Solid State LightBurst New PET Technology – GE PET/CT and PET/MR

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Disclosures

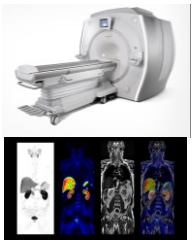
- SIEMENS Research grant
- GE research grant

Discovery MI

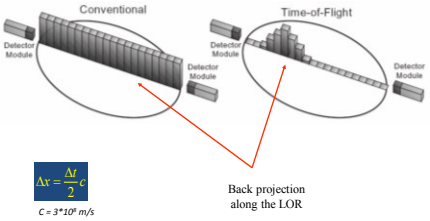
- LYSO
- TOF capable
- 385 ps (6 cm positioning error)
- PSF
- Regularized reconstruction
- SSPM detectors
- Modular 10, 15, 20, 25 cm
- 70 cm transverse FOV
- Water cooled

New GE Signa PET/MR

- PET
  - LYSO
  - TOF capable
  - ~ 385 ps (6 cm positioning error)
  - PSF
  - Regularized reconstruction
  - SSPM
  - 25 cm axial FOV
  - 60 cm transverse FOV
- 3 T MRI (MR750W)
  - 60 cm bore w/ 50cm FOV
  - Multi-drive XMIT with 32 ch + 33 T/m & 120 T/m/s gradient strength



Time-of-Flight Acquisition:



$$\Delta x = \frac{\Delta t}{2} c$$

$c = 3*10^8$ m/s

Back projection along the LOR

$$\Delta x = \frac{\Delta t}{2} c \qquad SNR_{TOF} \cong \sqrt{\frac{D}{\Delta x}} \cdot SNR_{conv}$$

Time Resolution (ns)	Δx (cm)	SNR improvement (20 cm object)	SNR improvement (40 cm object)
0.1	1.5	3.7	5.2
0.3	4.5	2.1	3.0
0.5	7.5	1.6	2.3
1.2	18.0	1.1	1.5

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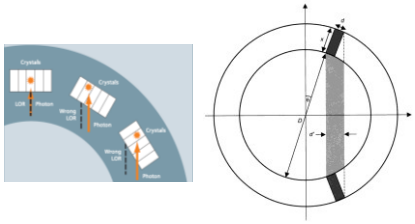
Resolution Recovery



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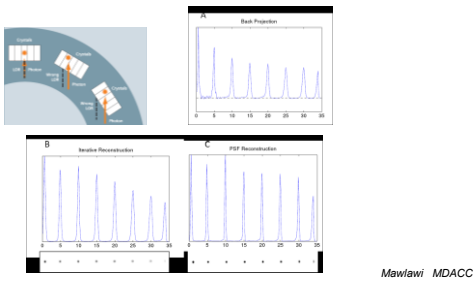
Resolution Recovery



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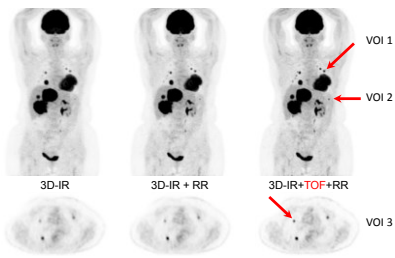
70 Kg, 280 MBq, 2.5 min/bed, 104 min post admin



SUV VOI 1:	3.1	4.3	5.6
SUV VOI 2:	1.8	2.4	3.7
SUV VOI 3:	1.2	2.1	4.0

Courtesy of D. Townsend

Regularized Reconstruction Technology

Data statistics (likelihood) General OSEM | **Regularization**

$$\bar{x} = \arg\max_{x \geq 0} \sum_{i=1}^{n_d} y_i \log[Px]_i - [Px]_i - \beta \sum_{j=1}^{n_v} \sum_{k \in N_j} \kappa_{jk} \phi(x_j - x_k)$$

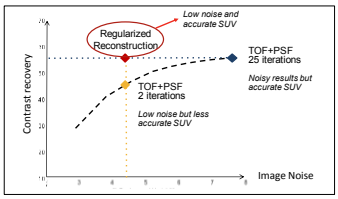
Weighting term to modulate the strength of the regularization term

Small pixel differences
Regularization favors this image

Big pixel differences
Regularization avoids this image

Adapted from GE HealthCare

Regularized Reconsturction

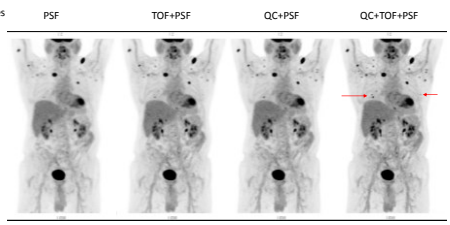


Achieve full convergence at low image noise

Adapted from GE HealthCare

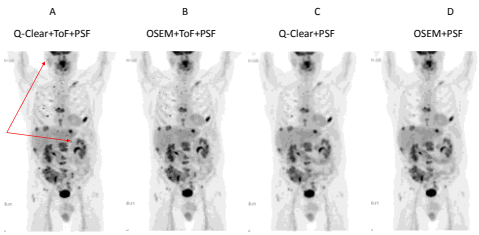
Regularized Reconstruction = Q-Clear

MIP Images



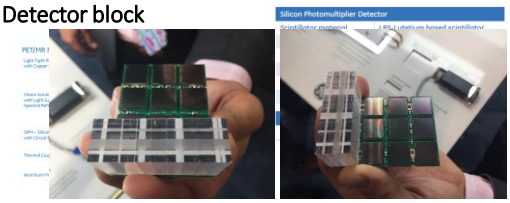
77 years male with follicular lymphoma, 80 kg, 25 BMI, 9.4 mCi, 60 min post injection

Regularized Reconstruction = Q-Clear



Left to right: PET MIP images of a patient (BMI=26) with algorithms A, B, C, and D. Arrows highlighting lesion conspicuity (red). All images are displayed with the same WW/WL settings.

Detector block



4x3 "optical block." The light from those crystals is directed towards a single SiPM chip.
What's hard to see in the figure is that the chip is a hex device, with 3x2 operationally independent devices on it.
So the light encoding is 12 crystals to 6 SiPM channels.
picture shows twelve blocks, or an assembly of 16x9 crystals, that is nominally 64x48 mm in size.

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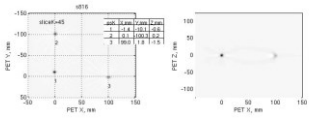
PET/(MR) PET Detector

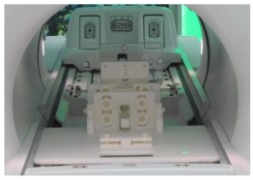
- Small
- Compact
- MR compatible

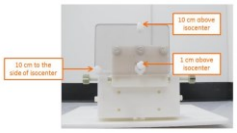
Resolution Center Position



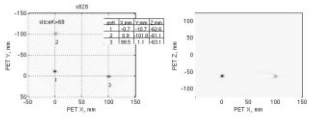
	ΔX	ΔY
PSe1	-1.4	-0.1
PSe2	0.1	-0.3
PSe3	-1.0	1.8

	ΔZ for Center	ΔZ for Quarter
PSe1	-0.6	61.9
PSe2	0.2	62.7
PSe3	-1.5	61.1



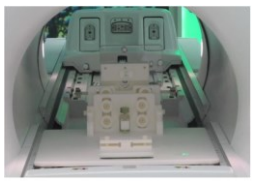


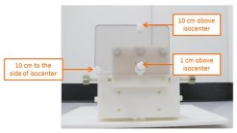
Resolution Quarter FOV Position



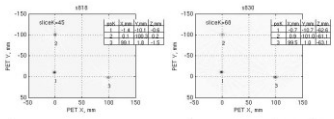
	ΔX	ΔY
PSe1	-0.7	-0.7
PSe2	0.9	-1.9
PSe3	-0.5	1.1

	ΔZ for Center	ΔZ for Quarter
PSe1	-62.8	-0.9
PSe2	-61.1	1.4
PSe3	-63.1	-0.5



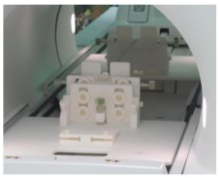


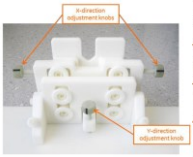
Resolution Results

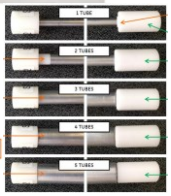


Test	Expected mm FWHM	Measured	Pass / Fail
Transverse @ 1 cm	<= 4.5	4.2	Pass
Axial @ 1 cm	<= 6.5	6.0	Pass
Radial @ 10 cm	<= 5.9	5.8	Pass
Tangential @ 10 cm	<= 4.6	4.4	Pass
Axial @ 10 cm	<= 7.4	7.1	Pass

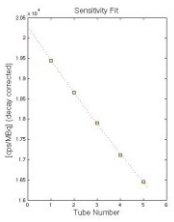
Sensitivity

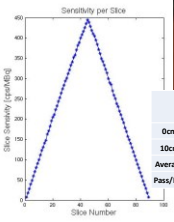






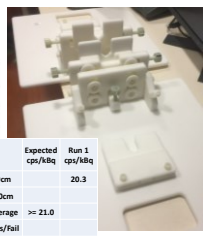
Sensitivity Center FOV 1st Run





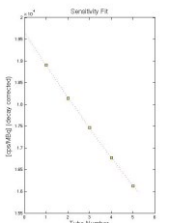
Sensitivity: 20.291 [cps/kBq]
Attenuation: 2.106e-02 [1/mm]
Half Life: 6586.2002 [s]
Fit Type: 5 Point

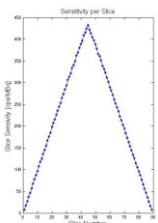
Study:
Series: e+1 NoMR: 0cm, tube_1
Acquired: 06-Mar-2017 17:30:36
Printed: 06-Mar-2017 18:12:10



	Expected cps/kBq	Run 1 cps/kBq
0cm		20.3
10cm		
Average	>= 21.0	
Pass/Fail		

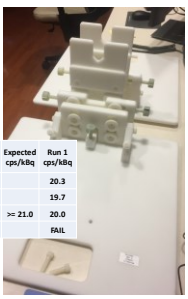
Sensitivity 10 cm 1st Run





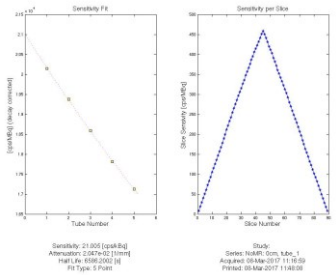
Sensitivity: 19.669 [cps/kBq]
Attenuation: 1.983e-02 [1/mm]
Half Life: 6586.2002 [s]
Fit Type: 5 Point

Study:
Series: NoMR: 10cm, tube_1
Acquired: 06-Mar-2017 18:04:53
Printed: 06-Mar-2017 18:13:32



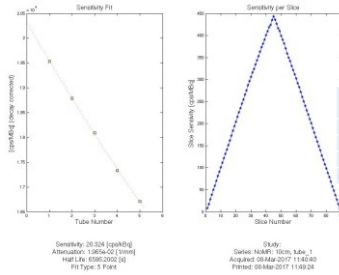
	Expected cps/kBq	Run 1 cps/kBq
0cm		20.3
10cm		19.7
Average	>= 21.0	20.0
Pass/Fail		FAIL

Sensitivity Center FOV 2nd Run



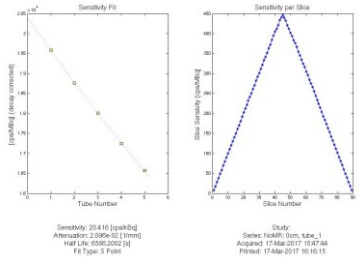
	Expected cps/kBq	Run 1 cps/kBq	Run 2 cps/kBq
0cm		20.3	21.0
10cm		19.7	
Average	>= 21.0	20.0	
Pass/Fail		FAIL	

Sensitivity 10 cm 2nd Run



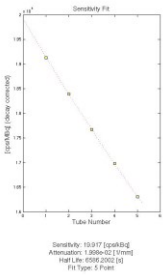
	Expected cps/kBq	Run 1 cps/kBq	Run 2 cps/kBq
0cm		20.3	21.0
10cm		19.7	20.3
Average	>= 21.0	20.0	20.7
Pass/Fail		FAIL	FAIL

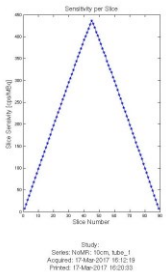
Sensitivity Center FOV 3rd Run



	Expected cps/kBq	Run 1 cps/kBq	Run 2 cps/kBq	Run 3 cps/kBq
0cm		20.3	21.0	20.4
10cm		19.7	20.3	
Average	>= 21.0	20.0	20.7	
Pass/Fail		FAIL	FAIL	

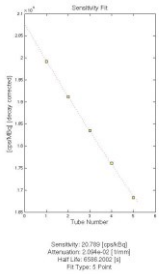
Sensitivity 10 cm 3rd Run

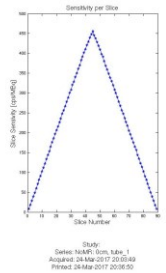




	Expected cps/kBq	Run 1 cps/kBq	Run 2 cps/kBq	Run 3 cps/kBq
0cm		20.3	21.0	20.4
10cm		19.7	20.3	19.9
Average	>= 21.0	20.0	20.7	20.2
Pass/Fail		FAIL	FAIL	FAIL

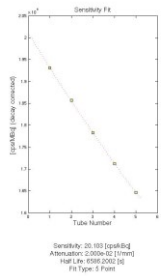
Sensitivity Center FOV 4th Run

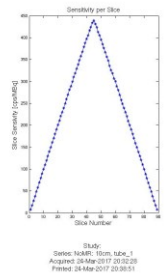




	Expected cps/kBq	Run 1 cps/kBq	Run 2 cps/kBq	Run 3 cps/kBq	Run 4 cps/kBq
0cm		20.3	21.0	20.4	20.8
10cm		19.7	20.3	19.9	
Average	>= 21.0	20.0	20.7	20.2	
Pass/Fail		FAIL	FAIL	FAIL	

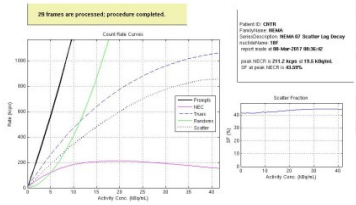
Sensitivity 10 cm 4th Run

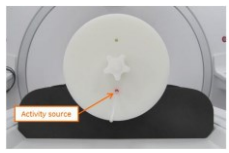




	Expected cps/kBq	Run 1 cps/kBq	Run 2 cps/kBq	Run 3 cps/kBq	Run 4 cps/kBq
0cm		20.3	21.0	20.4	20.8
10cm		19.7	20.3	19.9	20.1
Average	>= 21.0	20.0	20.7	20.2	20.4
Pass/Fail		FAIL	FAIL	FAIL	FAIL

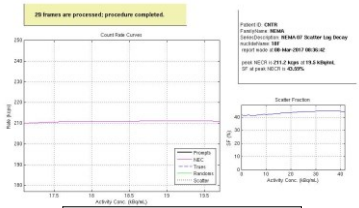
Count rate





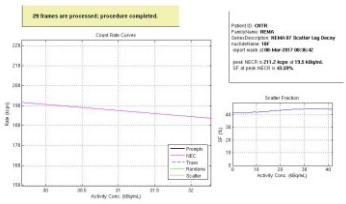
	Expected	Measured	P/F
Peak NECR	>= 210 kcps	211	Pass
NECR @ 17.5 kBq/ml	>= 210 kcps	210	Pass
NECR @ 30.0 kBq/ml	>= 175 kcps	191	Pass

Count rate @ 17 kBq/cc



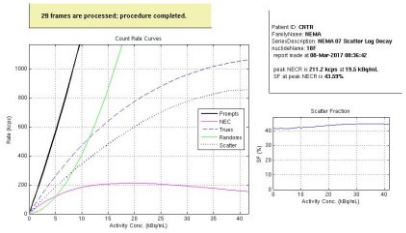
	Expected	Measured	P/F
Peak NECR	>= 210 kcps	211	Pass
NECR @ 17.5 kBq/ml	>= 210 kcps	210	Pass
NECR @ 30.0 kBq/ml	>= 175 kcps	191	Pass

Count rate @ 30 kBq/cc



	Expected	Measured	P/F
Peak NECR	>= 210 kcps	211	Pass
NECR @ 17.5 kBq/ml	>= 210 kcps	210	Pass
NECR @ 30.0 kBq/ml	>= 175 kcps	191	Pass

Scatter Fraction



	Expected	Measured	P/F
Scatter Fraction @ Peak NECR	<=45 %	44	Pass

PET NEMA (NU 2-2007) measurements – MR on and off

LightBurst Digital Detector	
Sensitivity[1]	13.5 cps/kBq
Timing Resolution	385 psec
Sensitivity/mm[1]	0.068 cps/kBq*mm
Scatter fraction[1]	41%
Clinical NECR[1]	53 kcps @ 2.4 kBq/ml
Peak NECR[1]	180 kcps @ 20 kBq/ml
Coincidence window	4.9 ns
Energy threshold	425 KeV

Levin et al, "Performance of a high sensitivity time-of-flight PET ring operating simultaneously within a 3T MR system", PSMR Conference, Kos, Greece 2014

[1]error estimate is standard deviation of three measurements at different sites

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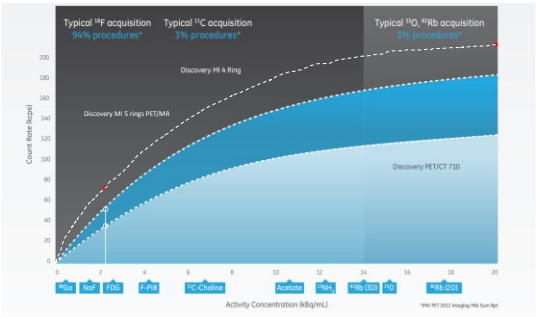
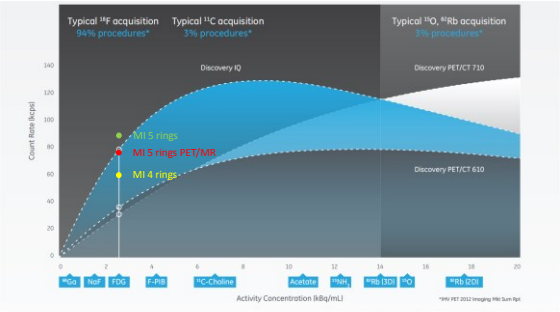
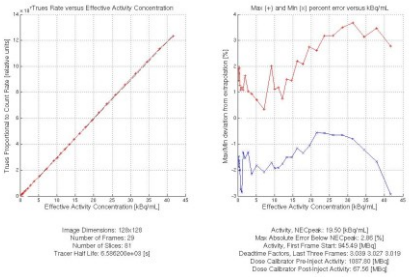




NECR curves for the Discovery IQ, 5 ring configuration[2]

Accuracy



Count Rate Accuracy	Expected	Measured	Pass/Fail
Max Error Below NECR	<= 5 %	3%	PASS

NEMA IEC Body Phantom

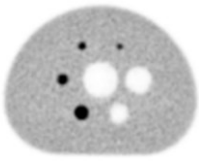
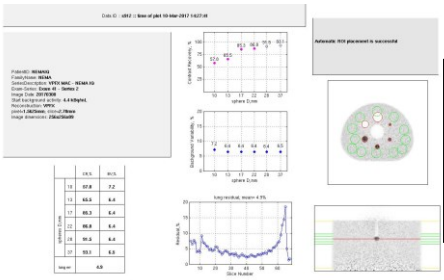


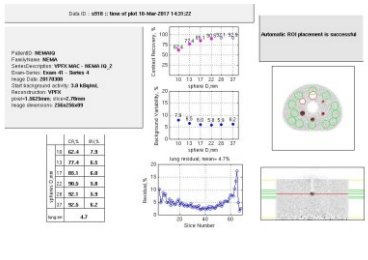
Figure 2-1: Cross Section of NEMA Image Quality Phantom (Demonstrating Proper Orientation of Hot and Cold Spheres)

IQ Run1



Contrast Recovery	Expected	Run 1	P/F
10 mm	>= 30 %	58	P
13 mm	>= 35 %	66	P
17 mm	>= 45 %	85	P
22 mm	>= 55 %	87	P
28 mm	>= 65 %	92	P
37 mm	>= 70 %	93	P
Background Variability			
10 mm	<= 10 %	7	P
13 mm	<= 9 %	6	P
17 mm	<= 8 %	6	P
22 mm	<= 7 %	6	P
28 mm	<= 6 %	6	P
37 mm	<= 5 %	7	Fail
Lung Error	<= 10 %	5	P

IQ Run2



Contrast Recovery	Expected	Run 1	P/F	Run 2	P/F
10 mm	>= 30 %	58	P	62	P
13 mm	>= 35 %	66	P	77	P
17 mm	>= 45 %	85	P	85	P
22 mm	>= 55 %	87	P	91	P
28 mm	>= 65 %	92	P	92	P
37 mm	>= 70 %	93	P	93	P
Background Variability					
10 mm	<= 10 %	7	P	8	P
13 mm	<= 9 %	6	P	7	P
17 mm	<= 8 %	6	P	6	P
22 mm	<= 7 %	6	P	6	P
28 mm	<= 6 %	6	P	6	P
37 mm	<= 5 %	7	Fail	6	Fail
Lung Error	<= 10 %	5	P	5	P

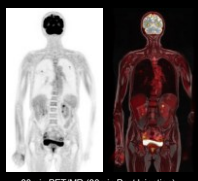
UP TO 26 CM AXIAL FIELD-OF-VIEW

UP TO 3x FASTER ACQUISITION

Courtesy of GE

PET/MR

4.8 mCi FDG



30min PET/MR (80min Post Injection)

*Courtesy University of Zurich

Full acquisition time
12 min

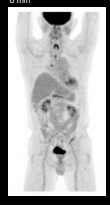
⅓ acquisition time
6 min

Full acquisition time
12 min

⅓ acquisition time
6 min

SUVmax: 7.45 Liver SUVmean: 2.07

SUVmax: 7.53 Liver SUVmean: 2.01



DISCOVERY MI sensitivity and LightBurst Digital detector provide reliable and consistent image quality, resolution and quantitative accuracy. With Discovery MI, research center will be able to free up scanner time for their research study without impact their daily clinical workload.

Courtesy Stanford University, A. Iagaru, MD

DISCOVERY MI sensitivity and 20cm Axial Field of View LightBurst Digital detector provide the ability to perform fast 2 meter scans without sacrificing image quality or resolution and improve patient comfort with shorter scan times.

Acquisition

20 minutes

383 MBq / 10.35 mCi FDG

96 minute uptake

Patient History

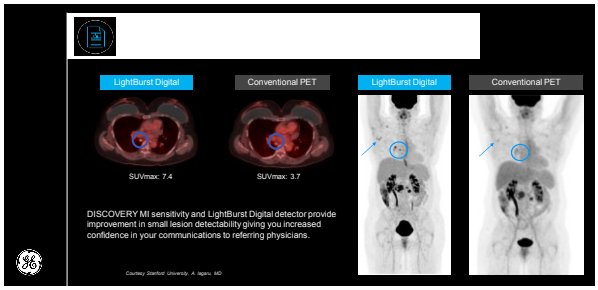
Patient referred to PET/CT for Restaging of Mantle Cell Non-Hodgkin's Lymphoma

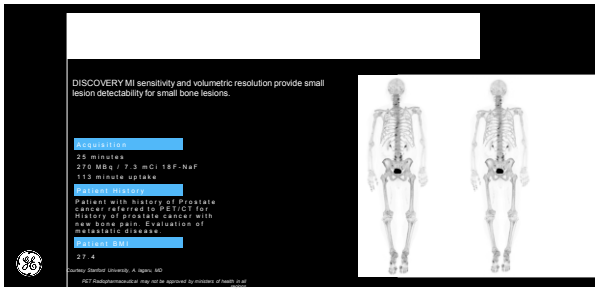
Patient BMI

28.4

Liver SUVmean: 2.22 g/ml
Liver Noise (STD): 0.17 g/ml

Courtesy Stanford University, A. Iagaru, MD


LightBurst Digital
Conventional PET
LightBurst Digital
Conventional PET
SUVmax: 7.4
SUVmax: 3.7
DISCOVERY MI sensitivity and LightBurst Digital detector provide improvement in small lesion detectability giving you increased confidence in your communications to referring physicians.
Courtesy Stanford University, A. Iagaru, MD


DISCOVERY MI sensitivity and volumetric resolution provide small lesion detectability for small bone lesions.
Acquisition
25 minutes
270 MBq / 7.3 mCi 18F-NaF
113 minute uptake
Patient History
Patient with history of Prostate cancer referred to PET/CT for History of prostate cancer with new bone pain. Evaluation of metastatic disease.
Patient BMI
27.4
Courtesy Stanford University, A. Iagaru, MD
PET Radiopharmaceutical may not be approved by ministers of health in all


Acquisition
196 MBq / 5.3 mCi FDG
67 minute uptake
Patient History
Patient referred to PET/CT for evaluation of Alzheimer's diseases
Low noise imaging demonstrate excellent image quality
Courtesy PET Center Uppsala

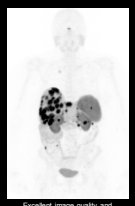
CONTRAST AND TRACERS

Ga-68 DOTATATE

Left
- 6 mCi / 222 MBq Injection
- 78 min uptake
- 2.6mCi / 96 MBq at Scan Time

Right
- 6.7 mCi / 248 MBq Injection
- 104 min uptake
- 2.2 mCi / 81 MBq at scan time

Low noise imaging demonstrate excellent image Quality

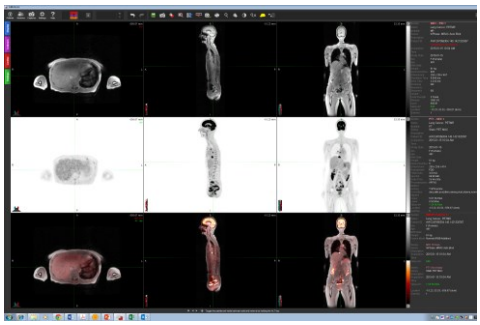


Excellent image quality and small lesions detectability

Courtesy Stanford University, A. Iagaru, MD

PET Radiopharmaceutical may not be approved by ministers of health in all regions

Thank You



Courtesy of University of Zurich