



UK PET Core Lab

Standard Operating Procedure

⁶⁸Ga Image Quality Phantom

A procedure for filling and scanning the NEMA image quality phantom for submission to the UK PET Core Lab based at the King's College London & Guy's and St. Thomas' PET Centre for accreditation purposes

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1 Introduction

This Standard Operating Procedure (SOP) applies to PET staff at local PET sites acquiring data for the purposes of site accreditation by the UK PET Core Lab at King's College London & Guy's and St Thomas' PET Centre. Specifically, this procedure applies to the filling and acquisition of the NEMA image quality phantom with ^{68}Ga .

2 Aim

The purpose of this SOP is to provide instructions on filling and scanning the NEMA image quality phantom with ^{68}Ga to ensure consistent and accurate results for assessment of image quality and quantitative accuracy.

3 Roles and Responsibilities

Staff at the local PET site are responsible for ensuring they have read the local rules, follow the relevant systems of work and complete risk assessments as appropriate prior to starting any phantom work.

Only persons trained in radiation safety for unsealed sources and competent at filling PET phantoms should attempt this procedure. As filling the phantom involves the use of radioactivity, appropriate radiation protection procedures of time, distance and shielding must be used at all times. Users must also be familiar with the local department policies regarding use of radioactivity – contact the local Radiation Protection Supervisor for advice. It is recommended that users practice this procedure using water first to familiarise themselves with all the steps involved

4 Phantom Filling Procedure

The steps in the following procedure are recommended to achieve the required spheres and background activity concentrations at the time of scanning. Deviations to the phantom filling protocol are allowed providing they result in the same activity concentrations. Where a different procedure is followed please make sure the exact activities and volumes used for dilution are recorded along with measurement times for decay correction.

4.1 Preparation

4.1.1 Radionuclide Calibrator – ^{68}Ga Factor

It has been shown that the default ^{68}Ga factor provided by calibrator manufacturers can contain systematic errors (Bailey *et al.*, 2018). It is therefore a requirement that all centres seeking UK PET Core Lab accreditation have a ^{68}Ga factor traceable to a primary standard and the cross calibration for ^{68}Ga has been checked on the PET scanner using a uniform cylinder. The results should be recorded in the NEMA acquisition form in Appendix A.

4.1.2 NEMA IQ Phantom

The volume of the background compartment has been found to vary between phantom designs. Where possible, please measure the volume for the phantom used (with the spheres and lung insert inserted), and record on the NEMA acquisition form in Appendix A.

4.1.3 Scanner Clocks

Before starting the procedure, make sure that the clock(s) used to record times is calibrated to the scanner clock.

4.2 NEMA Phantom Filling

The following instructions have been written for the Data Spectrum NEMA IEC body phantom set; phantoms from other manufacturers are acceptable but as the design may vary users should refer to the manufacturer's instructions for filling.

Users should allow about 1 hour for filling the phantom plus 20 minutes scanning time. The PET scan should be started 50 minutes after the activity in syringe 2 (background) is measured.

Equipment

- Empty NEMA IEC PET Phantom with 6 empty spheres and lung insert (Figure 1)
- Dose calibrator with traceable ^{68}Ga factor
- 2 x 2ml syringes
- 2 x standard length, 21G or similar needles
- Small plastic cup and funnel (if available)
- Measuring jug or beaker (>500ml)
- Stirrer
- 2 x 60ml syringes
- 2 x long, 22G or similar spinal needles (length \geq 80mm)
- Absorbent pads with plastic backing
- \sim 100MBq ^{68}Ga
- Access to tap water
- Clock or watch synchronised to the PET/CT scanner time
- Appropriate personal protective equipment (PPE) for working with unsealed radioactive sources: i.e. Film badge/finger TLDs, lab coat and disposable gloves.

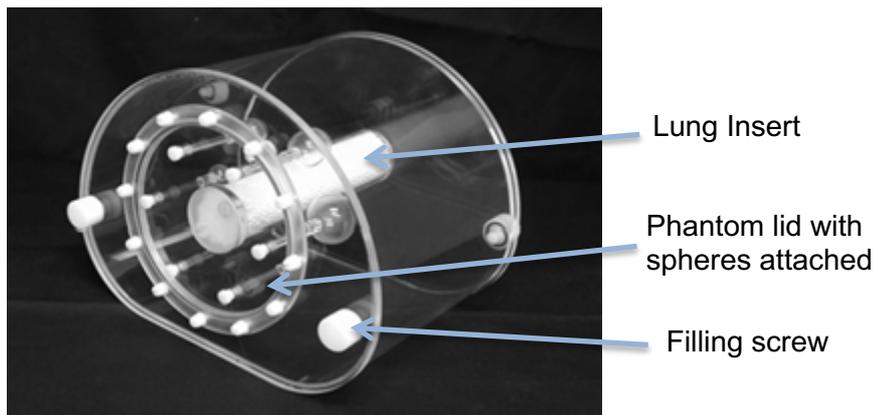


Figure 1: Picture of the NEMA IEC Image Quality Phantom

1. Put on the appropriate PPE.
2. Prepare the work area by removing clutter and covering the surfaces with absorbent pads.
3. Unscrew the phantom lid with the spheres attached and remove from the main body of the phantom.
4. Fill the phantom body to about $\frac{1}{4}$ with tap water or until just before the lung insert will float.

5. Secure the lid with the spheres attached onto the phantom body. The spheres should be orientated as shown in Figure 2 with the 17mm and 37mm spheres aligned with the horizontal axis of the phantom.
6. Finish filling the background with water through the filling screw hole, leaving a large air bubble for mixing the activity later. Ensure there are no leaks.
7. Remove the 6 sphere stopper screws from the lid.
8. Measure out 500ml of water into the measuring jug or beaker **as accurately as possible**, ideally using weighing scales.



Figure 2. Axial view of the NEMA IEC phantom

Spheres - Syringe 1: Aim to get 20kBq/ml in the spheres at the time of scanning:

9. Using a 2ml syringe draw up 18 ± 1 MBq ^{68}Ga and label this syringe 1.
10. Measure syringe 1 in the radionuclide calibrator using the ^{68}Ga factor and record the time and the volume of tracer on the NEMA Acquisition Form.
11. Place the syringe into a shielded area.

Background - Syringe 2: Aim to get 2.5kBq/ml in the background at the time of scanning:

12. Using a 2ml syringe draw up 45 ± 3 MBq ^{68}Ga and label this syringe 2.
13. Measure syringe 2 in the radionuclide calibrator using the ^{68}Ga factor and record the time (t_0) and the volume of tracer on the NEMA Acquisition Form.
14. Place the syringe into a shielded area.

the PET scan should be started 50 minutes after t_0

Syringe 1: Filling the Spheres:

15. Inject the contents of syringe 1 (18MBq) into the jug of water (500ml). Flush the syringe several times to ensure all the activity is injected.
16. Measure the residual in syringe 1 in the radionuclide calibrator using the ^{68}Ga factor and record the time on the NEMA Acquisition Form.
17. Stir the solution in the jug to homogenise being careful not to spill any.
18. Draw up a volume of the radioactive solution from the jug (spheres are ~50ml in total) into a large syringe using a long needle.
19. Carefully insert the long needle into the filling tube of the largest sphere (it should reach into the sphere itself).
20. Slowly inject the solution into the sphere being careful to remove any air bubbles.
21. Wipe off any excess solution from the top of the filling tube and screw in the stopper.

22. Repeat steps 18 to 21 for all remaining spheres working round from the smallest to the largest spheres to ensure all are filled.

Syringe 2: Filling the Phantom background:

23. Remove the background filling screw and inject the contents of syringe 2 (45MBq) into the phantom background. Flush the syringe several times to ensure all the activity is injected.
24. Measure the residual in syringe 2 in the radionuclide calibrator using the ^{68}Ga factor and record the time on the NEMA Acquisition Form.
25. Replace the filling screw and swirl/shake the solution in the phantom to homogenise the solution.
26. Get the air bubbles in the phantom to travel to the side with the filling screw by tilting and tapping the phantom.
27. Open the filling screw carefully to avoid spillage.
28. Use the cup and funnel to fill up the remainder of the phantom with water until almost full (bend the cup to form a funnel if a funnel is not available)
29. Put the screw back in and shake/tap the phantom to get all air bubbles to the area with the filling screw.
30. Open the filling screw carefully to avoid spillage.
31. Use a non-active syringe to fill up the remainder of the phantom so there are no air bubbles
32. Replace the filling screw.
33. Check the phantom carefully for leaks before transfer to the scanner.

4.3 NEMA Phantom Acquisition

the PET scan should be performed at 50 mins after t_0

1. About 15 minutes prior to the PET scan, transfer the phantom to the scanning room using a trolley to reduce radiation dose.
2. Place absorbent pads on the couch to prevent contamination.
3. Place the phantom on the couch on its side with the lid pointing orientated towards the foot of the couch and away from the gantry.
4. Use the scanner positioning lasers to line up the phantom so the lung insert is level and centralised in the gantry.
5. When setting up the patient demographics on the scanner enter the weight to be the same value as the measured volume, and the injected activity as the total activity in the background compartment (i.e. the contents of syringe 2) and the time this was measured – also enter the residual activity measured if this is significant.
6. Perform the scout scan and make sure the scan will cover the entire phantom –
 - a. Acquisition 1 should cover one bed position centred on the spheres (use the contrast/brightness on the CT scout to check the sphere locations).
 - b. Acquisition 2 should cover two bed positions with the overlap centred on the spheres or if using continuous flow the whole phantom.
7. Perform the PET-CT scan following the routine clinical protocol for oncology patients.
 - a. If a weight-based protocol is normally used for clinical patients, please use the parameters for a **70kg patient**.
 - b. if the clinical protocol normally uses **2 minutes per bed position or less** (*equivalent to 0.70mm/s for the mCT without TrueV or 1.10mm/s for the mCT with TrueV*), please **also perform a 3 minute per bed position** or equivalent acquisition immediately after, and include it in the data sent to the Core Lab.

8. Record the acquisition times for the PET scans on the NEMA Acquisition Form.

4.4 NEMA Phantom Reconstructions

Reconstruct the NEMA phantom acquired in step 4.3 as follows:

1. Iterative reconstruction without point spread function (PSF) or QClear (GE only).

If not used routinely, use the suggested parameters in Table 1 and include time-of-flight (TOF) where available:

	Siemens	GE	Philips
Iterative reconstruction algorithm	OSEM2D, OSEM3D OSEM3D+TOF	3D IR, VPHD or VPFX	BLOB-OS-TF
Iterations & subsets [product of iterations and subsets >30]	2i21s	2i24s	3i33s
Post Filter (Gaussian) [5-6.4]	5mm	6.4mm	N/A
Matrix	200x200	256x256	144x144
Slice Thickness (mm)	3	3.27	4

Table 1. Recommended parameters not including PSF modelling

2. Iterative reconstruction with PSF or QClear (GE only).

If not used routinely, use the suggested parameters below and include time-of-flight (note PSF is not recommended without TOF included):

	Siemens	GE
Iterative reconstruction algorithm	OSEM3D+TOF+PSF	VPFXS or QClear
Iterations & subsets [product of iterations and subsets >30]	2i21s	2i24s N/A for QClear, beta 800
Post Filter (Gaussian) [5-6.4]	5mm	6.4mm N/A for QClear
Matrix	200x200	256x256
Slice Thickness (mm)	3	3.27
PSF algorithm	HD or PSF	SharpIR or QClear (PSF is included as default)

4.5 NEMA Phantom Measurements

1. Load the PET data into the viewing software used for local clinical review.
2. Display the corrected PET images in axial view and navigate to a slice showing the spheres.
3. Set the viewing software to display values in activity concentration (i.e. bq/ml).
4. Draw a 3D VOI over the largest sphere and record the maximum activity concentration for the whole sphere in the NEMA Acquisition Form – please record all decimal places. If a 3D VOI is not available use a 2D ROI and scroll through the slices to find the maximum voxel value in the sphere.
5. Draw a 5cm circular ROI in a slice that doesn't contain the spheres or stalks (if the lung insert was used, make sure it is not included in the ROI). Record the mean activity concentration in the NEMA Acquisition Form.

4.6 Data Transfer

Send the following data sets in original DICOM format – please make sure the private header fields are kept intact during transfer from the scanner:

- Attenuation corrected PET (AC-PET) – standard clinical reconstruction
- Attenuation corrected PET (AC-PET) - without resolution recovery or QClear
- Non-attenuation corrected PET (NAC-PET)
- CT – please include the reconstruction used for clinical patient review as well as attenuation correction.

Scans can be transferred to the Core Lab electronically (please contact the Core Lab for instructions), or burned to disc and mailed to:

Physicists
UK PET Core Lab
PET Imaging Centre
1st Floor, Lambeth Wing
St Thomas' Hospital
Lambeth Palace Road
London, SE1 7EH

Please include a completed copy of the NEMA Acquisition Form or email a copy to pet-trials@kcl.ac.uk.

Retain the raw PET data until accreditation is confirmed, in case additional reconstructions are required by the Core Lab.

5 Appendix A: NEMA Acquisition Form

Please complete the following fields:

PET Scanner Details

PET Centre Name:	
Scanner Manufacturer & Model:	
Scanner Type:	Fixed <input type="checkbox"/> Mobile <input type="checkbox"/> Scanner ID: _____
Date of Phantom Scan:	
Name of Person Performing the Phantom Acquisition:	

Phantom Details

Phantom Manufacturer:	
Phantom Background Volume (ml):	

Radionuclide Calibrator Details

Calibrator Manufacturer:	
Calibrator Make & Model:	
⁶⁸ Ga Factor used:	

⁶⁸Ga Activity Details

Spheres (aim 18 ± 1 MBq ⁶⁸Ga):

Syringe 1 Activity (MBq):	
Measurement Time (hh:mm:ss):	
Dilution volume if not 500ml (ml)	
Volume in Syringe (ml):	
Residual Activity (MBq):	
Measurement Time (hh:mm:ss):	

Background (aim 45 ± 1 MBq ⁶⁸Ga):

Syringe 2 Activity (MBq):	
Measurement Time (hh:mm:ss):	

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Volume in Syringe (ml):	
Residual Activity (MBq):	
Measurement Time (hh:mm:ss):	

Phantom Acquisition Details

Acquisition 1: Single static bed PET Acquisition start time (hh:mm:ss):	
Acquisition 2: Two bed (or continuous flow) PET Acquisition start time (hh:mm:ss):	

Phantom Reconstruction Details

Reconstruction 1 (no PSF or Q.Clear applied):	Algorithm:	Iterations:
	Subsets:	Post Filter:
Reconstruction 2 (PSF or Q.Clear):	Algorithm:	Iterations:
	Subsets:	Post Filter:
	Or Beta Value (QClear):	

Phantom Quantitative Checks

Max kBq/ml measured for the largest (37mm) sphere	
kBq/ml measured for a 5cm ROI in the uniform background (should be accurate to within 5%)	