Quality Control in PET/CT

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Introduction

- ✓ A robust QA/QC program ensures consistent scanner performance by verifying image quality, quantification accuracy, spatial resolution, and co-registration fidelity.
- ✓ It allows for early detection of equipment failures, supports standardization across sites, and ultimately ensures patient safety, diagnostic reliability, and regulatory compliance.

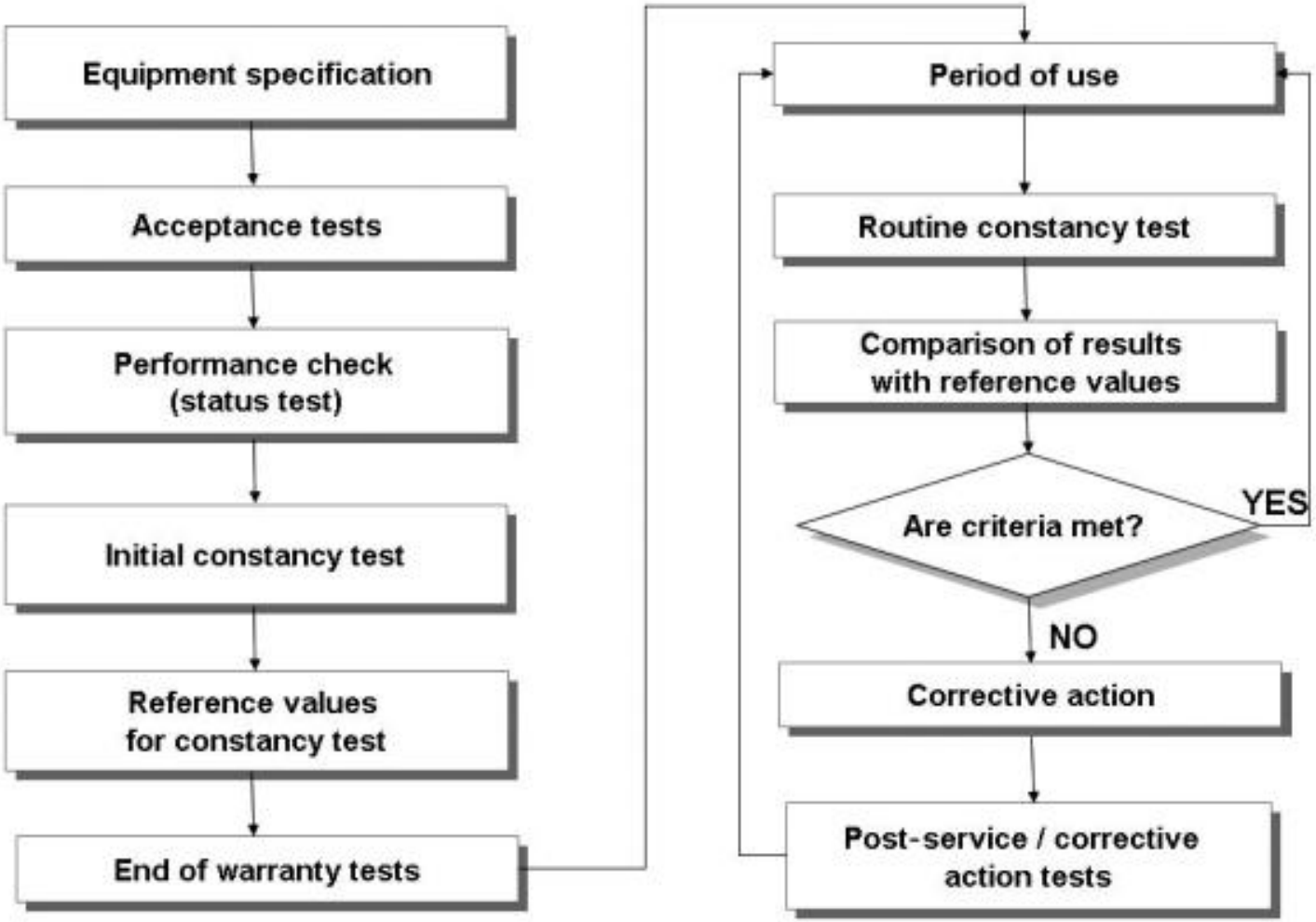


FIG. 10. Quality assurance and QC cycle for a medical imaging device (based on information from Ref. [26]).

Key QA/QC Concepts

Quality Assurance (QA): Systematic planned actions to ensure confidence.

Quality Control (QC): Operational techniques to fulfill QA requirements.

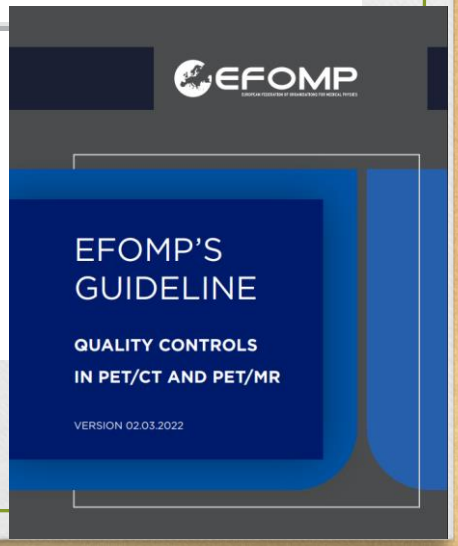
Acceptance Testing Done post-installation to ensure vendor specs are met.

Constancy Testing Repeated measurements over time to track performance.

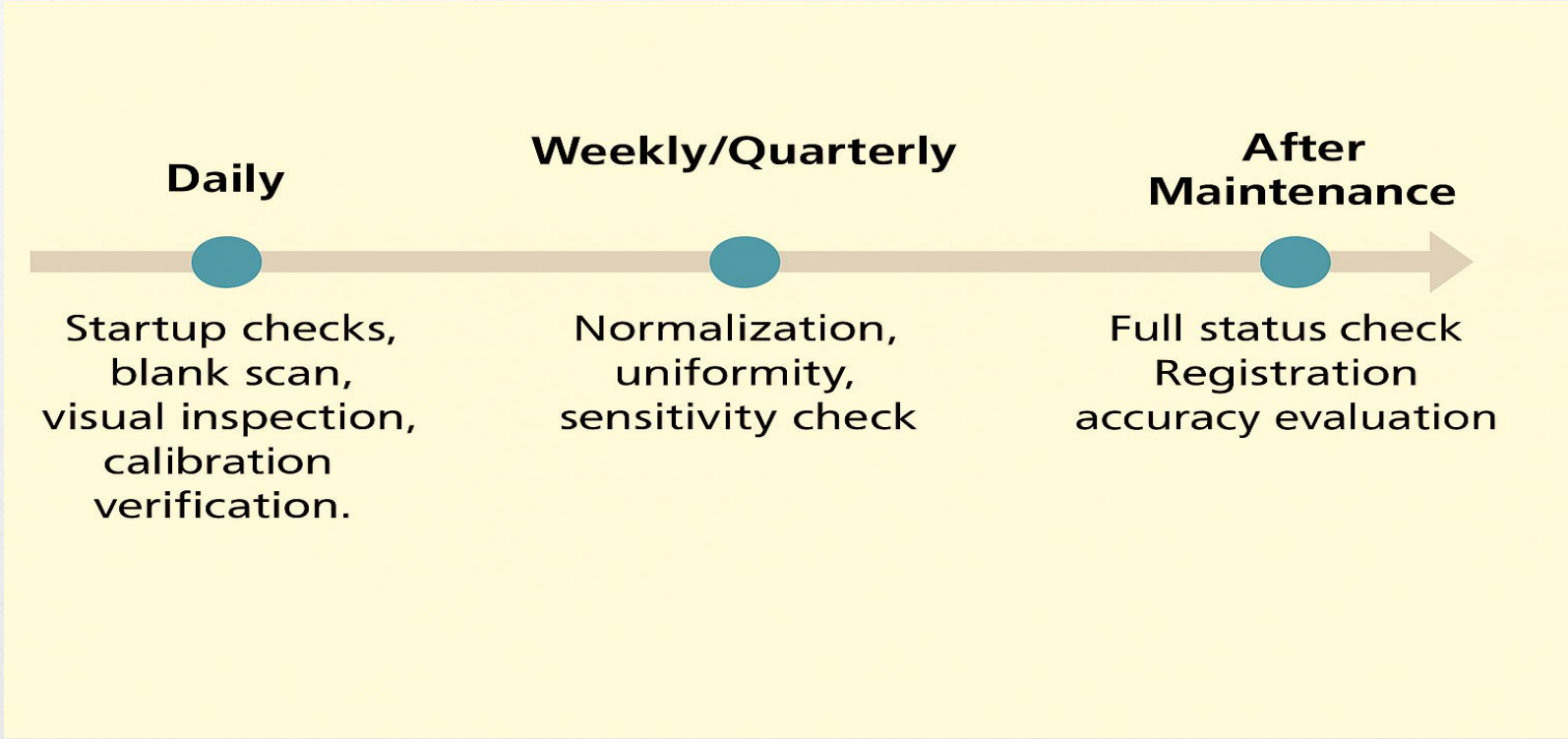
Ideally the scale should meet the following performance specifications:

Patient group	Recommended maximum scale interval
Adults	200g
Young Children	50/100g
Babies	10/20g

Table 2. Patient groups and related maximum scale interval.



Frequency of QC Tests



References:

AAPM TG-126

IAEA

IEC

NEMA

EFOMP Guidelines

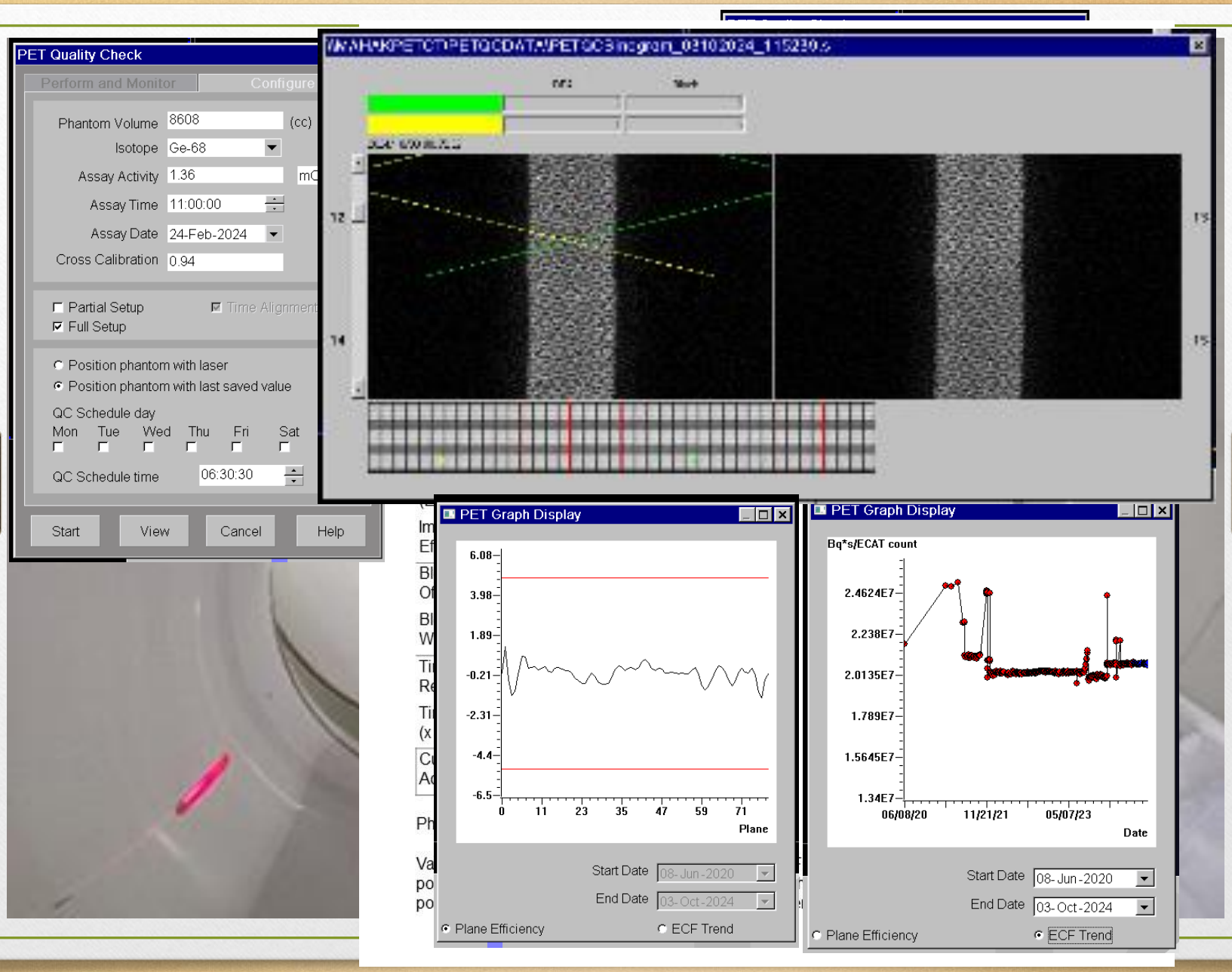
Table 1: Periodic tests

Test	Daily	Weekly	Quarterly	Semi-Annual	Annual
CT QC	X				
PET QC	X				
PET Update Gains and Coincidence Timing		X			
PET Normalization			X[2]		
PET Calibration			X[2]		
Preventive Maintenance and Inspection				X	
Source Replacement					X
PET Spatial Resolution					X
PET and CT Registration			X[1]		
PET Sensitivity					X[2]
PET Count Rate Performance					X[3]
PET Accuracy of Corrections					X
PET Image Contrast and Scatter/Attenuation Evaluation			X		
PET Image Uniformity Assessment					X[4]
Image Display Monitor Evaluation (TG-18)					X
Emergency Buttons Testing					X
Synchronize System Clocks		X			
Additional Daily Tests[4]					
Restart Computers	X				
Manufacturer-Recommended CT Warm-up Cycle and Calibrations	X				
Archive Patient Data	X				
Clear Scheduler	X				
Clear Local, Network, and Film Queries	X				

[1]Or after the gantry is opened
[2]Or if a detector module is replaced
[3]Or if the electronic boards are replaced
[4]Philips recommends these tests to be done on a quarterly basis

Daily QC - PET

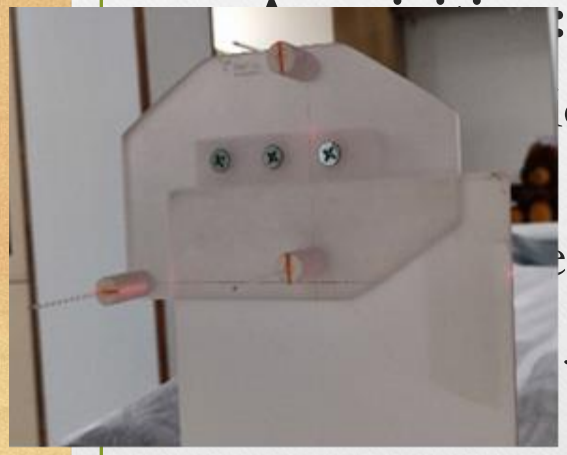
- ✓ Conducted before first patient scan after system initialization.
- ✓ Includes checks on detector blocks, gain, timing, and emission calibration factor (ECF).
- ✓ Visual inspection of sinogram or test image for artifacts.
- ✓ Pass/fail indicators guide corrective action.

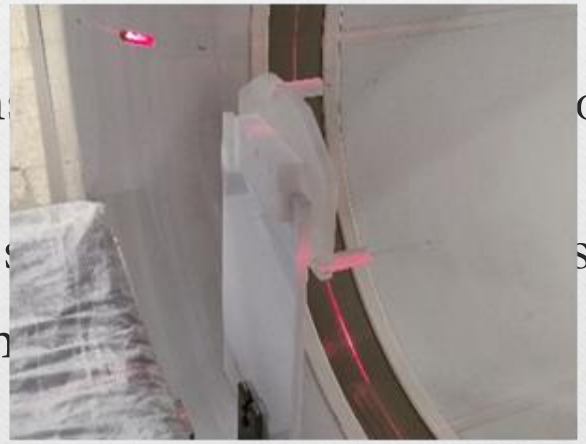

PET Quality Check
Perform and Monitor
Configure
Phantom Volume
8608
(cc)
Isotope
Ge-68
Assay Activity
1.36
Assay Time
11:00:00
Assay Date
24-Feb-2024
Cross Calibration
0.94
Partial Setup
Time Alignment
Full Setup
Position phantom with laser
Position phantom with last saved value
QC Schedule day
Mon
Tue
Wed
Thu
Fri
Sat
QC Schedule time
06:30:30
Start
View
Cancel
Help
PET Graph Display
6.08
3.98
1.89
-0.21
-2.31
-4.4
-6.5
0
11
23
35
47
59
71
Plane
Start Date
08-Jun-2020
End Date
03-Oct-2024
Plane Efficiency
ECF Trend
PET Graph Display
Bq*s/ECAT count
2.4624E7
2.238E7
2.0135E7
1.789E7
1.5645E7
1.34E7
06/08/20
11/21/21
05/07/23
Date
Start Date
08-Jun-2020
End Date
03-Oct-2024
Plane Efficiency
ECF Trend

Spatial Resolution Evaluation

- Capillary tubes of ≤1 mm inside diameter and ≤2 mm outside diameter
- Capillary tube positioning device
- 185–370 MBq/ml (5–10 mCi/ml) 18F-FDG
- 3- to 5-cc syringe
- 20- to 23-gauge needles
- Critoseal®
- CT contrast media (e.g., Optiray®)

placed at isocenter and at off-center positions (10 cm).





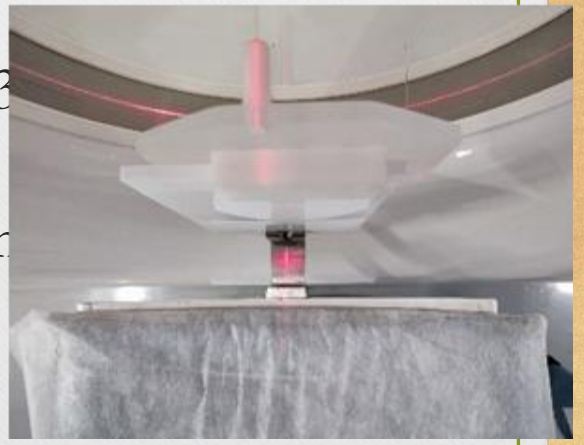


Table 4: PET spatial resolution evaluation record

Point Source Position (cm)	FWHM (mm)				Comparison	
	Line Profile	Center of FOV	1/4 or[1] 3/8 of FOV	Average	Baseline	Percent Difference
(0,1)	Radial	1.41	1.53	1.47	1.52	-3.29
	Tangential	5.83	5.95	5.89	5.81	1.38
	Axial	5.5	5.79	5.65	5.66	-0.27
(0,10)	Radial	1.88	1.96	1.92	1.87	2.67
	Tangential	5.83	5.7	5.77	5.	
	Axial	5.55	5.85	5.70		
(10,0)	Radial	1.78	1.83	1.81	1.	
	Tangential	6.01	6.11	6.06	6.1	-0.66
	Axial	5.82	5.96	5.89	5.88	0.17

[1]Circle choice for future reference

PET and CT Registration Accuracy

Purpose:

Verify accurate alignment of PET and CT datasets to ensure correct attenuation correction and lesion localization.

Materials:

- Same capillary tubes with CT contrast
- Fusion software or DICOM viewer

Procedure:

1. Fuse PET/CT images in sagittal, coronal, and axial planes.
2. For each point source, calculate distance between PET and CT centroids.

PET and CT Registration Accuracy

Data Analysis:

•Record

•Compa

Accepta

•PET-C

mm).

Table 5: PET and CT registration evaluation record

Axial Position	Distance between PET and CT		Comparison	
	Point Source Position	Distance (cm)	Baseline	Percent Difference
Center of FOV	(0,1)	0.04	0.04	0.0
	(0,10)	0.063	0.061	3.3
	(10,0)	0.06	0.058	3.4
1/4 of FOV	(0,1)	0.05	0.048	4.2
	(0,10)	0.052	0.05	4.0
	(10,0)	0.063	0.06	5.0

PET Sensitivity

- Innermost sleeve of NEMA PET Sensitivity Phantom:
  - 3.9 mm inside diameter (ID)
  - 6.4 mm outside diameter (OD)
  - 700 mm length
- Fillable plastic tubing:
  - 1 mm ID, 3 mm OD
  - 700 mm length
- 5.55–7.0 MBq (0.15–0.2 mCi) 18F-FDG
- 3- to 5-cc syringe
- 20- to 23-gauge needles
- Critoseal®
- Phantom positioning device (tension rod or equivalent)
- Level

Step	Symbol/ Calculation	Description	Isocenter			Offset			Units
			Scan 1	Scan 2	Scan 3	Scan 1	Scan 2	Scan 3	
Activity Calculation	*ti*	Initial assay time	18:22	18:22	18:22	18:22	18:22	18:22	
	Ai	Initial assay activity	7379	7379	7379	7379	7379	7379	kBq
	tr	Residual assay time	18:23	18:23	18:23	18:23	18:23	18:23	
	Ar	Residual assay activity	5623	5623	5623	5623	5623	5623	kBq
	AT,i	Activity in phantom at *ti*	1756	1756	1756	1756	1756	1756	kBq
Image	*ta*	Time of start of acquisition	18:40	18:42	18:44	19:04	19:06	19:07	
	ts	Scan duration	60	60	60	60	60	60	s
	CP	Total prompt counts	381813	376877	373042	324617	321220	318769	cts
	CR	Random counts (=0 if unavailable)	43421	43297	42905	41439	41375	40675	cts
Calculation	*S = RT / AT,a*	Sensitivity	3.597438014	3.591247586	3.59924702	3.501854263	3.504517397	3.5045991	cps/kBq
			3.59597754			3.503656913			

	Sensitivity (cps/kBq)				Comparison	
Source Position	Scan 1	Scan 2	Scan 3	Average	Baseline	Percent Difference (%)
Isocenter	3.60	3.59	3.60	3.60	3.55	1.17
10 cm Offset	3.50	3.50	3.50	3.50	3.45	1.54

Count Rate Performance & Accuracy of Corrections

- Right circular cylindrical phantom:
  - 20 cm diameter and ~19 cm length
- 700–750 MBq (~20 mCi) 18F-FDG
- One 3- to 5-cc and one 60-cc syringe
- 20- to 23-gauge needles

Assess PET detector behavior at various activity levels and validate system corrections (e.g., scatter, dead time).

❑ **Materials:**

Step	Description	Value	Units
Initial Assay	Time (*ti*)	13:20	
	Activity	711880	kBq
Residual Assay	Time	13:27	
	Activity	31376	kBq
	Activity decay-corrected to *ti*	32782	kBq
Uniform Phantom	Total activity (at *ti*) administered	678950	kBq
	Total volume	6280	cc
	Activity concentration (at *ti*)	108.113	kBq/cc

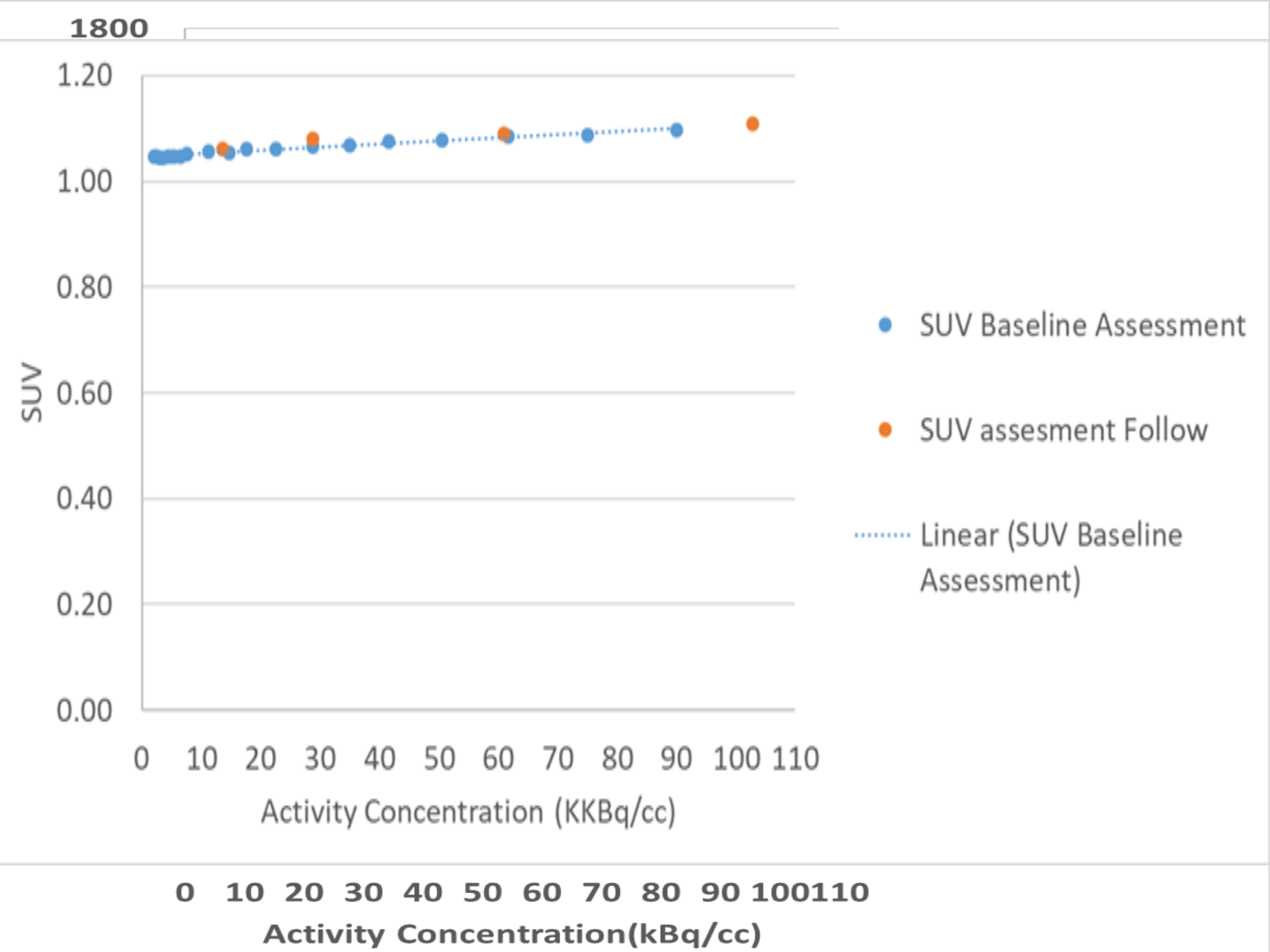

1800
1.20
1.00
0.80
0.60
0.40
0.20
0.00
SUV
0 10 20 30 40 50 60 70 80 90 100 110
Activity Concentration (KKBq/cc)
SUV Baseline Assessment
SUV assesment Follow
Linear (SUV Baseline Assessment)
0 10 20 30 40 50 60 70 80 90 100110
Activity Concentration(kBq/cc)

Table 21: ACR phantom preparation dose record

Step	Description		Value	Units
Doses (Table 16)	Patient dose		12	mCi
	Dose A (for "Hot" cylinders)		0.42	mCi
	Dose B (for Background)		0.99	mCi
"Hot" Cylinders (Dose A)	Initial assay	Time (*tA*)	15:39	
		Activity	0.22	mCi
	Residual assay	Time	15:40	
		Activity	0.00854	mCi
		Activity decay-corrected to *tA*	0.00859	mCi
	Bag (or bottle)	Total activity (at *tA*) administered	0.2114	mCi
		Total volume	500	ml
		Activity concentration (at *tA*)	0.0004228	mCi/ml
Background (Dose B)	Initial assay	Time (*tB*)	15:47	
		Activity	1.03	mCi
	Residual assay	Time	15:48	
		Activity	0.0076	mCi
		Activity decay-corrected to *tB*	0.0077	mCi
	Background phantom region	Total activity (at *tB*) administered	1.022	mCi
		Total volume	5400	mL
		Activity concentration (at *tB*)	0.000189259	mCi/ml
		Activity concentration (at *tA*)	0.000199043	mCi/ml
Ratio of "Hot" cylinder to background activity concentration (at *tA*) (target ratio = 2.15)				

Table 22: PET image contrast and scatter/attenuation correction evaluation (Adult Protocol)

	Background	Teflon	Air	"Cold" Water
Mean SUV	1.04	0.18	0.25	0.23
Minimum SUV	0.9	0.1	0.2	0.16
	25 mm "Hot"	**16 mm "Hot"**	**12 mm "Hot"**	**8 mm "Hot"**
Maximum SUV	2.23	1.95	1.62	1.21
Ratio to background mean SUV	2.144230769	1.875	1.557692308	1.163461538
Ratio to 25 mm "Hot" max SUV	1	0.874	0.726	0.543

Table 23: PET image contrast and scatter/attenuation correction evaluation (Pediatric Protocol)

	Background	Teflon	Air	"Cold" Water
Mean SUV	1.03	0.17	0.23	0.22
Minimum SUV	0.9	0.1	0.16	0.14
	25 mm "Hot"	**16 mm "Hot"**	**12 mm "Hot"**	**8 mm "Hot"**
Maximum SUV	2.32	2.14	1.6	1.07
Ratio to background mean SUV	2.252427184	2.077669903	1.553398058	1.038834951
Ratio to 25 mm "Hot" max SUV	1	0.922	0.690	0.461

Image Uniformity

- **Purpose:**
  Evaluate uniformity of PET signal both within a slice and across slices of a uniform phantom.
- **Materials:**

Uniform cylindrical phantom (~20 cm)
FDG (~700 MBq)

- **Procedure:**

Acquire at two activity concentrations
Reconstruct with clinical settings
Draw 5 circular ROIs per slice and propagate axially

Slice N	ROI 12 O`clock	ROI 9 O`clock	ROI 6 O`clock	ROI 3 O`clock	ROI Center	Maximum	Minimum	Uniformity in Slice N	Absolute Value of Uniformity in Slice N
2	414.25	413.234	419.174	409.942	419.386	419.386	409.942	0.011387533	1.1
3	411.086	423.47	411.558	432.762	431.14	432.762	411.086	0.025687091	2.6
4	410.052	418.648	418.33	417.538	433.972	433.972	410.052	0.028340426	2.8
5	425.014	415.536	419.708	415.91	432.88	432.88	415.536	0.020442802	2.0
6	421.216	418.462	413.154	422.144	428.012	428.012	413.154	0.017663577	1.8
7	412.372	419.454	419.522	425.59	432.05	432.05	412.372	0.023303514	2.3
8	419.122	423.06	420.294	428.382	436.678	436.678	419.122	0.020514139	2.1
9	420.252	425.192	417.66	424.13	435.76	435.76	417.66	0.021208783	2.1
10	418.642	425.49	426.416	423.978	438.756	438.756	418.642	0.02345935	2.3
11	427.822	419.656	424.792	424.132	441.566	441.566	419.656	0.025440595	2.5
12	427.21	425.518	417.39	423.836	441.144	441.144	417.39	0.027668095	2.8
13	418.41	423.912	416.418	422.416	428.774	428.774	416.418	0.014619163	1.5
14	417.232	427.83	414.966	420.61	426.162	427.83	414.966	0.01526348	1.5
15	418.136	427.676	408.34	416.58	432.25	432.25	408.34	0.028444307	2.8
16	419.88	427.502	414.552	426.512	440.55	440.55	414.552	0.03040339	3.0
17	417.016	424.602	410.496	432.982	431.32	432.982	410.496	0.026658668	2.7
18	419.898	425.322	418.336	415.342	427.378	427.378	415.342	0.014282324	1.4
19	411.11	431.332	422.192	422.796	440.258	440.258	411.11	0.034236664	3.4
N-1 or 20	425.318	417.676	411.258	410.068	441.086	441.086	410.068	0.036442289	3.6
Maximum	427.822	431.332	426.416	432.982	441.566				
Minimum	410.052	413.234	408.34	409.942	419.386				
Axial Uniformiyu Between Slices	0.021208439	0.021428757	0.021654232	0.027333425	0.02576218			Maximum Absolute Value of Uniformity in Slice	
Absolute Value of Axial Uniformitybetwe en Slice	2.1	2.1	2.2	2.7	2.6				
Maximum of Absolute Axial Uniformity					2.7			3.6	

QUESTIONS?

THANK YOU