CTN PET Uniform Phantom Protocol

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PET/CT Scanner Validation Materials

Forms	• PET Data Sheet (provided at the end of this document)
Equipment and Materials Needed **Site to Provide**	• Radionuclide calibrator • 20 cm Uniform PET Phantom for ^{18}F or ^{64}Cu Imaging • 5-10 liters of water (distilled preferred if readily available) to fill the main body of the 20 cm uniform phantom. • Syringe (1-3 mL) for ^{18}F, ^{68}Ga, or ^{64}Cu background fill of phantom (Syringe 1) • Needles for the syringes
Required Activity	• Approximately 0.5-1.0 mCi (18.5 - 37 MBq) radionuclide of interest • ^{18}F (^{18}F-FDG works well) • ^{68}Ga (should be labeled (e.g., ^{68}Ga-DOTATATE)) • ^{64}Cu (in stable chemical form (labeled form or with 20 g of citric acid))
Safety Equipment	• Absorbent plastic-backed pads • Disposable gloves • Radiation dosimeters • Lab coat • Timer or clock

Phantom Protocol Summary

1. Check the 20 cm uniform phantom for leaks.
2. Fill the 20 cm uniform phantom according to these instructions.
3. Image the phantom using clinical trial acquisition protocol that was previously established.
4. Reconstruct acquisitions using the clinical reconstruction parameters.
    i Harmonized PET reconstruction parameters are available upon request.
5. Process images in PAT for review and analysis.
6. Store the phantom for decay.

Note: **This PET/CT scanner validation procedure requires the use of ^{18}F, ^{68}Ga, or ^{64}Cu, positron emitting isotopes with half-lives of 109 minutes, 68 minutes, and 12.7 hours respectively. It is recommended that once the phantom is imaged, it is allowed to decay in a shielded, secure area for *at least* 10 half-lives before emptying.**

In all cases, local and national radiation regulations must be followed prior to emptying and disposal of phantom contents. The phantom must be completely emptied before it can be shipped.

Phantom Pre-fill Leak Test

Perform prior to adding radioactivity.

1. Weigh the empty phantom with a digital scale that has accuracy from 0 to 10 kg. ***Record the empty weight on the Data Sheet.***

2. Fill the body of the phantom until almost completely full through the top fill port with distilled water or, if not available, use tap water. The total fill volume of the 20 cm uniform phantom depends on the manufacturer and is often between 5-10 liters. The phantom need not be topped off at this point**.**

   Please note that the phantom can weigh nearly 20 pounds when it is filled with water. Use caution when lifting and handling the phantom. It can be slippery if the outside is wet. You may want to ask another person to assist you when lifting, moving, or mixing the phantom.

3. Dry the outside of the phantom, then let it sit for 10-20 minutes.

4. Check the phantom to ensure that there is no leakage of water.

5. **Assuming no leakage, you may keep the phantom body full.**

Radionuclide Calibrator Activity and Dial Setting Determination

Don lab coat, radiation dosimeters, and gloves. Clear a work area to fill the phantom and place absorbent plastic-backed pads on the work area.

Before starting, synchronize your radionuclide calibrator and PET/CT scanner clocks to the device(s) used to record time.

Record site, scanner, and radionuclide calibrator information on the Data Sheet for convenience and internal records.

1. Use a NIST traceable standard (e.g., RadQual ^{68}Ge source) to determine the correct ^{18}F, ^{68}Ga, or ^{64}Cu dial setting according to the instructions with the source.

2. Record the calibration number on the Data Sheet as a reference for your tracking.

Phantom Filling Instructions

1. The 20 cm uniform phantom background should be mostly filled with approximately 5-10 liters of water (from the leak test step). Remove 50-100 mL of water to allow enough air for mixing after the radiopharmaceutical is injected.

   If you are using $^{64}CuCl_2$ to fill the phantom, please add 20 g of citric acid powder.

2. If the 20 cm uniform phantom is not still full, from the leak test, place the phantom upright, resting it tilted slightly to the front resting on its edge.

3. Fill the background virtually full of water (minus 10-20 mL of water). This should take approximately 5-10 liters. Pre-filling this volume will save significant time when you start measuring the activity for the phantom fill.

Enter the 20 cm uniform phantom fill data on the Data Sheet for convenience and internal records.

Prepare a syringe with radioactivity.

4. Ensure that the background radioactivity levels are low and consistent during phantom fill activity assays.

5. Draw up radioactivity into a syringe to measure 0.5-1.0 mCi (18.5 – 37.0 MBq).
   - This activity will be used to fill the 20 cm uniform phantom.

6. **Record the activity assay and measurement time on the Data Sheet.**

7. Place the tip of the needle of **syringe 1** through the main fill port and into the edge of the liquid and inject the contents.

8. In this position, draw liquid into the syringe and inject it back into the water. Repeat this a couple of times to rinse out the syringe. **Replace the Fill Port plug/bolt. Make sure that it is tightly screwed in to avoid leakage.**

9. Measure the residual radioactivity of **syringe 1 and record the assay and measurement time on the Data Sheet.**

10. Hold the phantom ***firmly*** in both hands. The phantom will be quite heavy. *Gently* tilt the phantom back and forth for about one minute to thoroughly mix the radioactivity in the phantom liquid.

11. Remove the fill port and vent screws.

12. Top off the phantom by ***carefully*** adding the 10 - 20 mL of water that was removed earlier and additional water to fill the phantom completely.

If you accidentally overfill, then catch the liquid with some absorbent material. Small residual air bubbles are normal and acceptable.

13. Replace the fill port and vent screws. Make sure these are tightly screwed in to avoid leakage.

14. Weigh the full phantom with a digital scale that has accuracy from 0 to 10 kg. ***Record the full weight on the Data Sheet.***

15. **Make sure fill and vent ports are not leaking around the O-rings. If they are, tighten them until leak-free.**

16. After you are sure that the phantom is leak-tight, place an absorbent pad with plastic lining on the PET/CT table and place the phantom on top.

17. Position the phantom on the absorbent pad to mimic a patient in the supine position (Headfirst or feet first per your patient protocol).

    If you elevate one end of the uniform phantom ~ 1 inch, then PAT will estimate the spatial resolution performance of your scanner.

18. Center the phantom in the gantry with laser lights as you would a patient.

19. Perform a scout scan and the attenuation correction CT scan.

20. Start the PET scan as described on the following pages.

20 cm Uniform Phantom Imaging Instructions

PHANTOM SCAN	
PROTOCOL	Image the entire phantom for 5 minutes per bed position using the trial protocol. **BE SURE THAT THE CORRECT RADIONUCLIDE IS IDENTIFIED.**
ALIGNMENT	Align the phantom in the gantry centering the phantom in X, Y and Z.
AXIAL RANGE	Make sure to cover the entire phantom (plus 5 cm above and below) with the scan (likely 1-3 bed positions).
CT ATTENUATION SCAN	Please use your standard clinical CT attenuation scan for reconstruction.

Name the phantom acquisition in the scanner with the suggested naming convention as described below:

Patient Name	**20 cm Uniform** + facility abbreviations ○ *Example*: **20 cm Uniform *HCI***
Study Description	"F-18, Ga-68, or Cu-64 (based on which one you used) uniform"

Patient ID	Enter date of scan acquisition as the Medical Record Number: YYYYMMDD.
Patient Weight	Enter the net weight of the uniform phantom in kg. (Full weight – Empty weight = Net weight of liquid in the phantom).
Radioactivity	Enter Actual Activity of **Syringe 1** (=Original activity – Residual activity).
Injection time	Enter the time of **Syringe 1** radionuclide calibrator assay.

Enter the scan start date and time on the Data Sheet.

PET Reconstructions

Reconstruct images *with* attenuation correction. Use your clinical reconstruction protocol.

Phantom Analysis Toolkit (PAT) Instructions

1. Perform phantom studies according to these instructions.
   Other fill and imaging protocols are also allowed.

2. Navigate to the PAT website.

3. Login in with your SNMMI member username and password.

4. Select Upload Phantom PET scan for analysis.

5. Enter a Name for the analysis (e.g., site, scanner, radionuclide, recon, phantom)

6. Choose the Phantom type from the drop-down menu (i.e., Uniform).

7. Upload the PET AC Phantom DICOM images.

8. Enter the phantom fill activity assays and net volume of the liquid in the full phantom.

9. Initiate Analysis (Duration 1-5 minutes).

10. Download results.

Appendix I: PET Phantom Data Sheet

Facility Information					
Facility Name:					
Radionuclide Used: (^{18}F, ^{68}Ga, or ^{64}Cu)					
PET Scanner Information					
Manufacturer:			Model:		
Serial Number:			Year Installed (YYYY):		
Radionuclide Calibrator Information					
Manufacturer:		Model:			
Serial Number:		^{18}F, ^{68}Ga, or ^{64}Cu Radionuclide Calibrator Setting Number/Dial Value:			
20 cm Uniform Phantom Information					
Empty Weight: (X,XXX g)			Full Weight: (X,XXX g)		
Net Weight: (X,XXX g)			Net Weight = Full Weight - Empty Weight		
Preparation of Syringe 1					
Measured Activity: (FULL)	▢ mCi ▢ MBq		Measurement Date, Time, and Time Zone: (DD/MMM/YYYY HH:MM TZ)		
Residual Activity:	▢ mCi ▢ MBq		Measurement Date, Time, and Time Zone: (DD/MMM/YYYY HH:MM TZ)		
20 cm Uniform Phantom Scan Information					
Date of Scan: (DDMMMYYYY)			Scan Start Time: (HH:MM)		
Reconstruction Parameters (to be used on both AC and NAC)					
Reconstruction Method:			Matrix size:		
Iterations:			Subsets:		
Gaussian Filter FWHM (mm):			TOF (Y/N):		
Point Spread Function (Y/N): (i.e., GE SharpIR, Siemens HD-PET, Philips xSharp)			Advanced Regularized Reconstructions (Y/N): (i.e., GE Q.Clear)		