UTHealth Houston

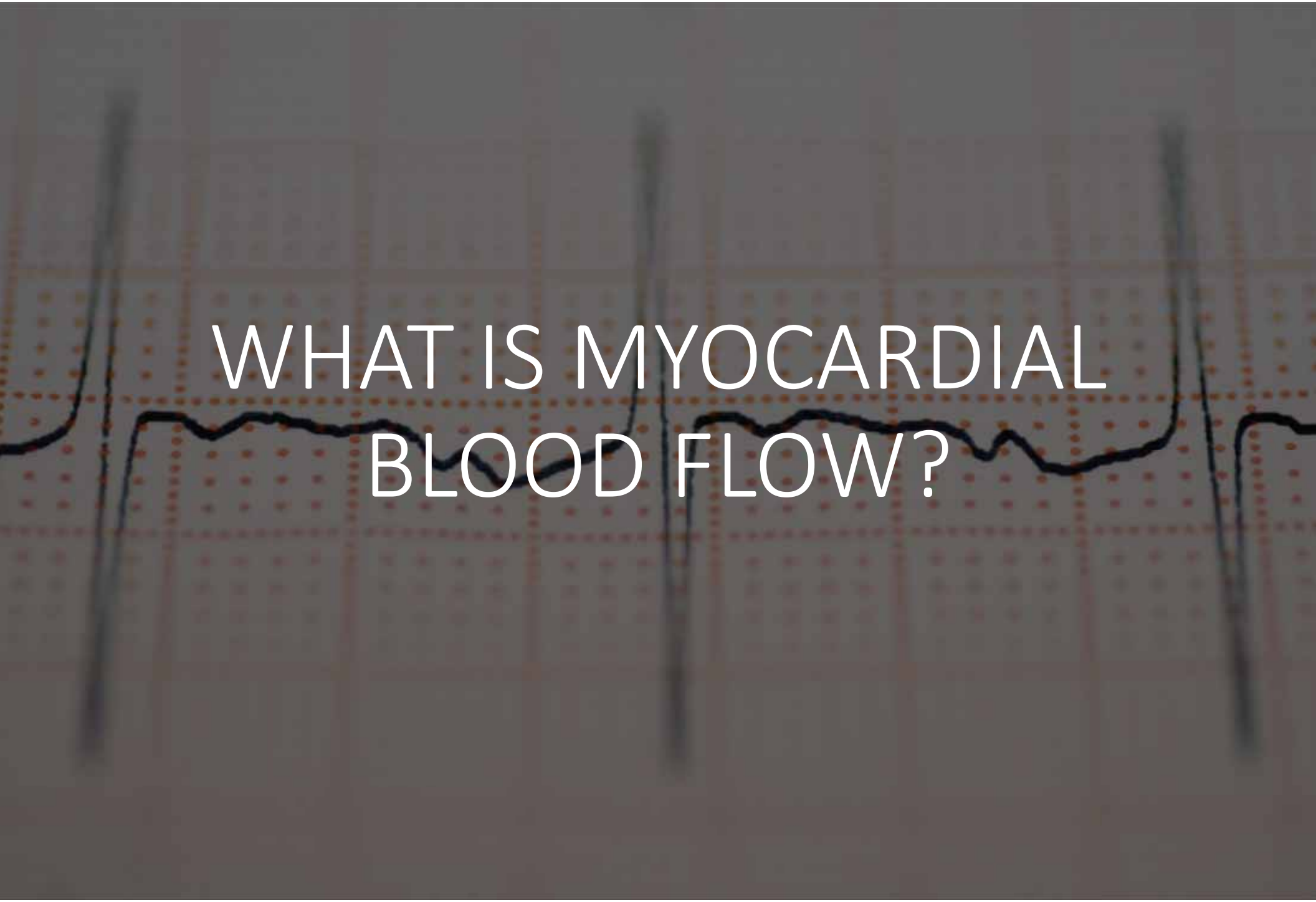
McGovern Medical School

Garbage in, garbage out…Protocols and processing for PET MBF.

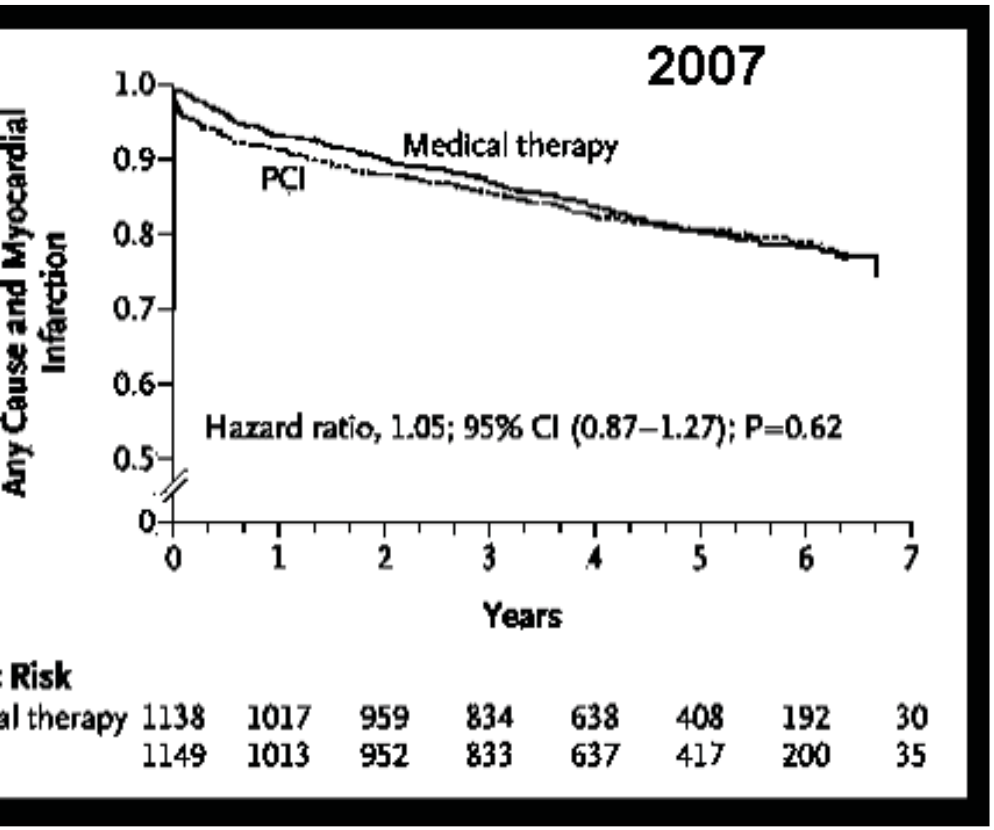
Amanda Roby MBA, PET, RT(N)

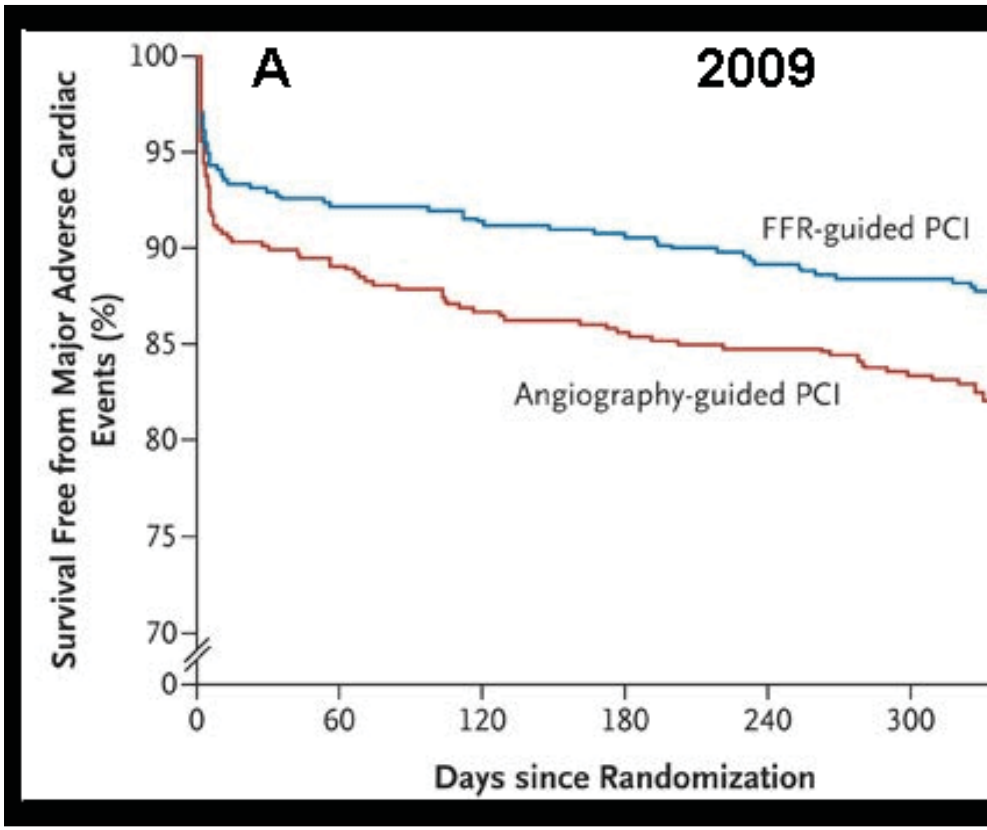
Weatherhead PET Imaging Center

Houston, TX


WHAT IS MYOCARDIAL
BLOOD FLOW?

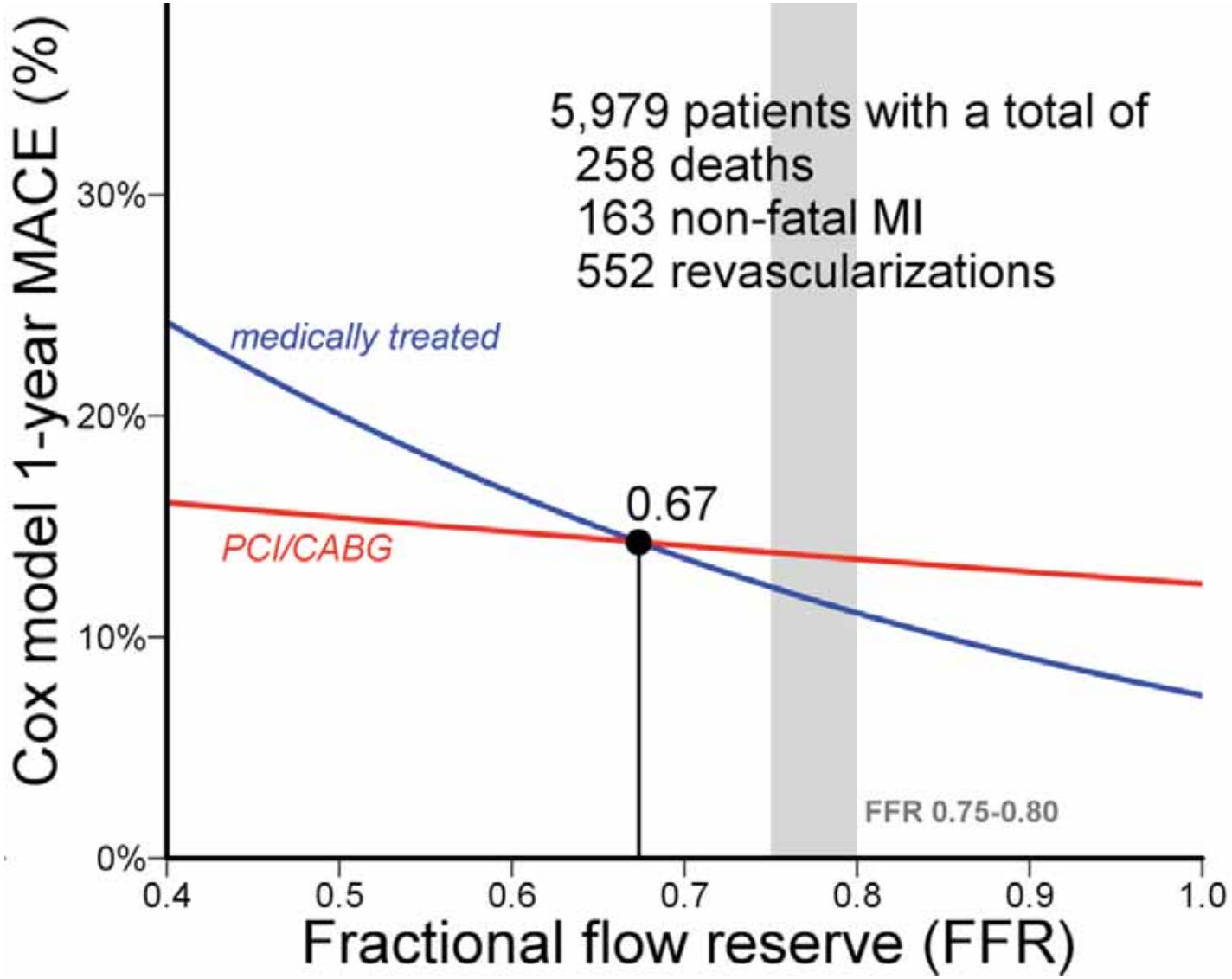
Courage Trial: PCI vs Medical Rx In Non-Acute CAD No benefit of stents over medical treatment alone based on angiogram FAME I showed physiology plays a major role.





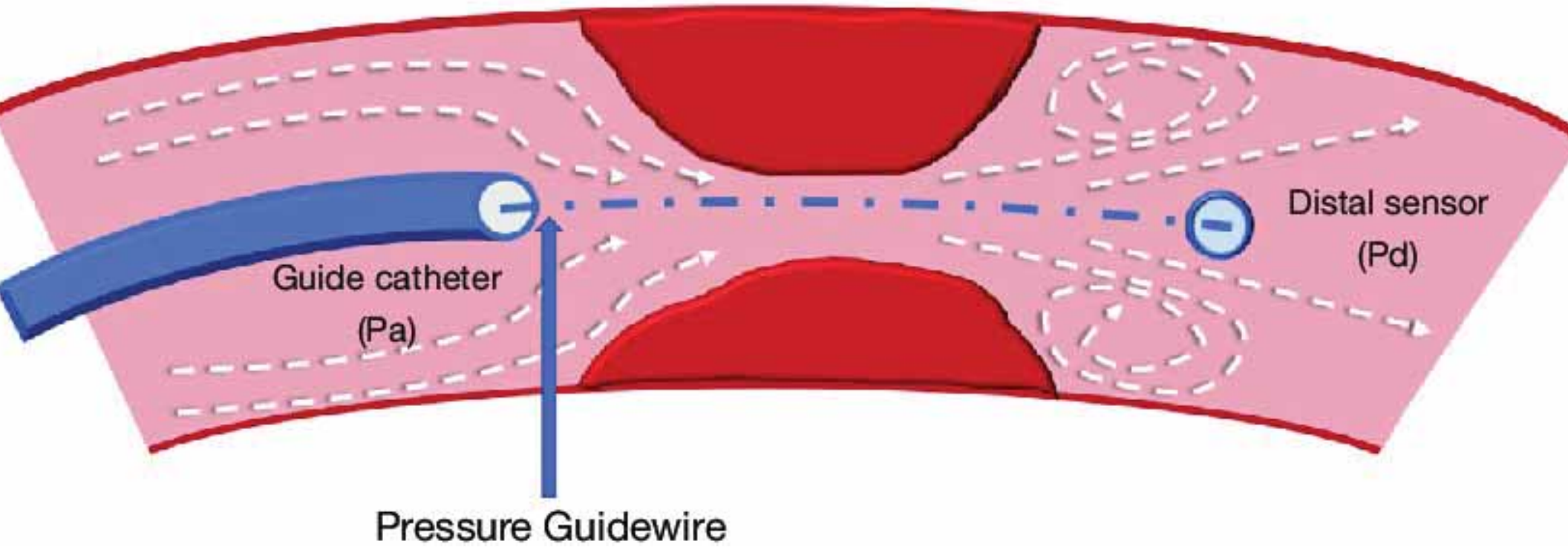
V et al. N Engl J Med 2007;356:1503

Tonino et al. N Engl J Med 2009;360:213 and Defer trial 5 yr f/u JACC 20



et al. JACC 2014;64:1641 original, adapted for Gould et al. Circ CV Imag 2015;8:e003099.

CA-FFR (fractional flow reserve)



et al. April 2020 Cardiovascular Diagnosis and Therapy 10(6):1954-1978

nvasive Coronary Angiography - FFR

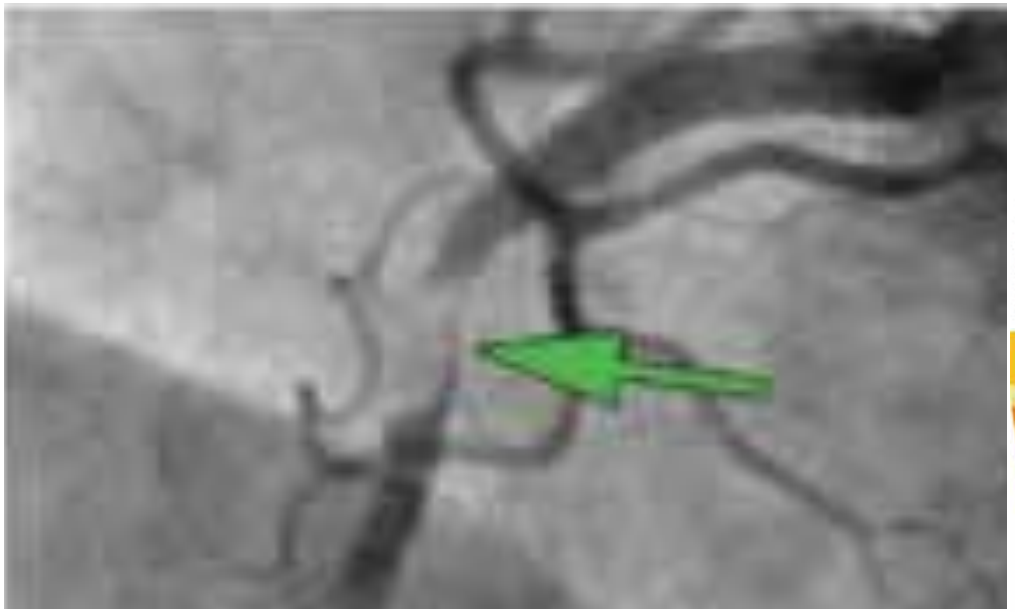
Pros

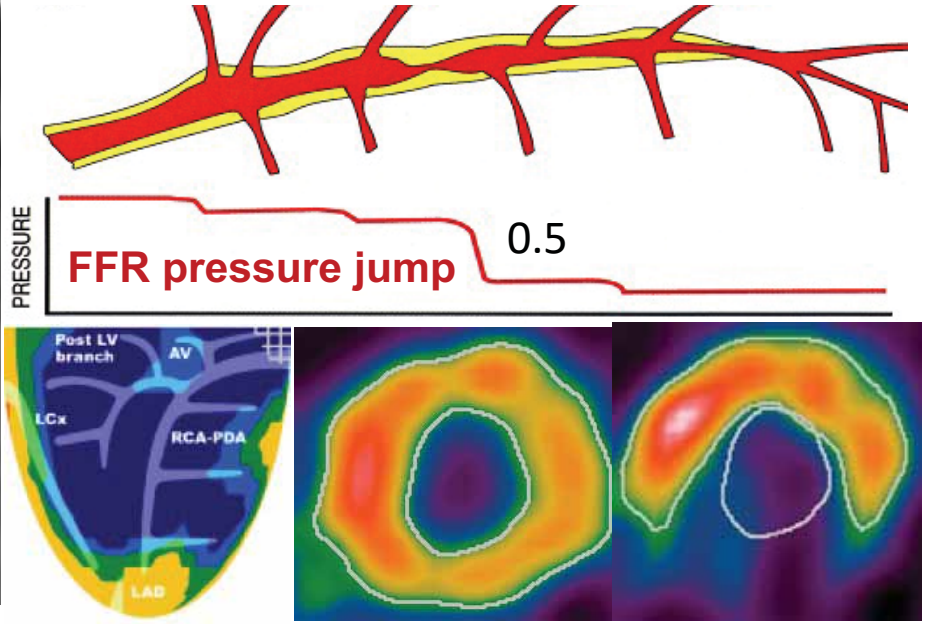
New gold standard for evaluating stenosis severity.

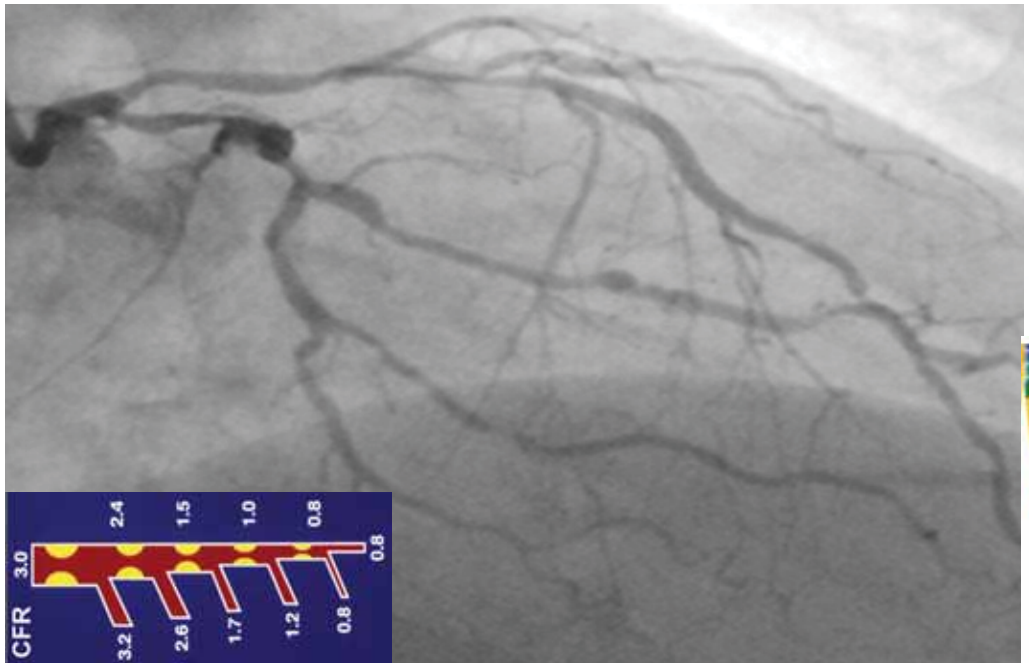
Eval and deploy therapy at the same time.

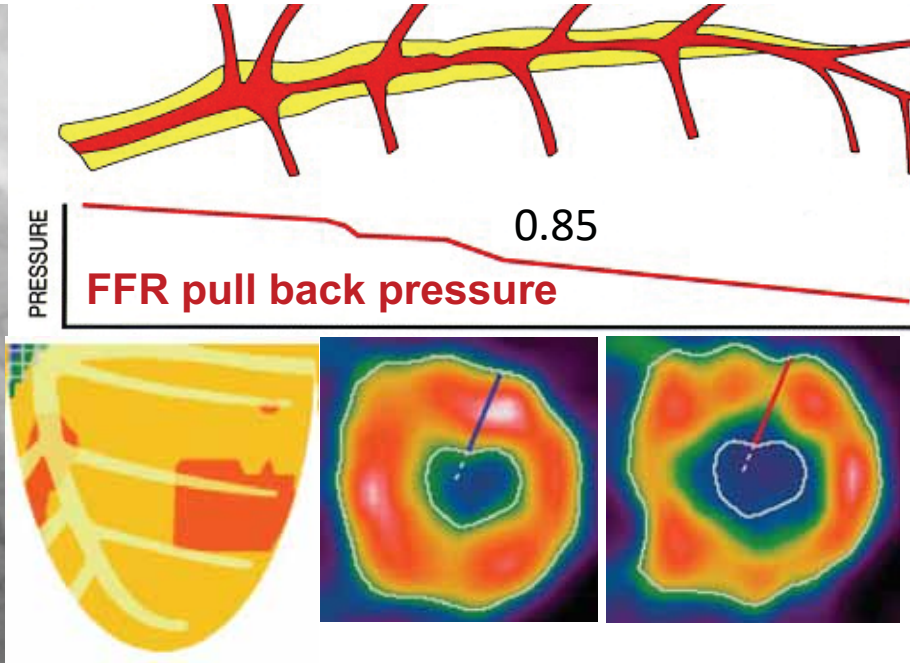
Cons

- Invasive
- Requires highly skilled invasive cardiologist
- Additional time
- Additional equipment
- Difficult to evaluate regional impact or diffuse disease



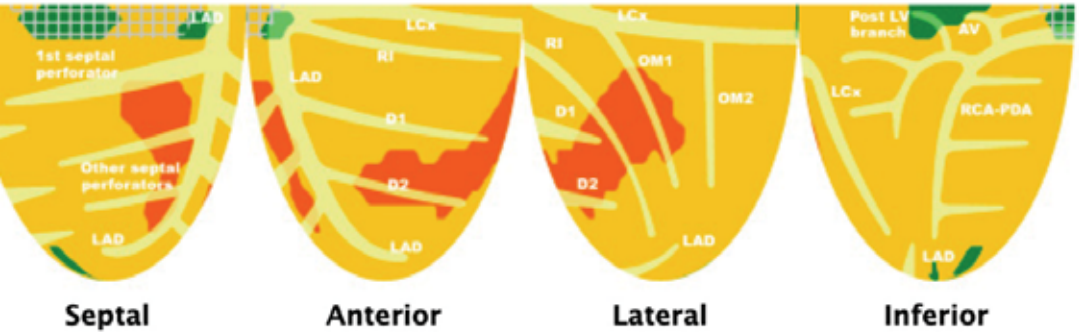

PRESSURE
FFR pressure jump
0.5
Post LV branch
AV
LCx
RCA-PDA
LAD


CFR
3.0
2.4
1.5
1.0
0.8
0.8
3.2
2.6
1.7
1.2
0.8


PRESSURE
0.85
FFR pull back pressure

e on renal dialysis with dyspnea on exertion, no angina, has HTN, DM, stress EF 65%, mia, hypothyroidism, coronary calcium, no angina or ST changes during stress.
surgeon: "No renal transplant until CABG is done". Angiogram called 60% to 90% DS.

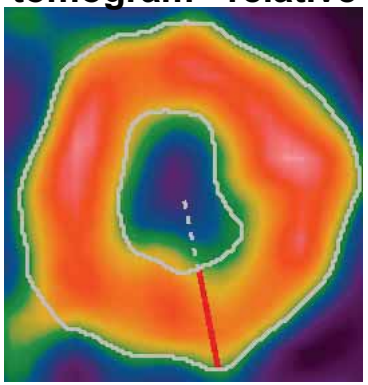
Pre-op Coronary Flow Capacity 9/2018, angio 8/2019, CABG 5/2020



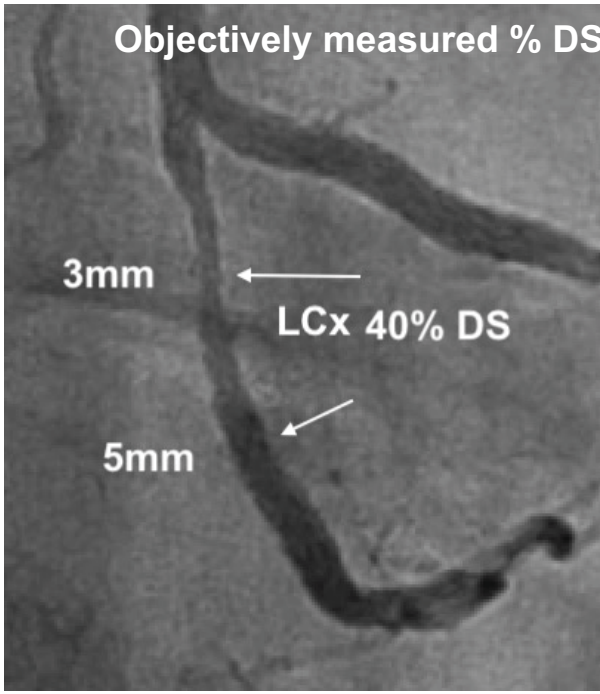
Septal Anterior Lateral Inferior

0% Normal, from healthy young volunteers
11% Minimally reduced, risk factors only
87% Mildly reduced
2% Moderately reduced
0% Severely reduced, definite ischemia

tomogram - relative

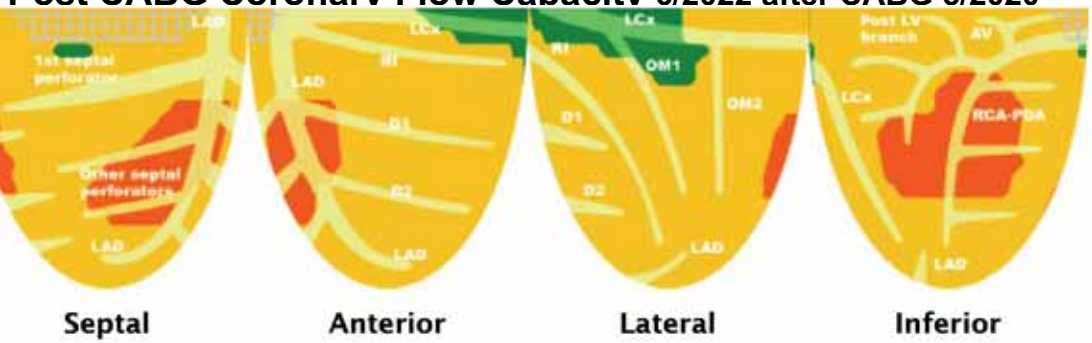


normal subendocardial stress perfusion



t-op CFC shows microvascular dysfunction & non-obstructive coronary calcification.

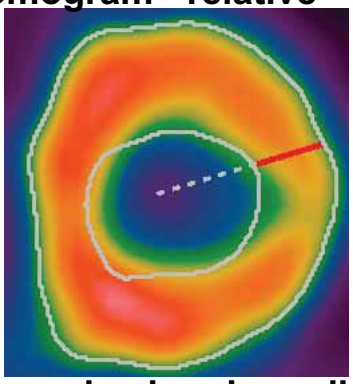
Post CABG Coronary Flow Capacity 6/2022 after CABG 5/2020



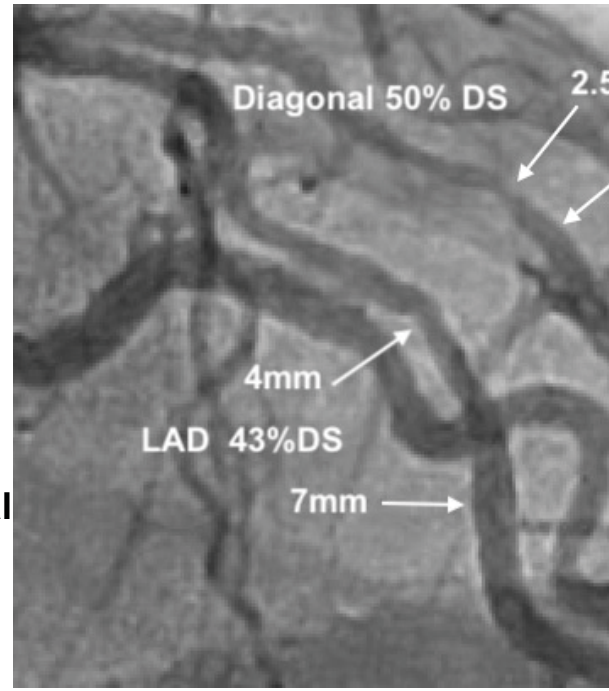
Septal Anterior Lateral Inferior

0% Normal, from healthy young volunteers
14% Minimally reduced, risk factors only
81% Mildly reduced
5% Moderately reduced
0% Severely reduced, definite ischemia

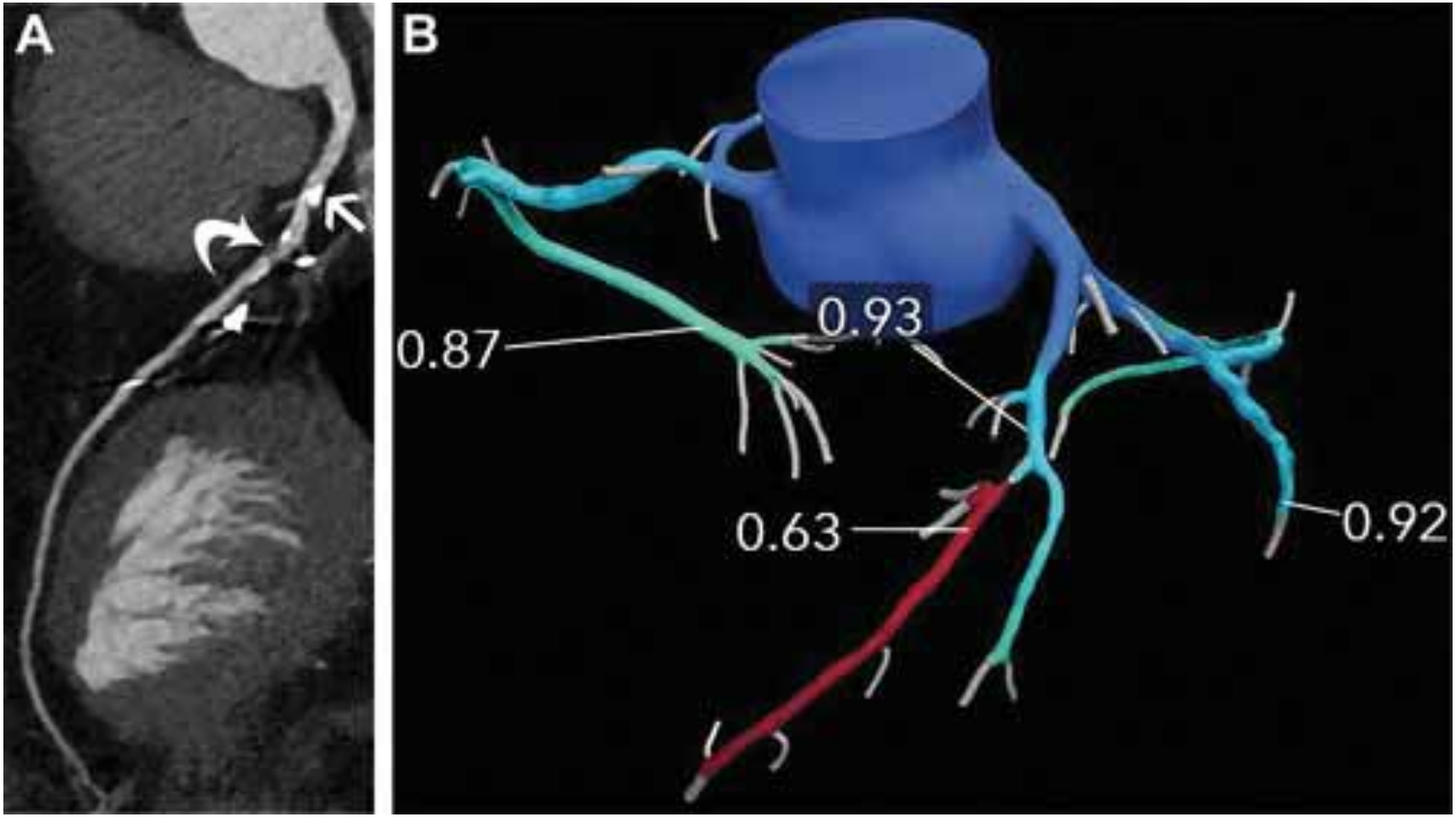
tomogram - relative



normal subendocardial stress perfusion



CTA with FFR_{CT}



n, et al. Feb 2022 Radiographics 42(2) 340-358

FFR_{CT} (HeartFlow)

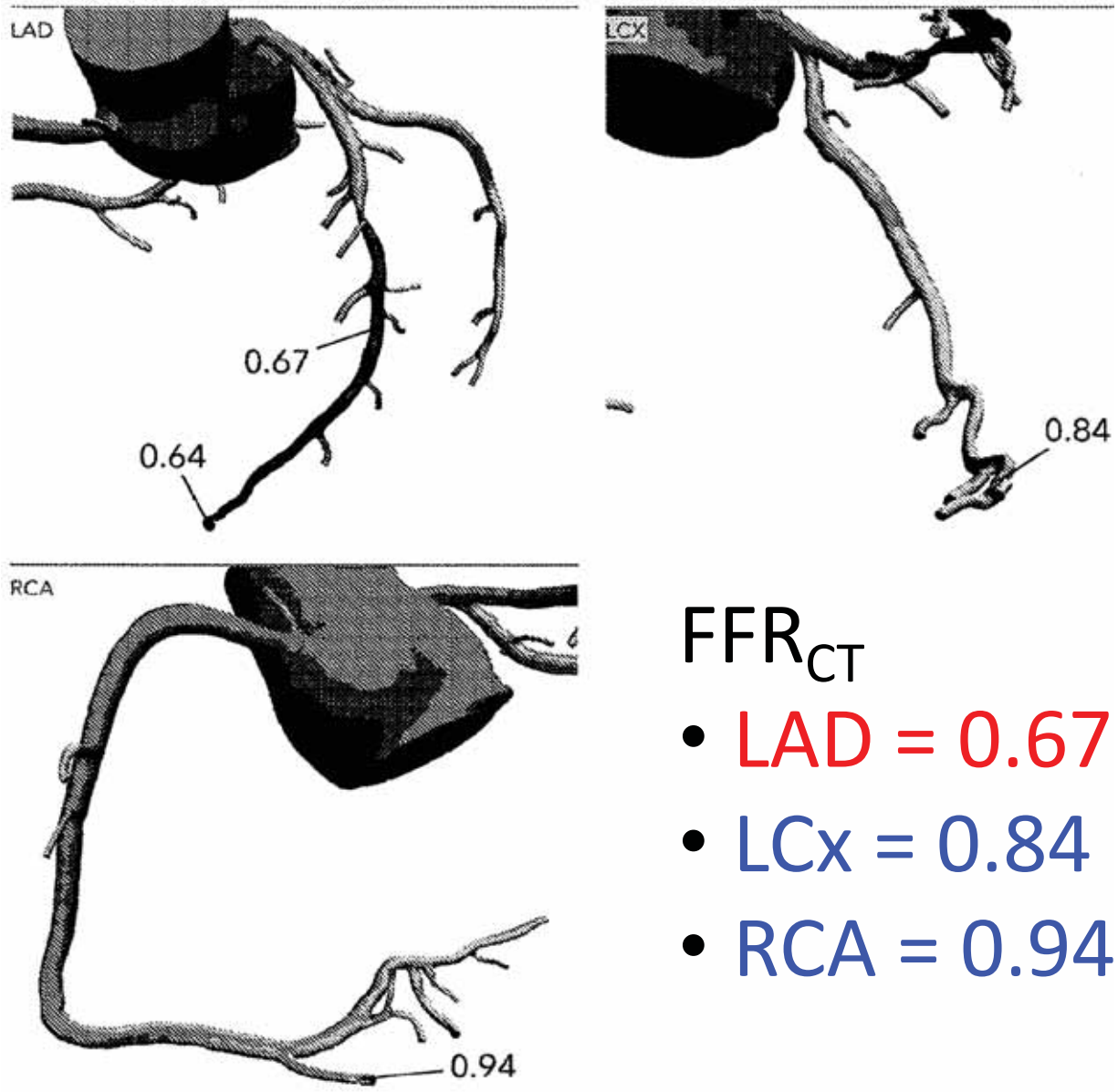
Pros

- Easily reimbursed
- FFR_{CT} performs better than CTA alone

Cons

- More expensive than SPECT, Echo, and CMR
- DeFACTO low specificity (54%) and positive predictive value (67%).
- NXT trial confirmed the positive predictive value of only 65%.
- Lower accuracy in intermediate lesions and high false+ in terminal vessels.
- Contraindication for contrast or prep
- Difficult in diffuse disease and serial stenosis

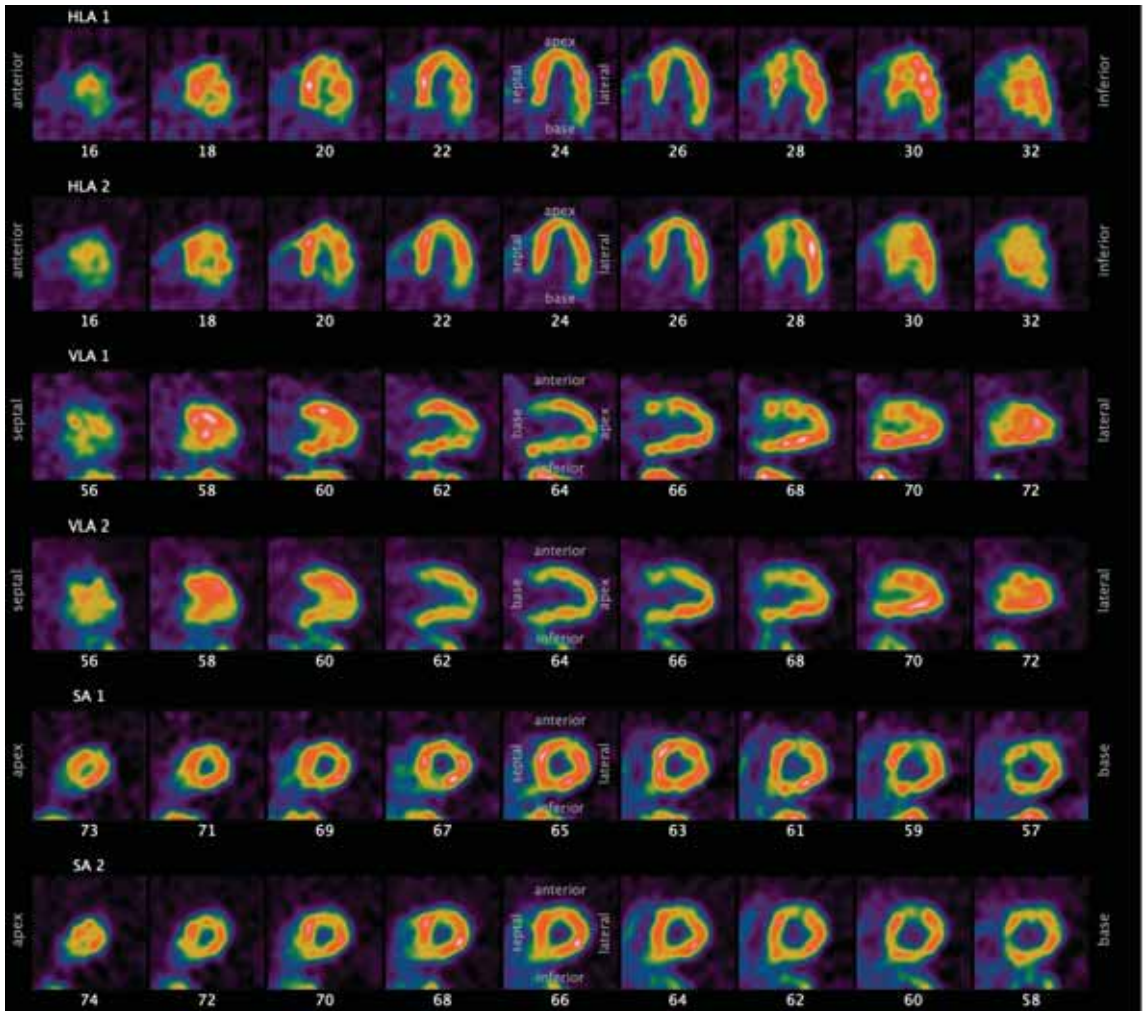
FFR_{CT} report

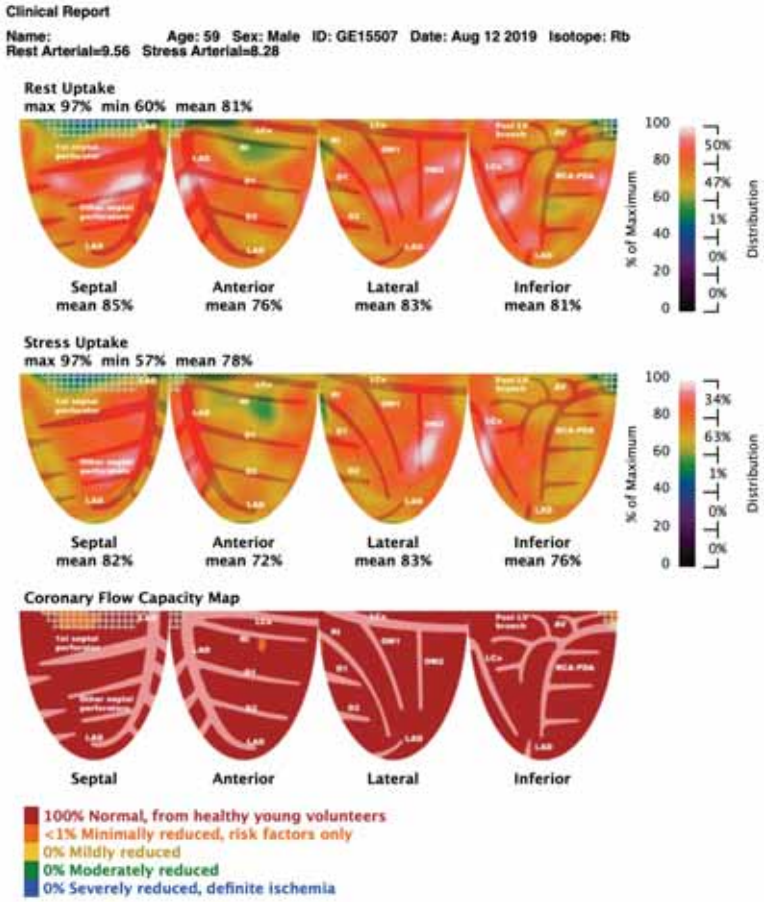


FFR_{CT}

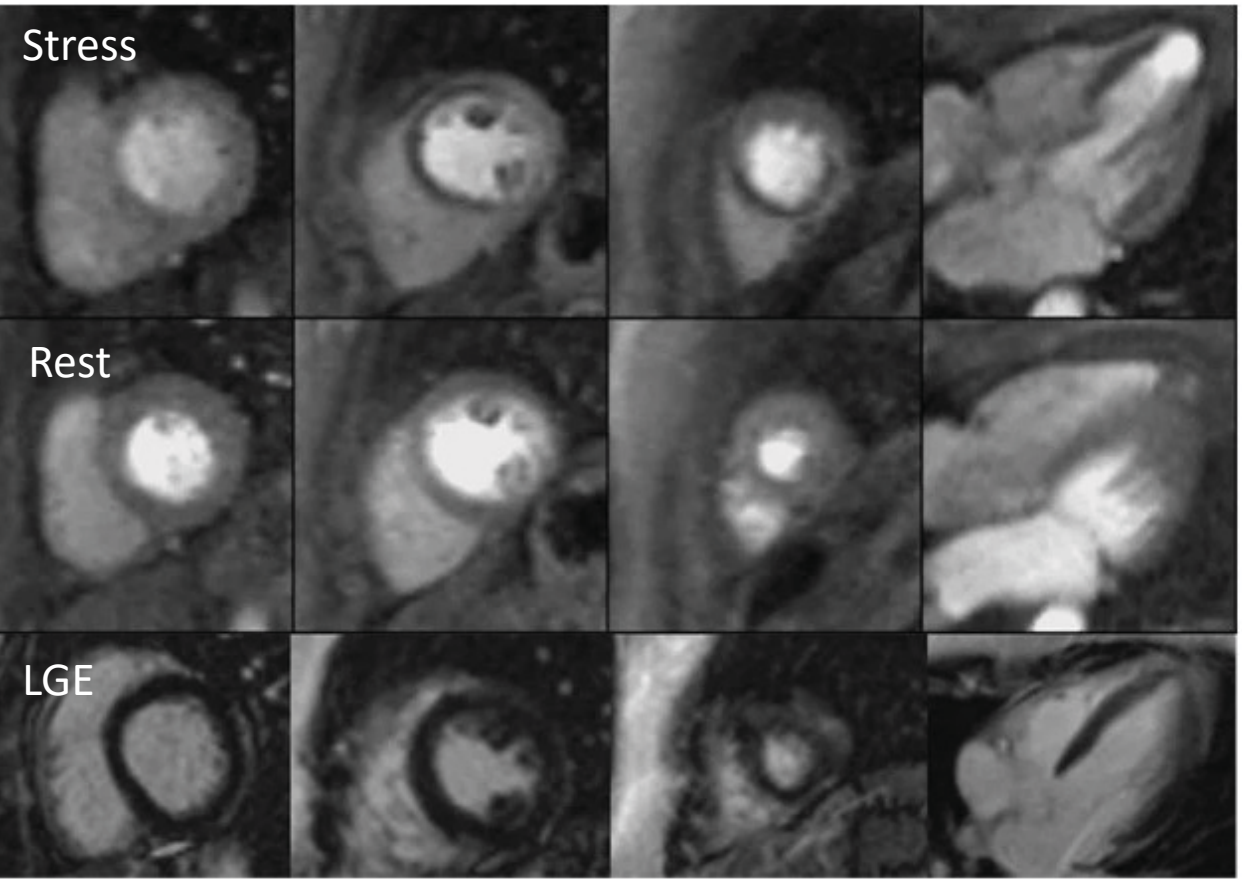
- LAD = 0.67
- LCx = 0.84
- RCA = 0.94

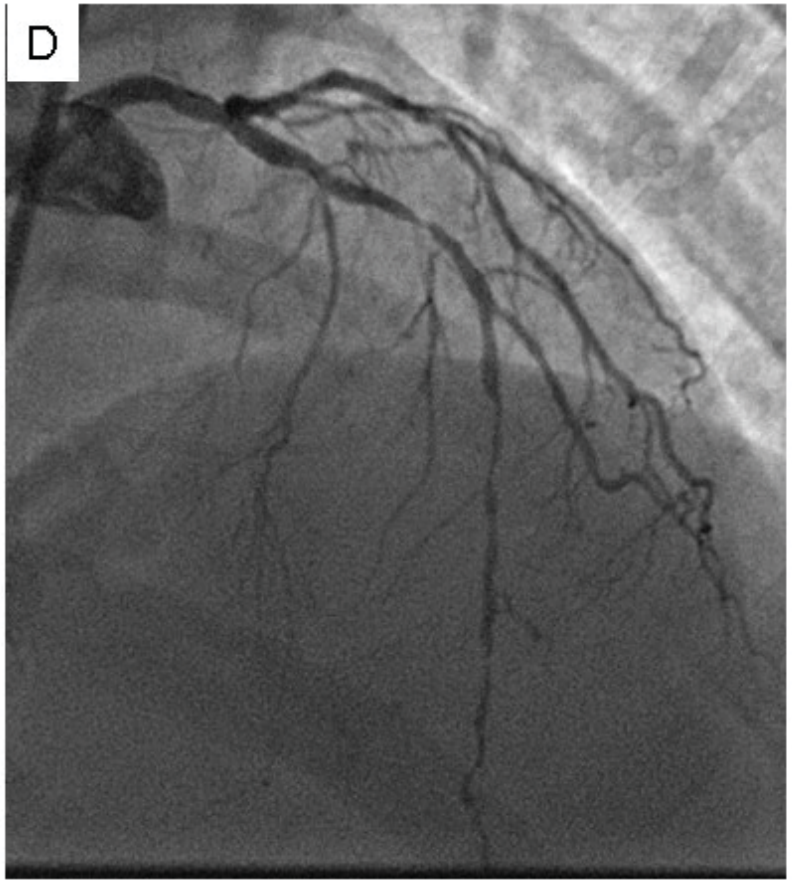
PET images


HLA 1
anterior
apex
septal
lateral
base
inferior
16 18 20 22 24 26 28 30 32
HLA 2
anterior
apex
septal
lateral
base
inferior
16 18 20 22 24 26 28 30 32
VLA 1
septal
anterior
base
apex
inferior
lateral
56 58 60 62 64 66 68 70 72
VLA 2
septal
anterior
base
apex
inferior
lateral
56 58 60 62 64 66 68 70 72
SA 1
apex
anterior
septal
lateral
inferior
base
73 71 69 67 65 63 61 59 57
SA 2
apex
anterior
septal
lateral
inferior
base
74 72 70 68 66 64 62 60 58


Clinical Report
Name: Age: 59 Sex: Male ID: GE15507 Date: Aug 12 2019 Isotope: Rb
Rest Arterial=9.56 Stress Arterial=8.28
Rest Uptake
max 97% min 60% mean 81%
Septal mean 85%
Anterior mean 76%
Lateral mean 83%
Inferior mean 81%
% of Maximum
Distribution
50%
47%
1%
0%
0%
Stress Uptake
max 97% min 57% mean 78%
Septal mean 82%
Anterior mean 72%
Lateral mean 83%
Inferior mean 76%
34%
63%
1%
0%
0%
Coronary Flow Capacity Map
Septal
Anterior
Lateral
Inferior
100% Normal, from healthy young volunteers
<1% Minimally reduced, risk factors only
0% Mildly reduced
0% Moderately reduced
0% Severely reduced, definite ischemia

CMR-CFR (coronary flow reserve)





r, et al. Apr 2008 JCMR 10 (18)

CMR Perfusion and CFR

Pros

Gold standard for anatomy, wall motion, and viability.

No ionizing radiation

Similar accuracy to ICA-FFR

Cons

- Least available in US
- Poorly reimbursed
- Device contraindications
- Technically difficult
- Contrast contraindications
- Small number of slices
- Poor artery specific perfusion

Stress CMR = PET

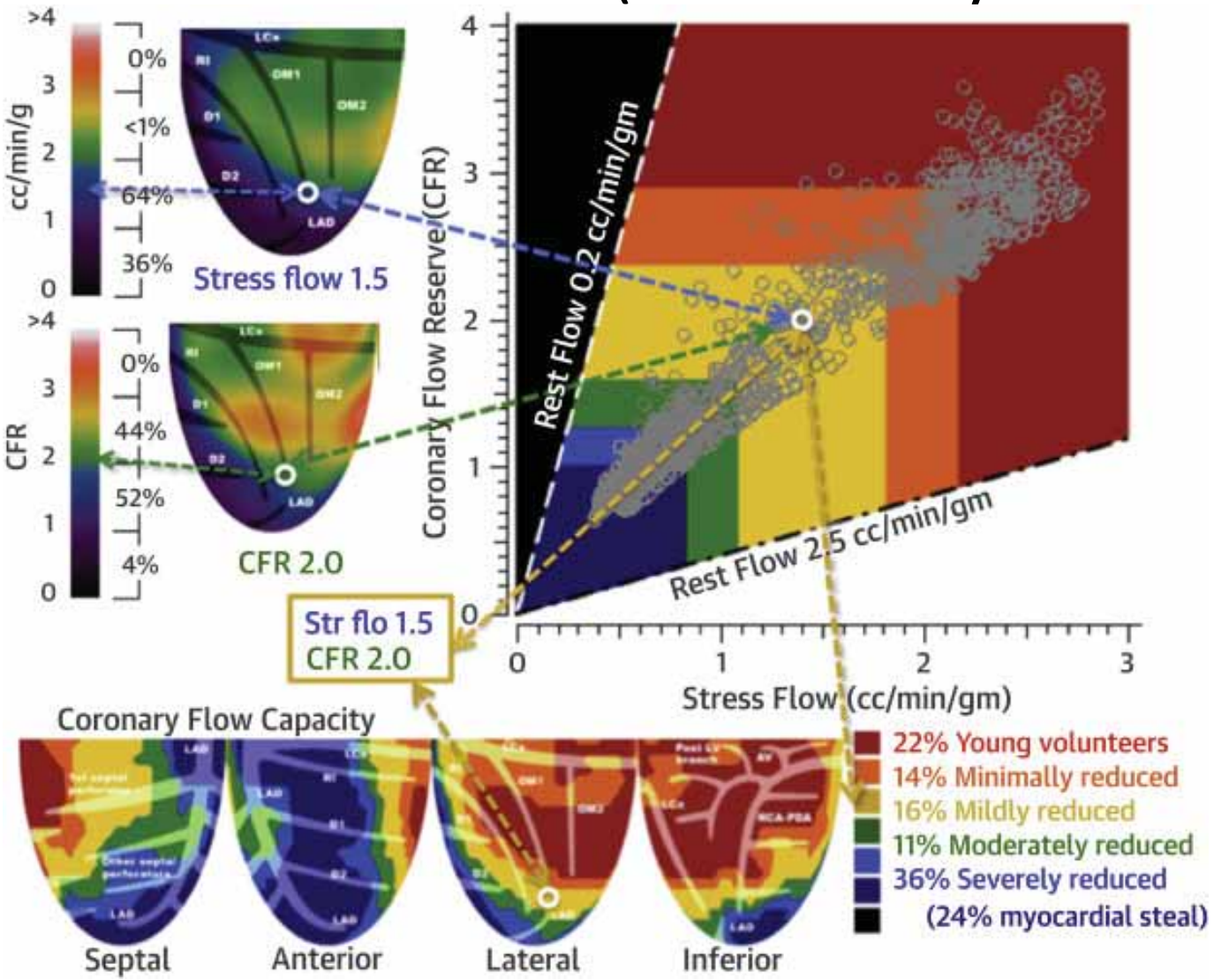
Functionally significant CAD

Test	Sensitivity (%), (95% CI)	Specificity (%), (95% CI)
ICA	68 (60–75)	73 (55–86)
Stress ECG	no data	
Stress echo		
CCTA	93 (89–96)	53 (37–68)
SPECT	73 (62–82)	83 (71–90)
PET	89 (82–93)	85 (81–88)
Stress CMR	89 (85–92)	87 (83–91)

- FFR as reference
- stable CAD
- 23 studies
- 4131 subjects

. 2018 Sep 14;39(35):3322-3330. (Table 1 portions with *annotations*)

ET MPI with CFR & CFC (coronary flow capacit



Johnson. Nov 2018. JACC 72 (21) 2642-2662

PET Myocardial Perfusion Imaging (MPI) Myocardial Blood Flow (MBF)

Pros

- Artery specific perfusion
- Fast patient turnaround
- PET flow precision is the same as ICA FFR 10%
- Improves mortality when used to direct patient management.
- Accurate in high BMI

Cons

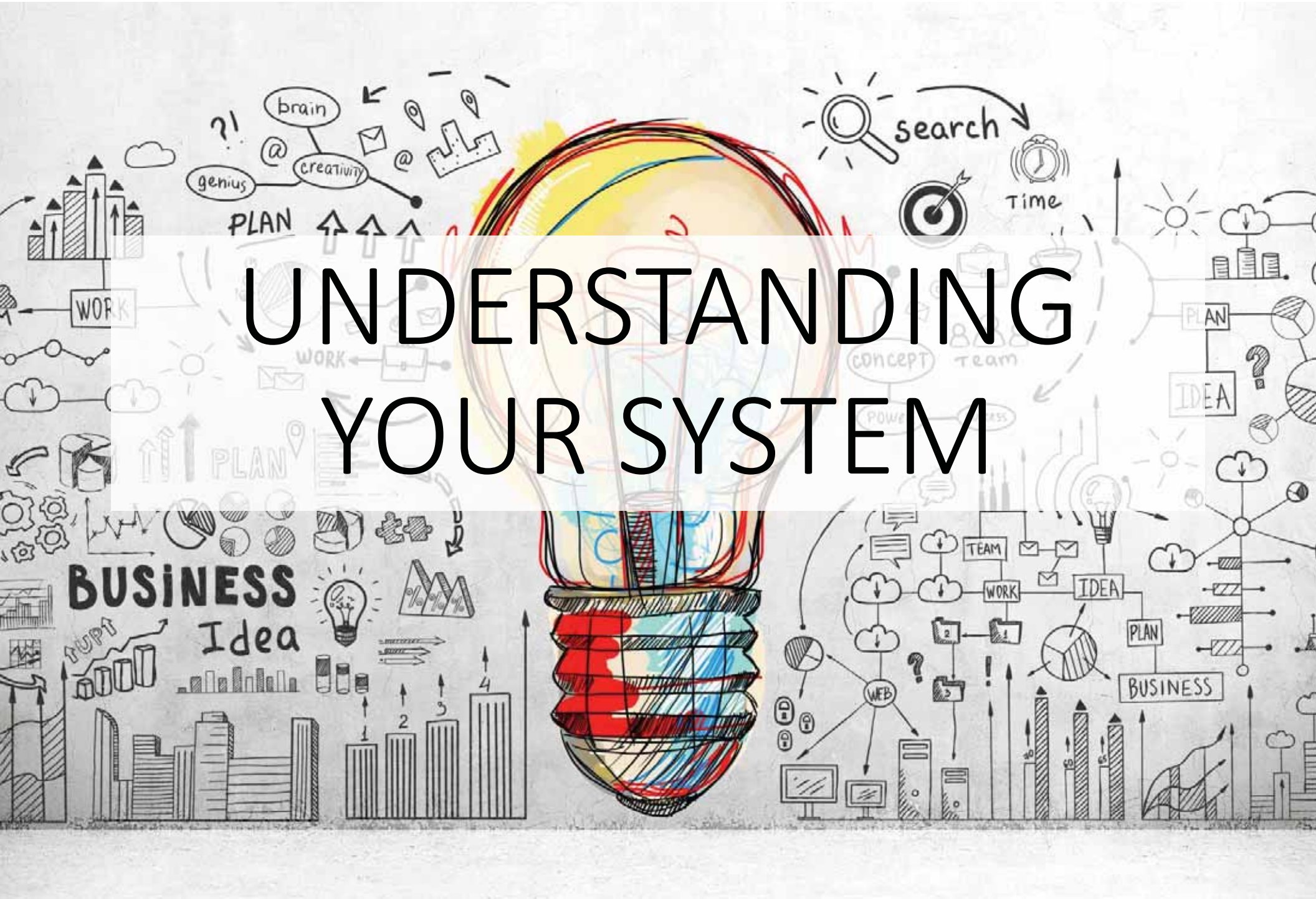
- Expensive capital investment
- Technical expertise required
- Reimbursement challenges

, *JACC*. 2019 Jan 22;73(2):161-173.

WHICH TOOL WOULD YOU WANT?

	Accuracy vs FFR*	Accuracy vs PCI/CABG	Imaging failure
PET	86%		2%
SPECT	68-76%	73%	2%
FFR_{CT}	70%	63%	13%

atient on intention-to-diagnose basis in PACIFIC, successful scans vs FFR in ReASSESS
Driessen RS, *JACC*. 2019 Jan 22;73(2):161-173. (Table 4 and results text)
S = Sand NPR, *JACC Cardiovasc Imaging*. 2018 Nov;11(11):1640-1650. (Figure 4 and Table 7)


UNDERSTANDING
YOUR SYSTEM
brain
genius
creativity
PLAN
search
Time
WORK
concept
Team
IDEA
BUSINESS
Idea
TEAM
WORK
IDEA
PLAN
WEB
BUSINESS

PET Hardware

2D

- Some have list-mode
- Capable of imaging a bolus 45-50mCi of Rb-82 or 20mCi of N-13 ammonia.
- Improved image quality over SPECT, but still has difficulty imaging patients with BMI > 30

3D

- Most have list-mode
- Capable of imaging a bolus of 30mCi or more of Rb-82.
- Improved image quality over 2D PET
- Diagnostic images up to table limit
  - 500-550 lbs

Example beaker test with Rb-82/N-13

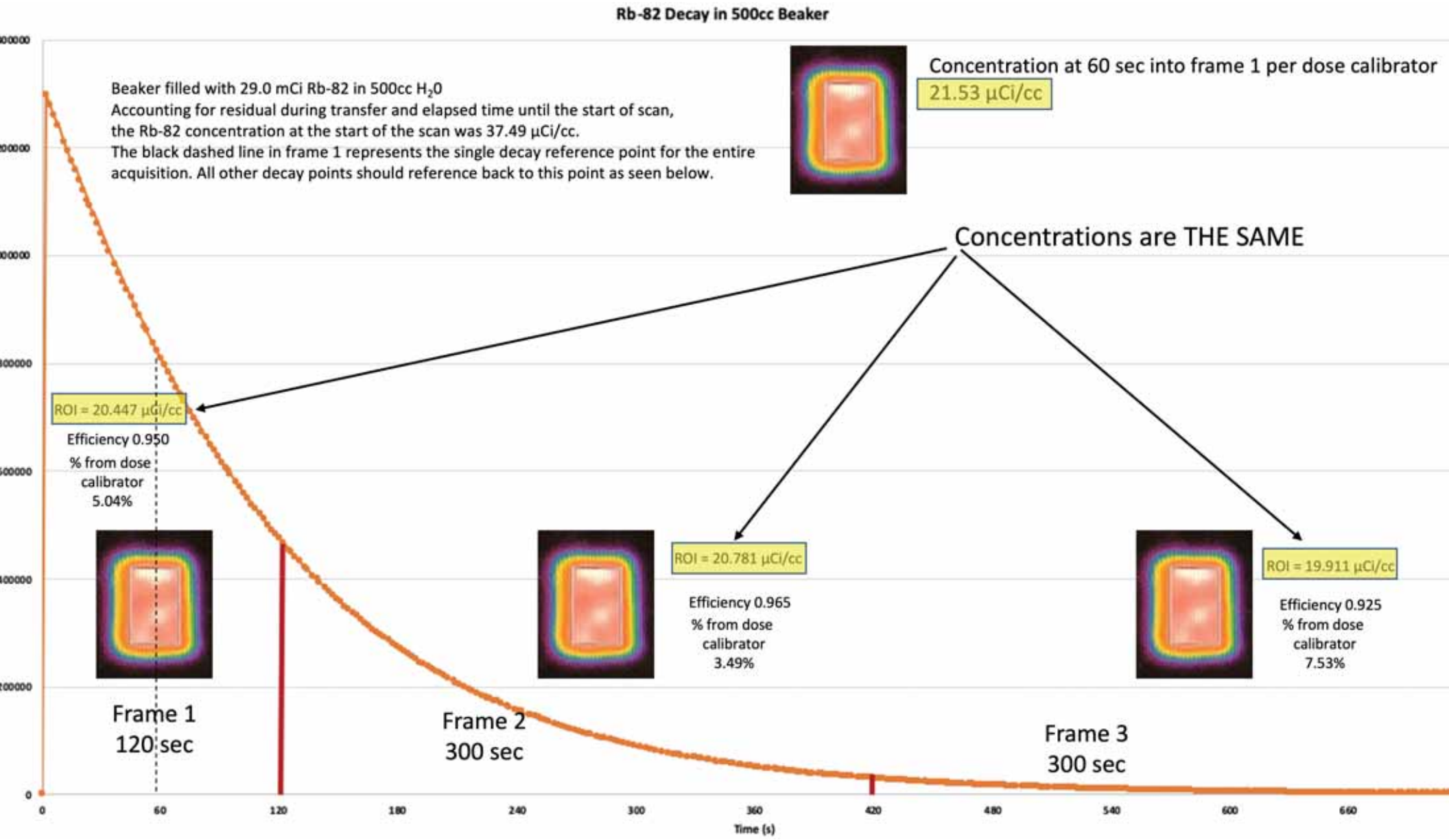
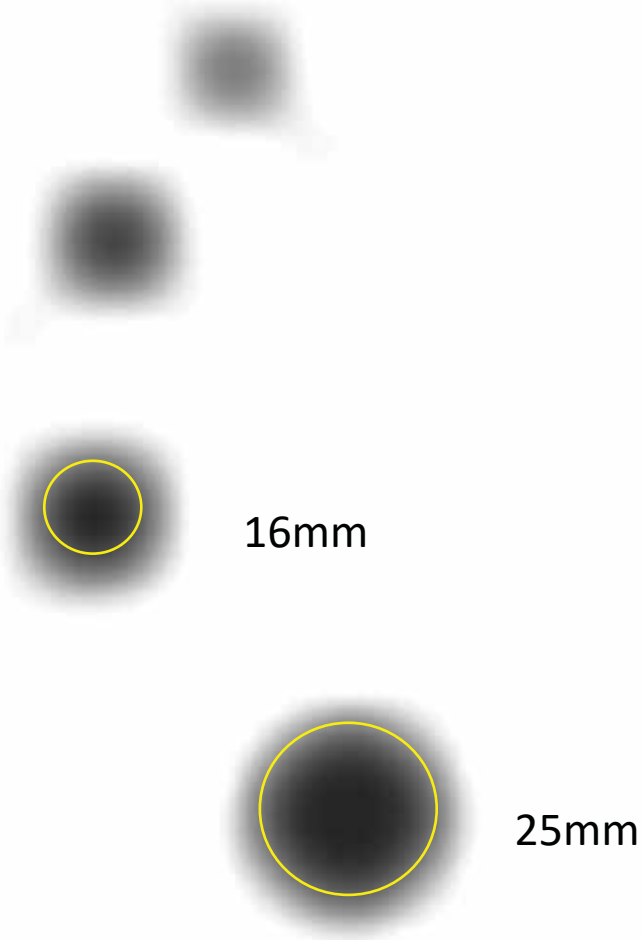


Image courtesy of Dr. Robert Bober (Ochsner, New Orleans)

PV Phantom tests



- Partial Volume test (ACR or Bracco)
  - Fill with Rb-82/N-13 tracer solution
  - Measure the uCi/cc of a small ROI divided by the larg ROI
  - Measures how well the system can resolve the thickness of the myocardium.

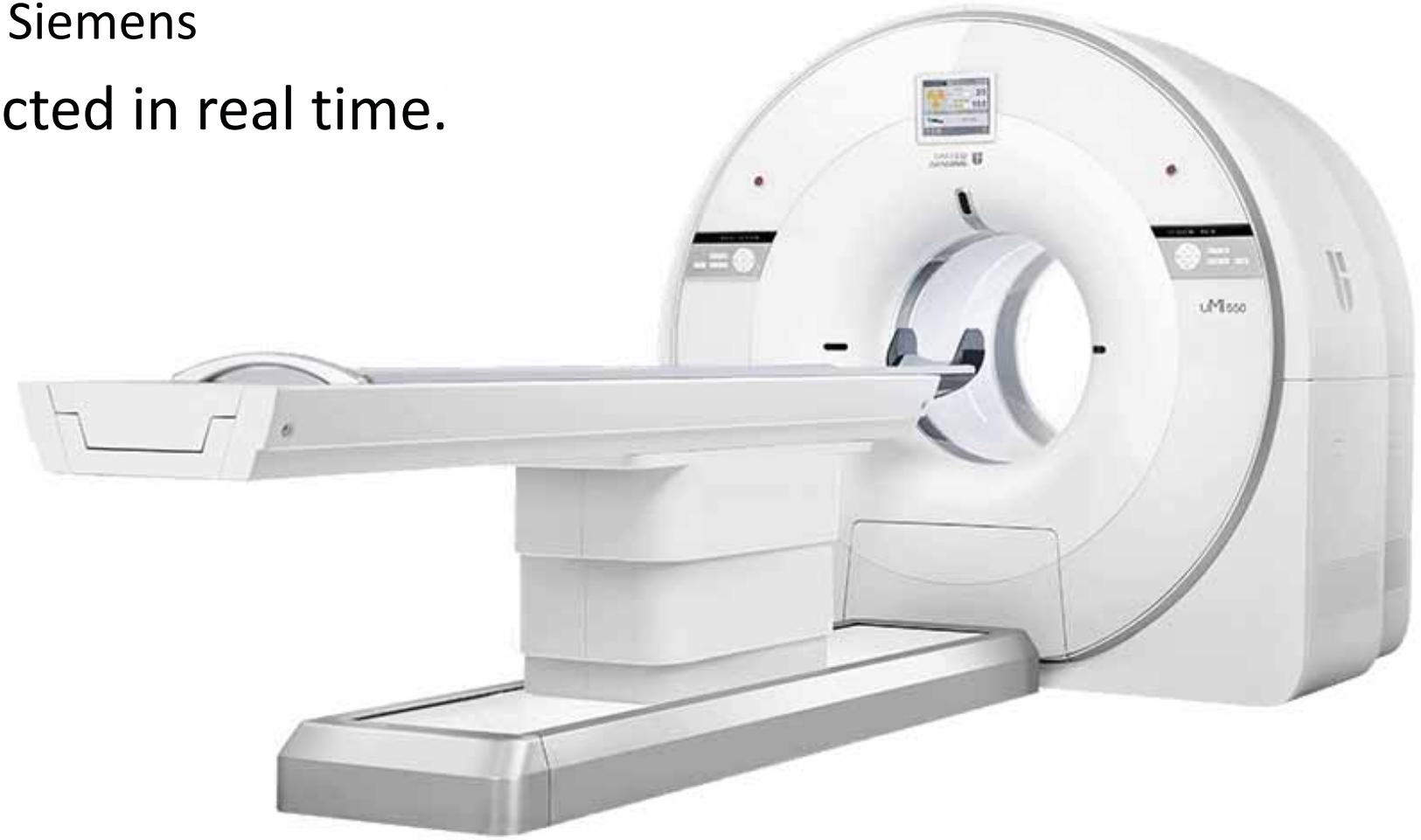
List mode structure

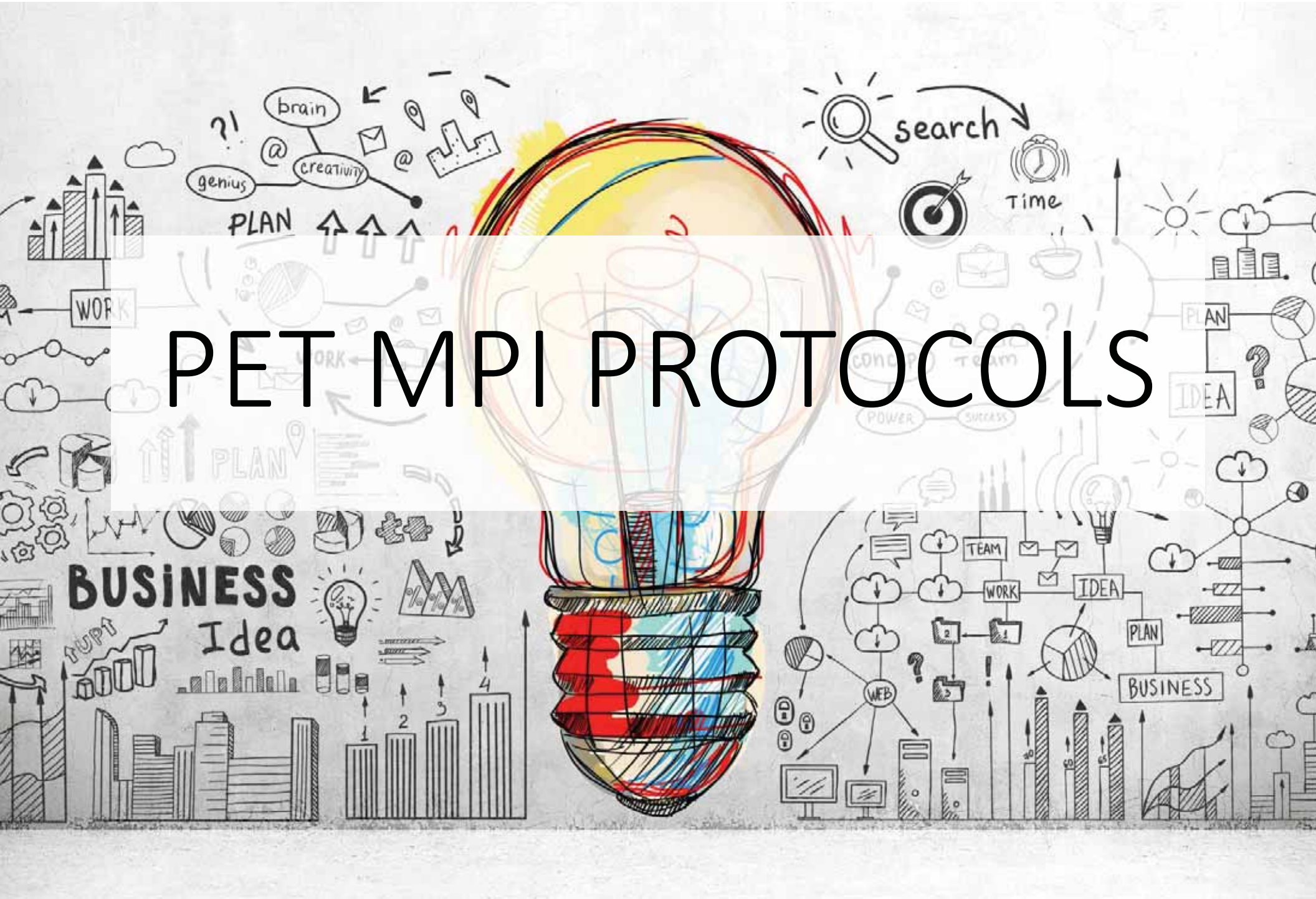
PET corrections attached to the acquisition and recon protocol.

- GE and Siemens

PET corrected in real time.

- United





PET MPI PROTOCOLS

Tracers are not interchangeable

Rb-82 (Bracco or RUBY-FILL)

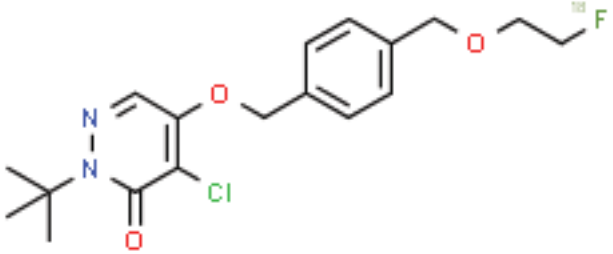
- Fastest
- Most difficult to correct
- 2 min flow, 5 min uptake

N-13 Ammonia (cyclotron/IONETIX)

- Myocardial washout
- Extra-cardiac uptake
- 80 sec flow, 10 min uptake

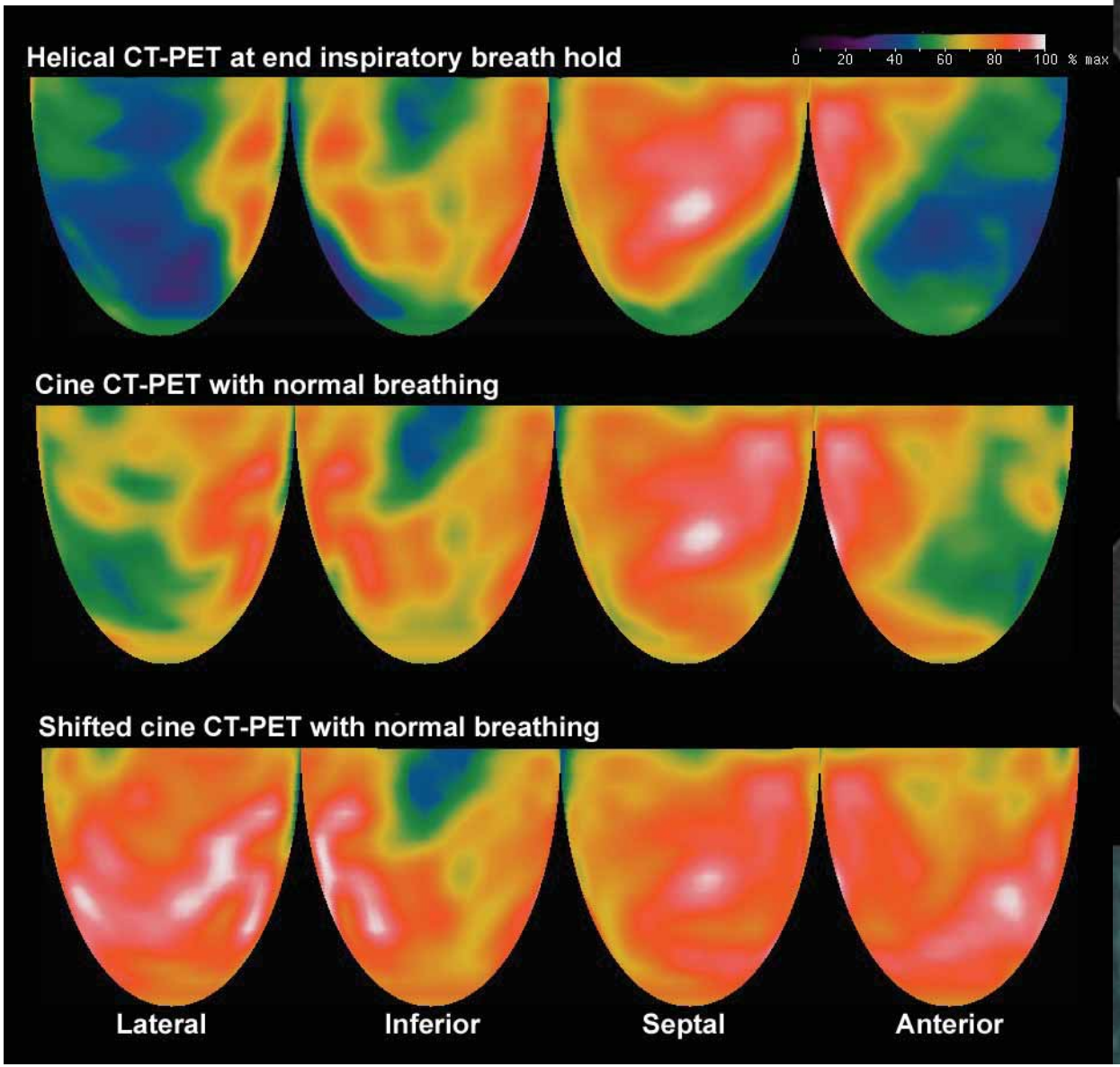
F-18 flurpiridaz (GE)

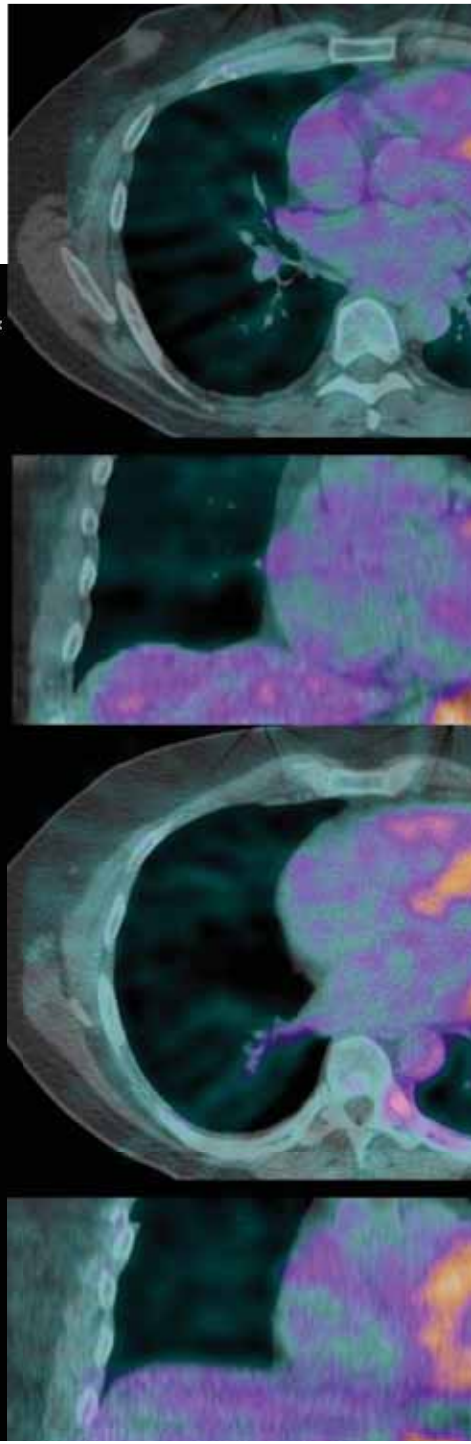
- Not yet approved by FDA
- MUST have subtraction
- Not validated for flow



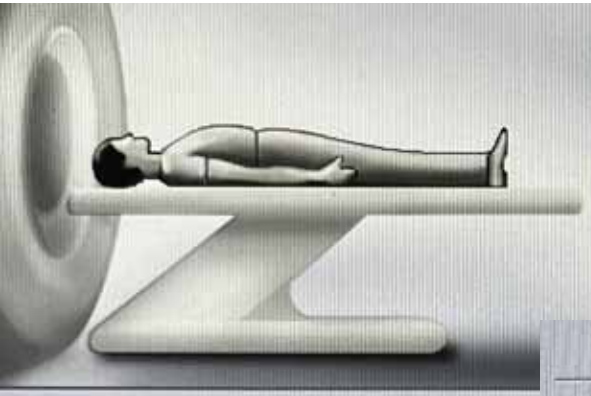
Attenuation Correction

Gould et al. J Nuclear Medicine 2007





- ne CT
  - Acquire 1st
  - Best map
  - United
  - GE
- lical
  - Acquire 2nd
  - Best for anatomy



XY

Patient Orientation
Head First

Patient Position
Supine

Copy Pt.Orient.

AutoFilm Setup

Camera
HPColorJet_1

Auto Store | Auto Transfer geaw | Dose Report Auto Transfer | Dose SR Report Auto Transfer

00:07:00

System Countrate (kcps)

0

Trues Rate: 0 kcps
Randoms Rate: 0 kcps
Total Prompts: 0 c

Scan Description: Rest_RAW
Series Description: c_resL

Add Scan | Insert Scan | Delete Selected Scan

ages	Scan Type	Start Location	End Location	S Dire
1-355	Dynamic Rest Record	S0.000	I195.300	To F
1-355	Dynamic Stress Record	S0.000	I195.300	To F

Dose	Nuclide/ Tracer	
0.00 mCi	82Rb	Rubidium chloride
0.00 mCi	82Rb	Rubidium chloride

Enter the Desired Scan Phase Information

# of Phases: 1

Total Scan Time: 00:05:00

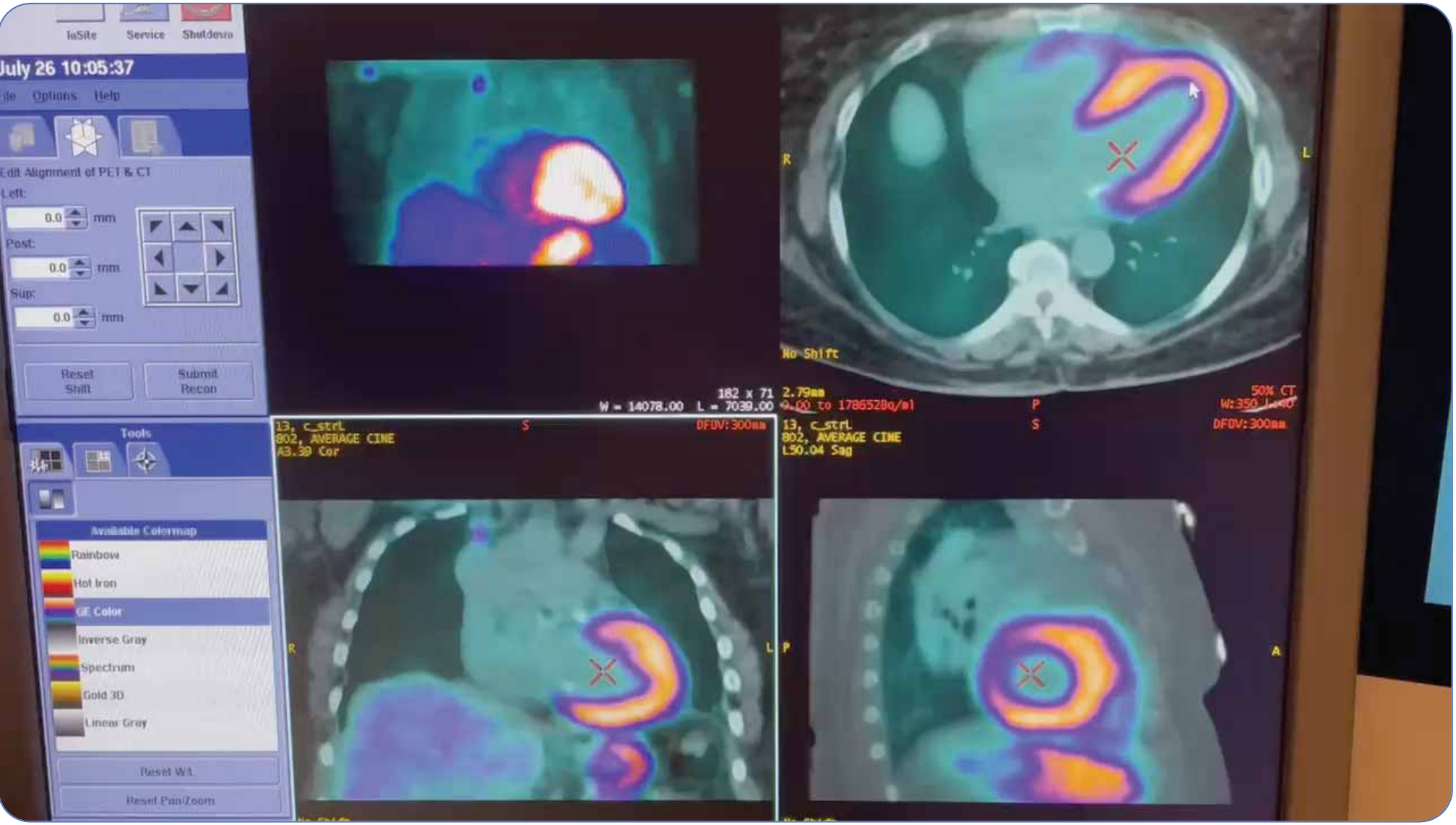
Prior | Next

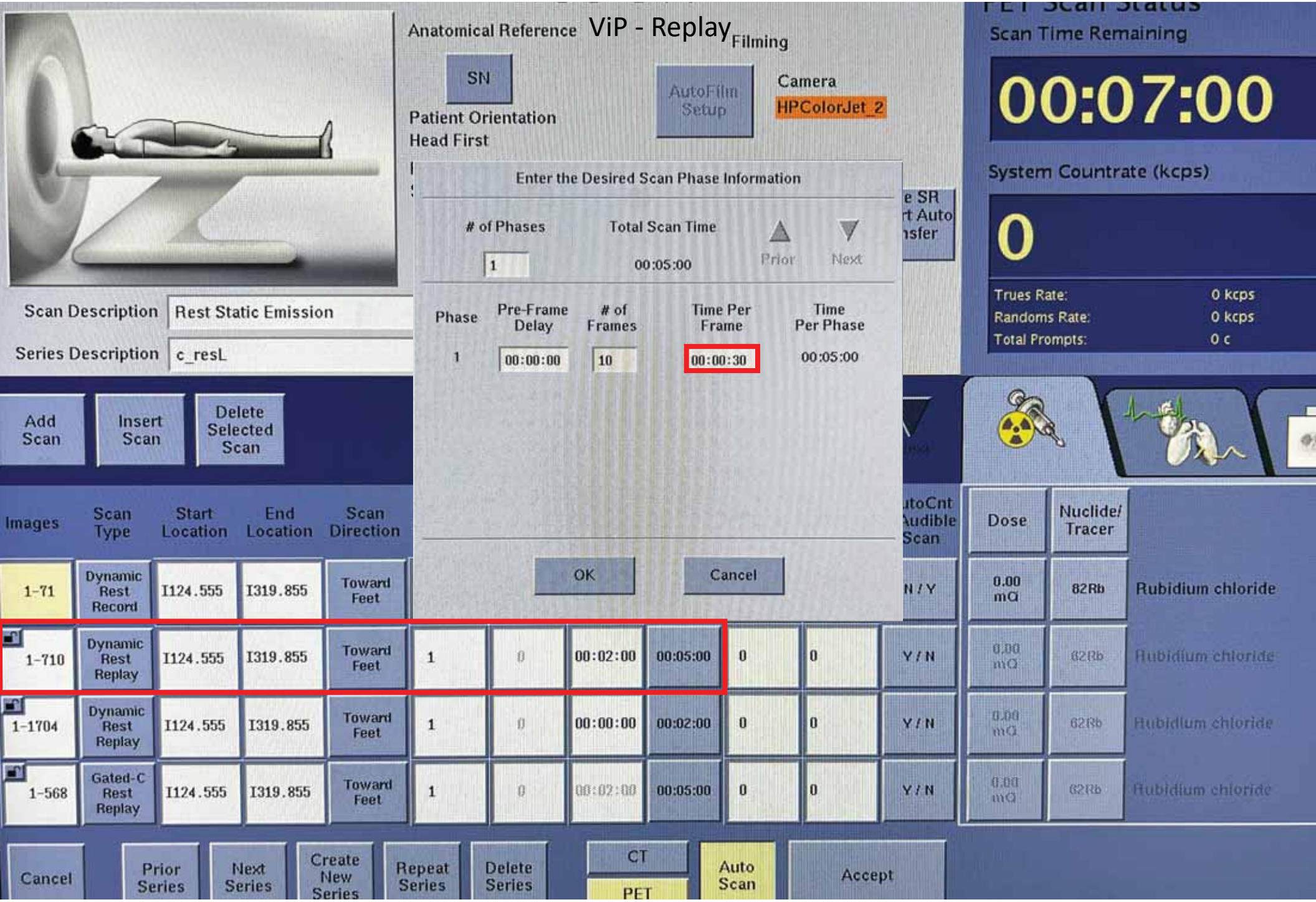
Phase	Pre-Frame Delay	# of Frames	Time Per Frame	Time Per Phase
1	00:00:00	5	00:01:00	00:05:00

OK | Cancel

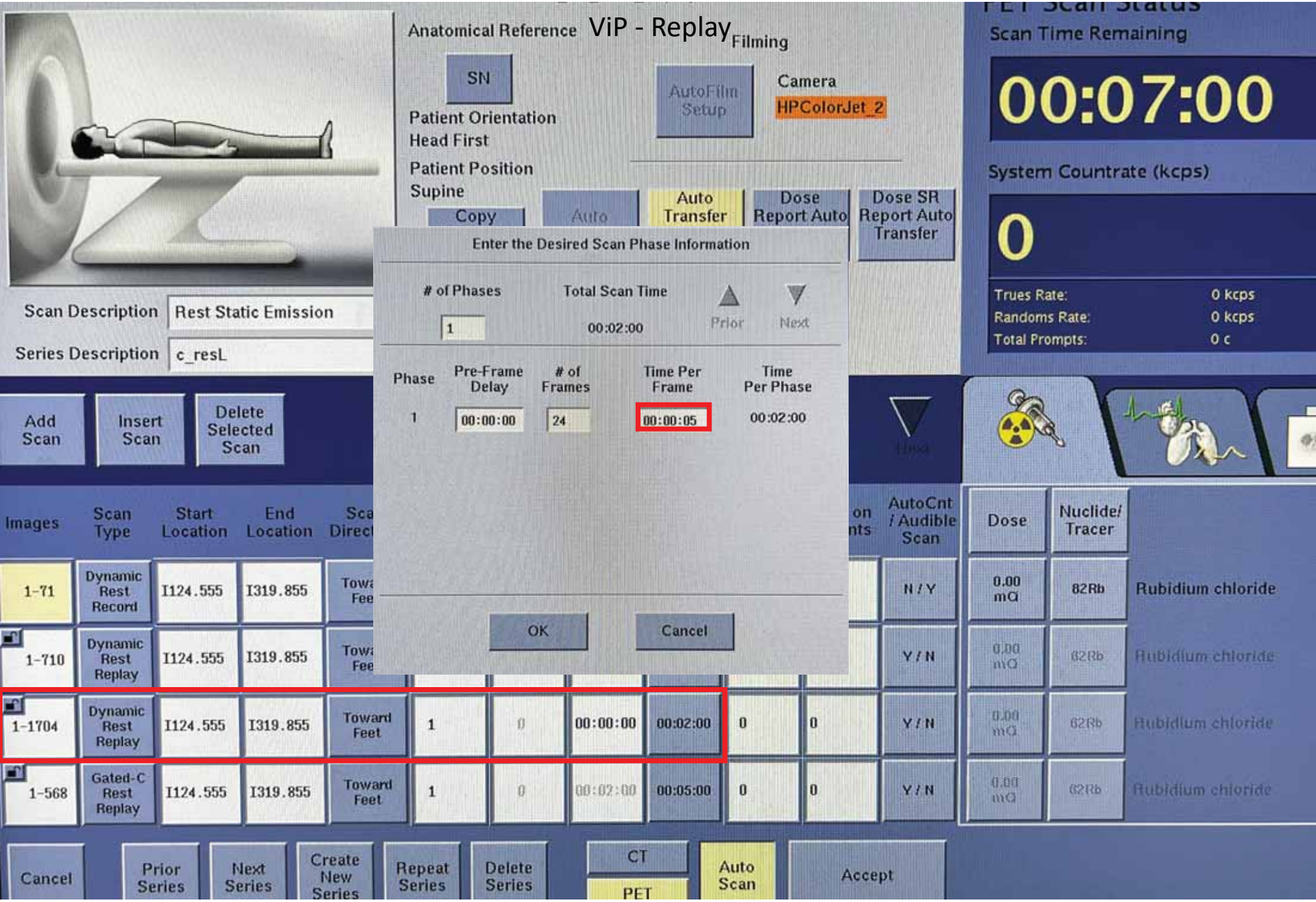
ancel | Prior Series | Next Series | Create New Series | Repeat Series | Delete Series | CT | PET | Auto Scan | Accept

GE Discovery MI




ViP - Replay
Anatomical Reference
Filming
SN
Patient Orientation
Head First
AutoFilm Setup
Camera
HPColorJet_2
Scan Time Remaining
00:07:00
System Countrate (kcps)
0
Trues Rate: 0 kcps
Randoms Rate: 0 kcps
Total Prompts: 0 c
Enter the Desired Scan Phase Information
# of Phases
Total Scan Time
Prior
Next
1
00:05:00
Phase
Pre-Frame Delay
# of Frames
Time Per Frame
Time Per Phase
1
00:00:00
10
00:00:30
00:05:00
OK
Cancel
Scan Description
Rest Static Emission
Series Description
c_resL
Add Scan
Insert Scan
Delete Selected Scan
Images
Scan Type
Start Location
End Location
Scan Direction
AutoCnt Audible Scan
Dose
Nuclide/ Tracer
1-71
Dynamic Rest Record
I124.555
I319.855
Toward Feet
N/Y
0.00 mCi
82Rb
Rubidium chloride
1-710
Dynamic Rest Replay
I124.555
I319.855
Toward Feet
1
0
00:02:00
00:05:00
0
0
Y/N
0.00 mCi
82Rb
Rubidium chloride
1-1704
Dynamic Rest Replay
I124.555
I319.855
Toward Feet
1
0
00:00:00
00:02:00
0
0
Y/N
0.00 mCi
82Rb
Rubidium chloride
1-568
Gated-C Rest Replay
I124.555
I319.855
Toward Feet
1
0
00:02:00
00:05:00
0
0
Y/N
0.00 mCi
82Rb
Rubidium chloride
Cancel
Prior Series
Next Series
Create New Series
Repeat Series
Delete Series
CT
PET
Auto Scan
Accept

ViP - Replay


Anatomical Reference
Filming
SN
AutoFilm Setup
Camera
HPColorJet_2
Patient Orientation
Head First
Patient Position
Supine
Copy
Auto
Auto Transfer
Dose Report Auto
Dose SR Report Auto Transfer
Scan Time Remaining
00:07:00
System Countrate (kcps)
0
Trues Rate: 0 kcps
Randoms Rate: 0 kcps
Total Prompts: 0 c
Enter the Desired Scan Phase Information
# of Phases
Total Scan Time
Prior
Next
1
00:02:00
Phase
Pre-Frame Delay
# of Frames
Time Per Frame
Time Per Phase
1
00:00:00
24
00:00:05
00:02:00
OK
Cancel
Scan Description
Rest Static Emission
Series Description
c_resL
Add Scan
Insert Scan
Delete Selected Scan
Images
Scan Type
Start Location
End Location
AutoCnt / Audible Scan
Dose
Nuclide/ Tracer
1-71
Dynamic Rest Record
I124.555
I319.855
N / Y
0.00 mCi
82Rb
Rubidium chloride
1-710
Dynamic Rest Replay
I124.555
I319.855
Y / N
1-1704
Dynamic Rest Replay
I124.555
I319.855
Toward Feet
1
0
00:00:00
00:02:00
0
0
Y / N
1-568
Gated-C Rest Replay
I124.555
I319.855
Toward Feet
1
0
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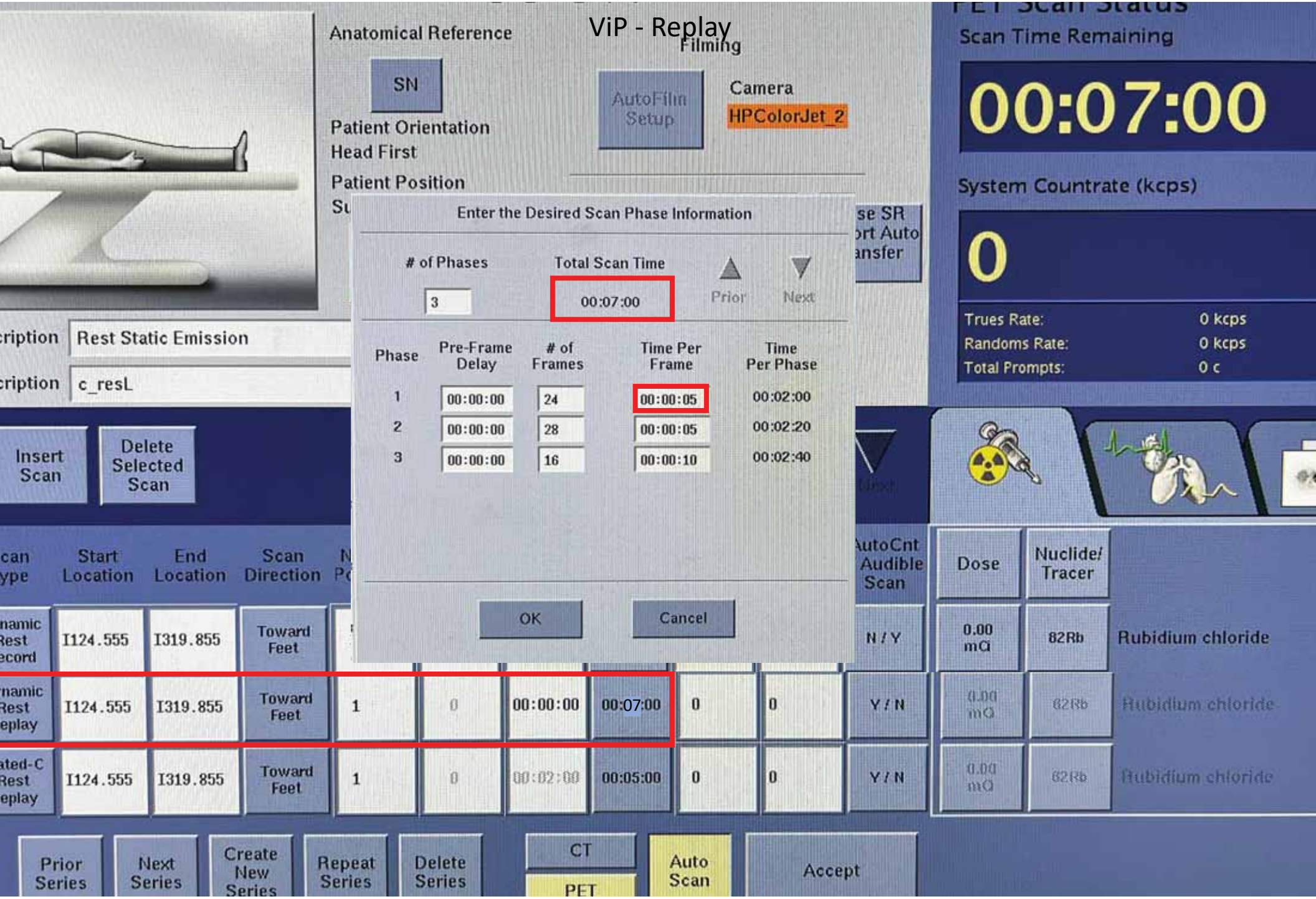
Y / N
Cancel
Prior Series
Next Series
Create New Series
Repeat Series
Delete Series
CT
PET
Auto Scan
Accept

ViP - Replay


Anatomical Reference
SN
Patient Orientation
Head First
Patient Position
Filming
AutoFilm Setup
Camera
HPColorJet_2
Scan Time Remaining
00:07:00
System Countrate (kcps)
0
Trues Rate: 0 kcps
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Total Prompts: 0 c
Enter the Desired Scan Phase Information
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3
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1 | 00:00:00 | 24 | 00:00:05 | 00:02:00
2 | 00:00:00 | 28 | 00:00:05 | 00:02:20
3 | 00:00:00 | 16 | 00:00:10 | 00:02:40
OK
Cancel
Rest Static Emission
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Start Location
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Nuclide/ Tracer
I124.555 | I319.855 | Toward Feet | N/Y | 0.00 mCi | 82Rb | Rubidium chloride
I124.555 | I319.855 | Toward Feet | 1 | 0 | 00:00:00 | 00:07:00 | 0 | 0 | Y/N | 0.00 mCi | 82Rb | Rubidium chloride
I124.555 | I319.855 | Toward Feet | 1 | 0 | 00:02:00 | 00:05:00 | 0 | 0 | Y/N | 0.00 mCi | 82Rb | Rubidium chloride
Prior Series
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Create New Series
Repeat Series
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CT
PET
Auto Scan
Accept


H
Weatherhead PET Imaging
CT
UIH uMI 550
OP: United
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-1021.5
L 339.4
FOV:365
-1260.9
Zoom: 0.91
727*768
WW: 200 /WL: -900
4.7
QC for shift
CountRate(Kcps)
1035
828
621
414
207
0
0 40 80 120 160 200 240 280 320 360 400
Time(s)
End Start Duration(s)
180 - 120 = 60
Recon
4.8
Late
CountRate(Kcps)
End Start Duration(s)
420 - 120 = 300
Recon
4.9
Early
CountRate(Kcps)
End Start Duration(s)
120 - 0 = 120
Recon
4.10
Gated
CountRate(Kcps)
End Start Duration(s)
420 - 120 = 300
Recon
4.2 cs_strL
4.3 cs_strE
4.4 cgs_strL
4.5 cs_strL
4.6 cs_strE
4.7 QC_PET STRE
4.8 cs_strL
4.9 cs_strE
4.10 cgs_strL
5 CARDIAC HELICAL
Recon Parameters
Algorithm OSEM
FOV 365mm
X-Center 40.00mm
Y-Center 0.00mm
TOF
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CT Contra
Count Rate (cps)
Prompts 1.1 k
Randoms 1.1 k
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ENV
TEMP 24.4 ℃
Bed Position
Horizontal
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A
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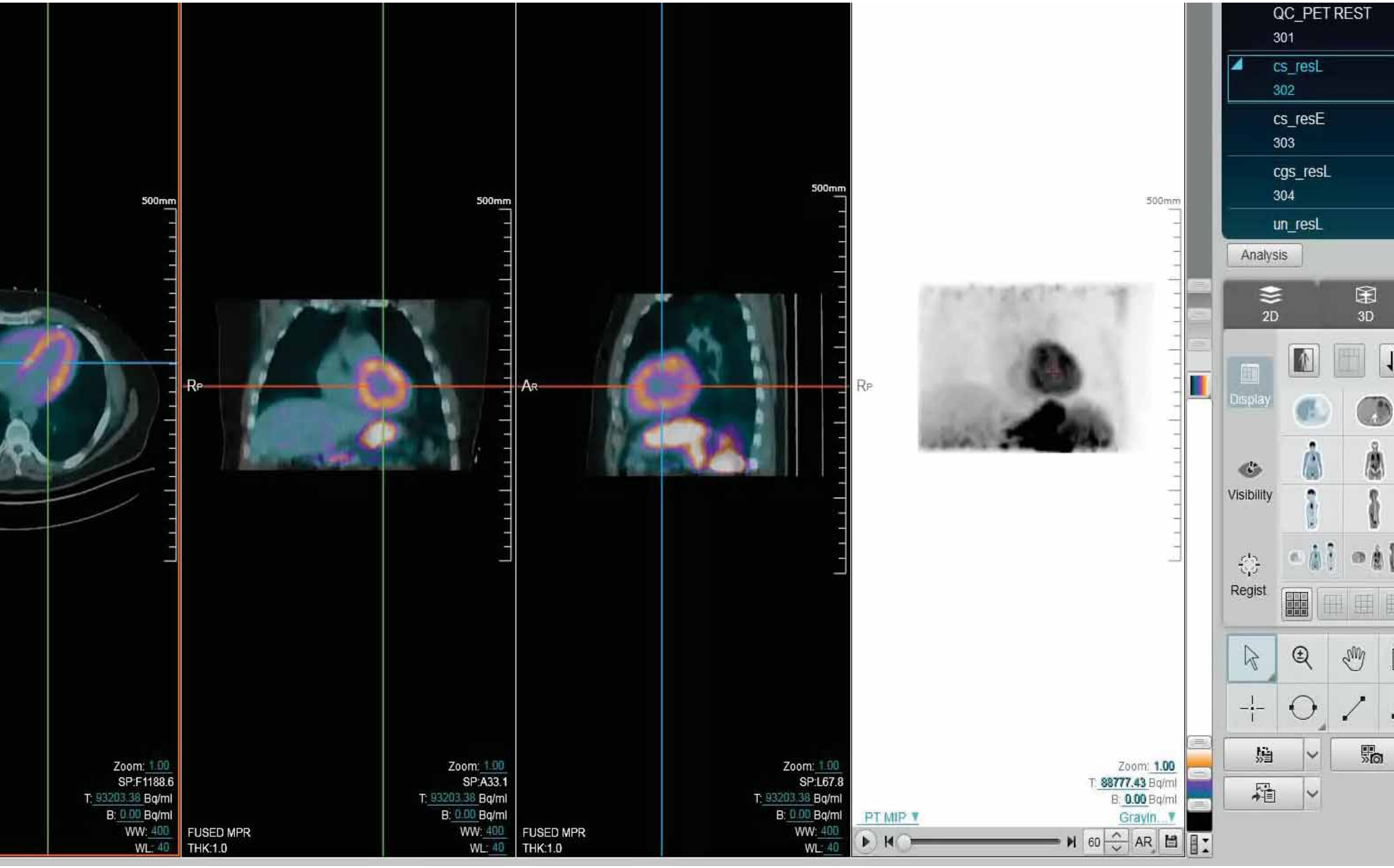
Offline Recon
Register
Offline Recon
Review
Filming
Report


500mm
500mm
500mm
RP
AR
RP
Zoom: 1.00
SP:F1188.6
T: 93203.38 Bq/ml
B: 0.00 Bq/ml
WW: 400
WL: 40
FUSED MPR
THK:1.0
Zoom: 1.00
SP:A33.1
T: 93203.38 Bq/ml
B: 0.00 Bq/ml
WW: 400
WL: 40
FUSED MPR
THK:1.0
Zoom: 1.00
SP:L67.8
T: 93203.38 Bq/ml
B: 0.00 Bq/ml
WW: 400
WL: 40
500mm
Zoom: 1.00
T: 88777.43 Bq/ml
B: 0.00 Bq/ml
PT MIP
Grayln...
60
AR
QC_PET REST
301
cs_resL
302
cs_resE
303
cgs_resL
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Analysis
2D
3D
Display
Visibility
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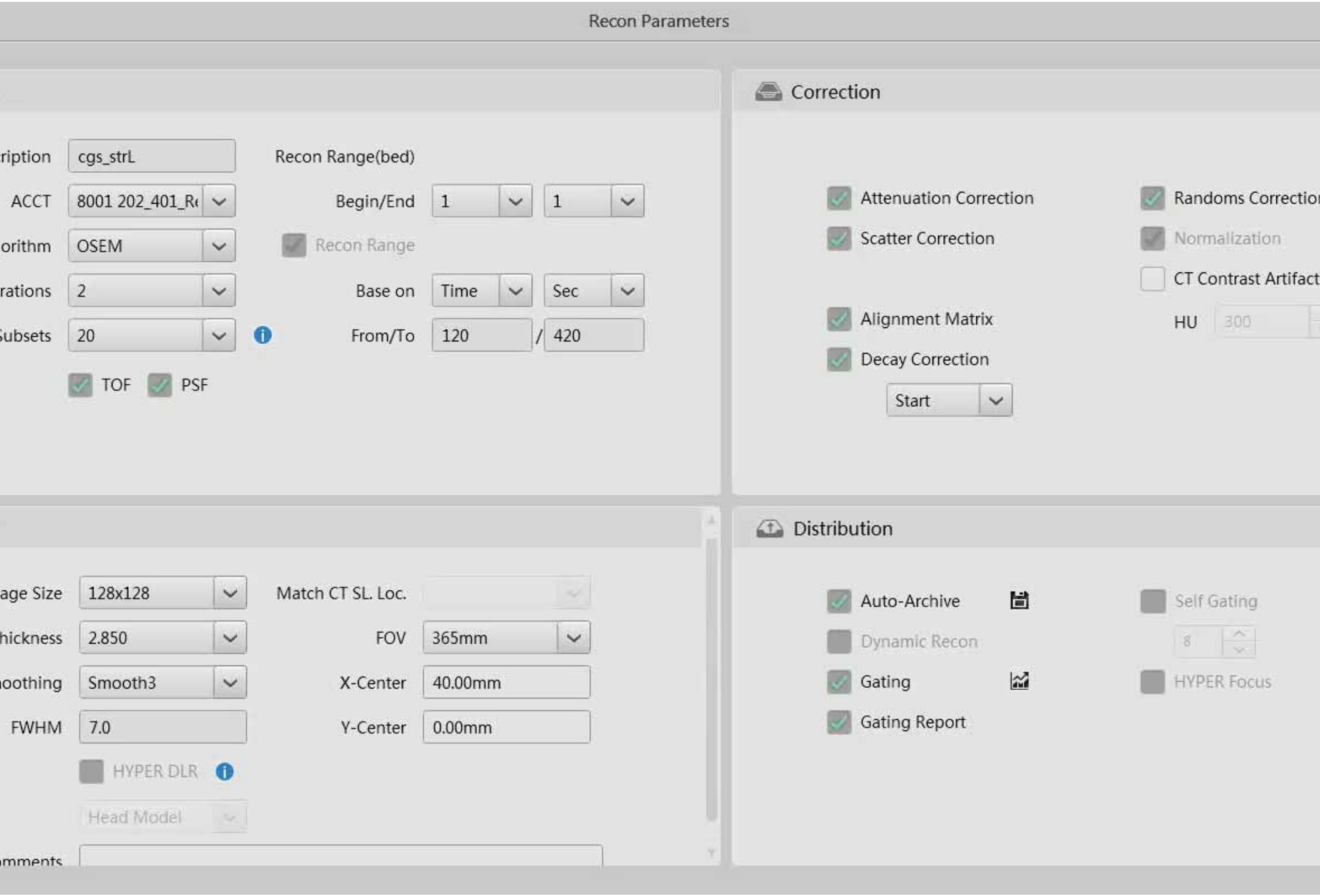
Recon Parameters
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cgs_strL
Recon Range(bed)
ACCT
8001 202_401_R
Begin/End
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1
orithm
OSEM
Recon Range
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2
Base on
Time
Sec
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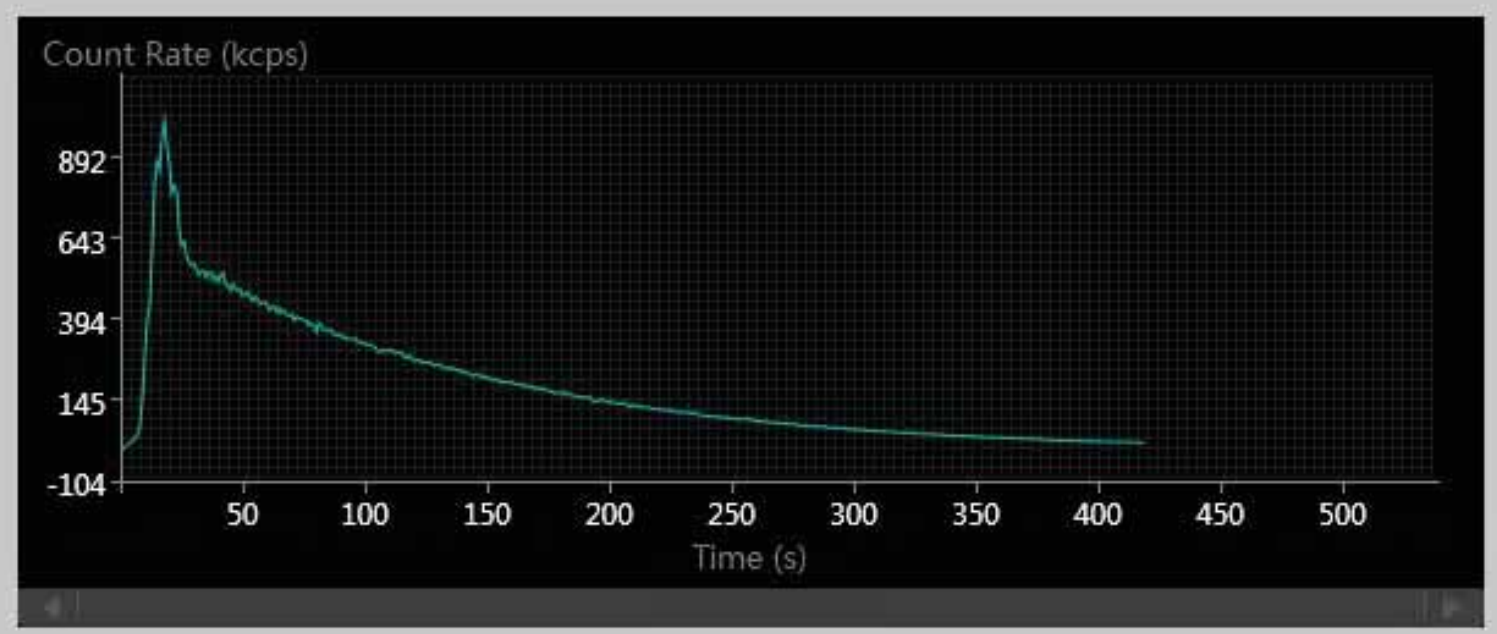
20
From/To
120
/
420
TOF
PSF
Correction
Attenuation Correction
Randoms Correctio
Scatter Correction
Normalization
CT Contrast Artifact
Alignment Matrix
HU
300
Decay Correction
Start
age Size
128x128
Match CT SL. Loc.
hickness
2.850
FOV
365mm
oothing
Smooth3
X-Center
40.00mm
FWHM
7.0
Y-Center
0.00mm
HYPER DLR
Head Model
mments
Distribution
Auto-Archive
Self Gating
Dynamic Recon
8
Gating
HYPER Focus
Gating Report

Dynamic Recon



No.	Frame Duration	Include in recon
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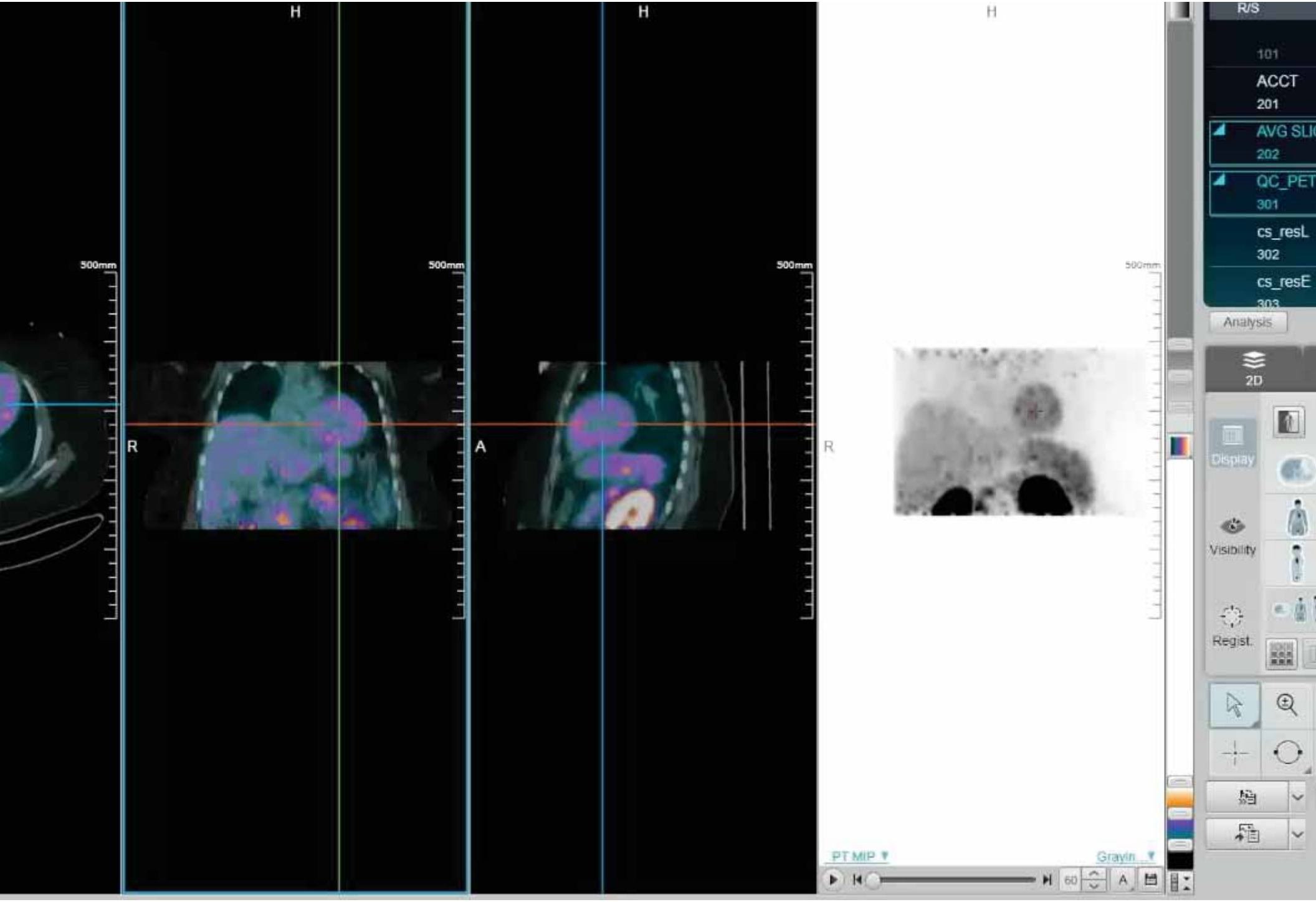
1	5	☑
1	5	☑
1	5	☑
1	5	☑
1	5	☑

Total ACQ

420

Sec

OK


H
H
500mm
500mm
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R
A
R
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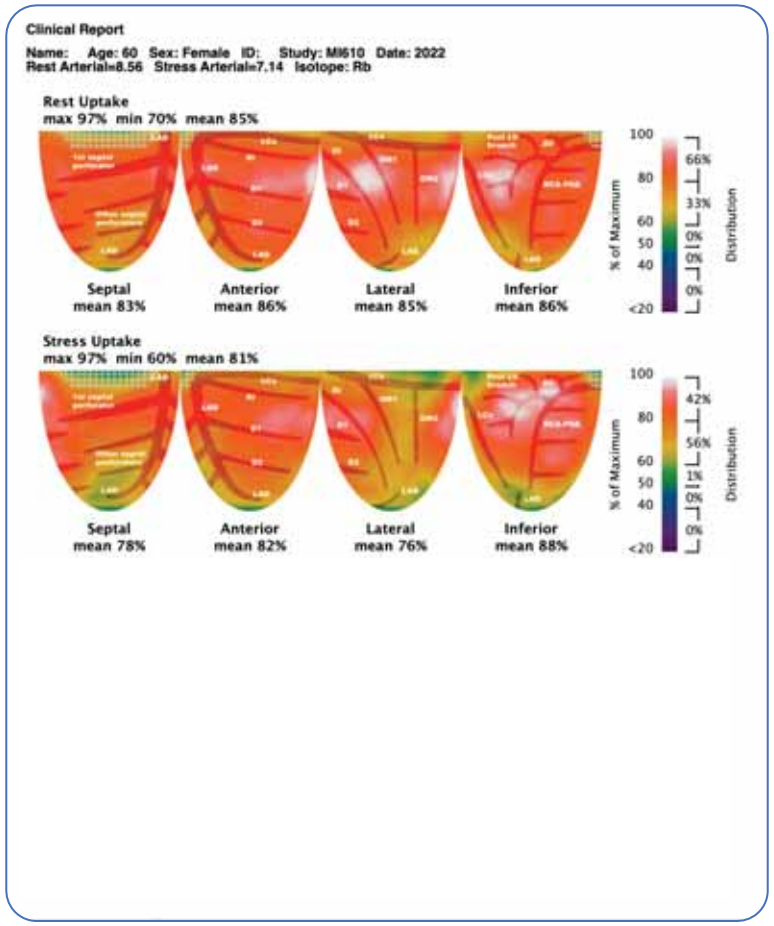
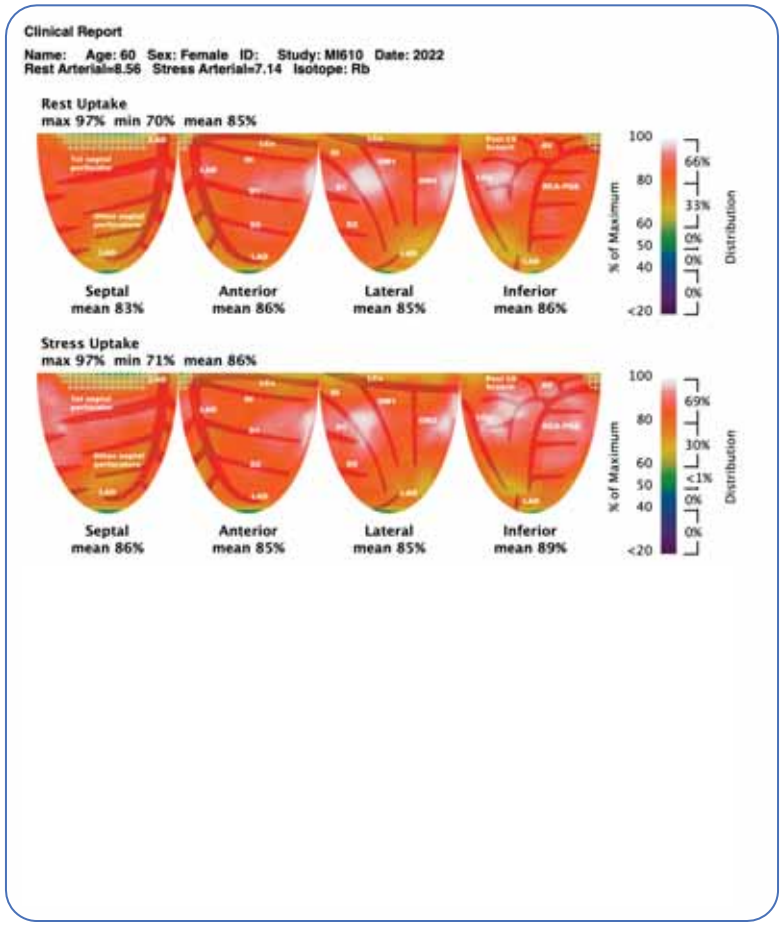
500mm
R/S
101
ACCT
201
AVG SLI
202
QC_PET
301
cs_resL
302
cs_resE
303
Analysis
2D
Display
Visibility
Regist.
PT MIP
Gray
60
A

Unshifted stress image dramatically effects the flow.



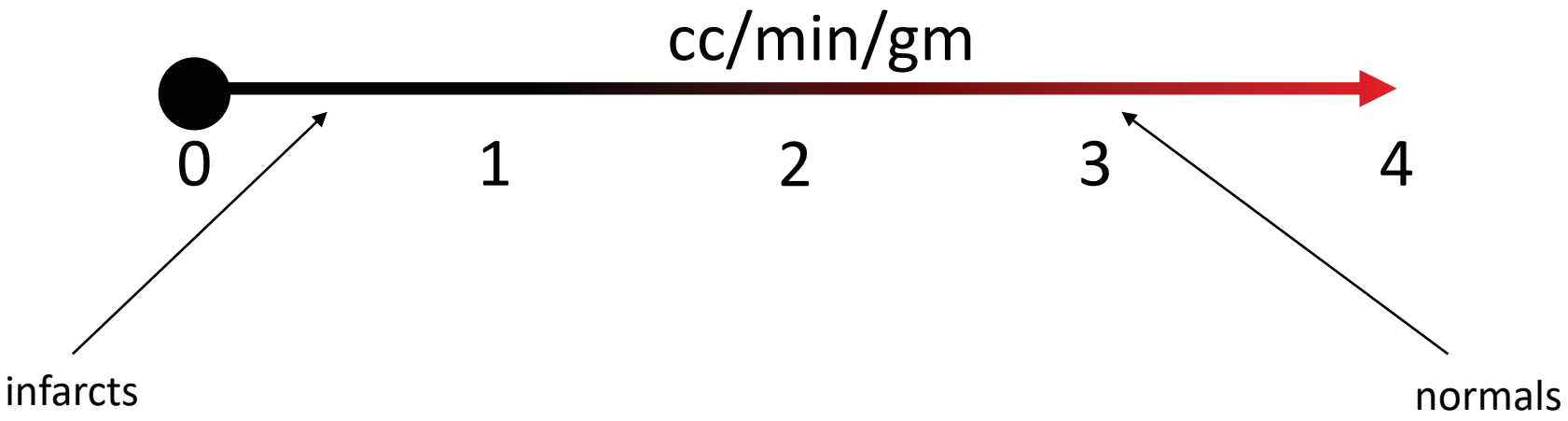


Philosophy = flow package

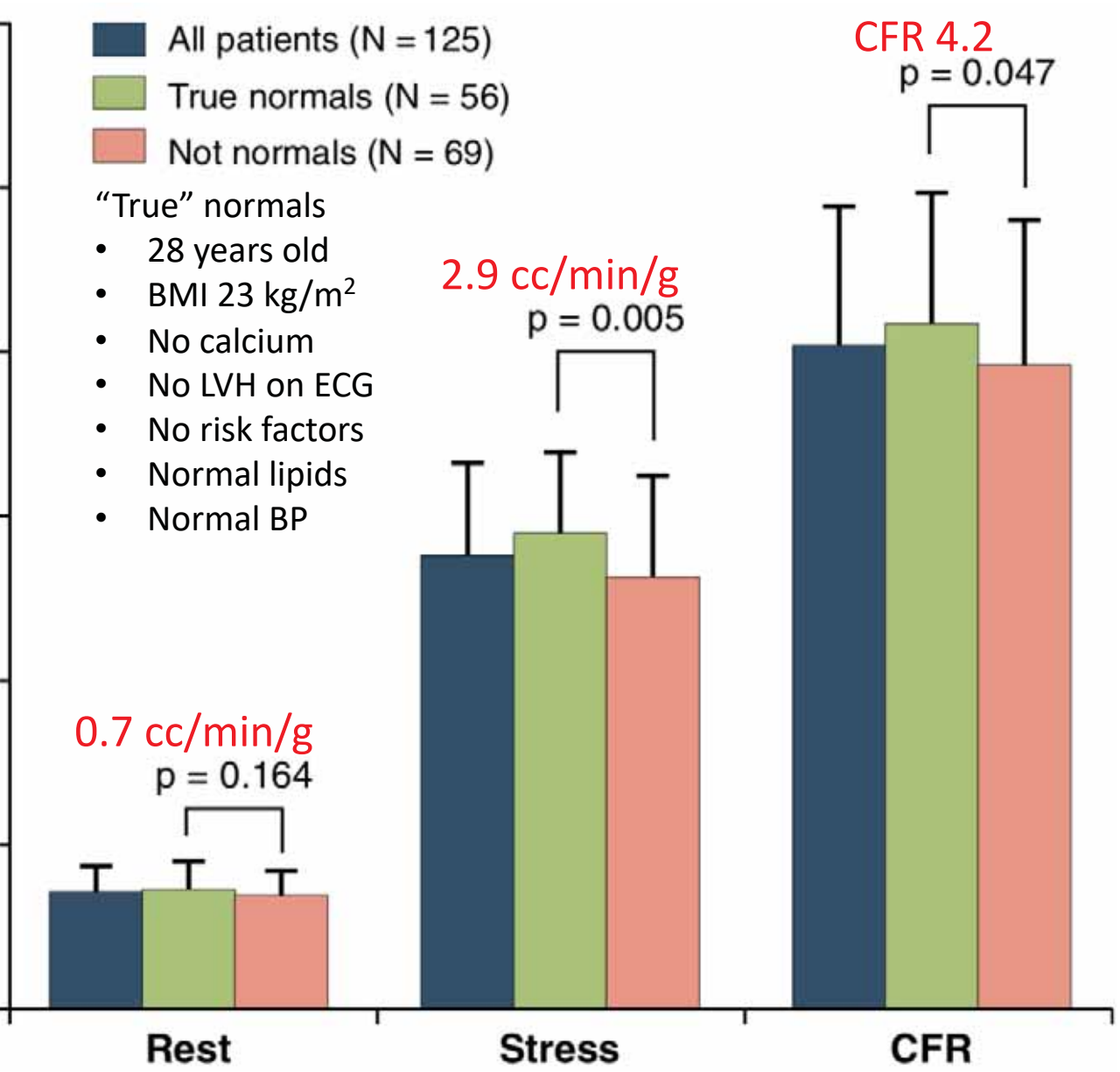
Feature	Description	Citation	N
Animal validation	Comparison of PET against flow meter or microspheres	Yoshida (1996)[6]	24
Flow spectrum			
Normal volunteers	Rest and stress flow in young, healthy people (not patients)	Sdringola (2011)[7]	125
Ischemia	Stress-induced perfusion defect with severe angina or ECG changes	Johnson (2011)[8]	1674
Stress agents	Interplay of vasodilator pharmacodynamics and radiotracer timing		
Dipyridamole		Kitkungvan (2017)[9]	120
Adenosine		Kitkungvan (2017)[10]	127
Regadenoson		Johnson (2015)[11]	176
Test/retest	Separate biologic variation from stochastic effects of imaging	Kitkungvan (2017)[9]	708
Arterial input	Scan-specific customization of arterial input to avoid underestimation	Vasquez (2013)[12]	288
Clinical outcomes	Size/severity association with outcomes as modified by treatment	Gould (2021)[14]	5274
Cost effectiveness	Cost simulation ideally based on data from a randomized trial	Delgado (2014)[15]	N/A
Randomized trial	Impact of PET-guided management on clinical outcomes	Kitkungvan (2021)[16]	1028

Johnson NP and Gould KL. "How shall we judge a PET flow model?" *J Nucl Cardiol*. 2021 Sep 24. doi: 10.1007/s12350-021-02805-5. (Table 1)

Spectrum of perfusion



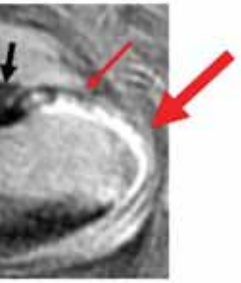
Are you normal?

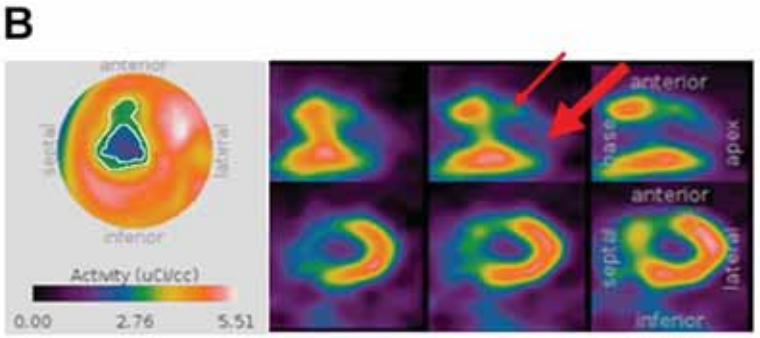


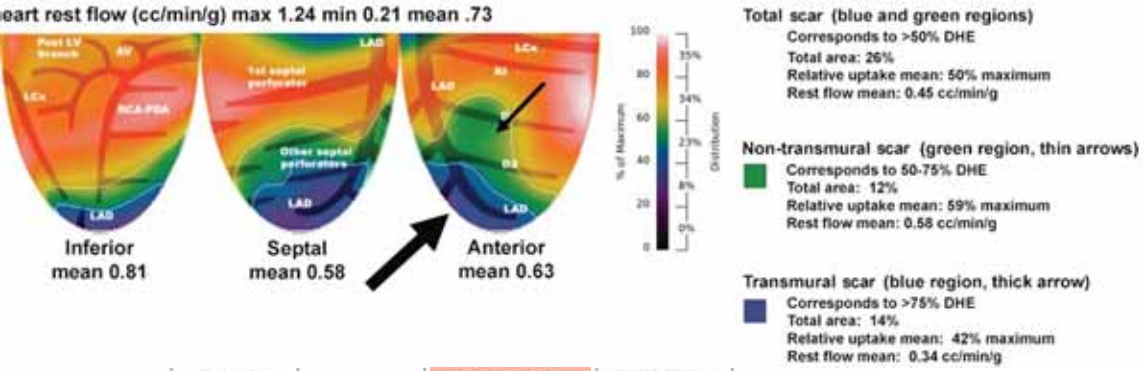
Isotope	Sample size	Author	Citation	Rest flow (cc/min/g)	St (c
F-18	7	Packard	JNM 2014;55:1438	0.73 ± 0.13	2.
N-13	20	Chan	JACC 1992;20:979	1.10 ± 0.20	4.
N-13	18	Czernin	Circulation 1993;88:62	0.76 ± 0.17	3.
N-13	11	Dayanikli	Circulation 1994;90:808	0.66 ± 0.09	2.
N-13	5	Beanlands	JACC 1995;26:1465	0.62 ± 0.09	2.
N-13	6	Sawada	JNC 1995;2:413	0.68 ± 0.12	2.
N-13	11	Czernin	JNM 1995;36:575		2.
N-13	19	de Jong	JNM 1995;36:581	0.96 ± 0.02	
N-13	8	DeGrado	JNC 1996;3:494	0.70 ± 0.14	2.
N-13	10	Muzik	JACC 1996;28:757	0.74 ± 0.15	3.
N-13	14	Yokoyama	JNM 1996;37:1937	0.70 ± 0.17	2.
N-13	15	Nitzsche	Circulation 1996;93:2000	0.64 ± 0.09	2.
N-13	30	Nagamachi	JNM 1996;37:1626	0.64 ± 0.15	2.
N-13	10	Böttcher	JNM 1997;38:442	0.61 ± 0.09	1.
N-13	10	Campisi	AJC 1997;80:27	0.68 ± 0.16	2.
N-13	20	Muzik	JACC 1998;31:534	0.67 ± 0.11	2.
N-13	14	Lortie	EJNMMI 2007;34:1765	0.69 ± 0.09	2.
N-13	10	Mather	Obesity 2009;18:63	0.61 ± 0.14	
N-13	10	Vincenti	Nuklearmedizin 2010;49:173		2.
N-13	14	Teragawa	EJNMMI 2010;37:368	0.86 ± 0.21	2.
N-13	26	Valenta	JNC 2010;17:1023	0.71 ± 0.13	2.
N-13	13	Scholtens	JNC 2011;18:238	0.70 ± 0.16	1.
N-13	15	Slomka	JNM 2012;53:171	0.87 ± 0.24	3.
N-13	14	Renaud	JNC 2013;20:578	0.71 ± 0.15	2.
O-15	4	Iida	Circulation 1988;78:104	0.97 ± 0.07	
O-15	11	Senneff	JNM 1991;32:2037	1.16 ± 0.32	4.
O-15	11	Araujo	Circulation 1991;83:875	0.84 ± 0.09	3.
O-15	8	Yamamoto	Circulation 1992;86:167	0.95 ± 0.13	
O-15	21	Uren	NEJM 1994;330:1782	1.13 ± 0.26	3.
O-15	15	Nitzsche	Circulation 1996;93:2000	0.66 ± 0.12	2.
O-15	19	Laine	JACC 1998;32:147	0.81 ± 0.21	3.
O-15	61	Kaufmann	JACC 2000;36:103	0.87 ± 0.14	3.
O-15	11	Lin	JNM 2001;42:201	0.92 ± 0.19	1.
O-15	12	Furuyama	Circulation 2002;105:2878	0.79 ± 0.18	3.
O-15	11	Yoshinaga	JNC 2003;10:275	0.96 ± 0.19	3.
O-15	11	Wyss	JNM 2003;44:146	1.24 ± 0.19	5.
O-15	27	Vermeltfoort	JNC 2011;18:650	1.20 ± 0.31	3.
O-15	11	Prior	EJNMMI 2012;39:1037	1.00 ± 0.24	3.
O-15	128	Danad	EJNMMI 2012;39:102	1.02 ± 0.32	3.
O-15	20	Tomiyama	JMRI 2015;42:754	0.71 ± 0.11	3.
O-15	10	Ochi	J Card 2016;68:316	0.66 ± 0.10	4.
Rb-82	11	Lin	JNM 2001;42:201	0.82 ± 0.26	1.
Rb-82	14	Lortie	EJNMMI 2007;34:1765	0.69 ± 0.14	2.
Rb-82	15	Manabe	JNM 2009;50:68	0.80 ± 0.25	3.
Rb-82	125	Sdringola	JACC CV Img 2011;4:402	0.70 ± 0.15	2.
Rb-82	11	Prior	EJNMMI 2012;39:1037	1.03 ± 0.42	3.
Rb-82	14	Renaud	JNC 2013;20:578	0.68 ± 0.12	2.
Rb-82	10	Pelletier-Galarneau	JNM 2018;59:100	0.45 ± 0.08	2.
All	*881*			*0.8*	

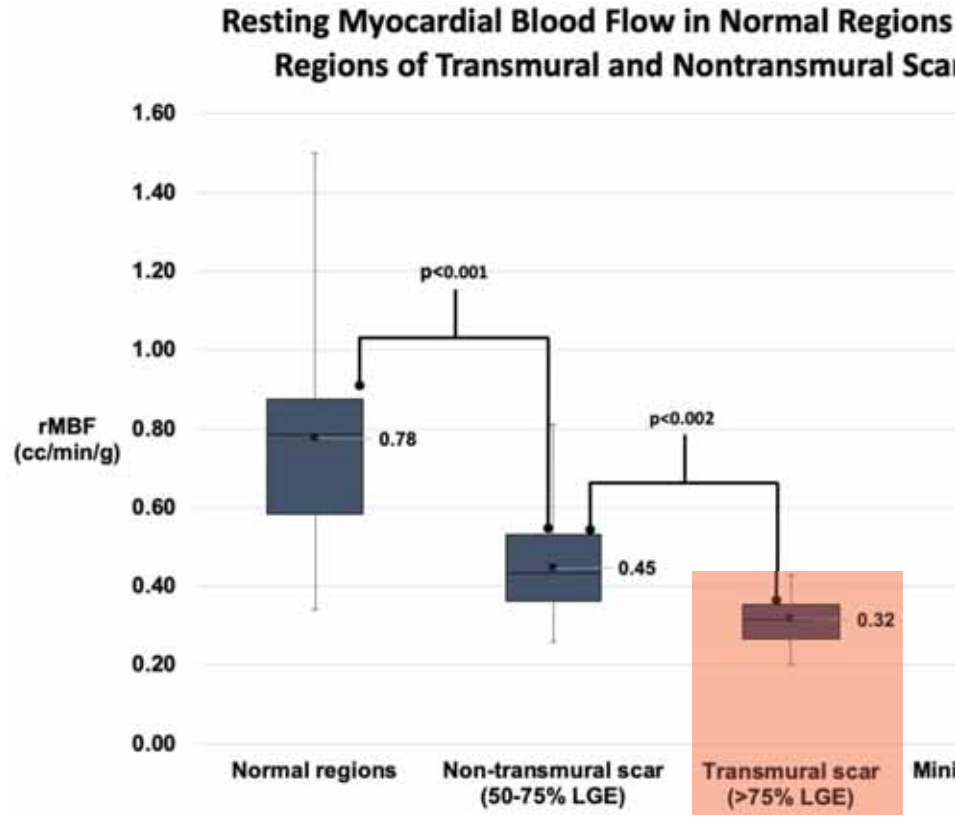
ingola S, *JACC Cardiovasc Imaging*. 2011 Apr;4(4):402-12. (Figure 3 with *annotations* and updated version on its Table X)

How low can you go?









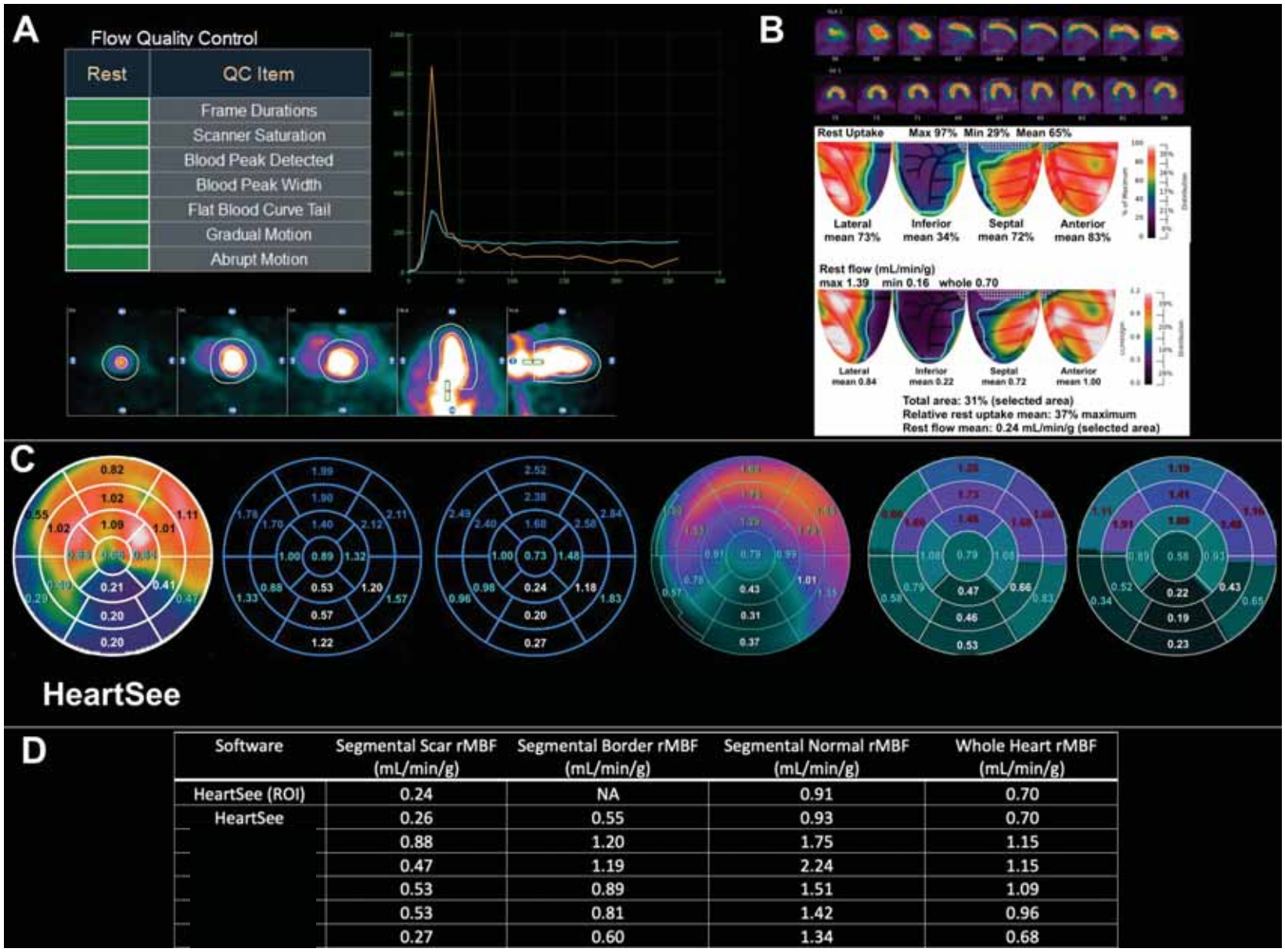
Study author	Study patients (n)	Isotope	rMBF in myocardial scar	rMBF in normal tissue	Minimal rest flow
zernin et al.	22	N^{13}	0.32	0.83	NR
un et al.	19	N^{13}	0.28	0.68	NR
ewirtz et al.	26	N^{13}	0.27	0.81	0.25
eanlands et al.	16	N^{13}	0.36	0.75	0.19
tewart et al.	16	Rb^{82}	0.37	0.78	0.19
		Weighted average	**0.34**	**0.75**	

absolute flow in MRI-verified scars

- transmural = 0.32 ± 0.07 cc/min/g
  (relative uptake 41 ± 6% max)
- non-transmural = 0.45 ± 14 cc/min/g
  (relative uptake 55 ± 8% max)

tewart M, *Annals of Nuclear Cardiology*. 2022;8(1):7-13. (Figures 1 and 2 plus Table 3 and results with *annotations*)

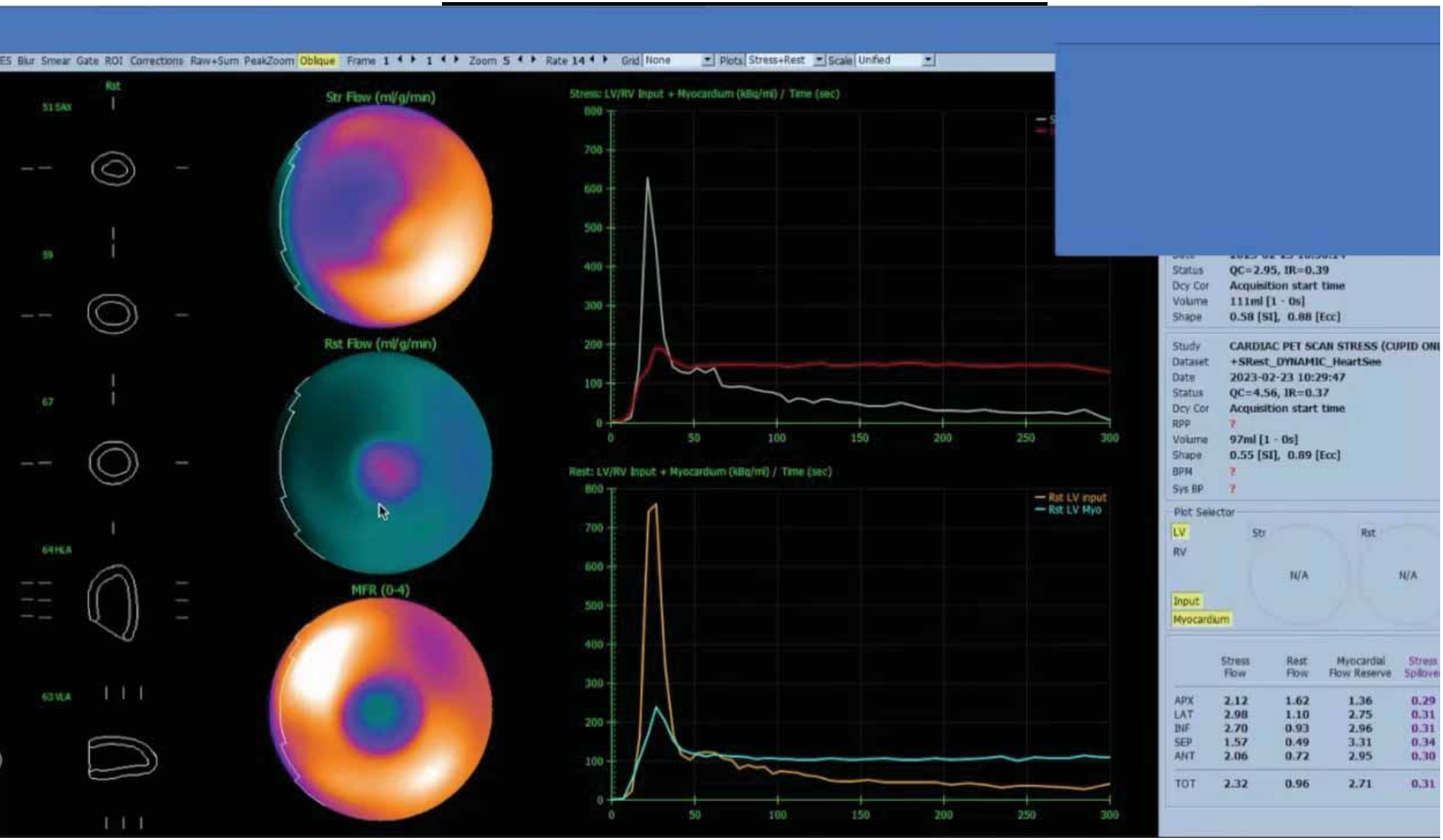
Variation in infarct flow among software packages



Software	Segmental Scar rMBF (mL/min/g)	Segmental Border rMBF (mL/min/g)	Segmental Normal rMBF (mL/min/g)	Whole Heart rMBF (mL/min/g)
HeartSee (ROI)	0.24	NA	0.91	0.70
HeartSee	0.26	0.55	0.93	0.70
	0.88	1.20	1.75	1.15
	0.47	1.19	2.24	1.15
	0.53	0.89	1.51	1.09
	0.53	0.81	1.42	0.96
	0.27	0.60	1.34	0.68

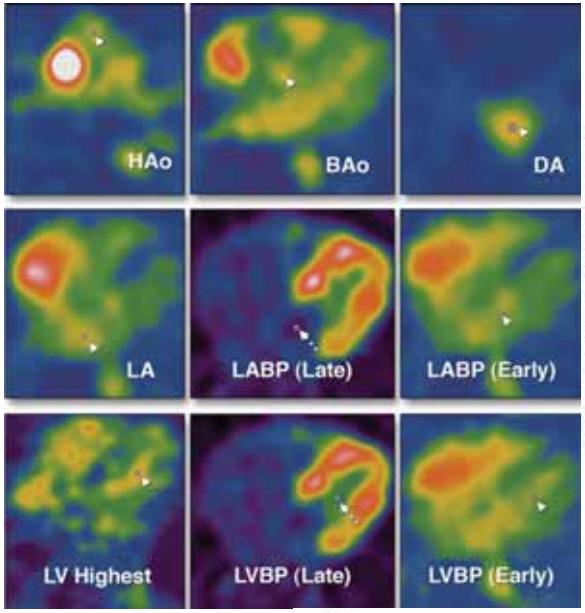
age courtesy of Dr. Robert Bober (Ochsner, New Orleans)

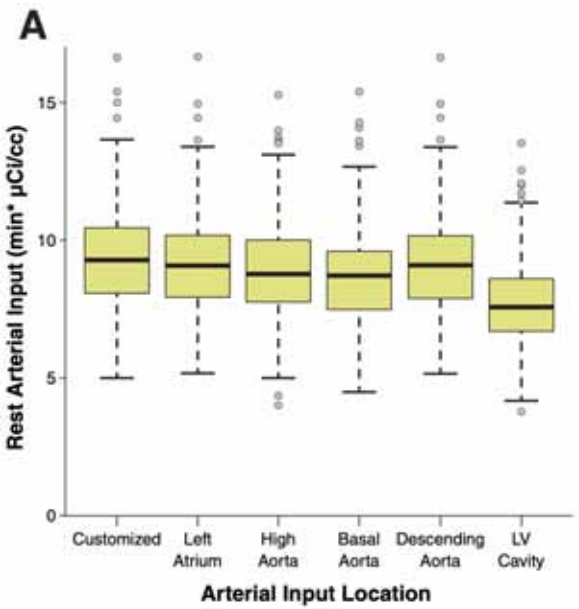
Motion correction

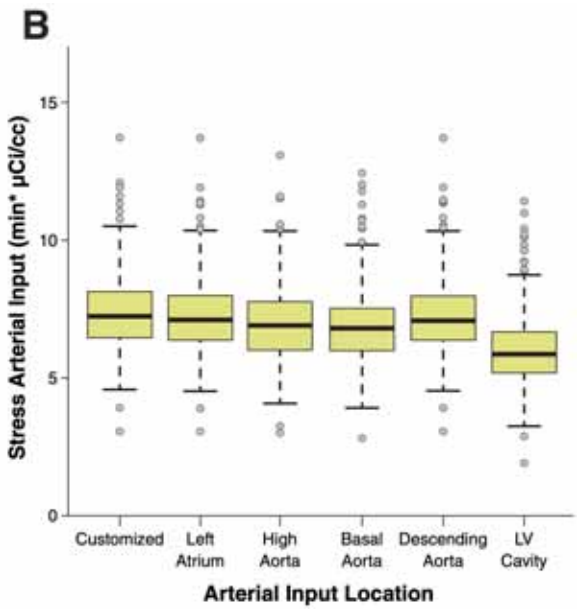


urtesy of Dr. Robert Bober (Ochsner, New Orleans)

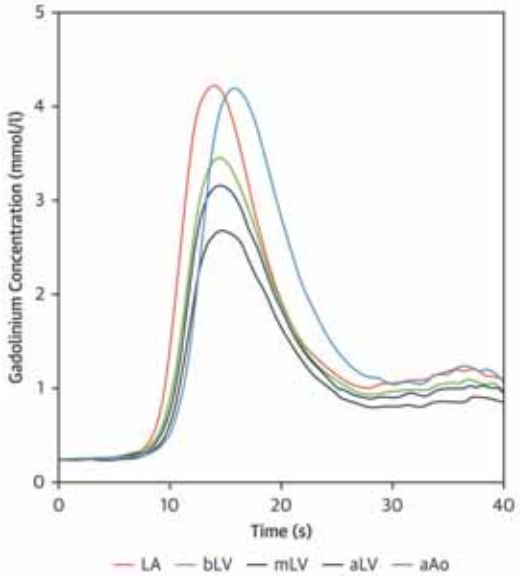
Location of arterial input

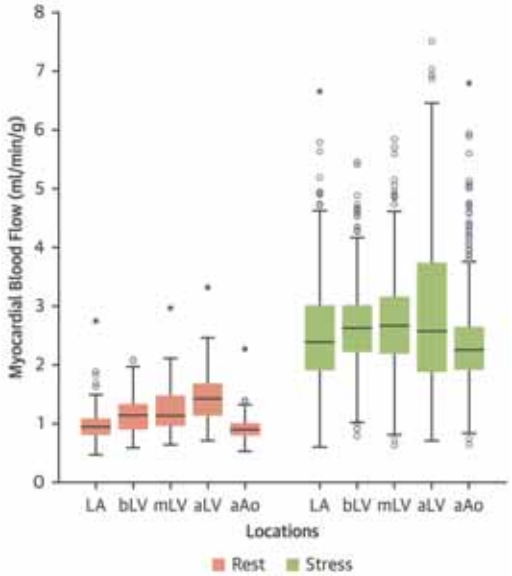






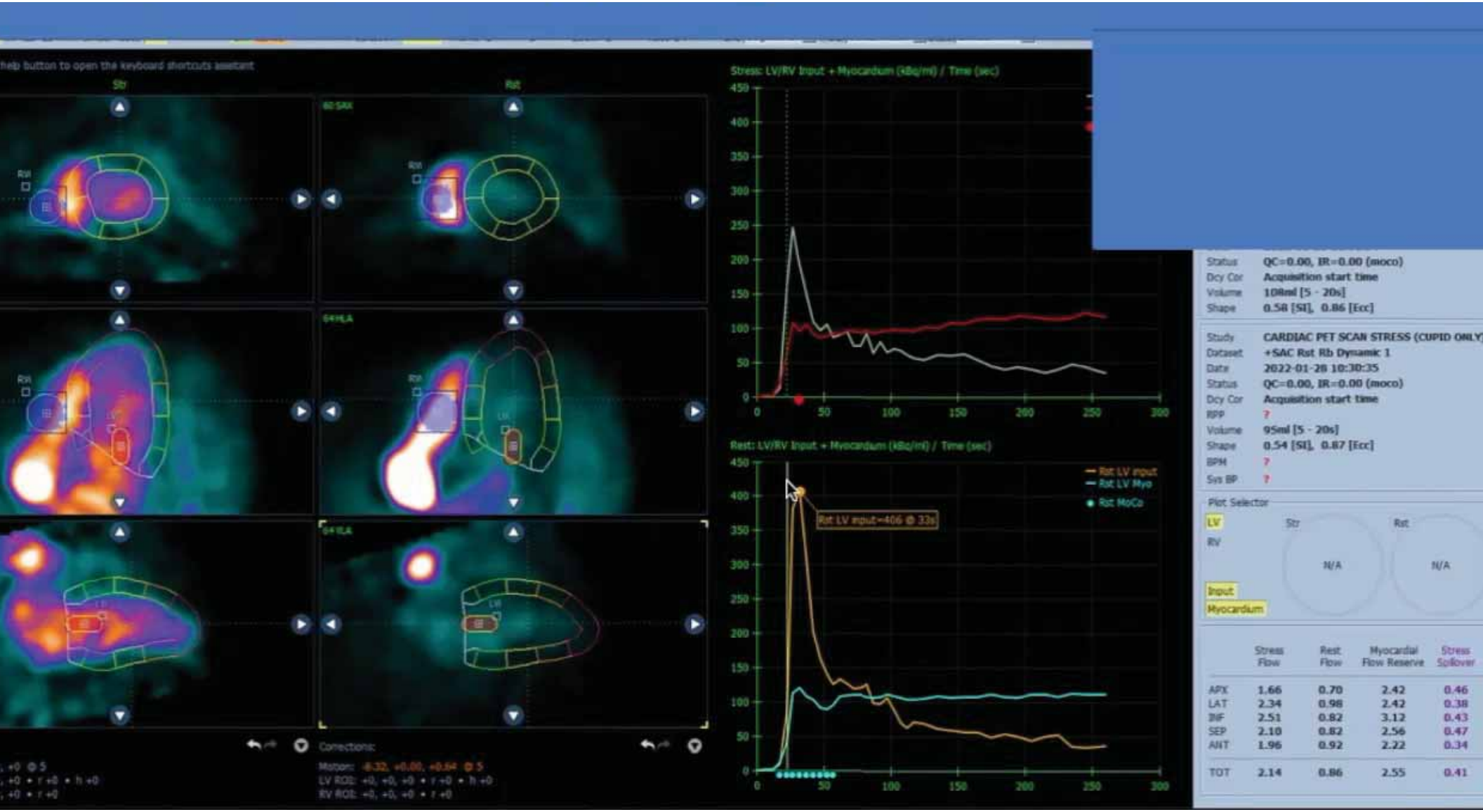
cardiac MRI





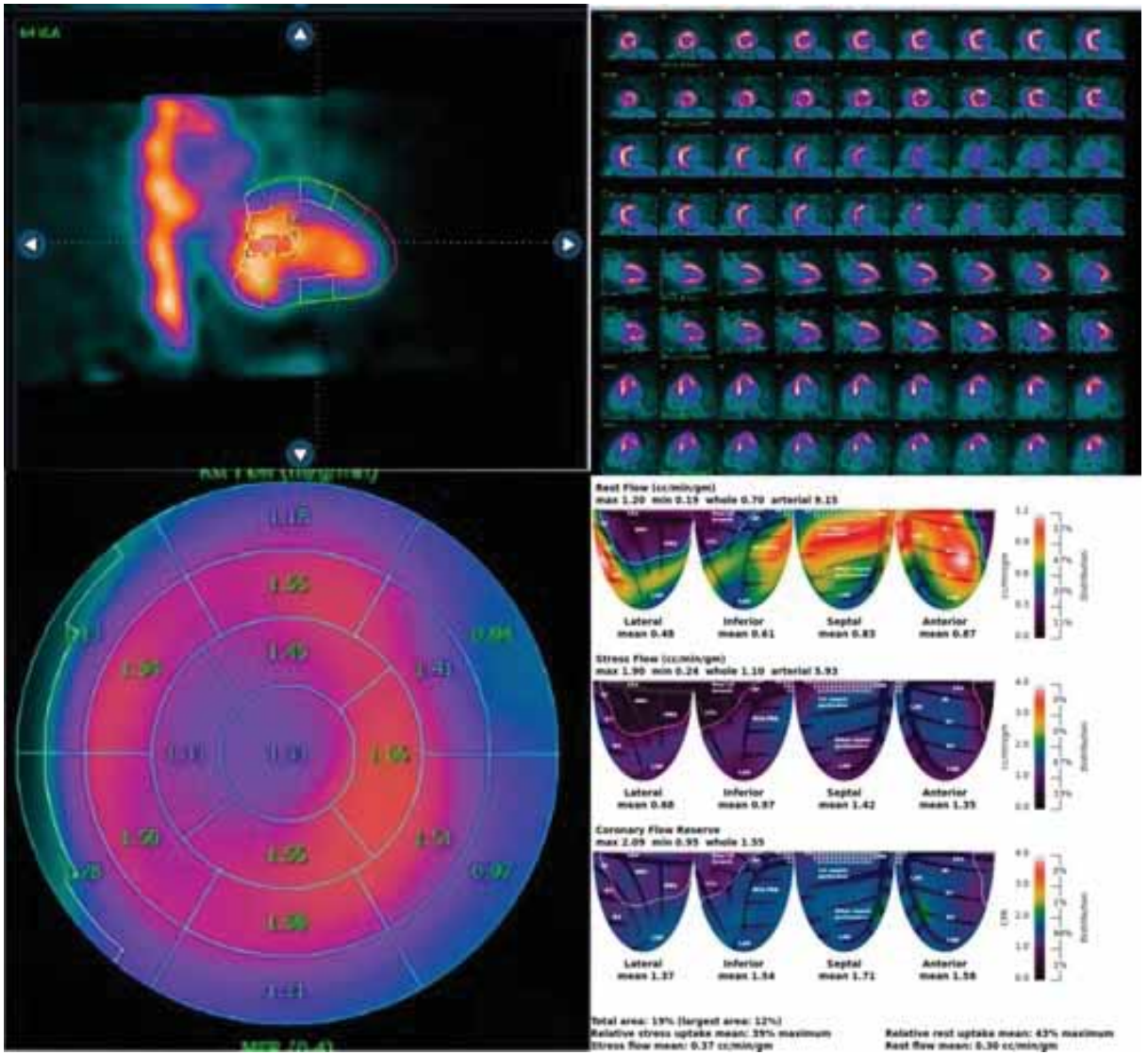
p = Vasquez AF, *JACC Cardiovasc Imaging*. 2013 May;6(5):559-68. (Figures 2 and 3)
ttom = Franks R, *JACC Cardiovasc Imaging*. 2020 Dec;13(12):2693-2695. (Figure 1)

Arterial input location



urtesy of Dr. Robert Bober (Ochsner, New Orleans)

Inferior infarct with aneurysm.



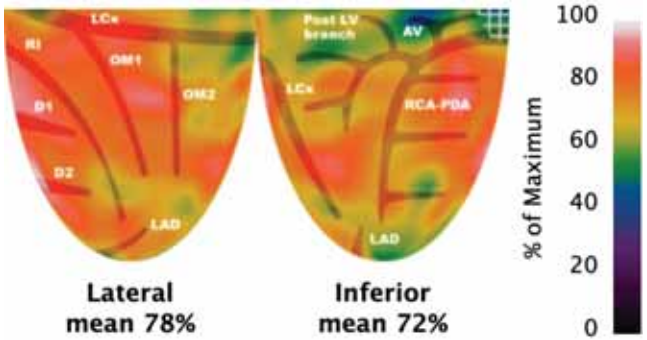
0.97 cc/min/gm

0.3 cc/min/gm

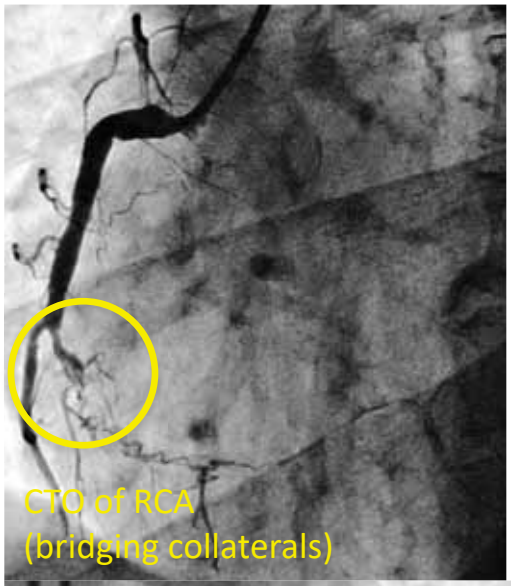
age courtesy of Dr. Robert Bober (Ochsner, New Orleans)

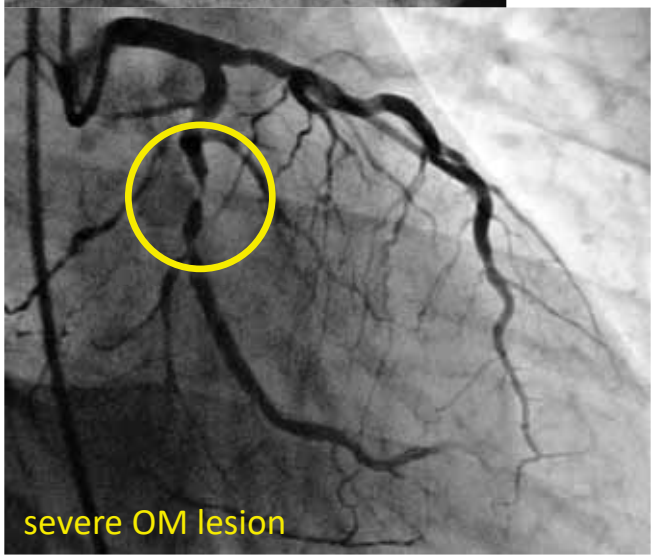
How can PET miss these severe lesions?

Relative stress uptake



Invasive angiogram

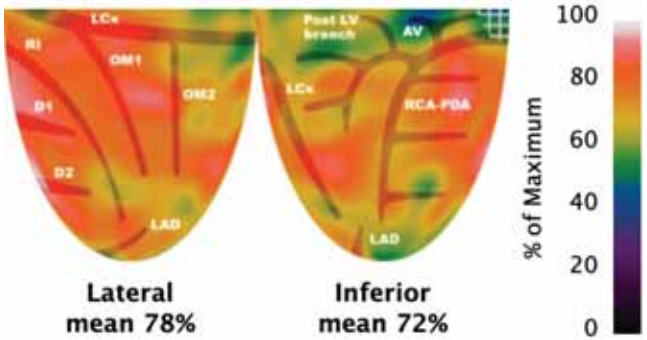




Caffeine can blunt hyperemia

Relative stress uptake

Invasive angiogram

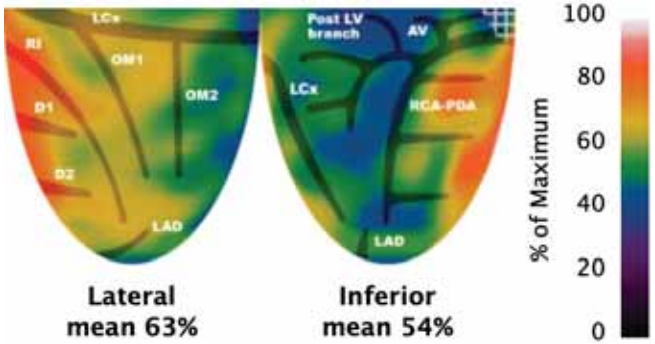


Lateral mean 78%

Inferior mean 72%

PET #1

ffeine *1.2 mg/L*



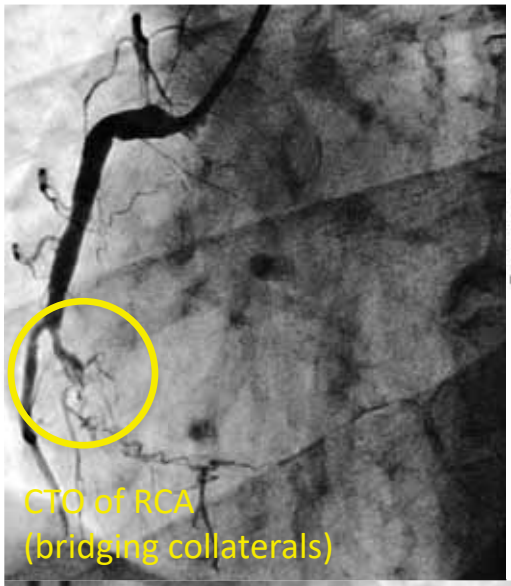
Lateral mean 63%

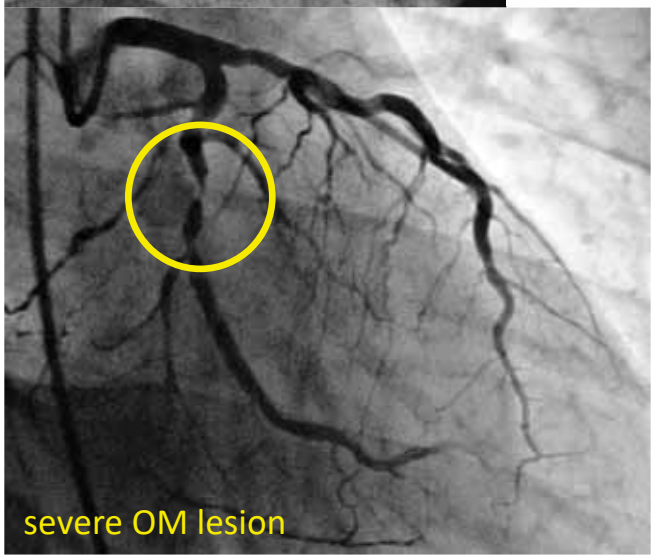
Inferior mean 54%

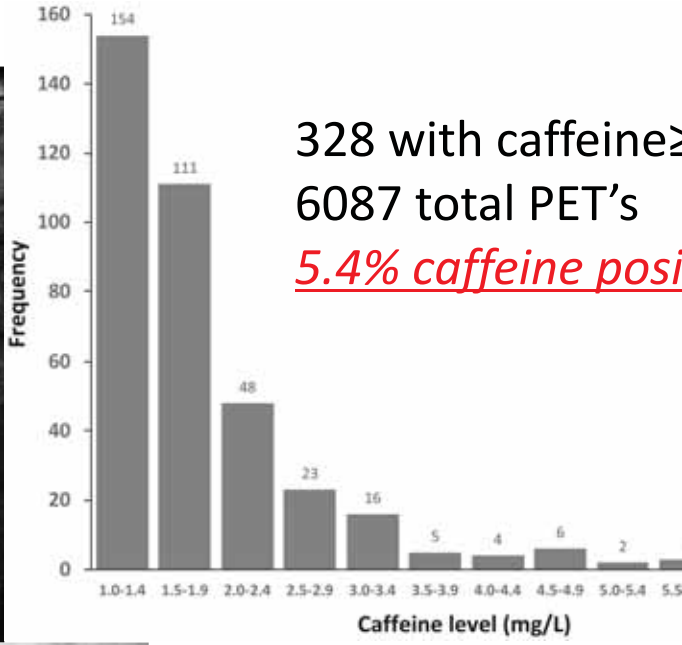
PET #2

ffeine *<1 mg/L*

28 days later)







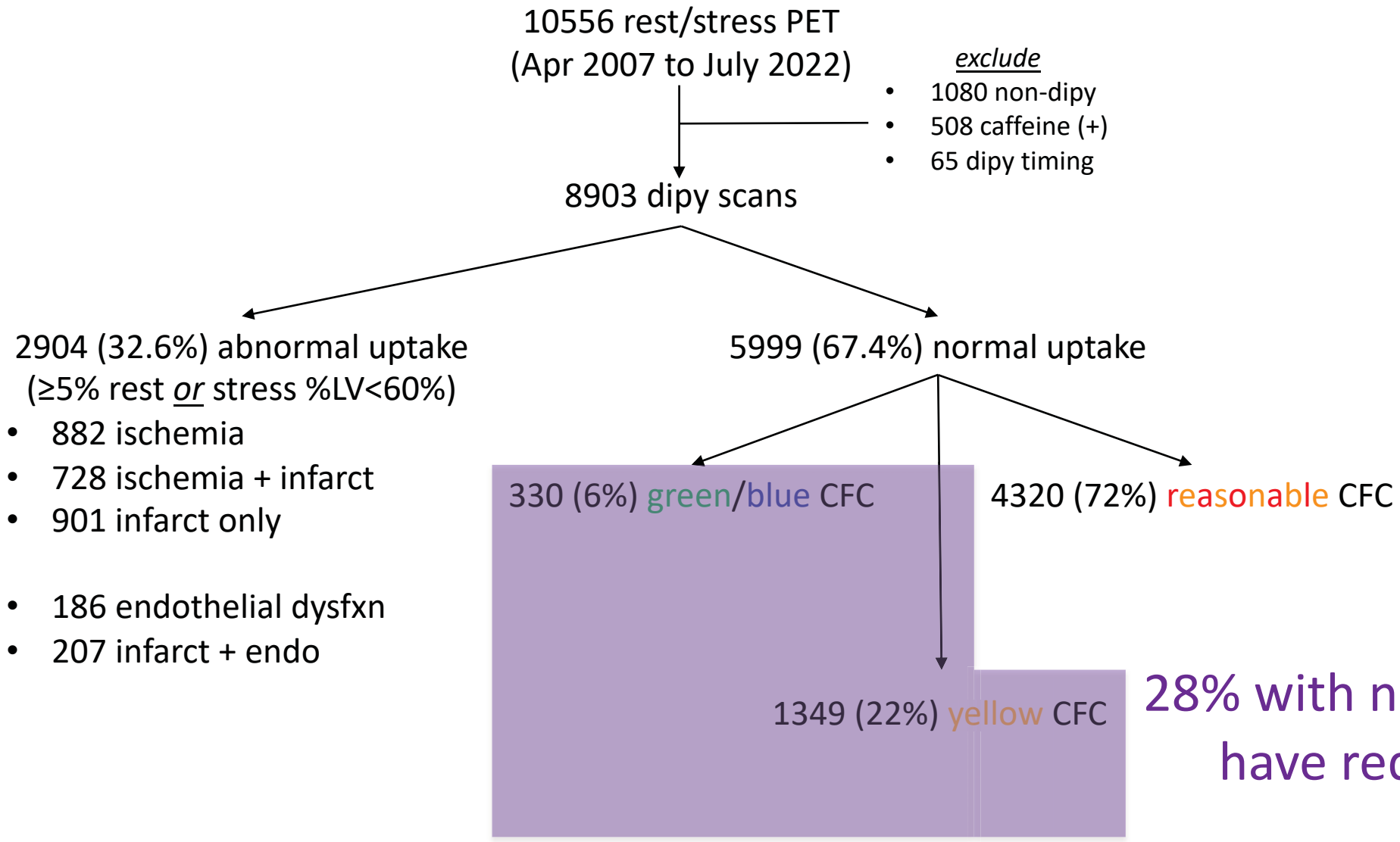
328 with caffeine≥

6087 total PET's

5.4% caffeine posi

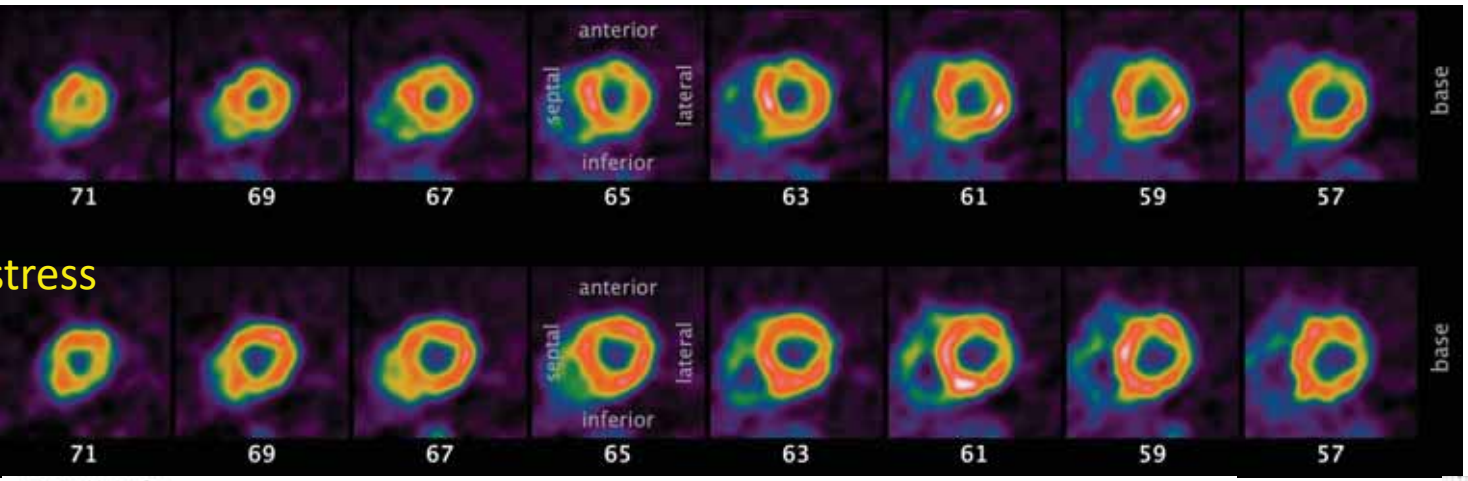
t upper = Kitkungvan D, *EHJ Cardiovasc Imaging*. 2019 Jul 1;20(7):751-762. (Figure 2)

But do we really need flow?

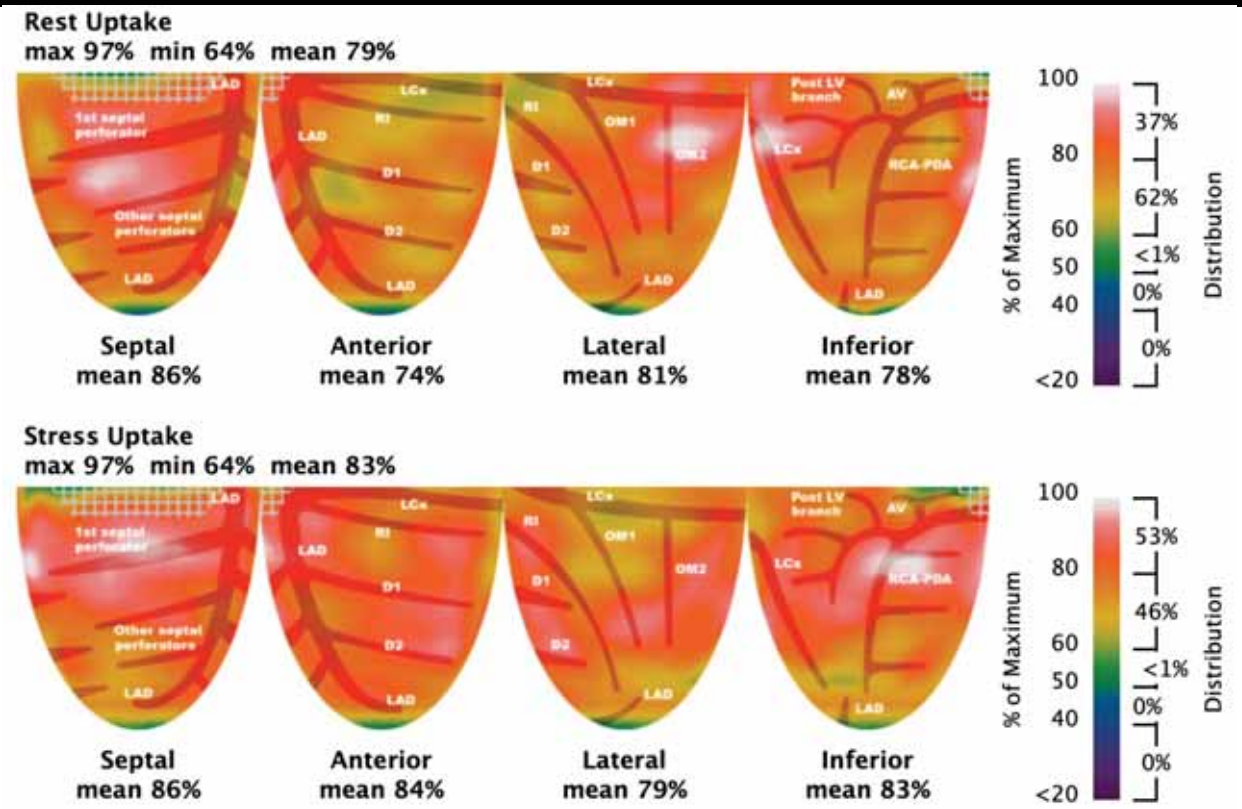


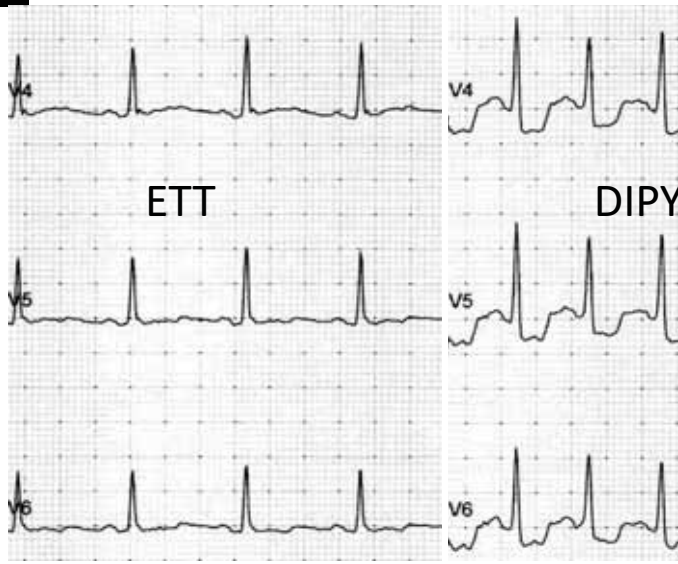
liminary unpublished data from UTHealth (Houston)

56 year-old man with severe angina



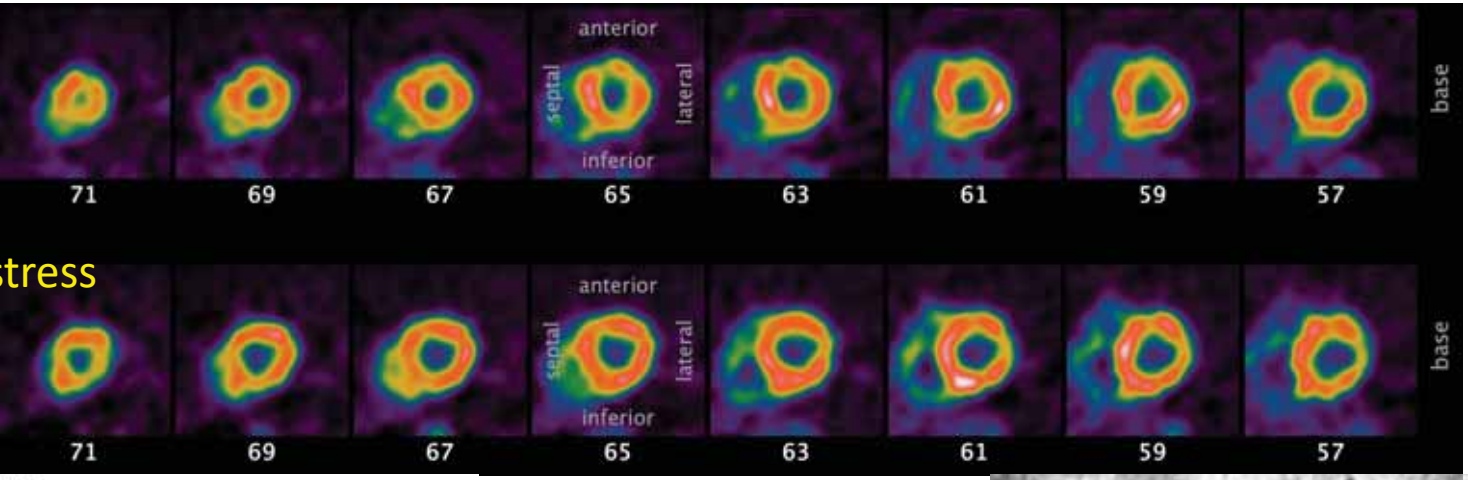
- diabetes, dyslipidemia
- dense CAC on CT
- Bruce treadmill
  - 5:12 minutes
  - reached 164/min (
  - 5-6/10 angina nea





stress EF 66%
angina, ST depression
with dipyridamole

56 year-old man with severe angina



- diabetes, dyslipidemia
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  - reached 164/min (
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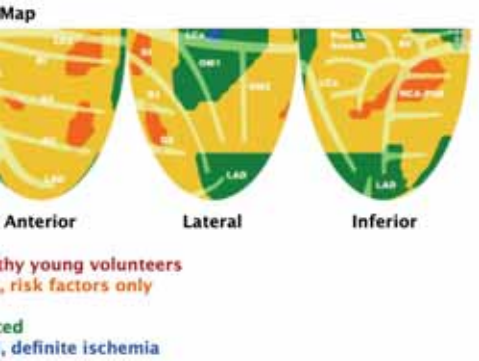
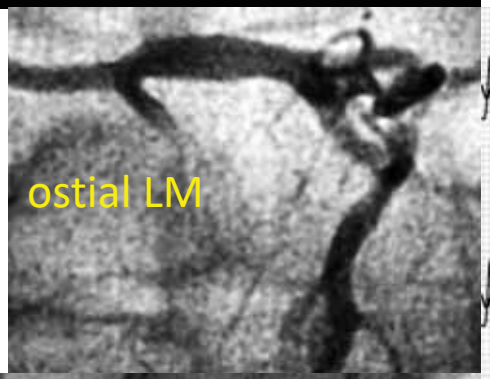
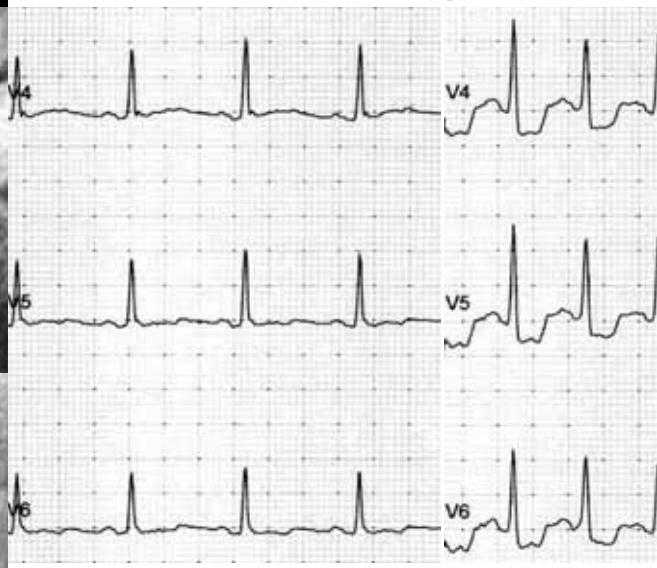
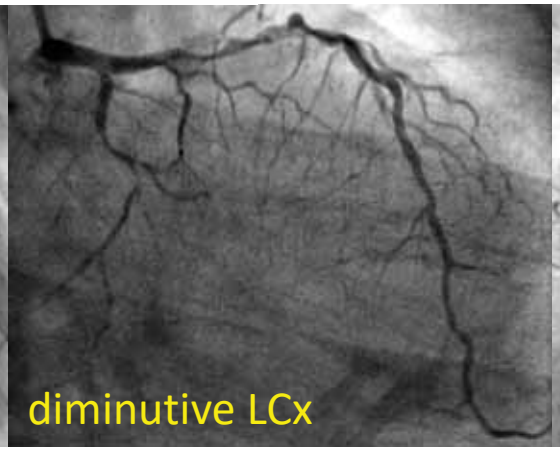
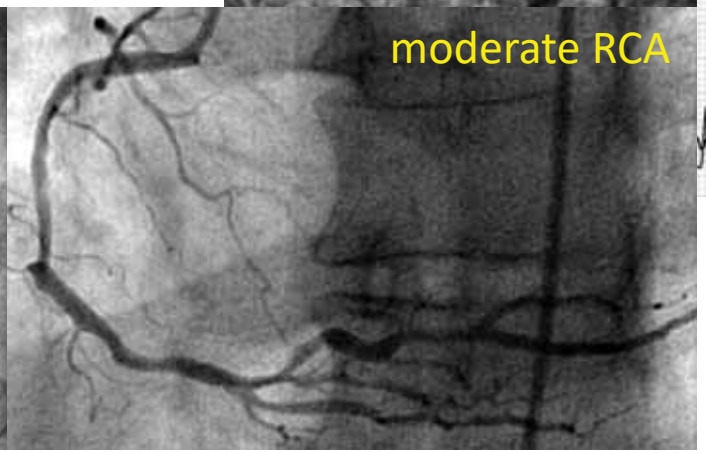


rest = 0.69
stress = 1.24
CFR = 1.84
<1%LV < 60% max
caffeine negative
angina, ST depression

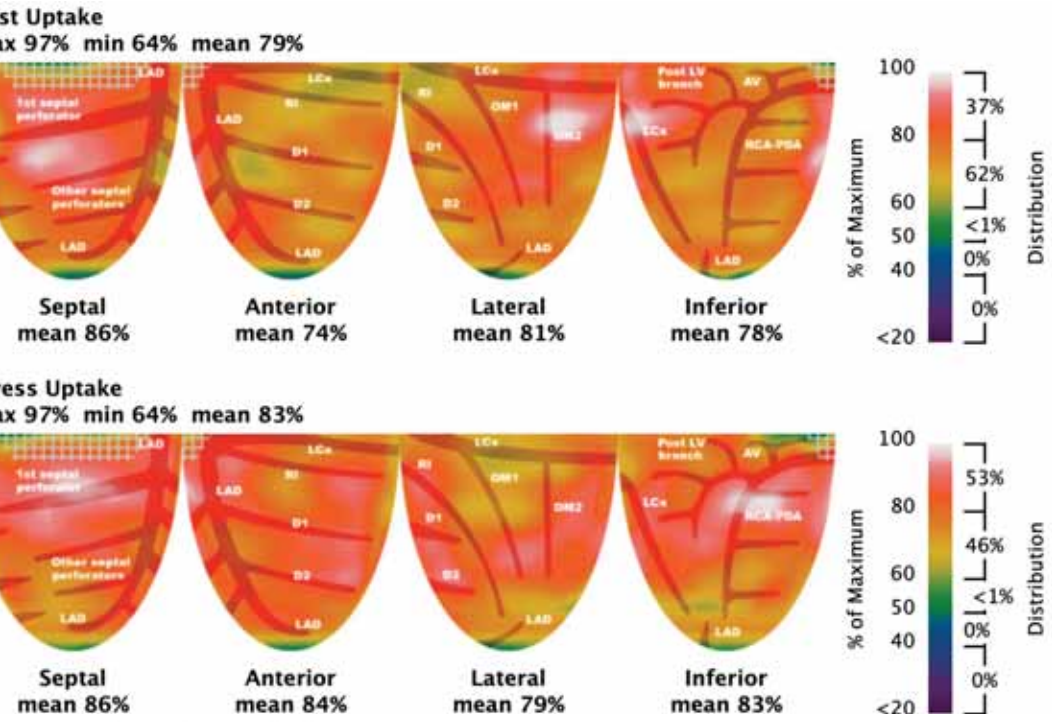


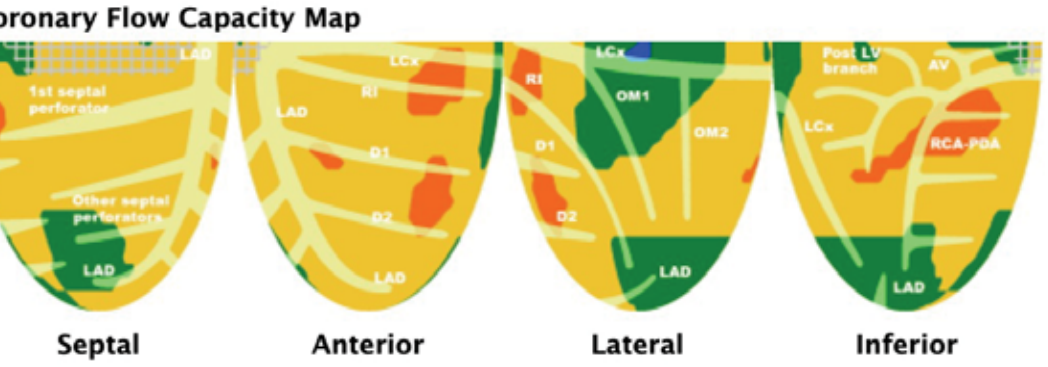






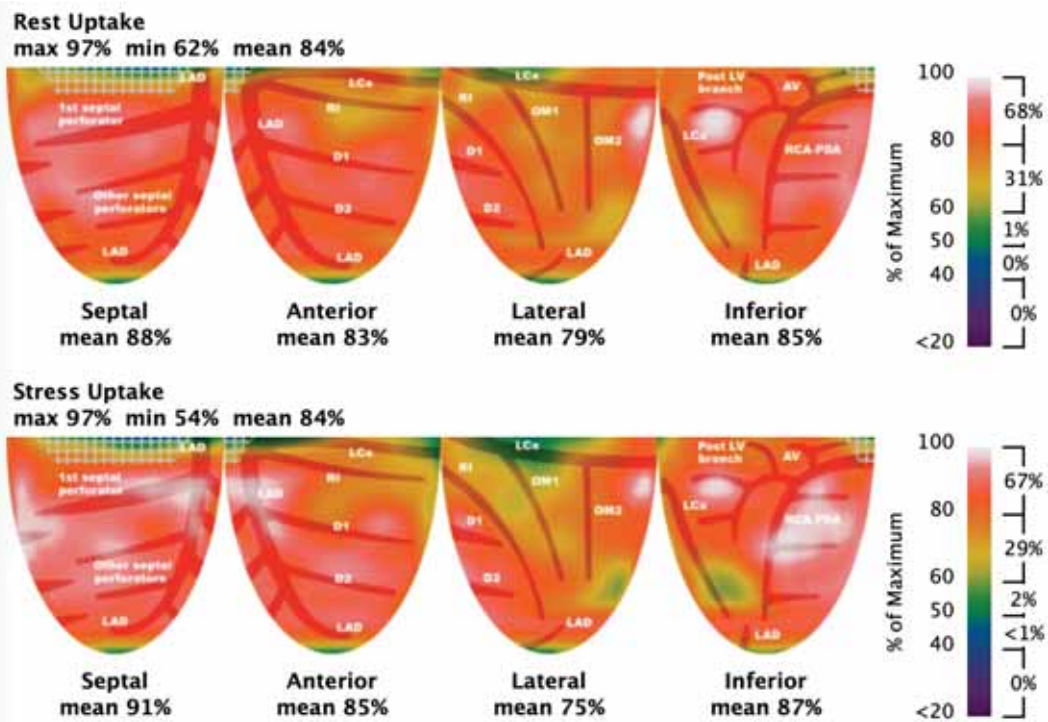
Underwent CABG (LIMA-LAD, SVG-DIAG, SVG-RCA

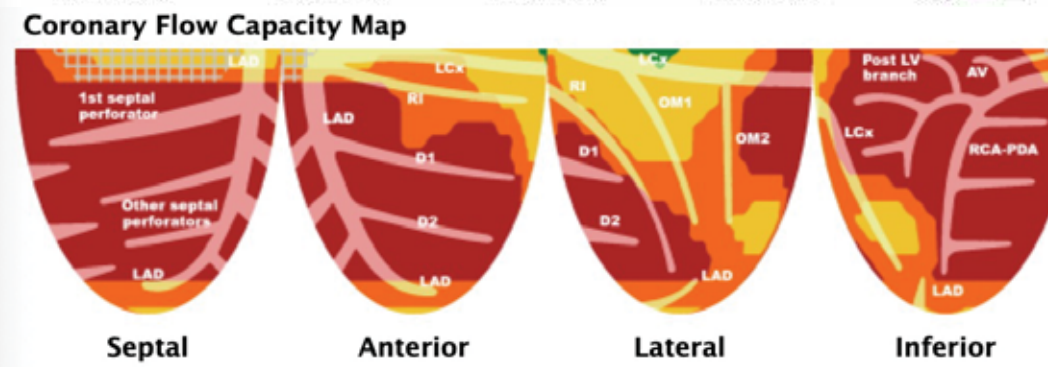




0% Normal, from healthy young volunteers
6% Minimally reduced, risk factors only
72% Mildly reduced
22% Moderately reduced
<1% Severely reduced, definite ischemia

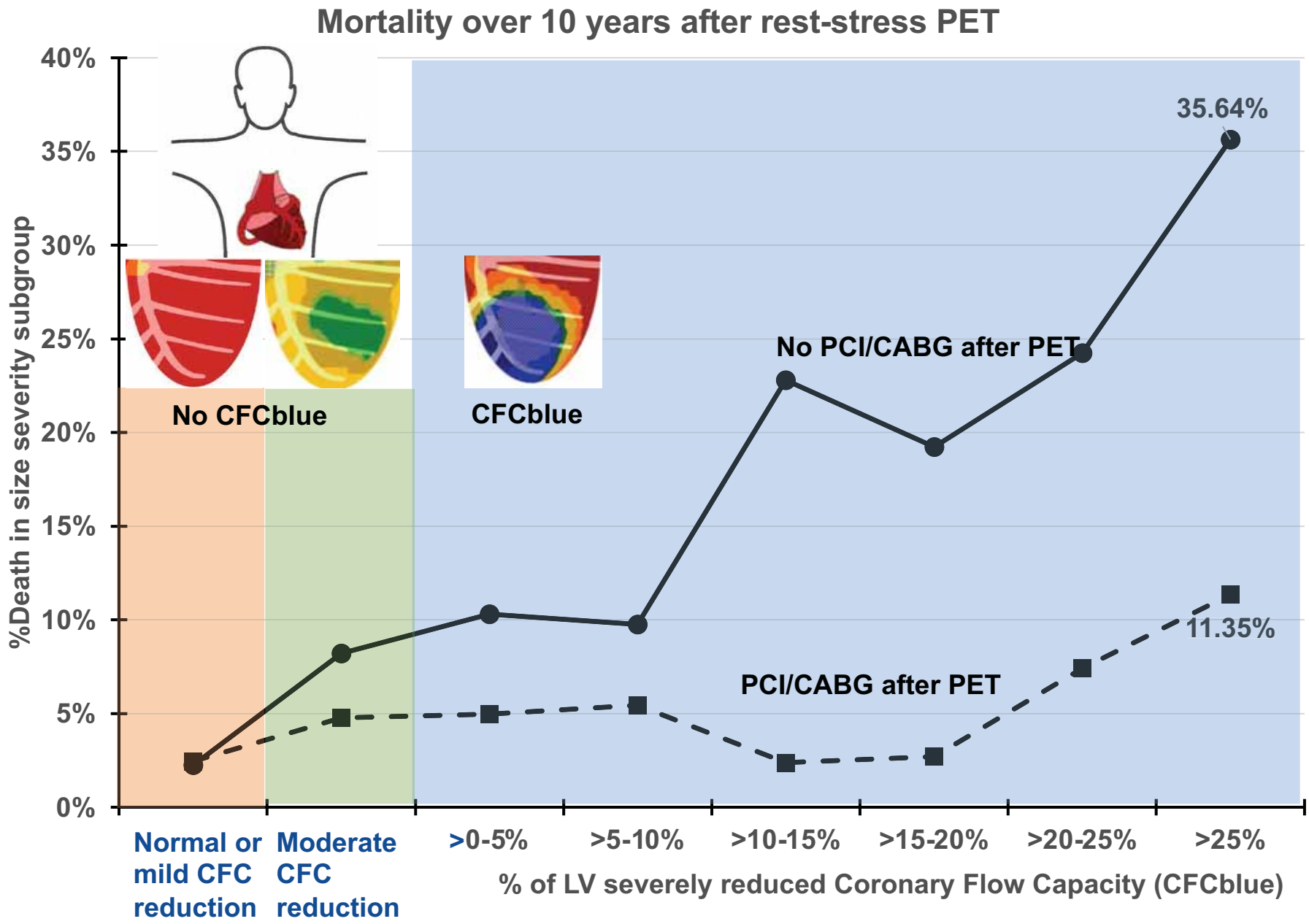
rest 0.69
stress 1.24
CFR 1.84





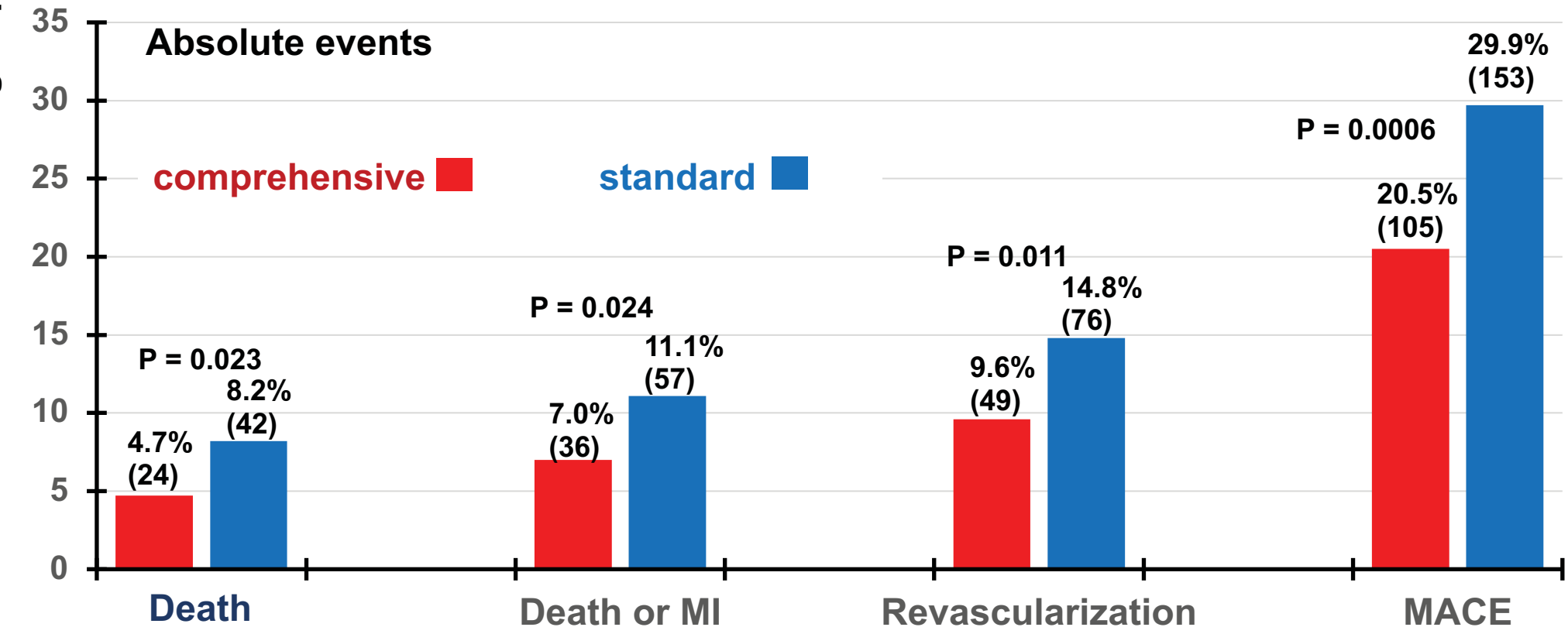
62% Normal, from healthy young volunteers
24% Minimally reduced, risk factors only
14% Mildly reduced
<1% Moderately reduced
0% Severely reduced, definite ischemia

rest 1.21
stress 2.41
CFR 1.98



uld KL *Curr Cardiol Rep* 23, 12 (2021) Figure 1

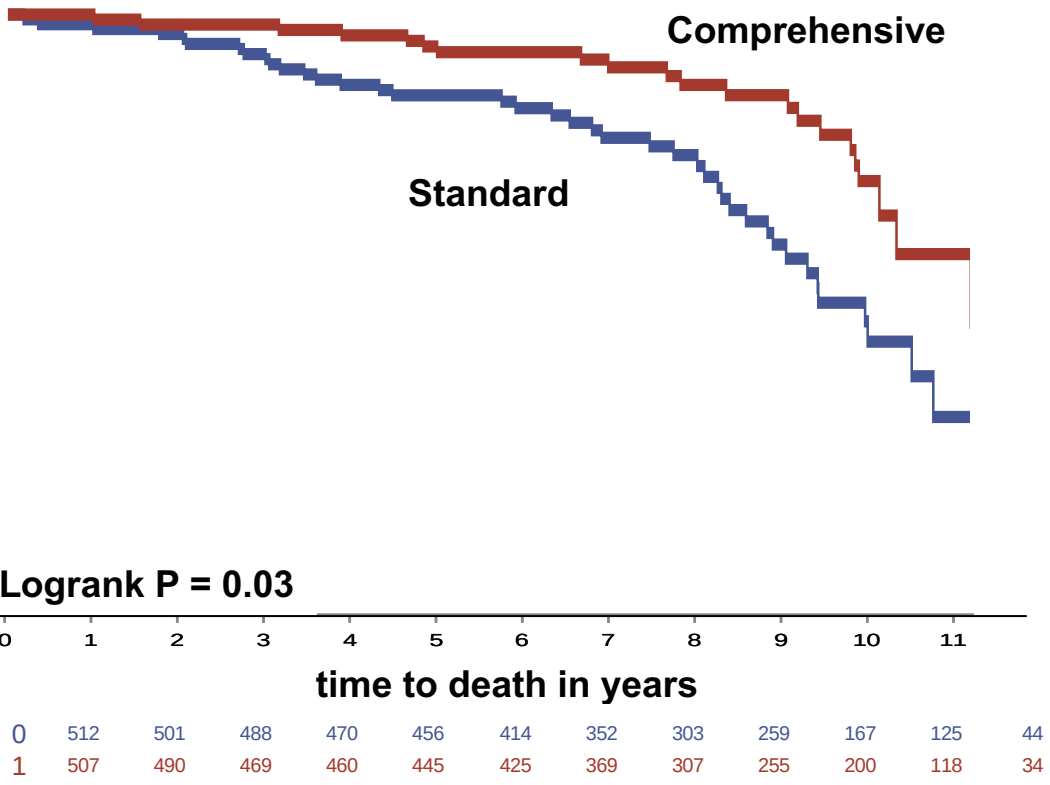
Randomized CENTURY Trial of Intense Lifestyle, Medical Treatment To Goals And PET Guided Interventions



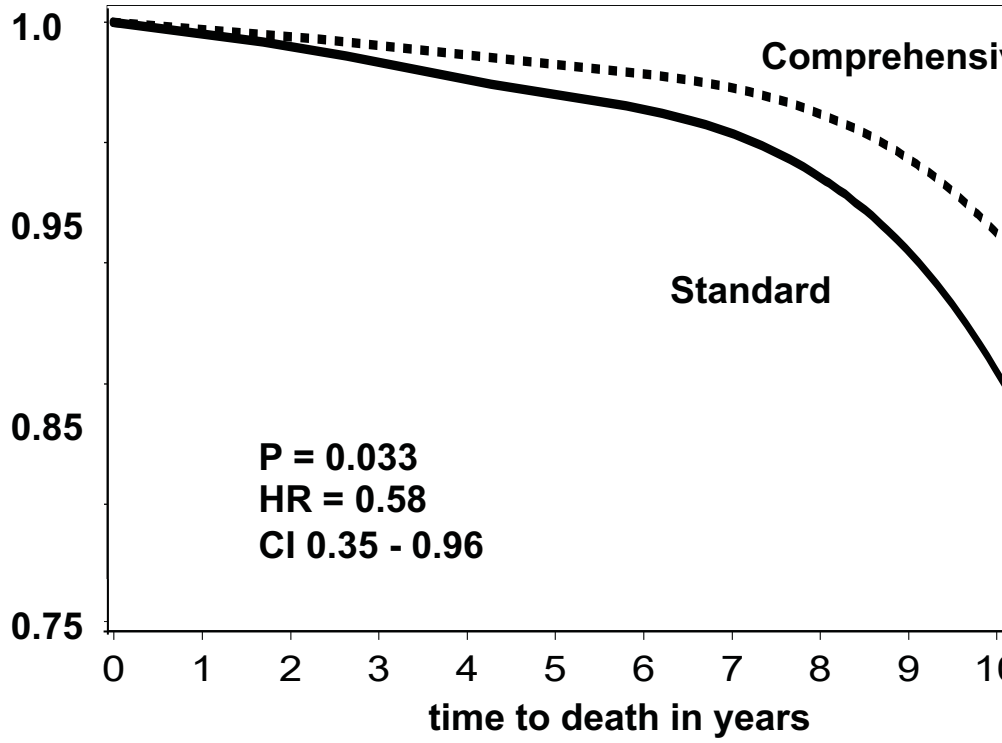
liminary unpublished data from UTHealth (Houston)

Randomized CENTURY Trial of Intense Lifestyle, Medical Treatment To Goals And PET Guided Interventions

Kaplan Meier Plot for death extended follow-up



Cox Regression Modeling for death extended fo



liminary unpublished data from UTHealth (Houston)

Accurate data into a validated flow package=

- Better precision and lower failure rate than FFR_{CT}
- Fewer contraindications than $FFR_{CT,}$ CMR, or ICA
- More information than CMR
- Artery specific diagnosis
- Predicts ICA-FFR and predicts PCI/CABG best outcomes

al. Mar 2021. Current Cardiology Reports 23(50)