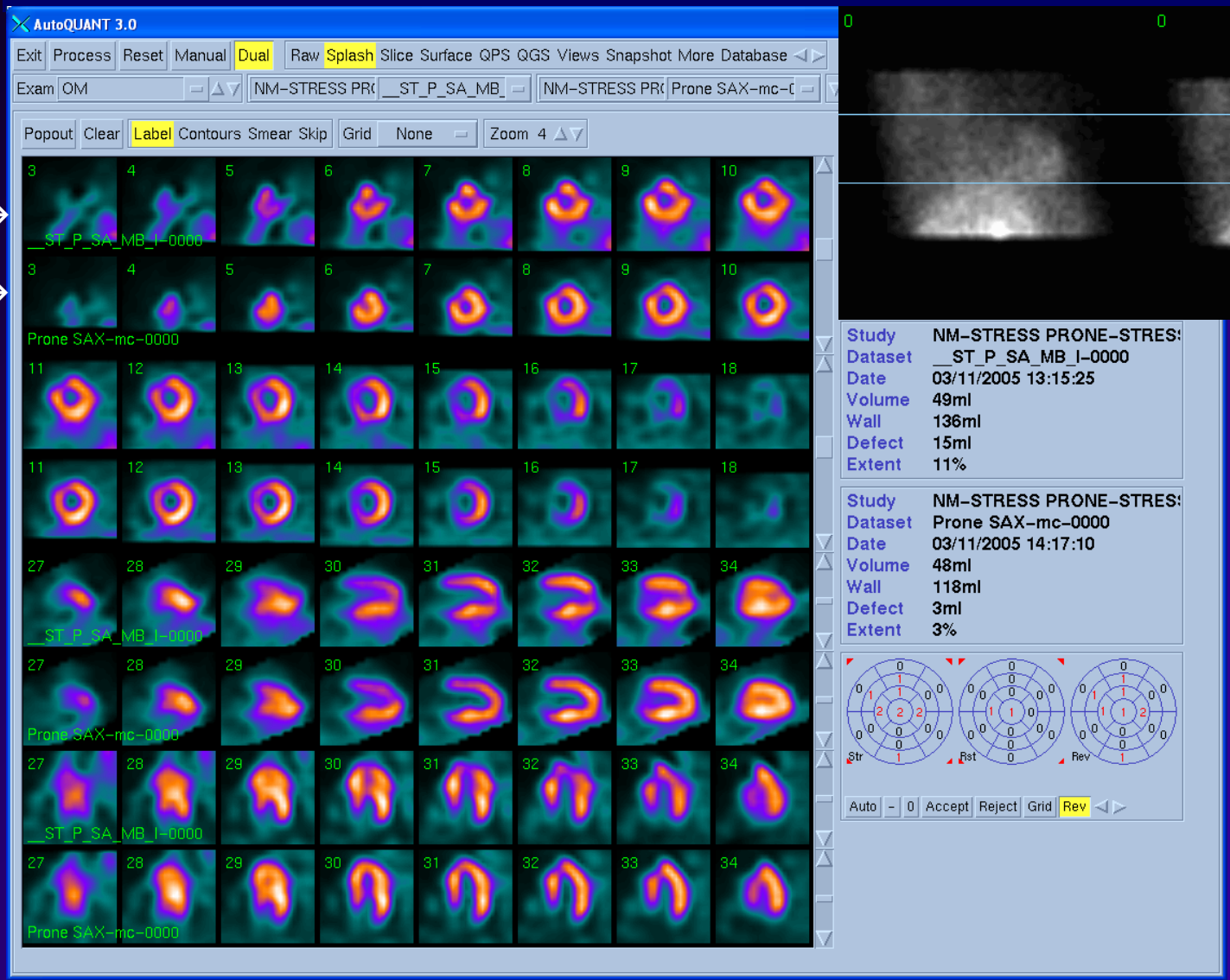
Time sec | Detector mCi/sec | Patient mCi/sec

1 0.004 0.000
2 0.004 0.000

Vertical Motion

Before →

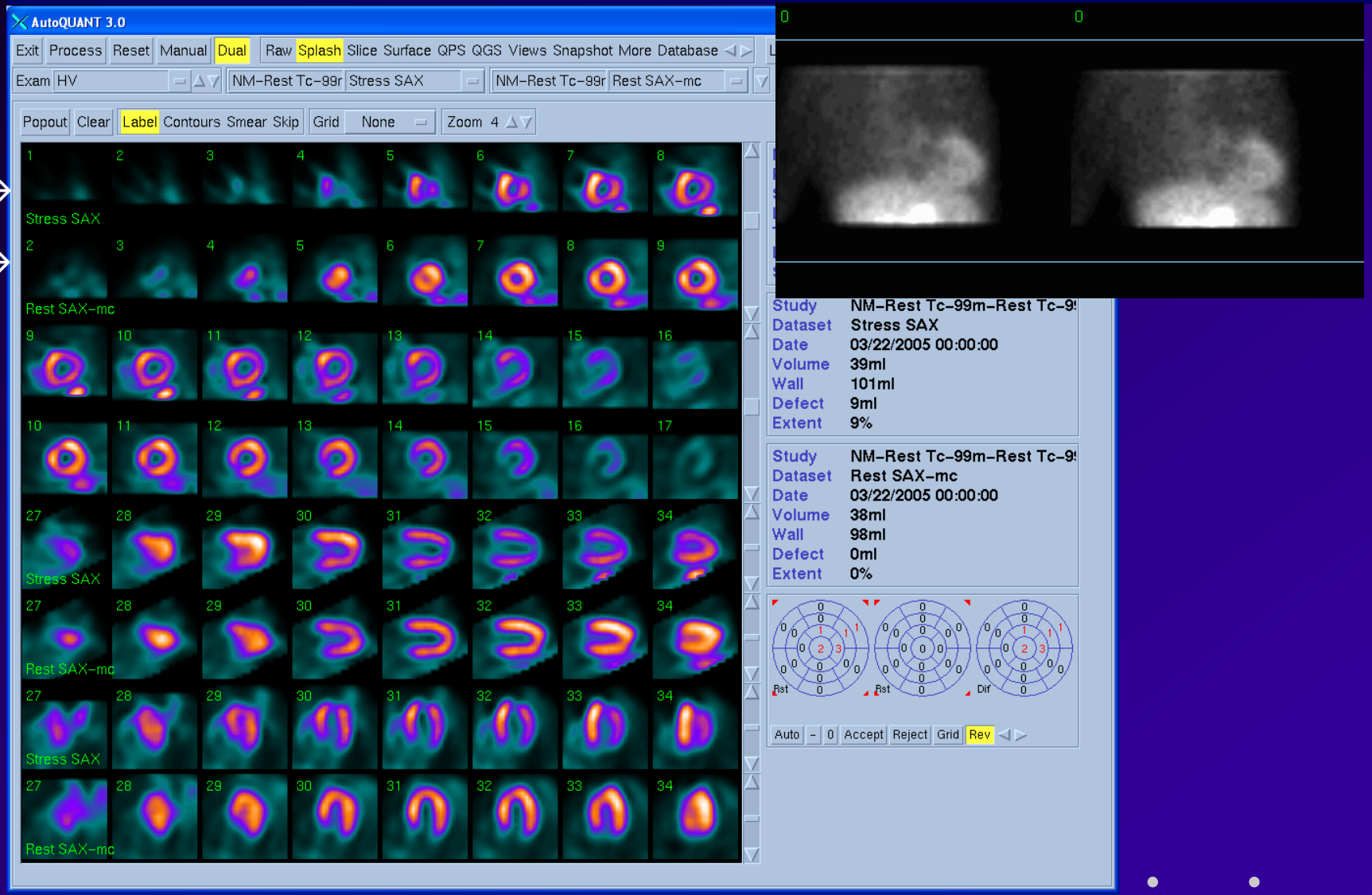
After →



Horizontal Motion

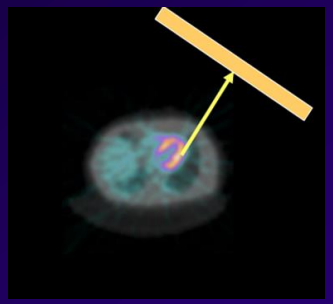
Before →

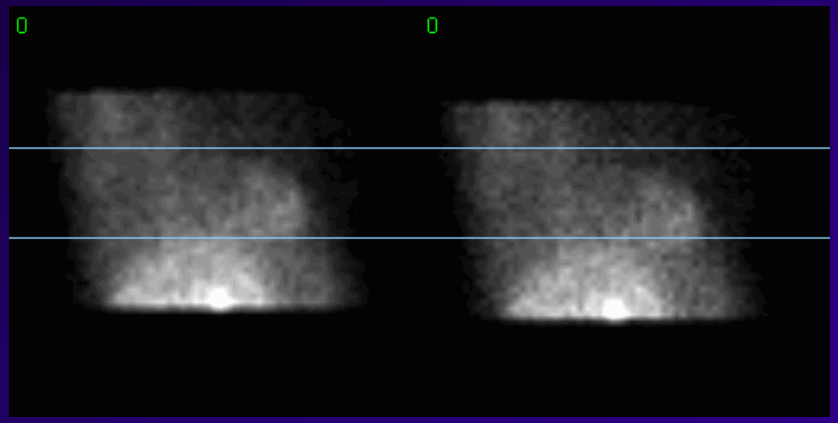
After →



Cardiac/Respiratory Motion

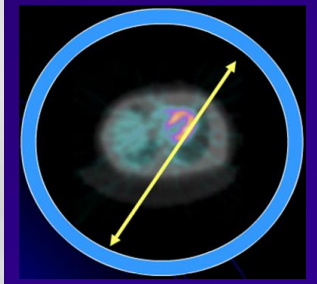
SPECT

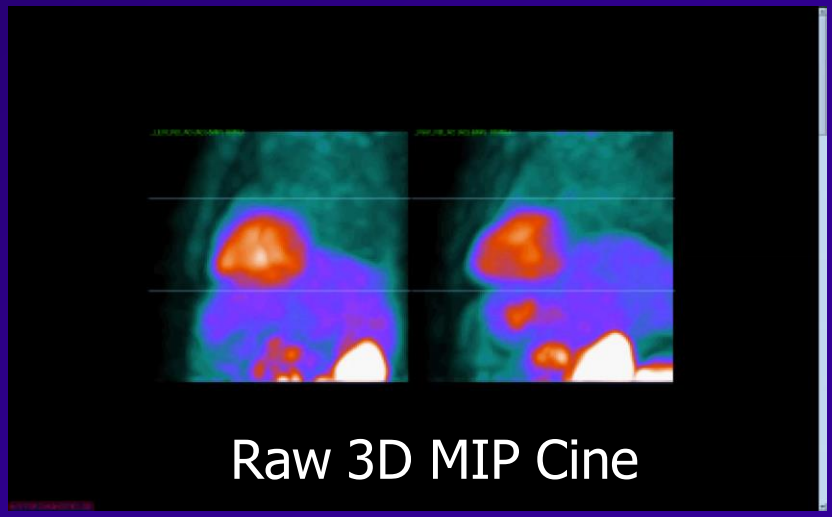




Raw Projection 2D Cine

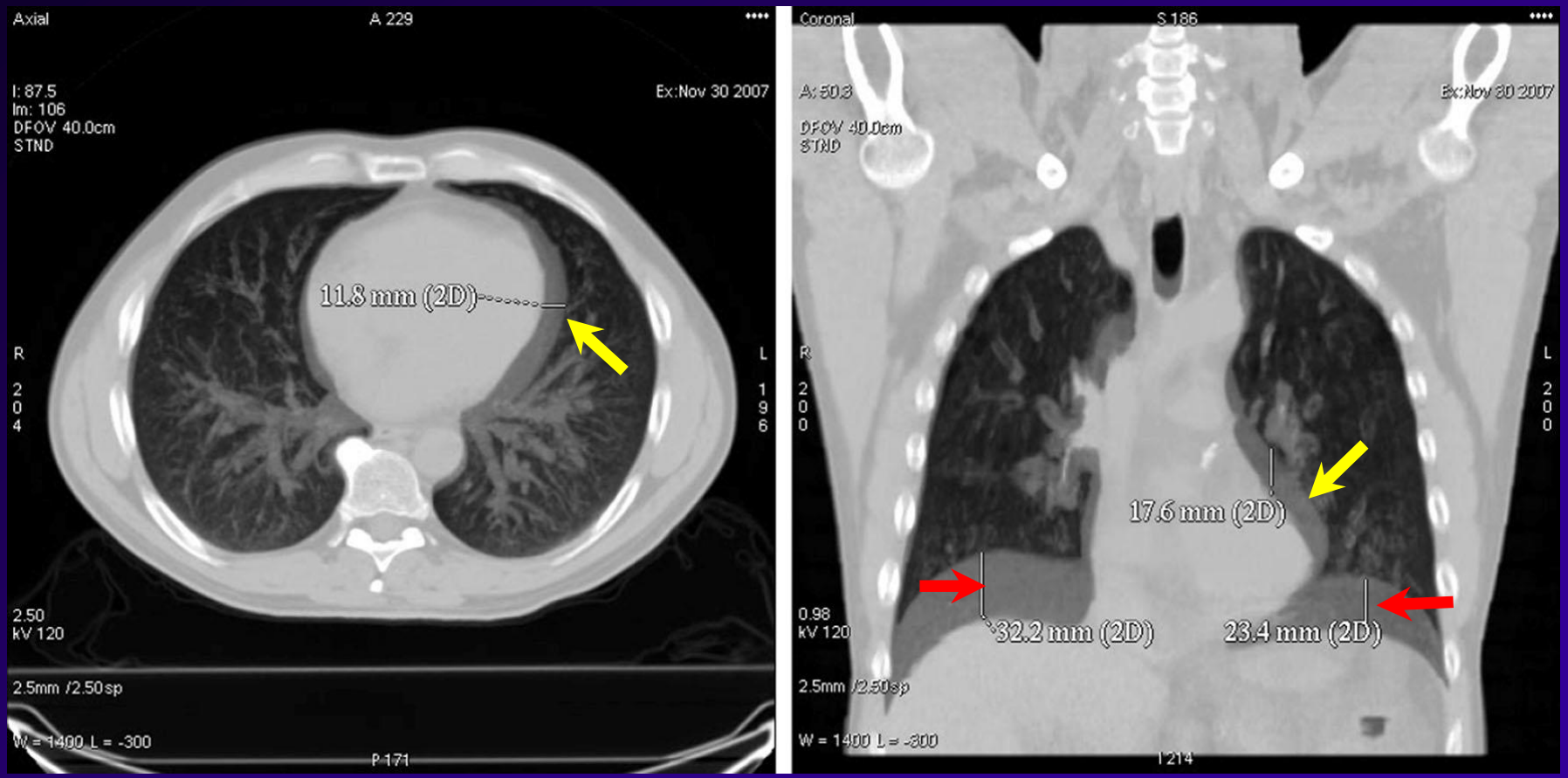
PET





Raw 3D MIP Cine

Cardiac/Respiratory Motion



Slomka et al, J Nucl Cardiolo 2016;23:486-90

Cardiac/Respiratory Motion

Listmode Replay

Series Description: Motion_Stress

StudyType

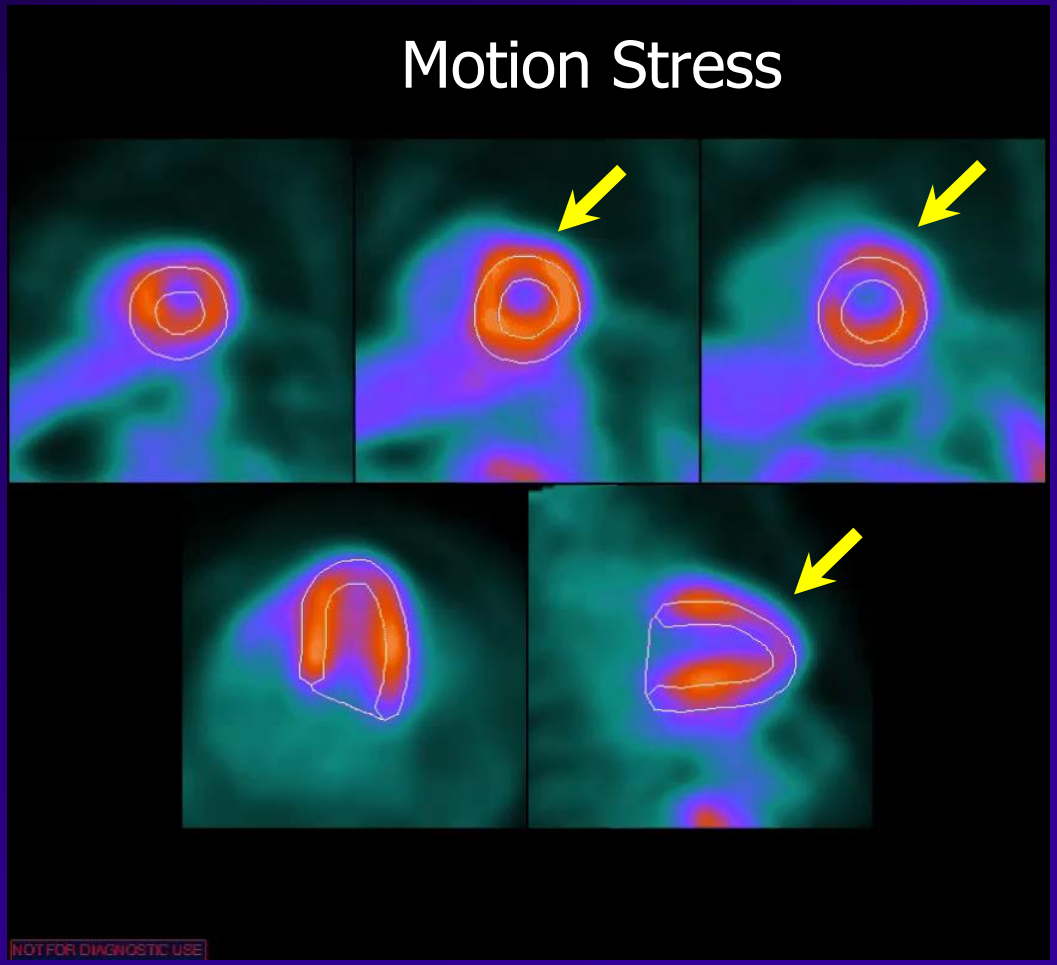
Dynamic

Frame Definition

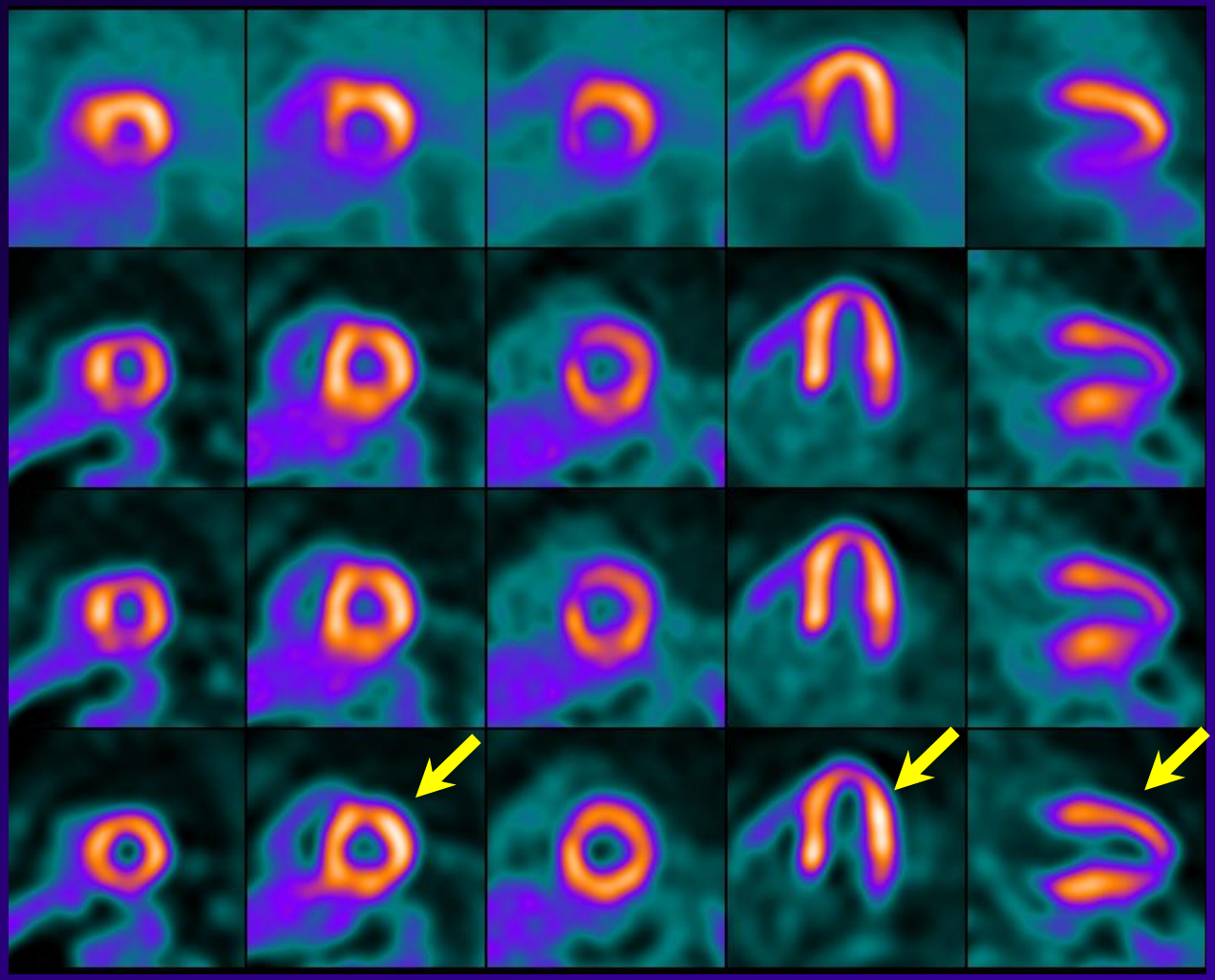
Index	Frames	Time (sec)	Delay
1	0	0	120
2	4	60	0
3			
4			
5			
6			
7			
8			
9			
10			

Total Duration 360 sec

Clear

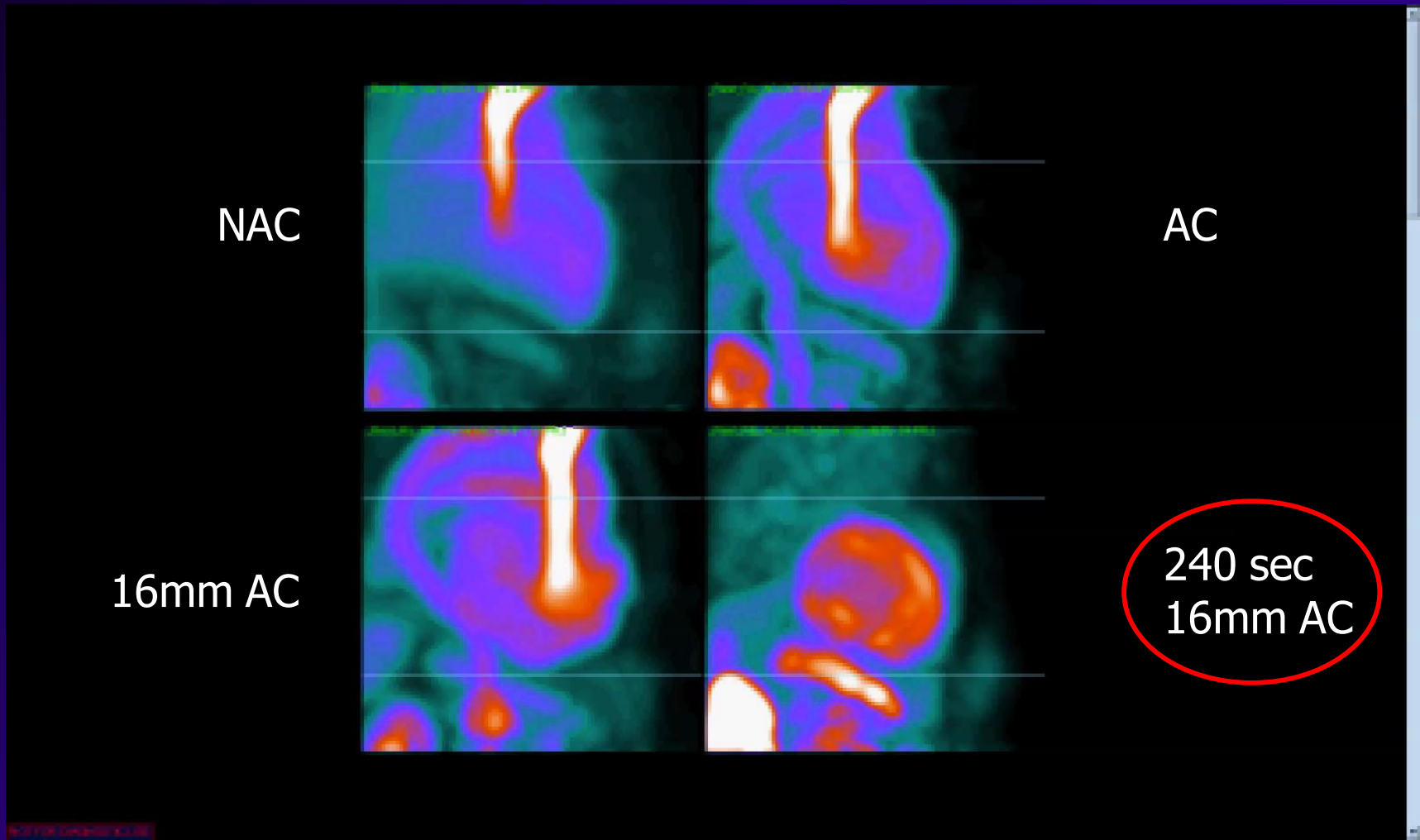


Cardiac/Respiratory Motion



Physiologic Artifact

CHF & Low EF



Physiologic Artifact

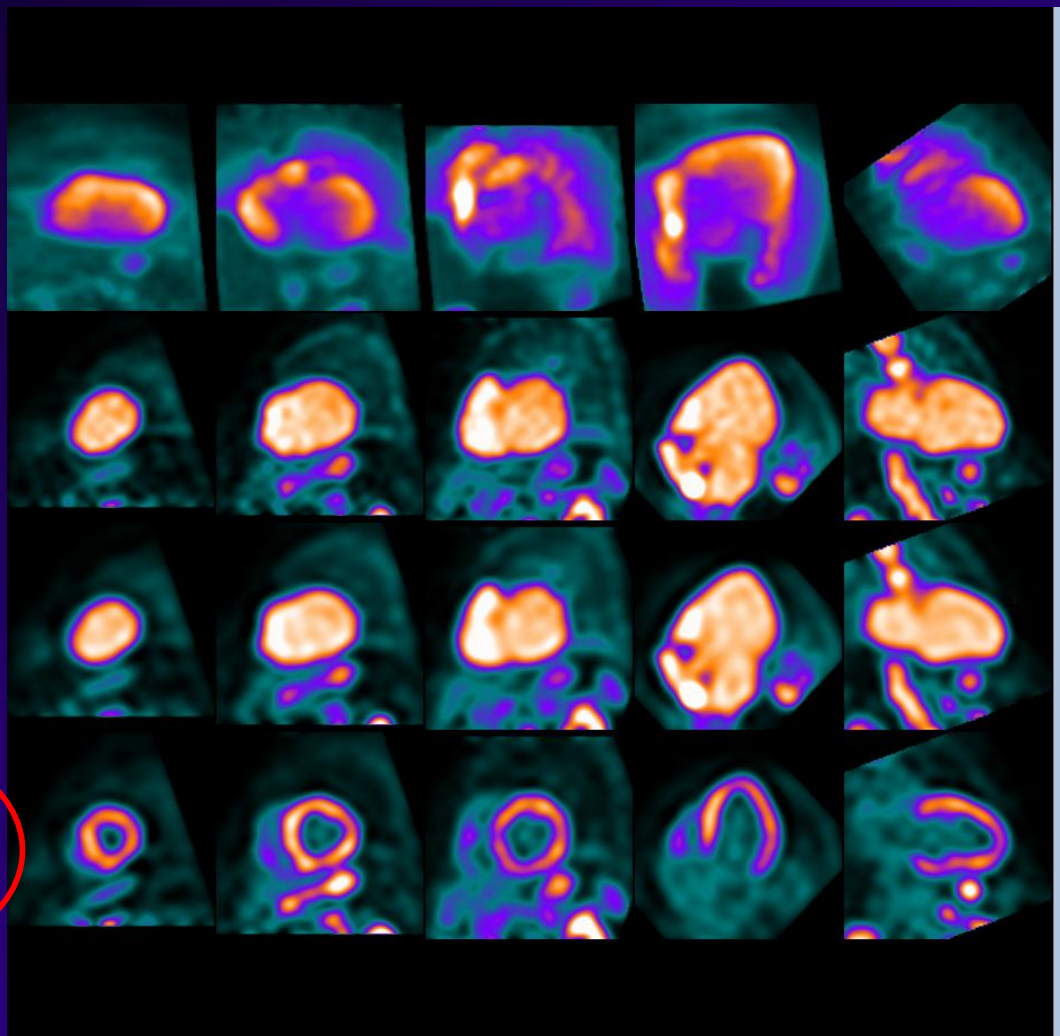
CHF & Low EF

NAC

AC

16mm AC

240 sec
16mm AC



Study	PET^2_Rest_Rubidium (Adult)
Dataset	_Rest_Rb_nac (NAC)
Date	2016-06-01 08:13:02
Status	QC=9.15, IR=0.21 (saved)
Database	Rb-PET-Rest-CSMC
Volume	481ml
Wall	513ml
Defect	235ml
Extent	46%
TPD	34%
Counts	798522k,592.2ml

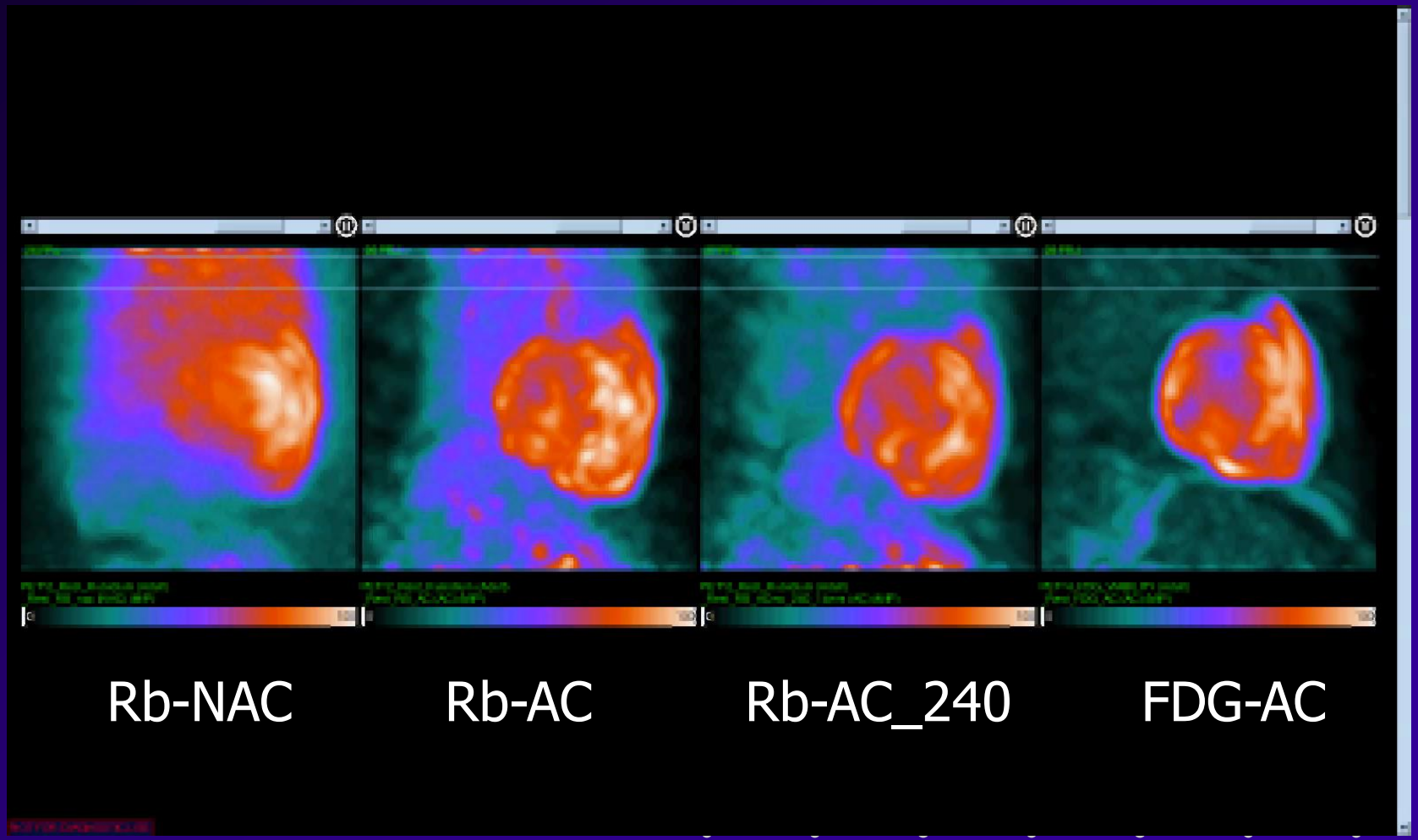
Study	PET^2_Rest_Rubidium (Adult)
Dataset	_Rest_Rb_AC (AC)
Date	2016-06-01 08:13:02
Status	QC=2.79, IR=0.33 (saved)
Database	Rb-PET-Rest-CSMC
Volume	179ml
Wall	201ml
Defect	20ml
Extent	10%
TPD	10%
Counts	3444557k,243.4ml

Study	PET^2_Rest_Rubidium (Adult)
Dataset	_Rest_Rb_AC_16mm (AC)
Date	2016-06-01 08:13:02
Status	QC=2.79, IR=0.33 (saved)
Database	Rb-PET-Rest-CSMC
Volume	179ml
Wall	201ml
Defect	16ml
Extent	8%
TPD	9%
Counts	3407204k,243.4ml

Study	PET^2_Rest_Rubidium (Adult)
Dataset	_Rest_RB_AC_240_16mm (AC)
Date	2016-06-01 08:17:02
Status	QC=2.79, IR=0.33 (saved)
Database	Rb-PET-Rest-CSMC
Volume	179ml
Wall	201ml
Defect	4ml
Extent	2%
TPD	3%

Physiologic Artifact

Lung Uptake, Ischemic Cardiomyopathy & Low EF



Physiologic Artifact

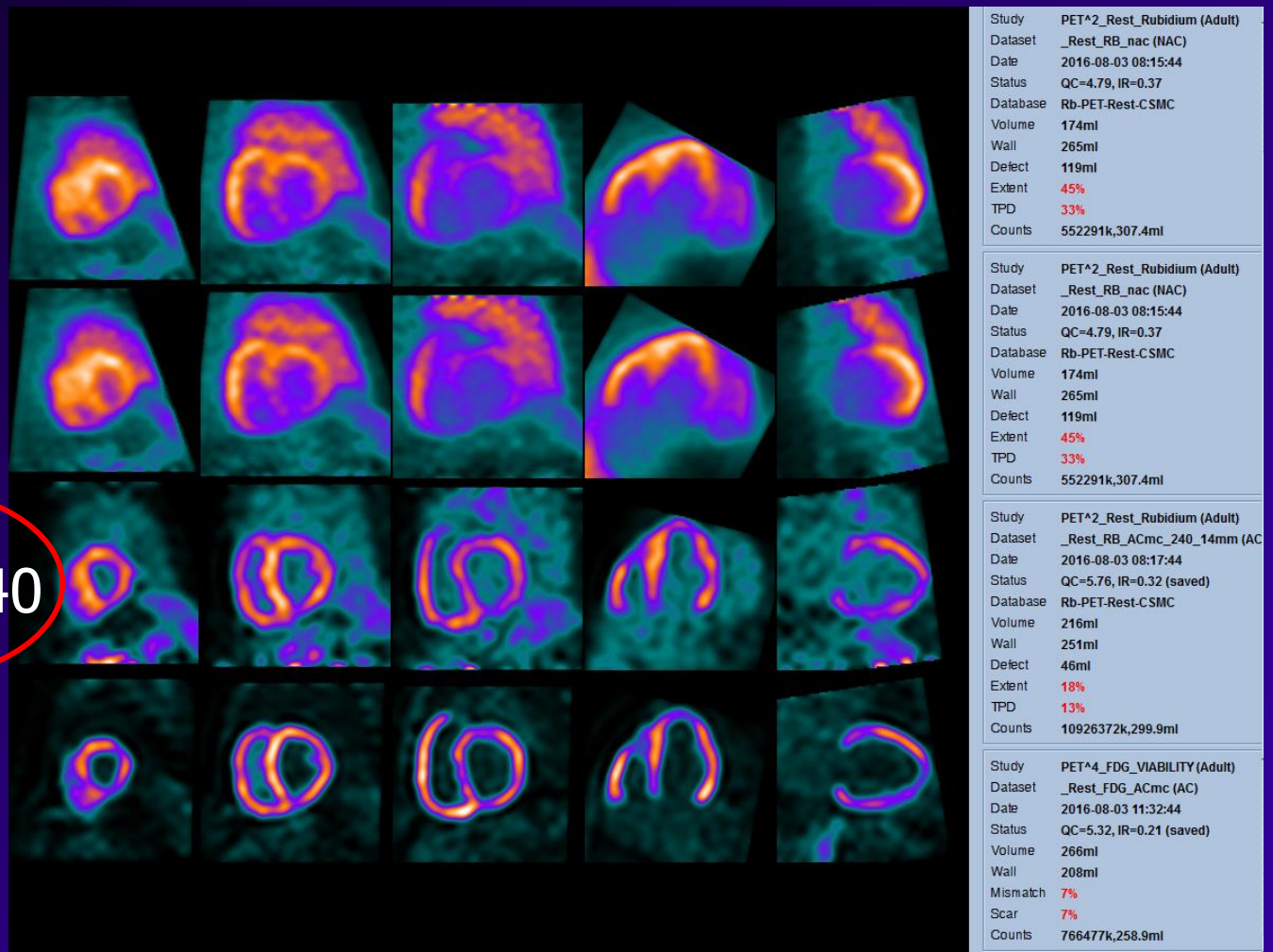
Lung Uptake, Ischemic Cardiomyopathy & Low EF

Rb-NAC

Rb-AC

Rb-AC_240

FDG-AC



Study	PET^2_Rest_Rubidium (Adult)
Dataset	_Rest_RB_nac (NAC)
Date	2016-08-03 08:15:44
Status	QC=4.79, IR=0.37
Database	Rb-PET-Rest-CSMC
Volume	174ml
Wall	265ml
Defect	119ml
Extent	45%
TPD	33%
Counts	552291k,307.4ml

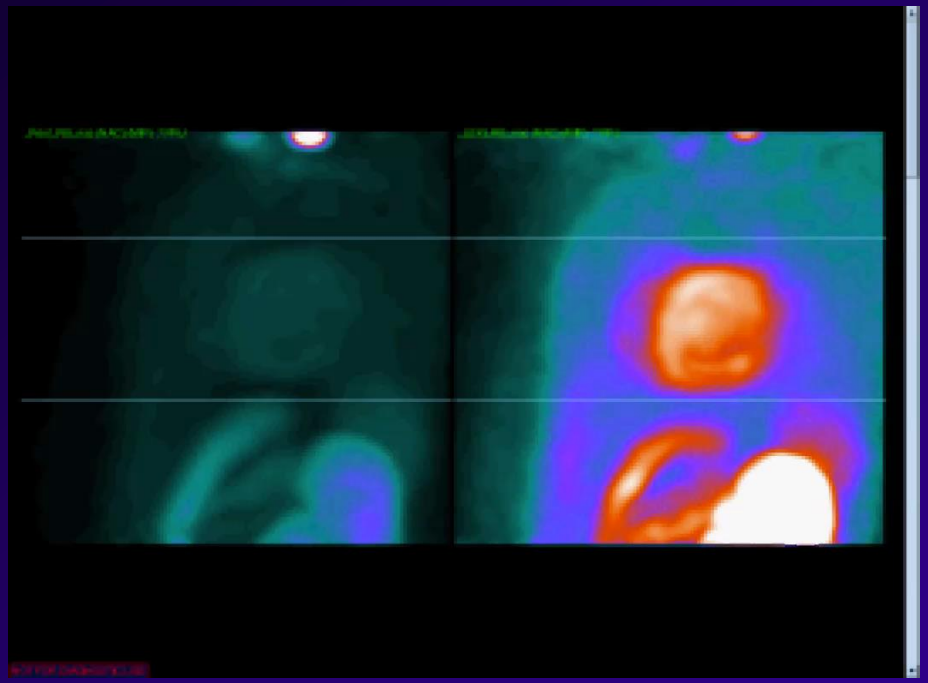
Study	PET^2_Rest_Rubidium (Adult)
Dataset	_Rest_RB_nac (NAC)
Date	2016-08-03 08:15:44
Status	QC=4.79, IR=0.37
Database	Rb-PET-Rest-CSMC
Volume	174ml
Wall	265ml
Defect	119ml
Extent	45%
TPD	33%
Counts	552291k,307.4ml

Study	PET^2_Rest_Rubidium (Adult)
Dataset	_Rest_RB_ACmc_240_14mm (AC
Date	2016-08-03 08:17:44
Status	QC=5.76, IR=0.32 (saved)
Database	Rb-PET-Rest-CSMC
Volume	216ml
Wall	251ml
Defect	46ml
Extent	18%
TPD	13%
Counts	10926372k,299.9ml

Study	PET^4_FDG_VIABILITY (Adult)
Dataset	_Rest_FDG_ACmc (AC)
Date	2016-08-03 11:32:44
Status	QC=5.32, IR=0.21 (saved)
Volume	266ml
Wall	208ml
Mismatch	7%
Scar	7%
Counts	766477k,258.9ml

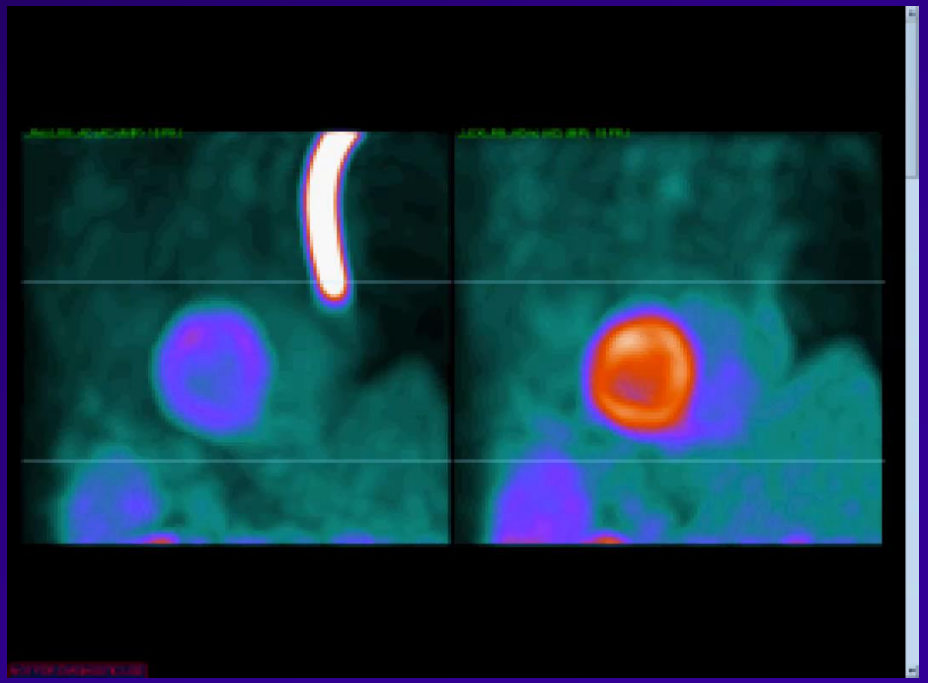
IV Problems

Small IV



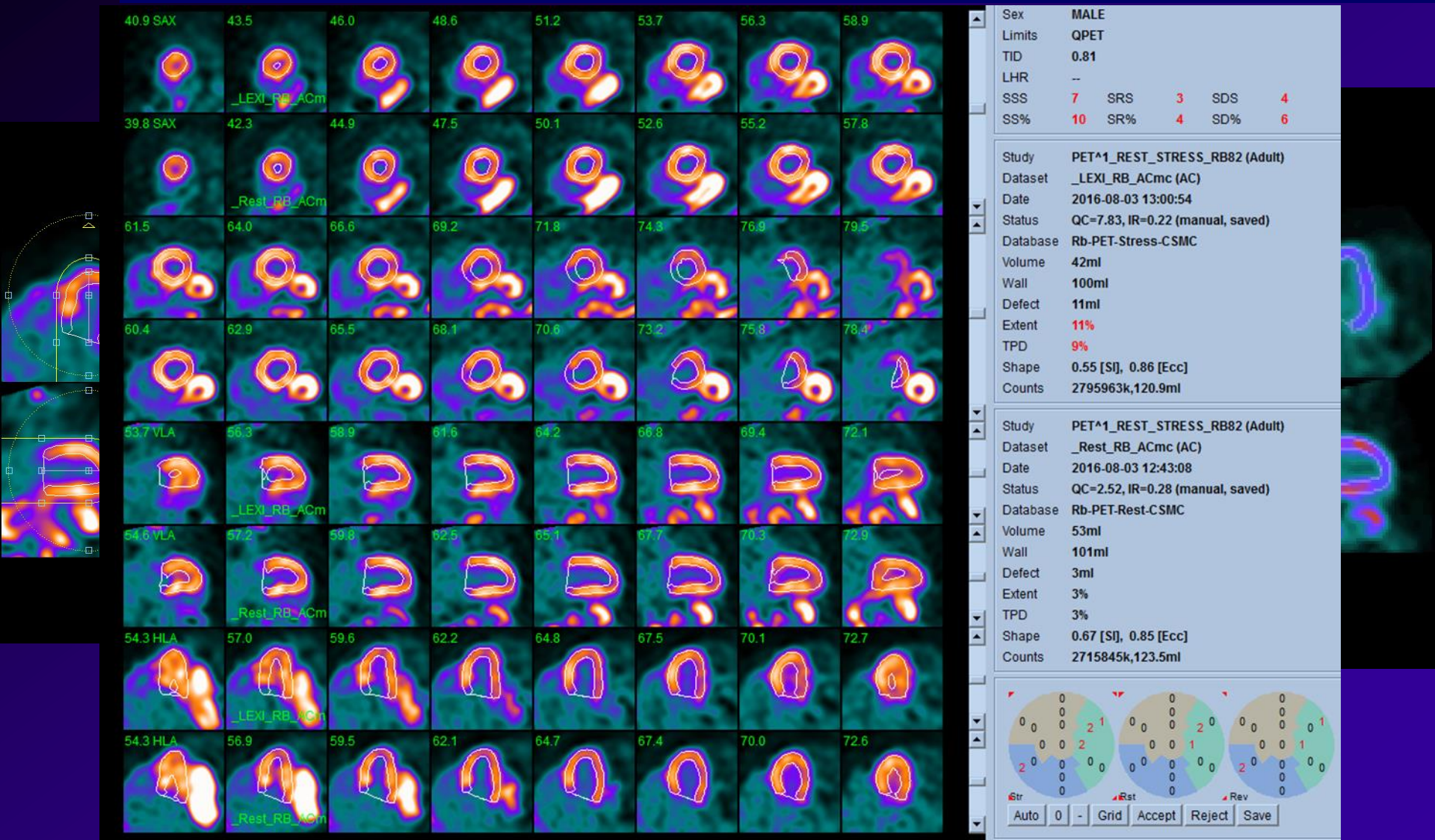
Rest Stress

PICC Line

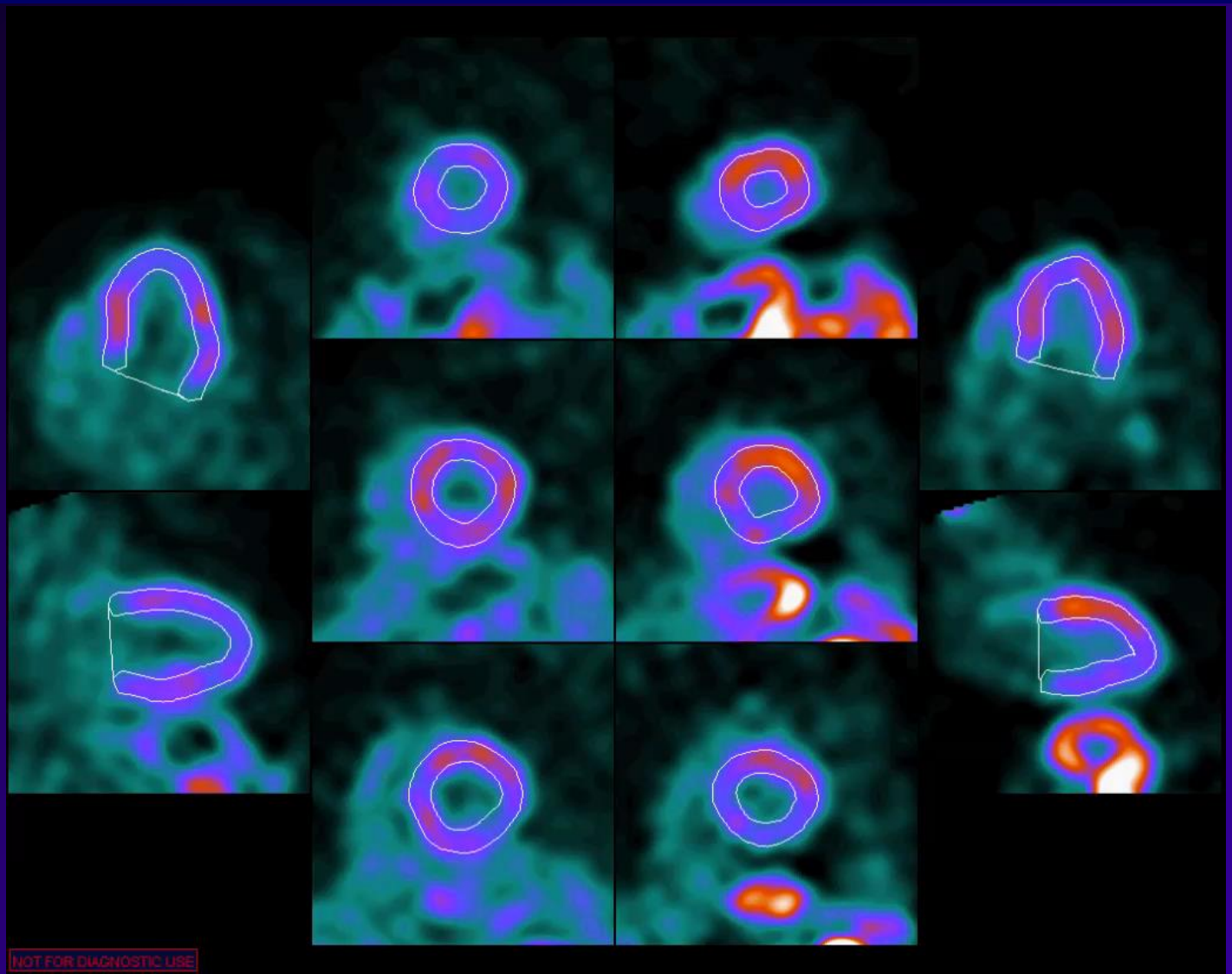


Rest Stress

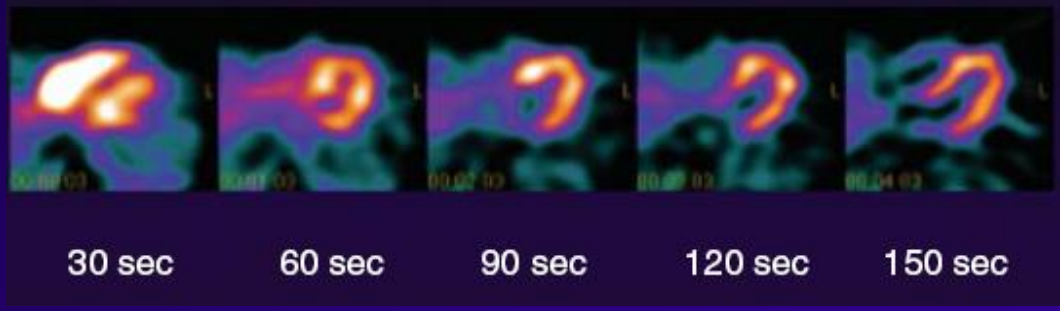
Excessive Gut Uptake



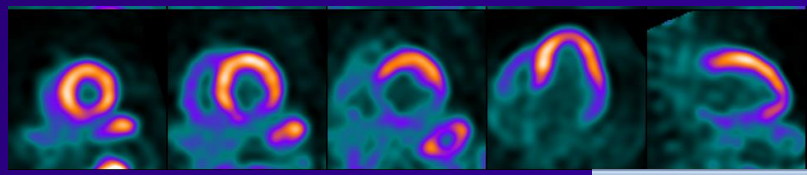
ECG Gating Artifact



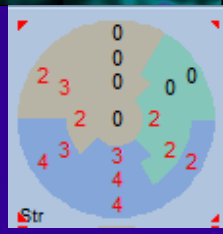
Rb-PET MPI Analysis



- Quality:
  - Blood pool activity
  - Lung uptake
- Perfusion defects
  - Location, qualitative (visual) evaluation of severity
  - Semi-quantitative segmental score



- Gated data
  - RV and LV size, relative uptake
  - Volume, EF and regional wall motion



- Dynamic data
  - Rest & peak stress myocardial blood flow and flow reserve
- Extra-cardiac findings and calcium score (CT)

Summary

- Cardiac PET imaging offers unique & robust technique in detecting and risk assessment of CAD in patient who is not able to exercise adequately.
- PET imaging artifacts are different than the SPECT
- Causes include; breathing, patient motion
  - 21% of PET scans (JNM 2004; 45:1029-39)
  - Up to 40% if CTAC (JNM 2007; 48: 1112-1121)
- Solutions;
  - Patient prep & history
  - Software based – realign transmission & emission scans
  - Reconstruct partial data (list mode)
  - Repeat study