Environment Protection Authority

Radiation Standard 6

Compliance requirements for ionising radiation apparatus used in diagnostic imaging: Part 5 – computed tomography

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ISBN 978 1 925790 08 5
EPA 2024P4506
First published August 1999
Second edition March 2004
Third edition October 2020

This edition March 2024

(This edition supersedes the October 2020 edition)

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Introduction

Computed tomography (CT) is an essential part of medical procedures, both for diagnosis and in research. Diagnostic medical and interventional procedures inevitably deliver a radiation dose to the patient. In most cases, the benefits of CT far outweigh any potential risks to the patient from radiation. However, the level of risk is justified only when patients may receive a possible health benefit and everything reasonable has been done to reduce the dose.

The complexities of modern apparatus used for CT make regular performance monitoring essential for maintaining the best image quality. It is important that the performance level of each apparatus is established during acceptance testing, and that performance standards are maintained over time by an appropriate quality assurance program. Quality assurance procedures that aren't good enough may cause an unnecessary increase in radiation exposure to the patient and staff and a decrease in the diagnostic value of the examination.

The objects of this standard are to:

- provide adequate safety measures to protect patients, occupationally exposed persons and the public from unnecessary radiation exposure
- improve and maintain the standard of radiation apparatus
- ensure better monitoring of apparatus performance
- provide reference dose levels as a guide for the best patient exposure.

This standard for computed tomography is for the information of the person responsible and licensed users of ionising radiation apparatus and persons accredited under section 8 of the *Protection from Harmful Radiation Act 1990* as consulting radiation experts. It is to be used by them in the assessment of apparatus for compliance with conditions of the radiation management licence and should be read with the Act and the Protection from Harmful Radiation Regulation 2013. In the event of amendment to the Act or Regulation, references to the legislation in this document must be deemed to refer to the current legislation. If there's an inconsistency between the standard and the amended legislation, the requirements of the legislation prevail.

This document sets out the minimum requirements for satisfactory compliance of diagnostic imaging apparatus, which are stated as '**must**' statements and are listed in Schedule 1 and promotes industry best practice in radiation safety to be implemented during the medical use of CT scanners.

The standard was developed by the Radiation Unit of the NSW Environment Protection Authority (EPA) in consultation with the Radiation Advisory Council.

The EPA acknowledges the assistance of A/Prof Lee Collins, Mr Paul Cardew, Dr Jennifer Diffey, Ms Lucy Cartwright, Mr Thomas Greig and Mr Peter Condon and the input received from stakeholders, in preparing this edition.

1. General requirements and recommendations

1.1. Advice to person responsible

1.1.1 The conditions of radiation management licences require licensees to make sure diagnostic imaging apparatus is tested for compliance with the EPA's mandatory requirements. An EPA-accredited consulting radiation expert **must** carry out testing for compliance with these requirements and certify that apparatus is compliant.

1.1.2 For CT scanners to comply with the requirements they **must** meet the requirements listed in Schedule 1 of this standard.

1.1.3 The responsible person **must** have equipment quality control records available to the inspecting authority and to a consulting radiation expert on request (details of quality assurance are discussed in section 3 of this standard).

1.1.4 Specifications for radiation shielding of protective barriers and the design details of rooms used for ionising radiation apparatus should be determined according to Radiation *Guideline 7: Radiation shielding design, assessment and verification requirements* and documented by an appropriately qualified person before building works start.

1.1.5 A protective shield **must** be provided for the operator's use.

1.1.6 Where a fixed protective shield is provided it should be not less than 2100 millimetres (mm) in height.

1.1.7 The operator, when behind the protective shield, **must** have a clear view of the patient and **must** be able to communicate easily with the patient at all times.

1.1.8 Where a viewing window is used as part of the protective shield, the lead equivalent and the kVp of the X-ray beam at which the lead equivalent was measured **must**, in the case of new installations, be clearly and durably marked on the viewing window.

1.1.9 In the case of new installations, the protective shield and all shielded walls and doors **must** be clearly and durably marked with the lead thickness or lead area density or, for non-lead material, the type and thickness of the building material they're constructed from.

1.2. Advice to consulting radiation expert

1.2.1 A consulting radiation expert **must** make sure any radiation monitoring device used for compliance testing is:

- suitable for the type of measurement for which it is to be used
- used only when it is fully operational and properly calibrated
- capable of measuring the type of radiation being assessed over the range of energies and dose rates required
- calibrated at least every two years to an Australian or international primary or secondary standard satisfactory to the manufacturers' requirements.

1.2.2 The following test equipment may be required to carry out compliance testing:

- a radiation meter/detector
- a pencil ionisation chamber

- a CT phantom specific to the manufacturer/model of the CT scanner
- a head and/or body phantom suitable for the measurement of the CT dose index
- GAFchromic film or a suitable device for measuring irradiated beam width
- tape
- aluminium filters (Grade 1100 or equivalent) (if measuring half-value layer)
- lead markers/paper clips
- pen

1.2.3 Manufacturer-specific acquisition protocols will be required for the testing of CT image quality and for the measurement of CT dose index.

1.2.4 Before starting to test the manufacturer's warm-up procedure should be followed.

1.2.5 All measurements **must** be in SI units (e.g. Gy for air kerma).

1.2.6 Test procedures and test conditions used **must** be clearly documented by the consulting radiation expert and **must** include the following information:

- Phantom or dosimeter
- Protocol used (e.g. sequential head, service menu)
- kV, mA, rotation time
- Collimation (n x T)
- Field of View

And additionally for image quality:

- Reconstruction kernel
- Reconstructed slice thickness
- Region of interest size

2. Compliance requirements: computed tomography

2.1. System performance

2.1.1 The consulting radiation expert must make sure all tests listed in **Table 1** that include any clause listed in Schedule 1 be carried out at the frequency specified and results **must** comply with the limits referenced in this standard.

Table 1: Tests required for computed tomography

Compliance Requirement	Test	Acceptance	2-Yearly	After tube replacement	After detector replacement
2.2	Radiation warning sign	✓	✓	×	×
2.3	Markings on X-ray generators and CT gantry	✓	✓	✓	×
2.4	Termination of exposure	✓	✓	×	×
2.5	Indicators of operation	✓	✓	×	×
2.6	Mechanical accuracy	✓	×	×	×
2.7	X-ray beam quality	✓	✓	✓	×
2.8	Image quality	✓	✓	✓	✓
2.9	Radiation dosimetry	✓	✓	✓	✓

2.2. Radiation warning sign

2.2.1 A radiation warning sign complying with Schedule 6 of the Regulation **must** be displayed on the outside of the entry doors to any room housing CT apparatus.

2.2.2 A radiation warning light **must** be positioned at the entry doors to all rooms housing CT apparatus, except where a consulting radiation expert has determined that not to do so would not pose a risk to the safety of any person.

2.2.3 Where a radiation warning light is provided, it should illuminate whenever the X-ray tube is placed in the preparation mode before exposure or when the beam is being produced. The light **must** remain illuminated for the duration of the exposure and **must** bear the words **'X-RAYS—DO NOT ENTER'** or similar. Illumination **must** be immediate.

2.3. Markings on X-ray generators and CT gantry

2.3.1 X-ray generator and gantry **must** be permanently marked in English and the markings must be clearly visible.

2.3.2 X-ray generators **must** bear either:

a. the name or trademark of the manufacturer, and
b. the type or model number, and
c. the serial number, or
d. an EPA-generated number that links to (a), (b) and (c).

2.3.3 Gantry **must** bear either of the following markings in a visible position:

a. the name or trademark of the manufacturer of the X-ray tube housing and insert, and
b. the type or model number of the X-ray tube housing and insert, and
c. the serial number of the X-ray tube housing and insert, or
d. EPA-generated number (s) that links to (a), (b) and (c).

2.4. Termination of exposure

2.4.1 There **must** be a way for the operator can terminate the exposure at any time during a scan.

2.5. Indicators of operation

2.5.1 Beam on indicator.

A visible signal **must** be displayed at the control panel and on the gantry to indicate when the X-ray tube is energised.

2.5.2 Audible signal.

An audible signal must be provided at the location from which the equipment is operated to indicate the duration or termination of the exposure.

2.6. Mechanical accuracy

2.6.1 Light localisation accuracy

The error of the scan localisation lights and the scan plane **must** not exceed ±2 mm.

2.6.2 Scout localisation accuracy.

The error in the correspondence of localisation image parameters with the actual slice position **must** not exceed ±2 mm with the gantry in the vertical position.

2.6.3 Coronal and sagittal plane lights.

The coronal and sagittal plane lights **must** intercept at the x = 0, y = 0 on the corresponding axial image. The error **must** not exceed ±2 mm.

2.6.4 Axial scan incrementation accuracy.

When the scanner is used in axial mode, the incrementation accuracy between successive axial slices **must** not exceed ±1 mm.

2.6.5 Couch positioning accuracy.

The couch positioning accuracy **must** not deviate by more than ±2 mm.

2.7. X-ray beam quality

2.7.1 The first half-value layer in the X-ray beam incident to the patient **must** be verified by direct measurement or inspection of service documents and **must** be greater than or equal to:

a. 3.2 mm of aluminium at 120 kVp; or
b. 3.5 mm of aluminium at 130 kVp; or
c. 3.8 mm of aluminium at 140 kVp.

2.8. Image quality

2.8.1 Baseline values for noise, mean CT number, uniformity and irradiated slice width **must** be established when the equipment is first brought into use or following any major service likely to affect these parameters.

2.8.2 Baseline values can be provided by the supplier.

2.8.3 If these figures have not yet been determined, the tests **must** be carried out at the first compliance test and should be performed according to the manufacturer-recommended protocols. As such, the requirements specified in section 2.8.7 do not apply for that initial test. This **must** be noted in the assessment report.

2.8.4 When establishing baseline values, all selectable values of scan parameters, the area of the test device to be imaged and the position of the test device during irradiation **must** be recorded in the assessment report, as the same test procedures, test conditions and test device **must** be used for future tests.

2.8.5 If a new baseline is set, justification **must** be provided in the assessment report. In such cases, the requirements specified in section 2.8.7 do not apply.

2.8.6 Values for parameters in clause 2.8.1 should comply with manufacturer's specifications.

2.8.7 Deviations from baseline values **must** not exceed those given in **Table 2** when using the same test procedures and test conditions as those used at baseline.

2.8.8 The mean CT number in water **must** be within 0 ± 5 HU.

2.8.9 The maximum absolute difference between the centre and peripheral values of an image of a uniform water phantom **must** be within ± 4 HU.

2.8.10 Visual inspection of an image of a uniform water phantom **must** be visually uniform and free from clinically significant artefacts.

2.8.11 Values of reconstructed slice thickness should be within the following limits: ± 1.0 mm for thicknesses > 2.0 mm or ± 50% for thicknesses ≤ 2.0 mm.

2.8.12 High contrast resolution should comply with manufacturer's specifications.

Table 2: Acceptable deviations from CT baseline levels

Parameter	Deviation
Noise	± 10% or 0.2 HU* (whichever is greater)
Mean CT number in water	± 5 HU (and also comply with Clause 2.8.4)
Irradiated slice width	± 20% or 1 mm (whichever is greater)

* HU = Hounsfield unit

2.9. Radiation dosimetry

2.9.1 Baseline values of CT dose index in air for all clinical kV settings and typical collimations **must** be established when the equipment is first used or following any major service likely to affect these parameters.

2.9.2 Baseline values can be provided by the supplier.

2.9.3. If baseline figures have not yet been determined, the tests **must** be carried out at the first compliance test and should be performed according to the manufacturer-recommended protocols. As such, the requirements specified in section 2.9.7 do not apply for that initial test. This **must** be noted in the assessment report.

2.9.4 When establishing baseline values, all selectable values of scan parameters and the position of the test device during irradiation **must** be recorded in the assessment report, as the same test procedures and test conditions **must** be used for future tests.

2.9.5 If a new baseline is set, justification **must** be provided in the assessment report. In such cases, the requirements specified in section 2.9.7 do not apply

2.9.6 Values for parameters in clause 2.9.1 should comply with manufacturer's specifications.

2.9.7 Subsequent CT dose index in air **must** be measured and **must** be within ±20% of the baseline values when using the same test procedures and test conditions as those used at baseline.

2.9.8 The weighted CT dose index (CTDIw) should be measured using perspex phantoms.

2.9.9 Measured values of CTDIw should be within 20% of the manufacturer's specifications.

2.9.10 The volume CTDI ($CTDI_{vol}$) and the dose length product **must** be available to the operator and recorded with the CT images.

3. Quality assurance requirements: computed tomography

3.1. Quality assurance program

3.1.1 A quality assurance program approved by a consulting radiation expert **must** be put in place and maintained. Where no program is in place, a consulting radiation expert should make appropriate recommendations.

3.1.2 The quality assurance program should make sure consistent, optimum-quality images are produced so that the radiation exposure of patients, staff and the public satisfies the 'as low as reasonably achievable' principle.

3.1.3 The quality assurance program should include checks and test measurements on all parts of the imaging system, as indicated in this standard, at appropriate time intervals. At a minimum this should include a weekly measurement of the CT number in water and the image noise in a water phantom. The CT number of water should be 0.0 ± 4 HU.

3.1.4 Quality assurance procedures **must** be standardised and documented in a quality assurance manual.

3.1.5 Equipment **must** be maintained and serviced according to the manufacturer's recommendations. This should be at least annually.

3.2. Diagnostic reference levels

3.2.1 The quality assurance program **must** include a dosimetric evaluation of routine CT procedures at least annually. This should include both paediatric and adult procedures.

3.2.2 Average patient values for $CTDI_{vol}$ in mGy and DLP in mGy.cm **must** be assessed against the current Australian national diagnostic reference levels for multidetector computed tomography as published by the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) on their website.

3.2.3 Dose levels that consistently exceed the national diagnostic reference levels should be investigated and appropriate action taken.

3.2.4 The results of the dosimetric comparison and any actions taken afterwards **must** be recorded and be available to the EPA and to a consulting radiation expert on request.

4. Test protocols

These test protocols provide a guide and should not be taken as the only method of testing. Some of them may not be suitable for a particular vendor and/or model of computed tomography apparatus. Vendors' test protocols should be used as guidance where necessary.

4.1 Radiation shielding

See *Radiation Guideline 7: Radiation shielding design assessment and verification requirements*.

Compliance requirement

See section 1.1.

4.2 Light localisation accuracy

Aim

To determine the coincidence between the internal and external localisation lasers and the physical scan plane.

Exposure factors

- Enough kV, mA and rotation time to produce film blackening (e.g. 120 kV, 100 mAs).
- A single axial rotation with the minimum available collimated beam width.

Method

- Position a strip of GaF film aligned with the coronal (y = 0) and sagittal (x = 0) lasers.
- Mark a line on the film aligned with the external z-axis laser.
- Move the couch automatically to the scan plane and mark the position of the internal z-axis laser.
- Perform a single axial scan with low technique factors.
- Measure the difference between the internal and external lasers and the centre of the scan plane as indicated by the centre of the blackened line on the film.

Compliance requirement

The difference between the internal laser, external laser and scan plane must not exceed 2 mm.

Notes

- Avoid placing the film on an object that will create significant scatter, as this may affect the film blackening.
- This test set-up can also be used for 2.6.4/4.5 axial scan incrementation accuracy and 2.8.1/4.9 irradiated slice width.
- Other methods are acceptable if they can determine the same result.

4.3 Scout localisation accuracy

Aim

To determine the coincidence of the localisation image and the physical scan plane.

Exposure factors

- Technique factors that are low but still able to produce an image of the test object.

- A single axial rotation with a total acquired collimated beam width of at least 5 mm, reconstructed using the thinnest slices available (e.g. 0.5 mm).

Method

- Position a thin dense object (e.g. a straight paperclip) aligned with the coronal (y = 0) and sagittal (x = 0) lasers, with the long axis placed perpendicular to the z-axis. The z-axis position should allow for the object to be scanned with a scout localiser.
- Perform an anterior/posterior scout localiser, making sure the object is scanned.
- Perform a single axial scan with low technique factors and the thinnest reconstructed slice thicknesses available, centred on the dense object as shown in the scout localiser.
- Scroll through the reconstructed slices and find the slice with the object in view.
- Count the number of slices between the central reconstructed slice and the slice with the object in view (e.g. if there are 32 reconstructed slices, the central slice is 16/17. If the object appears most in focus in slice 17/18, then the difference is one slice).
- Multiply this number of slices by the reconstructed slice width to determine the difference in mm e.g. one slice x 0.5 mm slice thickness = 0.5 mm difference.

Compliance requirement

The difference between the central slice and object position must not exceed 2 mm.

Notes

- This test relies on the reconstructed slice width being accurate (see 2.8.4). This accuracy may be verified with a suitable phantom e.g. CatPhan.
- Other methods are acceptable if they can determine the same result.

4.4 Coronal and sagittal plane lights

Aim

To determine the coincidence of the coronal and sagittal lasers and the physical scan plane.

Exposure factors

- Technique factors that are low but still able to produce an image of the test object.
- A single axial rotation with a collimated beam wide enough to cover the test object.

Method

- Position a thin dense object (e.g. a straight paperclip) aligned with the coronal (y = 0) and sagittal (x = 0) lasers, with the long axis placed parallel to the z-axis. The z-axis isocentre should be in the centre of the test object long axis.
- Perform a single axial scan with low technique factors.
- Measure the distance between the object (bright dot in the centre of the field of view) and the centre of the image using the system calipers. For systems that do not indicate the centre of the image (e.g. with a crosshair), the distance from the object to the four edges of the image can be used as an alternative (e.g. if the distance from the object to the left edge is 121 mm, and the distance from the object to the right edge is 119 mm, then the difference between the object and the centre of the image is given by (121-119)/2 = 1 mm.

Compliance requirement

The difference between the object and the centre of the image must not exceed 2 mm in the x and y directions.

Notes

- This test relies on the system calipers being accurate, which can be verified with a suitable phantom e.g. CatPhan.
- Take care to position the test object and calipers accurately.
- Other methods are acceptable if they can determine the same result.

4.5 Axial scan incrementation accuracy

Aim

To determine the accuracy of sequential scan positions.

Exposure factors

- Enough kV, mA and rotation time to produce film blackening (e.g. 120 kV, 100 mAs).
- Multiple single axial rotations with the clinically used range of collimated beam widths/detector configurations (this will simultaneously assess 2.8.1 irradiated slice width). Consult the manufacturer specifications or baseline testing report for detector configurations to use.

Method

- Use the same test set-up as for 2.6.1/4.2 light localisation accuracy i.e. GaF film aligned with the coronal (y = 0), sagittal (x = 0) and axial (z-axis) lasers.
- Record the original couch position.
- Move the couch enough to make sure the irradiated beam widths do not overlap. This will require knowledge of the irradiated beam width, as this will be wider than the nominal beam width indicated by the scanner e.g. if the first axial scan was got using 32 x 0.6 mm (irradiated beam width = 27 mm), and the second scan will be got using 96 x 0.6 mm (irradiated beam width 64 mm), then the couch movement will need to be at least 0.5 x 27 + 0.5 x 64 = 45.5 mm (an extra 10 mm buffer is recommended). Check the manufacturer specifications or baseline testing report for irradiated beam widths.
- Record the new couch position and calculate the distance moved.
- Perform another single axial scan with low factors and a different collimated beam width/detector configuration (this is used in test 2.8.1/4.9 irradiated slice width).
- Repeat for a number of clinically used collimated beam widths/detector configurations and movement positions (making sure the irradiated beams do not overlap on the film).
- Measure the distances between the centres of the blackened strips on the GaF film and compare with the distances indicated by the couch positions.

Compliance requirement

The difference between the indicated couch distances and the measured GaF distances must not exceed 1 mm.

Notes

Other methods are acceptable if they can determine the same result.

4.6 Couch positioning accuracy

Aim

To determine the accuracy of patient couch positioning.

Method

- Place a ‘patient’ load on the couch e.g. a colleague or large heavy phantoms.
- Place a marker on the moving part of the couch and align it with a corresponding marker on the stationary part of the couch.

- Note the couch start position.
- Move the couch a fixed distance and note the new couch position.
- Measure the physical distance moved between the two markers on the moving and stationary parts of the couch (e.g. with a tape measure).
- Compare the indicated couch position distance with the measured physical distance.
- Repeat for a number of distances both in and out of the gantry.

Compliance requirement

The difference between the indicated distance and the measured distance must not exceed 2 mm.

4.7 X-ray beam quality

Aim

To make sure the beam quality meets minimum specifications.

Exposure factors

120, 130 or 140 kV, enough mAs to produce an appropriate measurement (e.g. 100 mA).

Method

- Inspect the service documents to verify the minimum beam quality.

OR

- Use an appropriately calibrated dosimeter with direct half-value layer measurement capability.
- Align the dosimeter with the appropriate orientation to the anode-cathode axis at isocentre.
- Perform a scout localiser that covers the length of the detector, with the desired kV and enough mA to produce an appropriate measurement.
- Record the indicated half-value layer.

OR

- Use high purity aluminium filters.
- Place a dosimeter at isocentre, making sure there are no attenuating materials (e.g. the patient couch) between the X-ray tube and the dosimeter.
- Perform exposures (e.g. AP scout) with the desired kV and enough mA to produce an appropriate measurement.
- Make three exposures with no filters added (free in air), then take the average.
- Place 3 mm of the aluminium filters on the face of the X-ray tube, ensuring enough distance between the dosimeter and the filters to reduce scatter, and make another exposure.
- Repeat exposures with more aluminium filters until the measured dose falls to less than 50% of the unfiltered dose.
- Plot the measured dose against filter thickness using a semi-log scale.
- Halve the average free in air exposure and determine corresponding thickness of aluminium from the graph.

Compliance requirement

See Section 2.7.1.

4.8 Noise, mean computed tomography number and uniformity

Aim

To make sure the system meets manufacturer specifications and does not deviate significantly from baseline.

Exposure factors

As indicated by manufacturer specifications or those used at baseline.

Method

- Set up an appropriate water phantom at isocentre (consult the manufacturer specifications or baseline testing report).
- Perform scans using technique factors as indicated by manufacturer specifications, or that used at baseline (do at least the typical head and body protocols).
- For each scan:
  - Place a large (e.g. 40% diameter of test object, or consult manufacturer specifications or baseline test conditions) region of interest in the centre of the central slice and note the standard deviation in HU (noise).
  - Compare the computed tomography noise values with manufacturer specifications and baseline.
  - Measure the mean HU in five regions of interest (of size 10% diameter of test object) positioned at the centre and four peripheral locations (north, east, south and west). Peripheral regions of interest should be positioned approximately one diameter in from the phantom border.
  - Compare the central computed tomography T number value with manufacturer specifications, EPA tolerance and baseline.
  - Calculate the deviation in HU between each peripheral location and the centre, and determine the maximum deviation.
  - Compare the maximum deviation with manufacturer specifications and EPA tolerance.
  - Review the image for any significant non-uniformity or artefacts.

Compliance requirement

See Section 2.8.

Notes

If there is significant non-uniformity, this may affect the computed tomography number and noise measurements. In this case, the region of interest size should be adjusted to exclude significant non-uniformities.

4.9 Irradiated slice width

Aim

To make sure the irradiated beam width meets manufacturer specifications and does not deviate significantly from baseline.

Exposure factors

- Enough kV, mA and rotation time to produce film blackening (e.g. 120 kV, 100 mAs).
- Multiple single axial rotations with the clinically used range of collimated beam widths. Check the manufacturer specifications or baseline testing report for detector configurations to use.

Method

- Use the same test set-up as for 2.6.1/4.2 light localisation accuracy and 2.6.4/4.5 axial scan incrementation accuracy i.e. GaF film aligned with the coronal (y = 0), sagittal (x = 0) and axial (z-axis) lasers.
- Follow the test protocol for axial scan incrementation accuracy using a range of clinically used detector configurations/collimated beam widths.
- Measure the full width half maximum of the resulting radiation profiles.
- Compare with manufacturer specifications or baseline.

Compliance requirement

See Section 2.8.

Notes

Alternative methods are acceptable if they can determine the same result e.g. using a point dosimeter profiler.

4.10 Radiation dosimetry

Aim

To make sure the system output meets manufacturer specifications and does not deviate significantly from baseline.

Exposure factors

Clinically used range of kV and collimated beam widths/detector configurations with enough mA and rotation time to produce an appropriate measurement (e.g. 100 mA, 1 s). Check the manufacturer specifications or baseline testing report for technique factors to use.

Method

- Set up a 100 mm CTDI chamber free in air (overhanging the patient couch to avoid couch attenuation) with the centre of the detector length at isocentre.
- Perform a number of axial scans using the technique factors indicated in the manufacturer specifications or those used at baseline. (E.g. Three repeated scans at the most clinically used kV and collimated beam width/detector configuration to confirm repeatability, variation of the kV keeping all other factors constant, variation of the collimation keeping all other factors constant.)
- Convert the raw CTDI readings to $CTDI_{air,100}$ values where necessary (dosimeters typically quote mGy). If the dosimeter quotes mGy, multiply the raw mGy reading by 100 mm (the chamber length) and divide by the nominal collimated beam width (e.g. 32 x 0.6 = 19.2 mm). Ensure that all units are consistent.
- Compare to manufacturer specifications and baseline.

Compliance requirements

See Section 2.9.

Notes

- Maker sure there is no movement between each successive scan, as the dosimeter must measure the entire beam profile.
- The maximum collimation that can be captured by the dosimeter in a single scan is 60 mm.
- At acceptance, a number of the manufacturer $CTDI_{air}$ specifications should be verified.
- Manufacturer specifications are often normalised per 100 mAs, therefore your measurements should also be normalised per 100 mAs for direct comparison.

Schedule 1: Compliance requirements

The clauses of the Standard listed in this Schedule are the requirements referred to in Radiation Management Licence Condition 3.1 that a 'person responsible' must make sure an apparatus meets for compliance with this Standard.

Requirement	Clause(s)
Advice to person responsible	1.1.1, 1.1.2, 1.1.3, 1.1.5, 1.1.7, 1.1.8, 1.1.9
Advice to consulting radiation expert	1.2.1, 1.2.5, 1.2.6
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Quality assurance program	3.1.1, 3.1.4, 3.1.5
Diagnostic reference levels	3.2.1, 3.2.2, 3.2.4

References and further reading

Australian Radiation Protection and Nuclear Safety Agency *Code of Practice for Radiation Protection in the Medical Applications of Ionizing Radiation (2008)*, Radiation Protection Series Publication No. 14.

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Definitions

In this standard:

Absorbed dose means energy delivered from radiation per unit mass of absorbing material, measured in Gray (Gy) or mGy. One Gray equals one joule per kilogram.

Act means the *Protection from Harmful Radiation Act 1990*.

Air kerma means *kerma* measured in a mass of air.

Apparatus means computed tomography scanner.

Barrier means any wall, door, protective shield etc. between the CT scanner and an adjacent area.

CT means computed tomography.

CT dose index means the integral of the dose profile along a line perpendicular to the tomographic plane. It should be measured using a 10 centimetre (cm) chamber and expressed as $CTDI_{100}$ which means that the limits of integration are from -5 cm to +5 cm. The measured air kerma should be multiplied by the length of the chamber (*100 mm*) and divided by the product of the nominal slice thickness and the number of tomograms (*n.T*) produced in a single scan.

CTDIw, weighted CTDI means the value obtained by summing one-third of the CTDI at the centre of a standard head or body phantom and two-thirds of the CTDI at the periphery of the phantom, expressed in mGy.

$CTDI_{air}$ means the $CTDI_{100}$ measured in air, at the isocentre, and commonly expressed in units of mGy/100 mAs**$CTDI_{vol}$** means the $CTDI_w$ divided by the scan pitch and represents the average absorbed dose in the scan volume, expressed in mGy.

CT number means the number used to represent the mean X-ray attenuation associated with each elemental area of the CT image. It is normally expressed in Hounsfield units.

DLP, Dose Length Product means the product of the $CTDI_{vol}$ and the scan length, expressed in mGy.cm.

Dose profile means a representation of the dose as a function of the position along a line perpendicular to the tomographic plane.

EPA means the Environment Protection Authority.

High contrast resolution means the ability to resolve different objects in the displayed image, when the difference in attenuation between the objects and the background is large compared to noise. Also known as spatial resolution.

Kerma (K) means kinetic energy released in a material by ionising radiation and is determined as the quotient of dE_{tr} by dm, where dE_{tr} is the sum of the initial kinetic energies of all the charged ionising particles liberated by uncharged ionising particles in a material of mass dm ($K = dE_{tr}/dm$). The unit of kerma is the Gray (Gy), or joule per kilogram.

KAP means air kerma-area product i.e. air kerma multiplied by radiation area. The KAP value may be displayed on the operator's console, or on a separate kerma-area product meter. The units of KAP are typically $Gy.cm^2$, or similar e.g. $mGy.cm^2$, $cGy.cm^2$, $\mu Gy.m^2$. It is important to make a note of the unit when conducting a patient meter.

Kerma rate means kerma per unit time and is determined as the quotient of dK by dt, where dK is the increment of kerma in the time interval dt. Variants include incident air kerma rate (does not include backscattered radiation) and entrance surface air kerma rate (includes backscattered radiation).

Lead equivalent means the thickness of lead causing the same attenuation of a beam of a specified radiation quality as the material under consideration.

Mean CT number means the mean value of the CT numbers of all pixels within a certain defined region of interest.

Noise means the variation of CT numbers from a mean value in a defined area in the image of a uniform substance.

New installation means a completely new build or modifications to barriers in an existing room.

Operator means a person licensed under section 7 of the Act to use ionising radiation apparatus.

Person responsible means as defined in section 6 of the Act.

Phantom means a test object that simulates the average composition of various structures.

Primary beam means all ionising radiation that emerges through the specified aperture of the protective shielding of the X-ray tube and the collimating device.

Regulation means the Protection from Harmful Radiation Regulation 2013.

Scattered radiation means ionising radiation produced from the interaction of electromagnetic ionising radiation with matter. It has a lower energy than, or different direction from, that of the original incident ionising radiation.

X-ray tube housing means a container in which an X-ray tube is mounted for normal use, providing protection against electric shock and against ionising radiation except for an aperture for the useful beam. It may contain other components.

X-ray tube insert means a highly evacuated vessel for the production of X-radiation by the bombardment of a target, usually contained in an anode, with a beam of electrons accelerated by a potential difference.

X-ray tube potential difference means the peak value of the potential difference applied to the X-ray tube, expressed as kilovolts peak (kVp).

Unless otherwise defined, all words in this standard have the same meaning as in the Act and the Regulation.