Department of Health
PUBLIC HEALTH SERVICES - RADIATION PROTECTION UNIT

Tasmanian Government

# Recommended Quality Assurance Programme for PET-CT Scanners

This technical guide has been produced for radiation specialists, if you require this information in a different format, please contact Radiation Protection on (03) 6166 7256 or radiation.protection@health.tas.gov.au

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# Contents

# Summary of Quality Assurance requirements

This document provides recommendations to carry out the minimum quality assurance tests and performance criteria required for PET- CT scanners Tasmania. These tests are meant to be relatively simple and take a minimal amount of time to perform, making them ideal tests to be performed by radiographers or imaging technologists.

The recommended tests, their frequency and performance criteria are summarised in table 1 and are explained in more details in various section of this document. The testing schedule outlined here is limited PET- CT used for medical imaging and excludes PET-CT that are used for small animal imaging.

## Table 1: Quality Assurance tests for PET-CT Scanners – Summary of requirements.

| Test | Frequency[1] | Criteria |
|---|---|---|
| **Detector stability** | **Daily** | **Specific to manufacturers testing protocol. Sinograms should appear uniform and free of any artefacts** |
| **Mechanical and safety inspection** | **Monthly** | **See Section 2** |
| **Image display quality** | **Quarterly** | **See Section 3** |
| **Accuracy of radioactivity concentration** | **Six-monthly( ideally 3 monthly)** | **The calculated and measured activity concentrations shall not differ by more than 5%** |
| **CT quality assurance** | **see Recommended Quality assurance for Computed Tomography Apparatus** | **see Recommended Quality assurance for Computed Tomography Apparatus** |

[1] Where the frequency of the test is daily, this refers to each day the scanner is in use.

# 1. Detector stability

## Background

This test checks that all PET detectors modules are functioning properly and are stable over time [1-3]. Each manufacturer will have their own testing protocol which can be run daily before clinical use. The protocol may also include detector normalisation and checks of the Time-of-Flight (ToF) timing capabilities of the scanner.

## Equipment

- Specific to manufacturers testing protocol. This may use a rotating line source, a cylindrical phantom (volume source) or a point source.

## Procedure

- An automated daily QC procedure will usually be provided by the manufacturer. This includes checks of the sinograms[2] produced by the scanner. Any problems will be flagged by the software.

## Analysis

- Visually inspect the sinograms from all image slices for any non-uniformities or artefacts. An example of a normal set of sinograms is shown in figure 1.

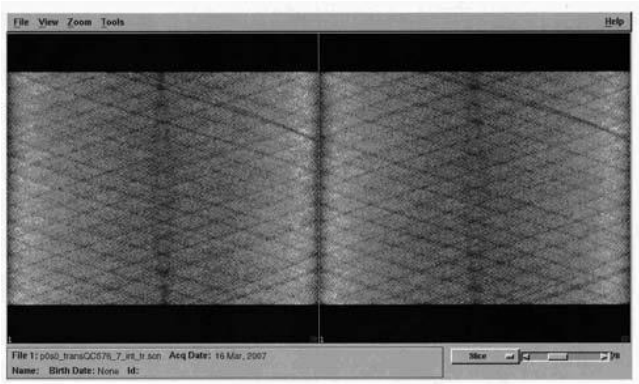


**Figure 1: Sinograms acquired for daily detector stability test on a PET-CT scanner using a rotating Cs-137 source. From reference 1.**

## Performance criteria

- Specific to manufacturers testing protocol. Sinograms should appear uniform and free of any artefacts.

[2] A sinogram is a 2D representation of all the 1D projections through a slice of an object in axial scanning (CT, SPECT, PET), as a function of the projection angle [1].

## Corrective action

Any failure of the QC procedure or non-uniform sinogram shall be reported to the manufacturer and any corrective action (eg. detector replacement) taken shall be noted.

# 2. Mechanical and safety inspection

## Background

A general inspection of PET- CT scanners must be carried out monthly to ensure patient and staff safety as well as proper operation of all mechanical parts [2].

## Procedure

Perform an inspection of the system using the below checklist.

- Check the operation of all emergency stop buttons.
- Check that gantry covers are properly fitted and not loose.
- Check the patient couch and driving mechanism for proper operation.
- Check for any loose or broken cable connections, or any damaged cables. Cables should be placed in such a way as not to impede patient access.

After each inspection, the following must be recorded:

- Date of inspection
- Model and serial number of equipment
- Person performing test
- Inspection results

## Corrective action

Issues directly impacting the safety of patient and/or staff must be resolved as soon as possible.

# 3. Image display quality

## Background

This test is mandatory for the nuclear medicine specialist's or radiologist's reporting monitor, and for the general operator's monitor. This test may require a degree of cooperation from the nuclear medicine specialist or radiologist. This test may be affected by user bias and so the test should be performed by the same person every time.

The test pattern contains:

- 18 incremental grayscale patches at the top with low-contrast bar patterns - to assess luminance response[3] and uniformity.
- Three large grayscale patches (black, mid-grey and white) - to assess maximum and minimum luminance and luminance uniformity.
- A continuous grayscale gradient at the bottom - used to assess luminance calibration errors and other artefacts.
- High-contrast bar patterns in the bottom right corner - used for qualitative spatial resolution measurements [5].

## Equipment

- TG270-sQC Quality Control Test Pattern, from the AAPM report No. 270 [4] (see figure 2).
- TG-18 QC Quality Control Test Pattern, from the AAPM report No. 18.

## Procedure

- Ensure the ambient light conditions are similar to those used for reviewing or reporting images.
- The window width and window level should be set using the full dynamic range of the display (eg. window width 256, window level 128).
- View the test pattern on the monitor to be tested.

## Analysis and performance criteria

- Review the three rows of small grayscale patches. The low-contrast bar patterns must be visible in at least 12 of the grayscale patches.
- Zoom and pan the three large grayscale patches across the display. These should be uniformly visible at all areas of the display (ie. no changes in brightness or contrast as they are moved across the display).
- The grayscale gradient at the bottom should be displayed as a continuous change in grayscale values. There should be no obvious artefacts relating to incorrect display of grayscale values.
- The high-contrast bar patterns at the bottom right-hand corner should show alternating black and white bars one pixel wide in the horizontal and vertical directions.

[3] Luminance refers to the intensity of visible light emitted from the surface of a display. Luminance response refers to the change in luminance per change in grayscale value [5].

# Corrective action

If the required detail (low and high contrast bar patterns) are not visible in the image, or individual grey levels are not distinguishable, this may be due to a number of issues:

- ambient lighting conditions not ideal
- image window level and window width need adjusting
- monitor brightness and contrast need adjusting

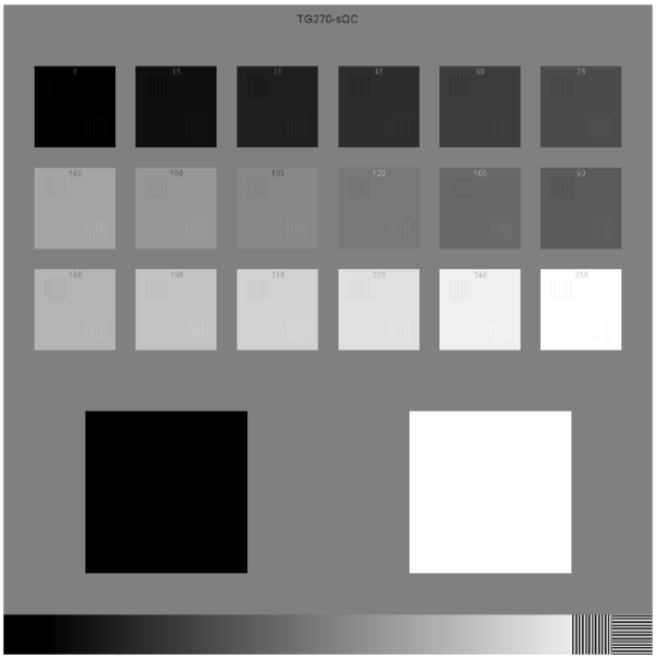


**Figure 2: TG270-sQC test pattern for quality control of operator and reporting monitors. From reference 5.**

If problems persist, contact the manufacturer of the monitor for remedial action.

# 4. Accuracy of radioactivity concentration

## Background

This test is a check of the radioactivity concentration measured by the scanner [1-3]. This is used to calculate the Standardised Uptake Value (SUV) that is a measure of tumour uptake. This test shall be performed for F-18, however if other radionuclides (eg. Ga-68) are used for PET imaging, accuracy should be checked for these radionuclides as well.

*Note:* It is important that before this test, the radionuclide calibrator used for assaying PET radiopharmaceuticals has undergone regular QC, including daily constancy testing. Moreover, the system clock on the radionuclide calibrator shall be synchronised with the system clock on the PET scanner. Records of annual testing must show that the accuracy, reproducibility and linearity of the dose calibrator are all within acceptable limits. See Recommended *Quality Assurance for Dose Calibrators* for more details.

## Equipment

- Fillable cylindrical phantom of known volume
- An F-18 solution in a syringe, calibrated for time $T_0$. The activity should be chosen to correspond to an activity concentration of 5.3 kBq/mL[4] when the solution is placed into the phantom (eg. for a phantom volume of 10.3L, the required activity is 55 MBq ± 5%)

## Procedure

- Fill the cylindrical phantom with water and insert the F-18 into the phantom. Measure the residual activity left in the syringe (this should only 1-2 MBq) and record the value. Ensure a uniform mixture of the F-18 solution within the phantom.
- Enter the decay-corrected F-18 activity into the scanner as well as the time of calibration and perform a scan of the phantom at time $T_0$ with a standard adult imaging protocol. The number of true counts acquired shall be 100 million counts over at least two bed positions.
- Reconstruct the image using standard settings including attenuation correction.

## Analysis

- On the reconstructed phantom image, draw a region of interest (ROI) on 6-12 slices. The ROIs should be centred on the slice and have a diameter that is at least 60% of the phantom diameter. The ROIs should not touch the edges of the phantom to exclude any edge effects.
- Record the activity concentration in Bq/ml measured by the PET/CT scanner for each slice and calculate the average value $A_{measured}$.
- Calculate the actual activity concentration in the phantom $A_{calculated}$ in Bq/ml.
- Calculate the calibration factor $C$, as

$$C = \frac{A_{calculated}}{A_{measured}}$$

[4] 5.3 kBq/mL is the activity concentration resulting from an activity of 370 MBq administered to an average 70 kg adult.

## Performance criteria

- The calculated and measured activity concentrations shall not differ by more than 5% (ie. $C$ must be in the range 0.95-1.05).

## Corrective action

If the difference between calculated and measured activity is more than 5%, the PET/CT scanner must be re-calibrated with the new calibration factor. Consult the manufacturer for the correct calibration procedure.

# 5. CT Quality Assurance

The suite of quality assurance tests used for CT scanners in diagnostic radiology also applies to CT scanners used for attenuation correction and anatomical localisation in PET-CT [1-3]. For these tests, refer to Recommended *Quality Assurance tests for Computed Tomography Apparatus*. More stringent criteria applies for CT component of PET-CT that are used for Radiotherapy planning.

The manufacturer may also have pre-defined protocols for carrying out these tests with vendor-supplied phantoms.

It is also important to ensure proper alignment of the PET and CT fields to allow image registration. The manufacturer will usually perform alignment at installation and quality assurance checks according to their preventative maintenance schedule. Any suspected mis-alignment must be reported to the manufacturer and resolved as soon as possible.

# 6. Record keeping

The results of all regular QA testing must be recorded either in writing or electronically. The records for the most recent three months must be available for inspection. In addition to the regular QC tests, it is recommended that nuclear medicine departments keep records of patient administered activities as well as records of the Dose-Length Product (DLP) for the CT part of PET/CT examination.

This record keeping will assist hospitals and practices in fulfilling the requirements of the Australian Government's Diagnostic Imaging Accreditation Scheme (DIAS) Practice Accreditation Standards. In particular, Standard 3.2 *Optimised Radiation Technique Charts Standard* requires that these dose metrics are compared with national Diagnostic Reference Levels (DRLs) annually. If the DRLs are consistently exceeded, then a review should be conducted to establish whether radiation exposure of patients has been optimised with regards to the required image quality [5].

For more information about DRLs in PET/CT, see:

www.arpansa.gov.au/research-and-expertise/surveys/national-diagnostic-reference-level-service/nm

# References


[1] International Atomic Energy Agency, *Quality Assurance for PET and PET/CT Systems*, IAEA Human Health Series No. 1 (2009)

[2] European Association of Nuclear Medicine, *Routine Quality Control Recommendations for Nuclear Medicine Instrumentation*, Eur J Nucl Med Mol Imaging (2010) 37:662-671

[3] Australian and New Zealand Society of Nuclear Medicine, *Requirements for PET Accreditation (Instrumentation and Radiation Safety 3rd ed.,* ANZSNM Technical Standards Committee (2017)

[4] The Royal Australian and New Zealand College of Radiologists*, MRI Safety Guideline*s, Version 2.0 (2017)

[5] American Association of Physicists in Medicine, *Display Quality Assurance,* AAPM Report No. 270 (2019)

[6] Department of Health, *Diagnostic Imaging Accreditation Scheme Practice Accreditation Standards*, Australian Government (2016)