Department of Health
PUBLIC HEALTH SERVICES- RADIATION ROTECTION UNIT

Tasmanian Government

Recommended Quality Assurance Programme for Computed Tomography(CT) Apparatus

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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Summary of Quality Assurance Requirements

This document provides recommendations to carry out the minimum quality assurance tests and performance criteria for Computed Tomography (CT) apparatus used in diagnostic imaging and nuclear medicine(excluding CT used for Radiotherapy planning). These tests are meant to be relatively simple and take minimal amount of time to perform, making them ideal tests to be performed by radiographers or imaging technologists. More rigorous testing will still need to be carried out by accredited testers as required under Regulation 6 of the Radiation Protection Regulations 2016.

The recommended tests, their frequency and performance criteria are summarised in table 1 and are explained in more detail in various section of this document. It should be noted that the test frequency and criteria may vary depending on the manufacturer of CT apparatus. In such instances, manufactures recommendation should be followed.

These tests and methods described in Table 1 are adapted from IAEA Human Health Series No. 19 *Quality Assurance Program for Computed Tomography: Diagnostic and Therapy Applications* [1] and AAPM Report No. 223 *Performance Evaluation of Computed Tomography Systems* [2] with some modifications.

Table 1: Recommended Quality Assurance tests for Computed Tomography (CT) Apparatus.

Test	Frequency[1]	Criteria
Detector calibration	Daily/ as required	Pass/Fail according to manufacturers protocol
CT number[2]	Daily	0 ± 5 Hounsfield Units (HU)
Image noise[2]	Daily	Manufacturers specification ± 10%
Image uniformity[2]	Daily	Central CT number differs from peripheral CT numbers by no more than ±4 HU
Image artefacts[2]	Daily	No artefacts that have the potential to compromise diagnostic confidence
CT alignment laser accuracy	Monthly	±5 mm
Scan Projection Radiograph (SPR) accuracy[3]	Monthly	±2 mm
Workstation image display	Reporting monitors - Monthly Operator monitors - Quarterly	See Section 7 for detail information

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

[2] The CT number, image noise, image uniformity and image artefacts tests may all be done with one scan of the phantom

[3] Depending on the manufacturer, the SPR may be called the 'topogram', 'scoutview', 'scanogram', 'surview' or 'pilot'.

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1. Detector calibration

Each manufacturer will have a detector calibration procedure that is prescribed to be performed regularly to ensure detector uniformity and stability. This will usually be done daily but the manufacturer may recommend a different frequency of calibration. It is recommended to follow the manufacturer's calibration protocol and any complications or failures should be escalated to service personnel.

2. CT number and image noise

Background

This test checks that the average CT number of water measured by the CT scanner is equal to, or close to 0 Hounsfield Units (HU). CT numbers of other materials are calibrated to the CT number of water. Thus, accurate calibration of CT numbers is crucial for accuracy of CT images.

Image noise (characterised by the standard deviation of the CT number in a region of interest or ROI) can affect the appearance of a processed CT image. Noise is unavoidable in the CT image, but it must be kept to a reasonable level.

Equipment

- Liquid water phantom or acrylic phantom of minimum dimensions 20 cm (diameter) by 20 cm (length).
- The manufacturer may supply a phantom to be used with their own recommended QC protocol.

Procedure

- Scan the phantom with an axial head or body protocol using the manufacturers recommended protocol settings (kV, mAs, filter) for testing of CT number and noise.
- Alternatively, if the manufacturer has provided an automated QC procedure, this may be used.

Analysis

- Draw a circular ROI in the centre of the phantom image with a diameter approximately 40% of the phantom diameter. See figure 1a) for an example.

Performance criteria

- The mean CT number in the ROI must be 0 ± 5 Hounsfield Units (HU) [1]. For some other phantoms, the mean CT number may be slightly different, refer to the manufacturer's specifications.
- The value of the noise (the standard deviation of the mean CT number) must not deviate from manufactures specification by ± 10% [1].

Corrective action

If the performance criteria are not satisfied, check that the manufacturers recommended protocol settings are being used. Otherwise contact the manufacturer for remedial action.

3. Image uniformity

Background

Image uniformity can affect the appearance of CT images, or the relative accuracy of different parts of a CT image. This test assesses the variation in CT number at different points in the image to check the overall uniformity.

Equipment

- See CT number and image noise.

Procedure

- See CT number and image noise.

Analysis

- Draw circular a region of interest (ROI) in the centre of the phantom image with a diameter approximately 10% of the phantom diameter.
- Also draw four circular ROIs at the 12, 3, 6 and 9 o'clock positions of the phantom, the same size as the central ROI. See figure 1b) for an example.

Performance criteria

- The difference between the mean CT numbers of the central ROI and the outer ROIs must not be more than ± 4 HU [1].

Corrective action

If the performance criteria are not satisfied, check that the manufacturers recommended protocol settings are being used. Otherwise contact the manufacturer for remedial action.

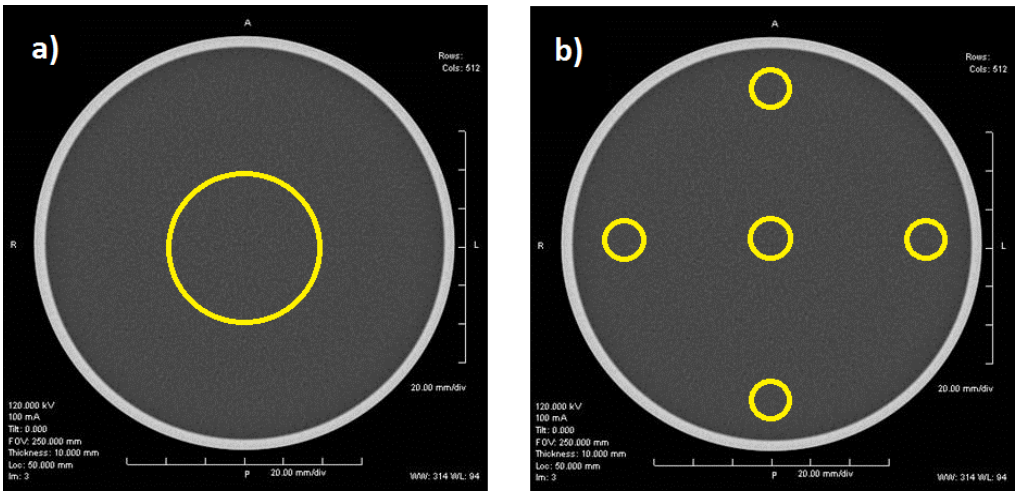

Figure 1: Example of proper ROI placement for analysis of a) CT number and image noise, and b) image uniformity.

4. Image artefacts

Background

Artefacts in the CT image can affect the diagnostic quality to varying degrees, depending on the severity of the artefact. A simple visual check of the phantom image is sufficient to check for any artefacts.

Equipment

- See CT number and image noise.

Procedure

- See CT number and image noise.

Analysis

- Visually inspect the image of the phantom to detect any artefacts. Examples of artefacts are defective pixels or ring artefacts which could also show up on a clinical image (see figure 2).

Performance criteria

- There should be no artefacts in the image that have the potential to compromise diagnostic quality.

Corrective action

Some artefacts (eg. ring artefacts) may be rectified by re-calibrating the CT detectors using the manufacturer's standard procedure. Otherwise contact the manufacturer for remedial action.

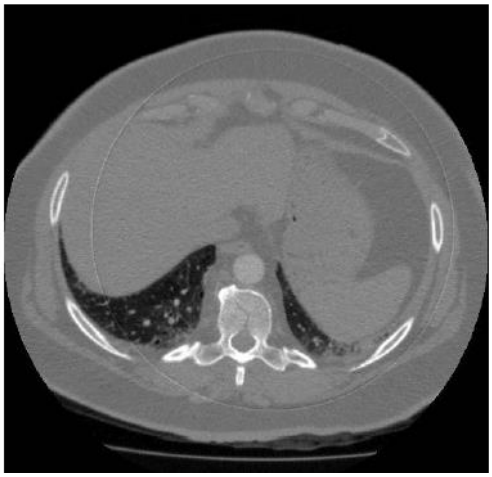

Figure 2: A clinical abdomen CT image showing a ring artefact. From reference 3.

5. CT alignment laser accuracy

Background

Internal lasers or CT lights are used to align the patient with the tomographic plane to allow accurate imaging of the required anatomy. This test is a simple check of the alignment of the lasers or CT lights with the imaging plane.

Equipment

- A thin radio-opaque marker (such as a thin wire of width 1-2 mm), placed on the CT couch or attached to a phantom as shown in figure 3.
- This test may also be done with a manufacturer-supplied phantom, in which case the manufacturer's specified QC procedure should be followed.

Procedure

- Align the radio-opaque marker with the CT internal laser lights (see figure 3)
- Align the centre of the CT scan length with the radio-opaque marker
- Scan the phantom with an axial head or body protocol. A thin slice thickness should be used to accommodate the thickness of the marker (eg. slice thickness 1.5 mm for a 1 mm thick marker).

Analysis

- Visually inspect the image of the phantom or radio-opaque marker. The marker should be clearly visible in the central image slice.
- If this is not the case, the extent of laser mis-alignment may be calculated by taking the number of slices the image of the marker is offset from the centre by, and multiplying this number by the slice width.

Performance criteria

- The CT laser lights shall be aligned with the tomographic plane to within ±5 mm [2].

Corrective action

If the performance criteria are not satisfied, check the alignment of the marker and/or phantom with the CT lasers. Otherwise contact manufacturer for remedial action.

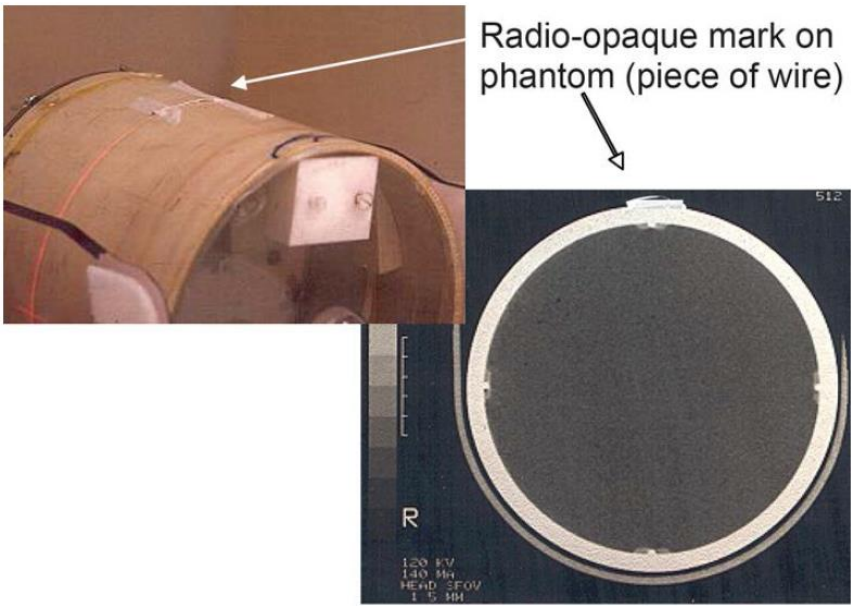

Figure 3: Test equipment for CT laser alignment test: radio-opaque marker (wire) on phantom. From reference 1.

6. Scan Projection Radiograph (SPR) accuracy

Background

The Scan Projection Radiograph (SPR) is a simple radiographic projection used to plan the particular area of the patient to be scanned and set the axial length of the scan. This test ensures that the axial length of the scan as set on the SPR corresponds to the actual scanned length.

Equipment

- A straight test tool, such as a metal or wooden ruler with a distance scale in mm and straight, well-defined edges.

Procedure

- Align the test tool on the CT couch to point straight down the bore and acquire an SPR.
- Use the SPR to plan the axial scan length, aligning the centre of the scan with the centre of the test tool. Ensure the ends of the test tool are within the axial scan length.
- Scan the phantom with an axial head or body protocol to cover the entire axial range of the test tool. A thin slice thickness (eg. 1 mm) should be used.

Analysis

- Visually inspect the image of the test tool. The ends of the test tool should be clearly visible in the first and last image slices.
- If this is not the case, the extent of SPR mis-alignment may be calculated by the slice offset multiplied by the slice width.

Performance criteria

- The CT laser lights shall be aligned with the tomographic plane to within ±2 mm [2].

Corrective action

If the performance criteria are not satisfied, check the alignment of the test tool with the scan area. Otherwise contact the manufacturer for remedial action.

7. Image display quality

Background

This test is mandatory for radiologists reporting monitors, and for general CT operator monitors. This test may require a degree of radiologist cooperation. 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[4] 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 [4].

Equipment

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

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) [4].
- View the test pattern on the radiologist reporting monitor or CT operators monitor.

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.

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

[4] 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 [4].

- image window level and window width need adjusting
- monitor brightness and contrast need adjusting

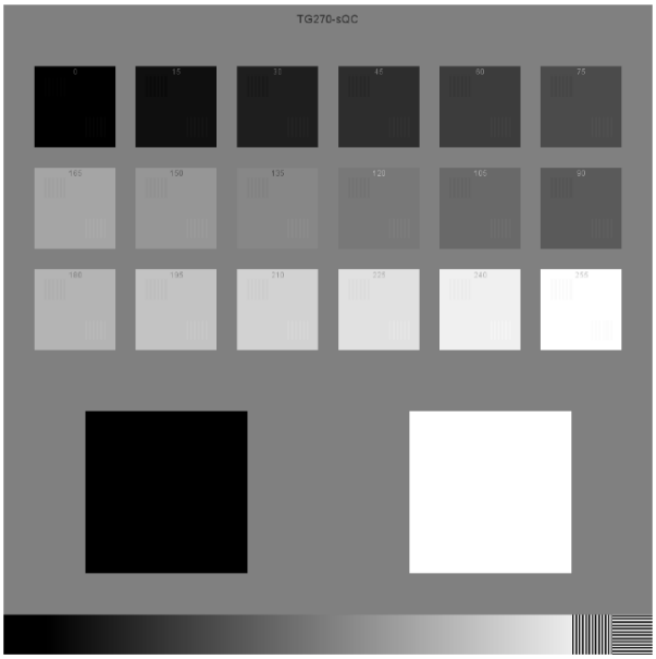

Figure 4: TG270-sQC test pattern for quality control of CT workstation and reporting monitors. From reference 4.

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

8. 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, CT departments are required to keep records of patient dose metrics for each scan region and examination description, including:

- Volumetric CT Dose Index, $CTDI_{vol}$ in mGy
- Dose-Length Product, *DLP* in mGy.cm

This record keeping will assist hospitals in fulfilling the requirements of the Australian Government's Diagnostic Imaging Accreditation Scheme 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 diagnostic quality [5].

For more information about DRLs in diagnostic CT imaging, see:

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

The current DRLs for diagnostic CT imaging can be found at:

www.arpansa.gov.au/research-and-expertise/surveys/national-diagnostic-reference-level-service/current-australian-drls-update/mdct

The Royal Australian and New Zealand College of Radiologists has published a resource titled "RANZCR CT Image Review Self-Audit Worksheet" which can assist CT departments in performing a review of image quality and data collection for dose audits. The worksheets are available from

www.ranzcr.com/fellows/clinical-radiology/quality-assurance-and-accreditation/ct

References

[1] International Atomic Energy Agency, *Quality Assurance Program for Computed Tomography: Diagnostic and Therapy Applications*, IAEA Human Health Series No. 19 (2012)

[2] American Association of Physicists in Medicine, *Performance Evaluation of Computed Tomography Systems,* AAPM Report No. 223 (2019)

[3] International Atomic Energy Agency, *Diagnostic Radiology Physics: A Handbook for Teachers and Students* (2014)

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

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