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SASQART: South African standards for quality assurance in radiotherapy

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The SASQART practice guidelines were set forth by the South African Medical Physics Society & South African Association of Physicists in Medicine and Biology. The intended purpose of this document and the individual topic-specific sections is to provide guidelines as to a minimum set of tests, result tolerances and a minimum frequency of these tests to be performed by medical physicists and radiation therapy staff in a radiation oncology department to promote patient safety. The tests, tolerances and frequencies from the international references have been adapted to realistically reflect the South African working environment and resource availability, while maintaining the highest clinical and scientific quality of care achievable.

Contribution: Replaces the 2014 guidelines, establishing recommended quality assurance standards for radiation oncology in South Africa.

Keywords: SASQART; radiotherapy; quality assurance; Linac; dosimetry; radiation protection.

Section list

Introduction

In November 2021, a task group was appointed by the South African Medical Physics Society (SAMPS), a member society of the South African Association of Physicists in Medicine and Biology (SAAPMB). This task team was chosen to be representative of multiple provinces in the country, private, academic and public radiotherapy facilities, and to incorporate medical

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Note: The manuscript is the contribution to the 'SASQART Practice Guidelines', under the expert guidance of guest editors Prof. Chris J. Trauernicht and Dr Hein Fourie.

TABLE 1: Definitions of frequency nomenclature.

Abbreviation	Frequency	Definition
D	Daily	Once during every treatment day and separated by at least 12 h
W	Weekly	On average once every 7 days or at intervals between 5 and 9 days
M	Monthly	On average once every 4 weeks or at intervals between 3 and 5 weeks
Q	Quarterly	On average once every 3 months or at intervals between 11 and 15 weeks
A	Annually	On average once every 12 months or at intervals between 10 and 14 months
B	Biennially (every 2 years)	On average once every 24 months or at intervals between 22 and 26 months
P	Per Patient (Patient Specific Tests)	For each relevant patient, usually before treatment starts
C	Commissioning (Once-off)	Before the equipment or procedure is used clinically

physicists with different areas of expertise. The task group was given a mandate to produce a document that was intended to update or replace the existing 2014 SASQART guidelines that are referred to in the South African Health Products Regulatory Authority (SAHPRA) license conditions for medical radiotherapy devices. The document was intended to cover all forms of quality assurance (QA) to be performed in a clinical Radiation Oncology Department at the time of the formation of the task group.

The intended purpose of this document and the individual topic-specific sections is to provide guidelines as to a *minimum* set of tests and tolerances, and a *minimum* frequency of these tests to be performed by medical physicists and radiation therapy staff in radiotherapy to promote patient safety. The tests and test frequencies were adapted based on both local experience and additional international guidelines, such as those from Canadian Association of Provincial Cancer Agencies (CAPCA), American Association of Physicists in Medicine (AAPM), International Atomic Energy Agency (IAEA), Institute of Physics and Engineering in Medicine (IPEM) and Netherlands Commission on Radiation Dosimetry (NCS). The CAPCA gave permission for us to use their Standards for Quality Control as a basis for the original 2014 SASQART documents. The assistance and information sharing of CAPCA is appreciated but they are not in any way responsible for the final SASQART documentation. The test frequencies from the international references have been adapted to realistically reflect the South African working environment, while ensuring patient safety. There was a long process of consultation between task team members, and the comments from the South African medical physics community were incorporated after the first round of edits in 2023. The final documents have been agreed upon by all task team members as recommendations to be proposed to SAMPS.

These tests and their frequency are unique to the environment of radiotherapy and should not be applied where the same equipment is used in other disciplines. For example, the tests for a computed tomography (CT) scanner are limited to the requirements for imaging for radiotherapy and do not cover the more rigorous demands of a CT scanner used in diagnostic radiology.

This document is only to be used as a *guideline* and not as a legally binding document for licensing conditions. If any clinic can show that their equipment shows historical stability beyond the frequency of testing suggested, then the professionalism of the medical physicist should allow for a reduction in the test frequency. In contrast, where equipment is known to have inherent instability below 'normal' standards, the medical physicist should perform tests at shorter intervals than suggested in this document.

The Radiation Protection document has been specifically designed for implementation by the Department of Health and SAHPRA to ensure radiation safety.

The techniques employed to establish the compliance of a particular test to the tolerances suggested in this document remain totally within the preference of the medical physicist, who should be able to explain the methodology adequately. It is beyond the scope of this document to prescribe experimental techniques and vendor-specific equipment. This should be left to the professional judgement of the physicist at each clinic. If tolerance cannot be reached because of economic, vendor, mechanical or electronic constraints, there should be documentation to show how the clinical procedures are adapted to accommodate these anomalies, without impacting upon patient safety. These tests should be conducted by a qualified medical physicist or radiotherapy personnel trained by a qualified medical physicist. Any test exceeding tolerance should be reported to a qualified medical physicist to determine the course of action.

The format of this document specifies tests which need to be performed within certain time periods. These time periods are depicted in Table 1.

The tests performed during commissioning may be repeated during the routine quality control intervals. For quantities that can be measured, the 'performance' of a test is compared to an action and tolerance level. If the difference between the measured and expected value is at or below the tolerance level, no action is required. If the difference is larger than the 'action' level, immediate action is required. If this is not immediately possible, the use of the system must be restricted to clinical situations in which the identified inadequate performance is of no, or acceptable and understood, clinical significance.

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Chair: SASQART Task Group

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Cobalt-60 teletherapy units

TABLE 2: Quality assurance tests for Cobalt-60 teletherapy units.

Designator	Test	Performance	
		Tolerance	Action
Daily			
DCO1	Door interlock or last person out	Functional	-
DCO2	Beam status indicators	Functional	-
DCO3	Patient audio-visual monitors	Functional	-
DCO4	Lasers/cross-wires	1 mm	2 mm
DCO5	Optical distance indicator	1 mm	2 mm
DCO6	Optical back pointer	2 mm	3 mm
DCO7	Field size indicator	1 mm	2 mm
Monthly			
MCO1	Motion interlock	Functional	-
MCO2	Couch brakes	Functional	-
MCO3	Room radiation monitors	Functional	-
MCO4	Emergency off	Functional	-
MCO5	Beam interrupt/counters	Functional	-
MCO6	Head swivel lock	Functional	-
MCO7	Wedge, tray interlocks	Functional	-
MCO8	Gantry angle readouts	0.5°	1°
MCO9	Collimator angle readouts	0.5°	1°
MCO10	Couch position readouts	1 mm	2 mm
MCO11	Couch rotation isocentre	2 mm	3 mm
MCO12	Couch angle	0.5°	1°
MCO13	Optical distance indicator	1 mm	2 mm
MCO14	Crosswire centring	1 mm	2 mm
MCO15	Light/Radiation coincidence	2 mm	3 mm
MCO16	Field size indicator	1 mm	2 mm
MCO17	Relative Dosimetry	1%	2%
MCO19	Records	Complete	-
Annually			
ACO1	Accessories integrity and centring	Functional	-
ACO2	Reference dosimetry	1%	2%
ACO3	Relative output factor reproducibility	1%	2%
ACO4	Central axis depth dose reproducibility	1%	2%
ACO5	Wedge transmission factor reproducibility	1%	2%
ACO6	Accessory transmission factor reproducibility	1%	2%
ACO7	Light/Radiation coincidence versus gantry angle	2 mm	3 mm
ACO8	Field size indicator versus gantry angle	1 mm	2 mm
ACO9	Output reproducibility versus gantry angle	1%	2%
ACO10	Beam symmetry reproducibility versus gantry angle	2%	3%
ACO11	Timer linearity	1%	2%
ACO12	Shutter error	0.03 min	0.05 min
ACO13	Collimator rotation isocentre	2 mm	3 mm
ACO14	Gantry rotation isocentre	2 mm	3 mm
ACO15	Couch rotation isocentre	2 mm	3 mm
ACO16	Coincidence of collimator, gantry, couch axes	2 mm	3 mm
ACO17	Coincidence of isocentres	2 mm	3 mm
ACO18	Couch deflection	3 mm	5 mm
ACO19	Independent quality control review	Complete	-

Relevant references:[1,2]

Notes: Please see full reference list of this article https://doi.org/10.4102/sajo.v9i0.329 for more information.

DCO1–3 The configuration of these tests will depend on the design of the facility and equipment. Safety is the concern and tests should be designed accordingly. As a minimum, the manufacturer's recommendations and applicable regulations must be followed.

DCO4 Alignment of cross-wires and appropriate lasers for collimator angle 0°, gantry angles 0°, 90° and 270° at an Source-to-Surface Distance (SSD) of Source-to-Axis Distance (SAD) – 10 cm.

DCO5 Gantry angle 0° and an SSD of SAD – 10 cm.

DCO6 Gantry angle 0° and an SSD of SAD+10 cm.

DCO7 Gantry angle 0°, nominal SAD, field sizes of 10 × 10 and 20 × 20 cm

MCO1–6 The configuration of these tests will depend on the design of the facility and equipment. Safety is the concern and tests should be designed accordingly. As a minimum, the manufacturer's recommendations and applicable regulations must be followed.

MCO7 Proper functioning of the accessories and indicators.

MCO8 Mechanical and digital gantry angle readouts must be verified using a spirit level, or other appropriate levelling devices, for at least 0°, 90°, 180° and 270°.

MCO9 Mechanical and digital collimator angle readouts must be verified using a spirit level, or other appropriate levelling devices, for at least 0°, 90° and 270°.

MCO10 Mechanical and digital couch position readouts must be verified over an appropriate clinical range in the directions of the three cardinal axes.

MCO11 Rotation of the couch about the optical collimator rotation axis must be verified.

MCO12 The couch rotation angle must be verified over an appropriate clinical range.

MCO13 A mechanical device, calibrated against the true radiation isocentre, is used to provide the base reading for the check of the optical distance indicator. The standards stated in the Table apply at the isocentre. The optical distance indicator should be checked over a clinically relevant range of SSD and gantry angle. The tolerance and action level may be twice as large (i.e., 2 and 4 mm) as the clinical limits of the optical distance indicator's range.

MCO14 The trajectory of the optical image of the cross-wires is measured at the appropriate SSD for collimator angles of 0°, 90° and 270°. Tolerances and Action Levels refer to the diameter of the optical isocentre so measured.

MCO15 Geometric alignment of the radiation and optical field edges must be established over a clinically relevant range of field sizes at gantry angle 0°.

MCO16 Compliance of the radiation and optical field sizes with the indicated dimensions must be established over a clinically relevant range of field sizes at gantry angle 0°.

MCO17 Although the radiation output (cGy/min) from a Co-60 unit should decay at a known rate, it is necessary to confirm this regularly to ensure that no unexpected changes have occurred (e.g. malfunction of shutter or source transport mechanism).

MCO19 Documentation relating to the daily quality control checks, preventive maintenance, service calls and subsequent checks must be complete, legible and the operator identified

ACO1 Proper functioning of accessories and indicators

ACO2 A full TRS398 calibration is performed annually.

ACO3–6 These tests confirm that essential parameters used for treatment time calculations have not changed because of, for example, a wedge being remounted. All accessories available in the treatment room must be checked.

ACO7 Geometric alignment of the radiation and optical field edges must be established over a range of field sizes at gantry angles 0°, 90° and 270°. Representative half-blocked fields must be included if available. A minimum of six field sizes will be required for this test.

ACO8 Compliance of the radiation and optical field sizes with the indicated dimensions must be established over a range of field sizes at gantry angles 0°, 90° and 270°. Representative half-blocked fields must be included if available. A minimum of six field sizes will be required for this test. If appropriate and efficient, different field sizes may be examined at different gantry angles.

ACO9 An ion chamber with a build-up cap may be used in air for these measurements. The chamber may be positioned at the isocentre or may be mounted on the head of the unit. In the latter case, effects because of head sag will not be observed.

AC10 Film and optical densitometry are used to confirm the symmetry of the radiation output and hence proper centring of the source with respect to the primary collimator. A large field, for example 30 × 30 cm^2 and gantry angles of 0°, 90° and 270° should be used.

ACO11–12 From a series of radiation measurements with different set times, the timer linearity and the timer offset or shutter errors are determined.

ACO13–15 Using film, star or spoke patterns are produced and the three radiation axes of rotation are determined. Tolerances and Action Levels refer to the diameters so measured.

ACO16 By referencing the films in 13–15 above to the laser system, the relative locations of the three axes of rotation at the isocentre may be determined.

ACO17 The radiation, optical and mechanical isocentres are determined with reference to the laser system and their degree of coincidence determined.

ACO18 Couch deflection is measured with 70 kg at the end with the couch extended to the isocentre.

ACO19 To ensure redundancy and adequate monitoring, a second qualified medical physicist must independently verify the implementation, analysis and interpretation of the quality control tests at least annually.

Kilovoltage x-ray radiotherapy machines and Intra-Operative Radiotherapy

TABLE 3: Quality assurance tests for external kilovoltage x-ray therapy machines.

Designator	Test	Performance	
		Tolerance	Action
Daily			
DK1	Patient monitoring audio-visual devices	Functional	-
DK2	Door closing mechanism and interlock	Functional	-
DK3	Couch movement and brakes	Functional	-
DK4	Unit motions and motion stops	Functional	-
DK5	Interlocks for added filters/kV-filter choice	Functional	-
DK6	Beam status indicators	Functional	-
DK7	Beam-off at key-off test	Functional	-
DK8	kV and mA indicators	Functional	-
DK9	Backup timer/monitor unit channel check	1%	2%
Monthly			
MK1	Mechanical stability and safety	Functional	-
MK2	Cone selection and competency	Functional	-
MK3	Physical distance indicators	2 mm	3 mm
MK4	Light/x-ray field size indicator	2 mm	3 mm
MK5	Light/x-ray field coincidence	2 mm	3 mm
MK6	Dosimetric test: Output check	3%	5%
MK7	Emergency off test	Functional	-
MK8	Records	Complete	-
Annual			
AK1	Accuracy of head tilt and rotation readouts	1°	2°
AK2	X-ray field uniformity/filter integrity	5%	8%
AK3	Timer and End Effect Error	Characterise	±0.05 min
AK4	Output linearity	1%	2%
AK5	Output reproducibility	Characterise	< 0.03 coefficient of variation (CoV)
AK6	Beam quality	10%	15%
AK7	Timer Accuracy Verification	2%	3%
AK8	Output Calibration Verification	2%	3%
AK9	Independent quality control review	Complete	-

Some of these tests may not apply to older stand-alone kV units and may be omitted where not relevant.

Notes: Please see full reference list of this article https://doi.org/10.4102/sajo.v9i0.329 for more information.

DK1 Functional check of the operation of patient monitoring audio-visual devices.

DK2 Functional check of the operation of door-closing mechanisms and interlock(s).

DK3 Functional check of couch motion and brakes (where applicable).

DK4 Functional check of unit motions and motion stops.

DK5 Functional check of interlocks for added filters, correct placement of filters and the matching of filters with kV value.

DK6 Functional check of the beam status indicators.

DK7 Functional check of beam-off at key-off.

DK8 Functional check of kV and mA indicators.

DK9 Quantitative verification of correct operation of back-up timer or monitor unit (MU) termination.

MK1 Verification that the unit and accessories are firmly anchored and may be used without endangering patients or staff.

MK2 Verification of the integrity of the cones and cone indicators.

MK3 Verification of the distance indicator.

MK4 Geometric test to verify the light field and radiation field sizes when a variable collimation system is provided. At least two field sizes must be checked.

MK5 Performance parameters refer to agreement at each edge and performed monthly when a variable collimation system is provided and annually for fixed cones. At least two field sizes must be checked.

MK6 Quantitative dosimetric test: Output constancy test at a representative set of energies and filter combinations using absolute or relative measurements.

MK7 Functional check of emergency off button.

MK8 Documentation relating to the daily quality control checks, preventive maintenance, service calls and subsequent checks must be complete, legible and the operator identified.

AK1 Verification of the angle readouts.

AK2 Using an appropriate dosimeter (e.g. film or 2D-array), the flatness and symmetry of the x-ray beam must be assessed for the largest cone.

AK3 Timer and end-effect error measurement may be performed in conjunction with AK4.

AK4 Output linearity measurement for a standard SSD and field size and a dose range of 10–1000 cGy.

AK5 Output reproducibility verification with the criterion being specified as the coefficient of variation of 10 readings under the same exposure conditions.

AK6 The Half Value Layer (HVLs) of any clinically used beams is measured. The HVLs measured in mm Al or Cu as appropriate are compared with the values obtained at commissioning. These tolerances acknowledge measurement uncertainty.

AK7 The accuracy of the timer (where applicable) must be checked against a stopwatch over a range of doses of 10–1000 cGy.

AK8 Using a high-quality absolute dosimetry system calibrated against the local secondary standard the calibration of all clinically used beams and filters is checked.

AK9 To ensure redundancy and adequate monitoring, a second qualified medical physicist must independently verify the implementation, analysis and interpretation of the quality control tests at least annually.

TABLE 4: Quality assurance tests for internal kilovoltage x-ray therapy machines.

Designator	Test	Performance	
		Tolerance	Action
Daily/Before each use			
DKI1	PDA Source Check (Isotropy)	± 10%	15%
DKI2	PAICH Output Check (Dose Rate)	± 5%	10%
DKI3	Patient vitals monitoring (Vitals Screen)	Functional	-
DKI4	Applicator integrity	Not Damaged	-
Monthly			
MKI1	PDA Source Check (Isotropy)	± 10%	15%
MKI2	PAICH Output Check (Dose Rate)	± 5%	10%
6-monthly			
SKI1	Chamber Constancy Check	± 1%	-
SKI2	Environmental dose survey	According to license conditions	-
Annually			
AKI1	Alignment (Probe Adjuster)	0.1	0.2
AKI2	Steering (Dynamic Offsets)	Successful	-
AKI3	Output – using chamber in water or solid water	± 5%	10%
AKI4	Isotropy – using chamber or thermoluminescent dosimeters (TLDs) in water	± 5%	10%
AKI5	Depth Dose – using chamber or film in water	± 5%	10%
AKI6	Calibration	Manufacturer's specification	-
AKI7	Date and time	± 5 min	-
AKI8	Temperature	± 1 °C	-
AKI9	Pressure	± 2 mbar	-
AKI10	Independent quality control review	Complete	-
Acceptance and Commissioning			
CMKI1	Internal radiation monitor (IRM) Linearity Test	± 3%	-
CMKI2	Reproducibility	Internal protocol	-
CMKI3	External kVp and mAs	Compare to preset value	-
CMKI4	Water Phantom Output Check	± 7.8%	-

Notes: Please see full reference list of this article https://doi.org/10.4102/sajo.v9i0.329 for more information.

DKI1 If available in the commercial system – verify that the XRS probe's x-ray emission pattern is as spherical as possible. Run the Photon Diode Array (PDA) source check test on the system. This is an internal system check, if unsuccessful might need to perform the probe adjustment.

DKI2 If available in the commercial system – The dose rate of the XRS is determined by means of an in-built ionisation chamber and UNIDOSE dosimeter. Run the Probe Adjuster Ion chamber holder (PAICH) output check test on the system.

DKI3 Check that the patients' vitals monitoring screen is functional.

DKI4 Check that the applicators are in good conditions for usage.

MKI1 Verify that the XRS probe's x-ray emission pattern is as spherical as possible. Run the PDA source check test on the system. This is an internal system check, if unsuccessful might need to perform the probe adjustment

MKI2 The dose rate of the XRS is determined by means of an in-built ionisation chamber and UNIDOSE dosimeter. Run the PAICH output check test on the system.

NOTE: If there above two test fails or you suspect the probe might be bent, do test AKI1 (Probe Adjustor) and AKI2 (Dynamic Offset).

AKI1 Mechanical straightness check of the probe should be performed during each source exchange and whenever the probe is suspected to be bent. Must be followed by electronic alignment of XRS probe (Dynamic Offsets). Frequency of this test will vary depending on probe alignment.

AKI2 Dynamic offset technique aligns the direction of the electron beam with the mechanical centre of the XRS probe by beam deflection adjustment. To be performed after probe adjustment.

AKI3 Output measurement check should be performed using an ion chamber in water or solid water.

AKI4 The isotropy should be checked using ionisation chamber or TLDs

AKI5 The depth dose should be measured in water using film or ionisation chamber.

AKI6 Have XRS x-ray source calibrated every year (recommended by manufacturer Carl Zeiss). Have the ionisation chamber and the UNIDOS E calibrated. PTW recommends calibration every 2 years. If shorter calibration intervals are stipulated by national codes and regulations these must be adhered to.

AKI7 Internal clocks on the control console and user terminal should be synchronised to ensure consistent recording of treatment parameters. This is an internal system check.

AKI8 Internal displayed temperature to be compared to external instruments and adjusted if necessary. This is an internal system check.

AKI9 Internal displayed pressure to be compared to external instruments and adjusted if necessary. This is an internal system check

AKI10 A second medical physicist must independently verify the implementation, analysis and interpretation of the quality control tests at least annually.

SKI1 Perform the chamber constancy check.

SKI2 Perform an environmental radiation survey.

Perform all daily, monthly, biannual tests, then the following:

CMKI1 Measure the proportionality of the IRM reading to beam current using the PDA attachment. This is an internal system check.

CMKI2 Measure the reproducibility of the x-ray output under a couple of exposures.

CMKI3 Measure the external kVp and mAs with a Unifors or similar device.

CMKI4 Perform a water phantom output check.

CT scanners and CT-simulators

TABLE 5: Quality assurance tests for Computed Tomography (CT) scanners and CT-simulators.

Designator	Test	Performance	
		Tolerance	Action
Daily			
DCS1	Beam status indicators	Functional	-
DCS2	CT number for water – mean (accuracy)	0 ± 3 HU	0 ± 5 HU
DCS3	CT number for water – standard deviation (noise)	5 HU	10 HU
DCS4	CT number for water – mean versus position (uniformity)	5 HU	10 HU
DCS5	Audio-video intercom systems	Functional	-
DCS6	Respiratory and surface monitoring system	Functional	-
DCS7	4D-CT: Calibration verification	Correct	-
Biannually			
BACS1	Emergency off buttons	Functional	
BACS2	Lasers: Alignment and motion	1 mm	2 mm
BACS3	CT number accuracy of other material	4 HU	10 HU
BACS4	Low contrast resolution	Reproducible	-
BACS5	High contrast resolution (in-plane)	5 lp/cm	-
BACS6	Slice thickness/sensitivity profile	0.5 mm	1 mm
BACS7	Artifacts	Acceptable	-
BACS8	Records	Complete	-
Annually			
ACS1	Gantry tilt (where used)	1°	2°
ACS2	Slice localisation from pilot	0.5	1
ACS3	Lasers: Parallel to scan plane	1 mm	2 mm
ACS4	Lasers: Orthogonality	1 mm	2 mm
ACS5	Lasers: Position from scan plane	1 mm	2 mm
ACS6	Lasers: Linearity of translatable lasers	1 mm	2 mm
ACS7	Couch level: Lateral and longitudinal	1 mm	2 mm
ACS8	Couch motions: Vertical and longitudinal	1 mm	2 mm
ACS9	Independent quality control review	Complete	-
Biennial (every 2 years)			
BECS1	CT number accuracy of other material	0.02 RED	0.03 RED
BECS2	Radiation Dose ($CTDI_{vol}$)	10%	15%
BECS3	4D-CT: Radiation Dose ($CTDI_{vol}$)	10%	15%
BECS4	4D-CT: Amplitude and periodicity of surrogate	1 mm, 0.1 s	-
BECS5	4D-CT: Reconstruction and phase binning	Functional	-
BECS6	4D-CT: Amplitude of reconstructed target	2 mm	-
BECS7	4D-CT: Spatial integrity and positioning of target	2 mm	-
BECS8	4D-CT: CT number accuracy and standard deviation	10 HU	-
BECS9	4D-CT: High contrast resolution	5 lp/cm	-
BECS10	4D-CT: Low contrast resolution	Reproducible	-
BECS11	4D-CT: Slice thickness (sensitivity profile)	0.5 mm	1 mm
BECS12	4D-CT: Intensity projection reconstruction	2 mm/10 HU	-
BECS13	4D-CT: Import into Treatment Planning System (TPS)	Correct	-
Commissioning/Major repair			
CCS1	Manufacturer's Acceptance Testing	Complete	-
CCS2	Safety of premises	1 mSv/year	5 mSv/year
CCS3	DCS1–7, BACS1–8, ACS1–9, BECS1–14	Baseline	-
CCS4	Demographic Data Transfer	Correct	-
CCS5	Image Orientation Transfer	Correct	-
ACS6	Simulated planning	1 mm	2 mm

Imaging and output tests must be performed for all protocols in clinical use; including reconstruction filters and kernels, dose reduction techniques and extended Field of View (FOV) and extended HU settings.

CT, Computed Tomography; CTDIvol, Computed Tomography Dose Index-Volume; HU, hounsfield units; RED, relative electron density.

Relevant references: [3,4,5,6,7,8]

Notes: Please see full reference list of this article https://doi.org/10.4102/sajo.v9i0.329 for more information.

DCS1 All radiation warning lights and indicators must function correctly when the x-ray beam is generated.

DCS2 The mean CT number of water shall be checked using a typical CT simulation protocol and a cylindrical water phantom, using a large region of interest (ROI).

DCS3 Standard deviation of water in ROI at image centre and periphery using a typical CT-simulation protocol and a cylindrical water phantom.

DCS4 Maximum deviation of the mean CT# in any ROI from the mean CT# in an ROI at the centre of a cylindrical water phantom.

DCS5 Ensure any audio-video monitoring and coaching equipment is functioning properly.

DCS6 Before use, ensure the external surrogate is visible on any in-room monitor and its motion is being tracked and recorded by the monitoring software. Also, ensure that the interface between the monitoring software and the CT is functional.

DCS7	Before use, ensure the calibration of the 4D-CT is still valid and within the allowed tolerance.
BACS1	As with other radiation-producing devices, CT-scanners are equipped with emergency off switches. *The frequent use of emergency off switches can damage the CT-scanner.* These switches should be tested under conditions which will not harm the scanner and are generally performed by the manufacturer during routine maintenance.
BACS2	To confirm the fixed external lasers coincide with the gantry lasers. Alternatively, a warm-up phantom with radiopaque markers can be used to perform this test. The accuracy of moveable laser's motion shall be verified.
BACS3	CT image performance is highly dependent on the scan technique used and should be checked for all clinical protocols used. Baseline values should be established at acceptance testing. A general phantom with non-human type material may be used.
BACS4	Typically evaluated with a phantom that contains objects of varying sizes which differ only slightly in density from background. Baseline low contrast resolution for each clinically used scan protocol should be set at acceptance testing. Vendors quote 3 mm – 5 mm at 0.3% contrast level but this is seldom achieved with large FOV simulation protocols. Generally, at least 10 mm or smaller is visible at a 0.3% density difference.
BACS5	Baseline high contrast resolution for each clinically used scan protocol should be set at acceptance testing. The quoted minimum performance value is based on the methods to assess spatial resolution using high-contrast line-pair patterns or the MTF@10% (i.e. less line-pairs per centimeter indicates a degradation in the system). Generally, baseline ± 0.5 lp/cm is obtainable or ±15% of the established baseline value, whichever is greater.
BACS4–5	Various definitions of characterising resolution exist, such as the line-pairs/cm, Point Spread Function (PSF), Line Spread Function (LSF), Edge Spread Function (ESF), Modulation Transfer Function (MTF) (traditionally using high-contrast objects) and Task Transfer Function (TTF) (recommended for objects of a contrast that represents the imaging task under study and CT systems deploying non-linear reconstruction techniques). See reference 3. Whichever definition is chosen, routine quality assurance (QA) should ensure minimal deviation from the baseline.
BACS6	Accuracy of the reconstructed image slice width according to the expected slice width (i.e. ±1 mm from baseline for slices ≥ 2 mm and ± 0.5 mm from baseline for slices < 1 mm). Spatial resolution z-direction (sensitivity profile) can be determined in terms of Full-width-at-Half-maximum (FWHM), Modulation Transfer Function (MTF) or Task Transfer Function (TTF) and compared to baseline.
BACS7	To ensure the images are free from artifacts which may compromise treatment accuracy.
BACS8	Documentation relating to the quality control checks, preventive maintenance, service calls and subsequent checks must be complete, legible and the operator identified.
ACS1	Digital gantry angle readouts must be verified using a spirit level for gantry 0°.
ACS2	Slice localisation from pilot/scout should be checked over the total scannable length of the couch.
ACS3–6	Alignment of lasers should match minimally the tolerance set for those in the treatment delivery rooms. Laser lines should also be parallel to three principal axes of the CT images.
ACS7	The CT-scanner tabletop should be level and orthogonal with the imaging plane. This test shall be performed radiographically as a spirit level will provide readings relative to a horizontal reference and not to the imaging plane.
ACS8	The couch motions should be in directions parallel to the principal axes of the images and be accurate and reproducible as reflected by the digital indicators.
ACS9	A second qualified medical physicist must independently verify the implementation, analysis and interpretation of the quality control tests at least annually.
BECS1	Any attempts to link HU change to TPS dose change must consider the algorithm used and also the body region imaged. It has been reported that the following HU changes, ± 20 HU for soft tissue and ± 50 HU for lung and bone, would achieve a < 1% calculated dose change. A HU-RED phantom is required.
BECS2	Computed Tomography Dose Index (CTDI) should be measured biennially or when there is a change in the tube model that may affect x-ray output. CTDI is measured in units of dose and the tolerance and action levels refer to deviations from the manufacturer's specification or baseline values.
BECS3	Qualitative estimates of the CTDI should be made for 4D-CT protocols, similar to BECS2.
BECS4	The surrogate is a phantom used to simulate patient motion for QA purposes. The 4D-CT monitoring software must be able to calculate accurately the amplitude and periodicity of the surrogate. For systems that use a bellows device or belt, ensuring functionality and reproducibility of the signal is required.
BECS5	Ensure that the console software reconstructs the data into the appropriate number of respiratory phases, each containing the same number of axial slices.
BECS6	The amplitude of the target must be measured using the 4D-CT datasets. This can be accomplished by using appropriate imaging grid tools or by calculating the centroid motion of the target. Motion of the target in all 3 dimensions allows for a more comprehensive test as long as the 3D trajectory is known.
BECS7	The geometry as well as the location of the target at all respiratory phases should be accurate and reproducible.
BECS8–11	The 4D-CT image quality parameters should be evaluated at each phase of the reconstructed respiratory cycle similar to that of conventional CT scans.
BECS12	The created time averaged CT images, maximum intensity projection (MIP) images and minimum intensity projection images (MinIP) should be analysed by using the line profile tool to measure the diameter of the target and the expected CT number variation in the direction of motion.
BECS13	Successful export of the 4D-CT dataset into the treatment planning system must be demonstrated, maintaining the phase information located in the Digital Imaging and Communications in Medicine (DICOM) headers.
CCS1	Manufacturer's acceptance testing protocol should be followed where available.
CCS2	Controlled areas 5 mSv/year, for uncontrolled areas 1 mSv/year.
CCS3	All daily, biannual, annual and biennial tests should be conducted during acceptance testing and tolerances levels established.
CCS4–6	A phantom with various markers can be scanned with a CT-simulation protocol, the images transferred to the TPS, virtually simulated and marked with the lasers according to the laser/couch output data. Distance measurements of implanted markers should be accurate to ± 1 mm.

Dosimetry equipment

Devices for absolute dosimetry

TABLE 6: Quality assurance tests for secondary standard chambers and electrometers.

Designator	Test	Performance	
		Tolerance	Action
Before Initial Use and following Chamber Repair			
ISS1	Extra-cameral signal (Stem effect)	0.5%	1.0%
ISS2	Linearity	0.5%	1.0%
ISS3	Leakage	0.1%	0.2%
ISS4	Ion Collection Efficiency	Baseline	0.5%
ISS5	Polarity Correction	Baseline	0.2%
At each use			
ESS1	Reproducibility	0.2%	0.5%
Biennial (every 2 years)			
BSS1	Calibration at Secondary Standard Dosimetry Laboratory (SSDL) lab	Every 2 years	

Secondary standard (chamber and electrometer combination).

TABLE 7: Quality assurance tests for field standard chambers and electrometer.

Designator	Test	Performance	
		Tolerance	Tolerance
Before Initial Use and following Chamber Repair			
IFS1	Extra-cameral signal (Stem effect)	0.5%	1.0%
IFS2	Linearity	0.5%	1.0%
IFS3	Leakage	0.1%	0.2%
IFS4	Ion Collection Efficiency	Baseline	0.5%
IFS5	Polarity Correction	Baseline	0.2%
Semi-Annual			
SFS1	Signal Reproducibility	0.2%	0.5%
Annual			
AFS1	Cross calibration	Characterise and document	

Field standard (chamber and electrometer combination).

Notes:

ISS1–5 Tolerances based on AAPM TG-40 and Canadian Association of Provincial Cancer Agencies (CAPCA)/CPQR. Action levels are suggested and may be modified based on experience. Suggested methods for measurement may be found in AAPM TG-51.

BSS1 Secondary standard chambers must be sent for absolute calibration at a secondary or primary standards laboratory and have a valid calibration certificate.

AFS1 Field standard chambers to be cross-calibrated with a secondary standard chamber (BSS1). Modified frequency from AAPM TG-40 based on local experience.

Devices for relative dosimetry

TABLE 8: Quality assurance tests for *in vivo* Tthermoluminescent dosimeters (TLD) systems.

Designator	Test	Tolerance
Initial use or following malfunction and repair		
IRD1	Linearity or supralinearity	Characterise and document
At each use		
ERD1	Individual calibration	Characterise and document

TLD systems.

TABLE 9: Quality assurance tests for film dosimetry.

Designator	Test	Tolerance
Initial use or following malfunction and repair		
IRD2	Dose response curve	Characterise and document
IRD3	Film reader linearity	Characterise and document
IRD4	Film reader uniformity and geometric accuracy	Characterise and document

Film dosimetry systems.

TABLE 10: Quality assurance tests for *in vivo* diode systems.

Designator	Test	Performance	
		Tolerance	Action
Initial use or following malfunction and repair			
IRD5	Linearity (dose and dose rate)	Characterise and document	
IRD6	Energy Dependence	Characterise and document	
IRD7	Angular Dependence	Characterise and document	
IRD8	Reproducibility and Stability	0.5%	1.0%
Monthly			
MRD1	Calibration	2.0%	3.0%

Diode systems.

TABLE 11: Quality assurance tests for automated beam scanning systems.

Designator	Test	Performance	
		Tolerance	Action
Initial use or following malfunction and repair			
IBS1	Alignment	Characterise and document	
IBS2	Hysteresis	Characterise and document	
IBS3	Orthogonality	Characterise and document	
Annual			
ABS1	Positional accuracy	1 mm	2 mm
Detectors			
Initial use or following malfunction and repair			
IBS4	Extra-cameral signal (Stem effect)	0.5%	1.0%
Annual			
ABS3	Collection Potential Reproducibility	0.5%	1.0%
ABS4	Leakage	0.5%	1.0%
ABS5	Linearity	0.5%	1.0%
Data acquisition/analysis			
Initial use or following malfunction and repair			
IBS5	Scan speed insensitivity	Characterise and document	
IBS6	Agreement with static measurements	1.0%	2.0%
IBS7	Symmetry/Flatness calculations	1.0%	2.0%
IBS8	Energy/Bremsstrahlung calculations	1.0%	2.0%
IBS9	Ionisation-to-dose calculations	1.0%	2.0%
IBS10	Accuracy of output (soft and hardcopy)	1 mm	2 mm

Automated beam scanning devices and detector arrays.

Notes: Please see full reference list of this article https://doi.org/10.4102/sajo.v9i0.329 for more information.

IRD1 & ERD1 Based on AAPM TG-40.

IRD2–3 Can be established using classic Hurter and Driffield (H&D) curve at initial use. Each batch film changed should be remeasured.

IRD4 Determine the uniform readout of the film scanner across the entire bed, the reproducibility of the measured reading across the bed and the geometric distortion of the scanner.

IRD5–8 Based on AAPM TG-40.

MRD1 Diode readings should be compared to monthly absolute dose measurements and recalibrated if required.

IBS1–3 Based on clinical experience. Tolerances on the order of 0.5 mm should be achievable. Acceptance test criteria may be provided by the vendor as a guideline.

ABS1 Based on local experience. Users may adapt and document criterion to local needs.

ABS3 Based on similar criteria for IFS4.

ABS4 & 5 Based on similar criteria for IFS3 and IFS2.

IBS5–10 Tests based on clinical experience and may be modified to meet the user criteria. Tests may also be modified to follow the vendors' acceptance test criteria.

Quality assurance devices

TABLE 12: Quality assurance tests for diode arrays.

Designator	Test	Performance	
		Tolerance	Action
Initial use or following malfunction and repair			
IQD1	Accuracy (Distance to Agreement [DTA])	1 mm	2 mm
IQD2	Linearity (Dose and Dose rate)	Characterise and document	
IQD3	Agreement with static measurements	1.0 %	2.0 %
IQD4	Symmetry/Flatness calculations	1.0 %	2.0 %
IQD5	Accuracy of output (soft and hardcopy)	1 mm	2 mm
Annual			
AQD1	Energy Dependence	Characterise and document	
AQD2	Calibration	Characterise and document	

Diode arrays (2D and 3D).

TABLE 13: Quality assurance tests for general phantom materials.

Designator	Test	Tolerance
Initial use		
IPM1	Physical density, composition, electron density, homogeneity	Characterise and document
IPM2	Dimensions of slabs of pieces	Characterise and document
IPM3	Homogeneity, internal defects	Characterise and document

Phantom materials.

TABLE 14: Quality assurance tests for thermometers and barometers.

Designator	Test	Tolerance
Biennial		
BETM1/BEBM1	Calibration	Characterise and document

Thermometers and barometers.

TABLE 15: Quality assurance tests for spirit levels and self-levelling lasers.

Designator	Test	Tolerance
Initial use and routine check		
ISL1	Calibration	Characterise and document

Spirit level and self-levelling laser system.

TABLE 16: Quality assurance tests for distance measuring devices.

Designator	Test	Tolerance
Initial use		
IMD1	Calibration	Characterise and document

Distance measuring devices (rulers, tape measure, graph paper).

TABLE 17: Quality assurance tests for radiation survey meters.

Designator	Test	Tolerance
Initial use and Biennially		
BERS1	Calibration	Characterise and document

Radiation survey meters.

Notes: Please see full reference list of this article https://doi.org/10.4102/sajo.v9i0.329 for more information.

IQD1–5 Based loosely on IBS5 to IBS10 and AAPM TG-40. In addition, the manufacturers' acceptance test procedures may be used to modify the users' criteria.

AQD1&2 If devices are used across a range of beam energies, care must be taken to ensure the correct calibration factors are applied. Calibration and inspection once a year based loosely on AAPM TG-40, if used for absolute dosimetry.

IPM1–3 Inspection and radiographic verification prior to use is recommended. The tolerance depends on the intended use of the material and may be appropriately chosen by the user.

BETM1 Tolerance of within 3°C of absolute temperature is suggested. The thermometer should be tested at multiple temperature points applicable to the range of intended use.

BEBM1 Tolerance of within 10 hPa of absolute pressure is suggested. The barometer should be tested at multiple pressure points applicable to the range of intended use.

ISL1 For a spirit level, its reading when placed on a flat or vertical surface should be the same when it is 180° rotated along an axis perpendicular to the surface. The verticality and horizontality of the lines projected by the self-levelling laser should also be checked at each use.

IMD1 Rulers and tape measures should be free of damage, not bent and the markings visible.

BERS1 Electronic survey meters should be sent for calibration to a laboratory traceable to a Primary Standards Laboratory or at least their accuracy determined by such a laboratory.

Brachytherapy remote afterloaders

TABLE 18: Quality assurance tests for High Dose Rate (HDR), Pulse Dose Rate (PDR) and Low Dose Rate (LDR) remote afterloaders.

Designator	Test	Performance	
		Tolerance	Action
Daily			
DBR1	Door interlock/last person out	Functional	-
DBR2	Treatment interrupt	Functional	-
DBR3	Emergency off (console)	Functional	-
DBR4	Room radiation monitor(s)	Functional	-
DBR5	Room radiation warning lights	Functional	-
DBR6	Console displays (treatment status indicator, correct date, time, source strength)	Verify	-
DBR7	Printer operation, Paper supply (if used)	Functional	-
DBR8	Data transfer from Planning Computer	Functional	-
DBR9	Audio/Visual communication system	Functional	-
DBR10	Source positional accuracy	1 mm	2 mm
DBR11	Dwell time accuracy	1%	2%
DBR12*	PDR Sequencing	Functional	
Quarterly (or at source replacement)			
QBR1	Mechanical integrity of applicators, guide tubes, connectors	Functional	-
QBR2	Emergency off (in room)	Functional	-
QBR3	Power failure recovery	Functional	-
QBR4	Source strength calibration	3%	5%
QBR5	Source positional accuracy	1 mm	2 mm
QBR6	Dwell time accuracy	1%	2%
QBR7	Timer linearity	1%	2%
QBR8	Records	Complete	-
Annually			
ABR1	Transit dose reproducibility	1%	2%
ABR2	X-ray marker positional accuracy	1 mm	2 mm
ABR3	Review emergency response procedures	Complete	-
ABR4	Independent quality control review	Complete	-
ABR5	Radiation survey around afterloader (source retracted)	Complete	-

*, Test required for PDR units only.

Notes: Please see full reference list of this article https://doi.org/10.4102/sajo.v9i0.329 for more information.

DBR1–8, 11 The configuration of these tests will depend on the design of the facility and equipment. Safety is the concern and tests should be designed accordingly. As a minimum, manufacturer's recommendations and applicable regulations must be followed.

DBR9 Accuracy of source drive mechanism to be verified using autoradiographs, ion-chamber measurements or visual checks with in-room cameras.

DBR10 Comparison of dwell time accuracy with external standard such as a stopwatch. The dwell time used should be sufficiently long such that errors in the measurement of the time (e.g. reaction time of the observer) are less than 1%.

QBR1 Verification of damage (excessive wear, kinks, etc.) to applicators, guide tubes, connectors.

QBR2 The objective of this test is to confirm that the appropriate warnings and interlocks appear on the console when the in-room emergency off buttons are depressed. This test can be performed without exposing the source.

QBR3 The objective of test is to verify that the equipment safely terminates and resumes a treatment after a power failure.

QBR4 Comparison of measured source strength with manufacturer's supplied value. On installation of a new source, source strength must be measured using an Secondary Standard Dosimetry Laboratory (SSDL)-calibrated re-entrant chamber. Discrepancies exceeding the action value between the measured and the manufacturer's supplied source strengths must be investigated. Stability of re-entrant chamber should be verified prior to use.

QBR5 Accuracy of source drive mechanism to be verified using autoradiographs, ion-chamber measurements or visual checks with in-room cameras. Deviation should be set to 0 mm at source replacement.

QBR6 Comparison of dwell time accuracy with an external standard such as a stopwatch. The dwell time used should be sufficiently long such that errors in the measurement of the time (e.g. reaction time of the observer) are less than 1%.

QBR7 Verification of the linearity of the timer over a clinically relevant range. The tolerance and action levels represent deviations of measured values from those calculated using a linear fit to the measured data.

QBR8 Documentation relating to the daily quality control checks, preventive maintenance, service calls and subsequent checks must be complete, legible and the operator identified.

ABR1 Reproducibility of transit dose or source speed between dwell positions. Can be verified using autoradiographs, ion-chamber measurements or visual checks with in-room cameras.

ABR2 Autoradiograph of source positions superimposed on to radiograph of applicator with x-ray markers. The mechanical integrity and spacing of the x-ray markers should be checked prior to performing the autoradiograph. To be performed for each type of applicator used.

ABR3 The configuration of these tests will depend on the design of the facility and equipment. Review of the emergency procedures when a source fails to retract properly and is still exposed in the room.

ABR4 To ensure redundancy and adequate monitoring, a second qualified medical physicist must independently verify the implementation, analysis and interpretation of the quality control tests at least annually.

ABR5 Perform radiation survey around the afterloader, while source is retracted, to ensure that the source is fully retracted and to check leakage.

Megavoltage electronic portal imaging devices

TABLE 19: Quality assurance tests for Electronic Portal Imaging Device (EPID).

Designator	Test	Performance	
		Tolerance	Action
Daily			
DE1	Mechanical and Electrical integrity	Functional	-
DE2	Functionality and Repositioning	1 mm	2 mm
Monthly			
ME1	Collision interlocks	Functional	-
ME2	Positioning in the imaging plane	1 mm	2 mm
ME3	Image quality	Reproducibility	-
ME4	Artifacts	Reproducibility	-
ME5	Spatial distortion	1 mm	2 mm
ME6	Monitor controls	Reproducibility	-
ME7	Records	Complete	-
Annually			
AE1	Positioning perpendicular to the imaging plane (if applicable to EPID type)	5 mm	10 mm
AE2	Contrast and Spatial resolution	Reproducibility	-
AE3	Noise	Reproducibility	-
AE4	On screen measurement tools	0.5 mm	1 mm
AE5	Set-up verification tools	0.5 mm, 0.5°	1 mm, 1°
AE6	MV Isocentre and panel alignment	As per manufacturer	-
AE7	Independent quality control review	Complete	-
Commissioning			
CE1	DE1–2, ME1–7, AE1–7	As Above	-

TABLE 20: Quality assurance tests for Electronic Portal Imaging Device (EPID) dosimetry.

Designator	Test	Tolerance		Frequency
Before initial use and as indicated				
EP1	Fluence map – relative reproduction and uniformity	2%/2 mm	3%/3 mm	Quarterly
EP2	Calibration	1%	2%	As needed

EPID (if used for dosimetry and machine quality assurance [QA]).

Notes: Please see full reference list of this article https://doi.org/10.4102/sajo.v9i0.329 for more information.

DE1 The imager must be visually inspected for loose or damaged components, loose connectors, frayed cables or potential electrical hazard.

DE2 The most commonly used clinical modes to image a known phantom to evaluate the functionality, repositioning accuracy and image quality for daily use.

ME1 All collision prevention devices must be tested for correct operation.

ME2 Alignment of the mechanical centre/central pixel of the imager with the axis of collimator rotation must be established at the four cardinal gantry angles.

ME3 An image quality detail phantom must be imaged at available x-ray energies and the most commonly used acquisition mode. Image quality tests to include signal-to-noise ratio, low and high contrast resolution.

ME4 Artefacts should be absent.

ME5 Spatial distortion across the imager is determined using a large grid.

ME6 The monitor must be checked for optimum focus, brightness and contrast.

ME7 Documentation relating to the daily quality control checks, preventive maintenance, service calls and subsequent checks must be complete and legible.

AE1 The distance of the imager from the x-ray source (or isocentre) must agree with that set or indicated.

AE2 Using a high contrast bar pattern, or some similar device, the spatial resolution of the imager is measured at least three representative positions and the values compared with those measured at acceptance.

AE3 An image of a uniform thickness attenuator is obtained under a standard exposure condition. Using the imager's software, the standard deviations of pixel values in three or more predefined regions of interest are compared with the values measured at acceptance.

AE4 A geometrically accurate phantom is used to compare the system's estimate of distance with the true distance. The comparison should be made in orthogonal directions and at several locations in the imaging plane. The Tolerance and Action Levels may need to be modified to accommodate the actual pixel size of the unit of interest.

AE5 Software tools which report spatial discrepancies between images should be checked.

AE 6 Determine the displacement of the MV isocentre (e.g. Winston-Luts ball phantom) from the EPID central pixel and should be within manufacturer's specifications. Repeat for all cardinal angles.

AE7 A second qualified medical physicist must independently verify the implementation, analysis and interpretation of the quality control tests at least annually.

CE1 All daily, monthly and annual tests should be conducted during acceptance testing and tolerances levels established.

EP1 Fluence map for a reference field(s) are reproducible, with a 95% pass rate for distance or dose to agreement not more than tolerances shown. Tolerance of 1%/1 mm are suggested at commissioning.

EP2 Calibration of Calibrated Unit (CU) value against chamber calibrated at the level of PSDL/SSDL.

Image guided radiotherapy

TABLE 21: Quality assurance tests for kV-based imaging.

Designator	Test	Performance	
		Tolerance	Action
Commissioning			
CIG1	Tube warm-up	Functional	-
CIG2	Collisional and safety interlocks	Functional	-
CIG3	Tubes and generators – kVp accuracy and repeatability	5%	> 5%
CIG4	Tubes and generators – Tube current linearity and reproducibility	5%	> 5%
CIG5	Tubes and generators – Timer accuracy and linearity	5%	> 5%
CIG6	Tubes and generators – Half Value Layer (HVL)	DoH minimum	-
CIG7	kV source mechanical position readout	2 mm	> 2 mm
CIG8	kV imager mechanical position readout	2 mm	> 2 mm
CIG9	kV imager panel virtual alignment	2 mm	> 2 mm
CIG10	Coincidence of the laser, treatment and imaging isocentres	1.0 mm	1.5 mm
CIG11	Image registration and couch shift accuracy	0.5 mm/0.5°	1 mm/1°
CIG12	Geometric measurement and scaling	1 mm	2 mm
CIG13	High contrast spatial resolution	Correct	-
CIG14	Low contrast sensitivity	Correct	-
CIG15	CBCT number accuracy	40 HU	> 40 HU
CIG16	CBCT image uniformity and noise	40 HU	> 40 HU
CIG17	CBCT dose	Manufacturer's specification	
Daily			
DIG1	Tube warm-up	Functional	-
DIG2	Collisional and safety interlocks	Functional	-
DIG3	Image registration and couch shift accuracy	1 mm/1°	2 mm/1°
DIG4	Coincidence of the laser, treatment and imaging isocentres	1.0 mm	1.5 mm
Biannually			
BIG1–5	CBCT Image quality (CIG12–16)	-	-
Annually			
AIG1–16	Commissioning tests	Baseline	-

Planar kV imaging and CBCT.

TABLE 22: Half Value Layer (HVL) values for x-ray tubes (Directorate: Radiation Control, Diagnostic QC).

X-ray tube kVp	71	80	90	100	110	120	130	140	150	> 150
Minimum HVL (mm of Al)	2.1	2.3	2.5	2.7	3.0	3.2	3.5	3.8	41	Note 1
Minimum HVL (mm of Al), manufactured after June 2006	2.5	2.9	3.2	3.6	3.9	4.3	4.7	5.0	5.4	-

Note: 1. Half-value layers for selected voltages not listed are to be obtained by extrapolation.

Relevant references:[8,9,10,11,12,13,14]

Notes: Please see full reference list of this article https://doi.org/10.4102/sajo.v9i0.329 for more information.

CIG1 A successful tube warm up before system can be safely operated.

CIG2 Ensure that the production of kV x-rays will not be permitted if the room door is open, activation of collision interlocks and terminate buttons and the radiation warning lights and indicators are functioning correctly.

CIG3 For the various imaging modes available, verify that the indicated kVp agree with the mean measured kVp. Repeat the test for a range of clinically used kVp settings.

CIG4 As accurate measurement of the absolute tube current is generally not possible, the mA is implicitly tested from dose/mAs measurements. For the various imaging modes available, hold the kVp and time constant, and test clinically used mA settings. The dose should increase linearly (linearity: 1 ± 0.05) with current. The tube output for each exposure setting can be compared routinely to baseline values.

CIG5 Similarly to test CIG5, hold the kVp and mA constant, and test clinically used time settings. The dose should increase linearly (linearity: 1 ± 0.05) with exposure time.

CIG6 Measure the HVL for clinically used tube voltage and filters and compare with manufacturer's specifications. Minimum HVL for kV x-ray tubes are specified by the Directorate: Radiation Control in the Code: Diagnostic QC document (Table 22).

CIG7–8 For moveable kV source units, the source actual position and readouts shall be correct or within the tolerance stated.

CIG9 The centre pixel of the imager panel shall be aligned to the kV beam isocentre path.

CIG10 The kV source and kV detector axes must be coincident to the gantry rotation axis within a sphere of less than 1.5 mm radius throughout the entire 360° of gantry rotation. Daily checks of this test can be incorporated into CIG11. A simultaneous test of the laser and radiation isocentre coincidence with the imaging system, enables the use of the laser system as a surrogate for the isocentre, for daily consistency tests.

CIG11 Acquire images of a phantom with known offsets using the standard acquisition process. Assess the accuracy of the matching performed by the software and then verify the applied shifts in the room. Submillimeter accuracy is generally only achievable with 6 degree of freedom couch and software systems. Perform this test for both planar kV and CBCT (head and body image modes).

CIG12 The imaging software measurement tools must be within the tolerances specified in all dimensions. For systems with vertically moveable kV detectors, the image scaling must be corrected for by the system. Perform this test for both planar kV and CBCT (head and body image modes).

CIG13 Verify the imaging system can resolve the number of line pairs per mm (lp/mm) as specified by the manufacturer. Perform this test for both planar kV and CBCT (head and body image modes).

CIG14 Verify that the system can resolve low contrast objects in the phantom as per the manufacturer's specifications. Perform this test for both planar kV and CBCT (head and body image modes).

CIG15 This test applies to CBCT only. Verify the accuracy of the CT number calibration using a standard CT phantom that has inserts of varying densities/HUs. Perform this for both the head and body image modes. The calibration shall be within manufacturer's specifications or the tolerance stated.

CIG16 This test applies to CBTC only. Verify that the CT number measured at a variety of equal-density points in the phantom are within the manufacturer's specifications or the tolerance stated. Perform this test for both the head and body image modes.

CIG17 3D dose in a head and body CTDI phantom (following the IAEA or ICRU/AAPM method). Within ± 10% of manufacturer's specifications. Extensive efforts to reduce imaging dose while maintaining image quality should be made (e.g. additional filtration or collimation).

DIG3 See test CIG11. Depending on user experience and data demonstrating stability of the system, the frequency of this test may be relaxed to weekly.

DIG4 See test CIG10. Depending on user experience and data demonstrating stability of the system, the frequency of this test may be relaxed to weekly.

Intensity modulated radiotherapy and Volumetric modulated arc therapy

TABLE 23: Quality assurance tests for Intensity Modulated Radiotherapy and Volumetric Modulated Arc Therapy.

Designator	Test		Performance	
			Tolerance	Action
Commissioning				
CVM1	Isocentre calibration	I,V	0.5 mm	1 mm
CVM2	Leaf position transfer	I,V	Correct	1 mm
CVM3	MU transfer	I,V	Correct	0.1 MU
CVM4	Diaphragm transfer *(if applicable)*	I,V	Correct	1 mm
CVM5	Gantry, collimator and couch transfer	I,V	Correct	1°
CVM6	Interleaf transmission	I,V	2%	3%
CVM7	Arc Dosimetry	V	2%	3%
CVM8	Picket fence at various gantry angles	I,V	0.5 mm	1 mm
CVM9	Picket fence during arc delivery	V	0.5 mm	1 mm
CVM10	Gantry speed verification	V	2%	3%
CVM11	Dose rate verification	I,V	2%	3%
CVM12	Beam flatness and symmetry during arcing	V	3%	4%
CVM13	Beam flatness and symmetry during arcing and at lower dose rate	V	3%	4%
CVM14	Interrupt test	I,V	2%/2 mm	3%/3 mm
CVM15	Composite relative dose reproduction (dose or distance) in uniform phantom	I,V	3%/3 mm	4%/4 mm
CVM16	Composite absolute dose reproduction (dose or distance) in uniform phantom or point dose verification	I,V	3%/3 mm	4%/4 mm
CVM17	Small field output model	I,V	2%	3%
CVM18	Records	I,V	Complete	-
Patient specific				
PVM1	Composite relative dose reproduction (dose or distance) in uniform phantom	I,V	3%/3 mm	4%/4 mm
PVM2	Composite absolute dose reproduction in uniform phantom or point dose verification	I,V	3%/3 mm	4%/4 mm
PVM3	Records	I,V	Complete	-
Biannually				
BVM1	Isocentre verification	I,V	0.5 mm	1 mm
BVM2	Arc Dosimetry	V	2%	3%
BVM3	Picket fence at various gantry angles	I,V	0.5 mm	1 mm
BVM4	Picket fence during arc delivery	V	0.5 mm	1 mm
BVM5	Gantry speed verification	V	2%	3%
BVM6	Dose rate verification	I,V	2%	3%
Annually				
AVM1	Beam flatness and symmetry during arcing	V	3%	4%
AVM2	Beam flatness and symmetry during arcing at lower dose rate	V	3%	4%
AVM3	Interrupt test	I,V	2%/2 mm	3%/3 mm

Applicability to IMRT (I), VMAT(V) or both (I,V) indicated per test.

Relevant references:[15,16,17,18]

Notes: Please see full reference list of this article https://doi.org/10.4102/sajo.v9i0.329 for more information.

CVM1 Using film (star or spoke patterns produced) or a ball-bearing test, the radiation axis of rotation is determined. Tolerances and Action Levels refer to the radius measured.

CVM2 Numerical value of each leaf for each segment is transferred to linac correctly.

CVM3 Numerical value of monitor units for each segment is transferred to linac correctly.

CVM4 Numerical value of the backup diaphragms transferred to linac correctly *(if applicable).*

CVM5 Numerical value of gantry, collimator and couch position is transferred to linac correctly.

CVM6 Interleaf transmission agrees with TPS model.

CVM7 Verify that ionisation chamber readings (in air with build-up or phantom) at isocentre are equivalent for a variety of static and arc field settings (e.g. 10 × 10, 100 MU, static vs. 10 × 10, 100 MU, 360° arc; 10 × 10, 1800 MU, static vs. 10 × 10, 1800 MU, 360° arc)

CVM8 Tests may be performed using EPIDs or film. Junctions must appear straight and uniform and must be within a 1 mm tolerance.

CVM9 As for CVM8 for an arc field.

CVM10 Set a variety of MU and arc combinations. Verify that the stop angle and MU delivered are the same as was initially set.

CVM11 Perform absolute dose measurements of equal MU for low, medium and high dose-rate settings.

CVM12 Verify beam flatness for an arc field at nominal dose-rate compared to a static field.

CVM13 Verify beam flatness for an arc field for a low dose-rate setting.

CVM14 Interrupt treatment delivery midway and restart. Verify that 98% of points are in agreement to 2% and 2 mm compared to uninterrupted test.

CVM15 The dose distribution (2D or 3D), of all beams/arcs treated simultaneously, is reproduced in a uniform scanned phantom, over the treatment area. Can be measured using relative dosimetry techniques such as EPID, film or diode/ion chamber arrays.

CVM16 The dose distribution, of all beams/arcs treated simultaneously, is reproduced in a uniform scanned phantom. Must be measured using absolute dosimetry techniques such as a temperature pressure corrected ion chamber reading. Dose verification (at clinically relevant point) may be performed for IMRT and VMAT via measurement using ion chamber arrays, a single ion chamber (point dose verification at clinically relevant point) or EPID calibrated for dose against chamber traced to a PSDL/SSDL. The dose verification process to be determined by medical physicist. Otherwise, a secondary check programme (secondary dose calculation) can be used as a substitute to verify the TPS dose calculation and/or point dose, however CVM15 is still required.

CVM15–16 Appropriate gamma criteria, resolution and threshold settings should be determined by the medical physicist, considering the equipment and software characteristics. A gamma analysis is recommended with a pass rate ≥ 95% with the tolerance and action levels mentioned.

CVM17 Small field output model agrees with measurement down to smallest segment employed.

CVM2–6, 15,16 Test compliance should be established for at least 10 plans before commissioning can be considered complete.

PVM1 As for CVM15.

PVM2 As for CVM16. If a relative measuring device is used (such as in PVM1), absolute cross-calibration should be verified routinely.

BVM4 As for CVM9. Tolerance and action limits are relative to baseline values.

BVM5 As for CVM10. Tolerance and action limits are relative to baseline values.

Medical linear accelerators

TABLE 24: Quality assurance tests for Linacs.

Designator	Test	Performance	
		Tolerance	Action
Daily			
DL1	Door interlock/last person out	Functional	-
DL2	Beam status indicators	Functional	-
DL3	Patient audio-visual monitors	Functional	-
DL4	Motion interlock	Functional	-
DL5	Couch brakes	Functional	-
DL6	Room radiation monitors (where available)	Functional	-
DL7	Beam interrupt/counters	Functional	
DL8	Output constancy – photons	2.00%	3.00%
DL9	Output constancy – electrons	2.00%	3.00%
Monthly			
ML1	Emergency off (alternate monthly)	Functional	-
ML2	Lasers/crosswires	1 mm	2 mm
ML3	Optical distance indicator	1 mm	2 mm
ML4	Field size indicator	1 mm	2 mm
ML5	Wedge factors (dynamic or virtual)	1.00%	2.00%
ML6	Gantry angle readouts	0.5°	1°
ML7	Collimator angle readouts	0.5°	1°
ML8	Couch position readouts	1 mm	2 mm
ML9	Couch isocentre	1 mm	2 mm
ML10	Couch angle	0.5°	1°
ML11	Collimator Rotation isocentre	1 mm	2 mm
ML12	Light/radiation coincidence	1 mm	2 mm
ML13	Beam un/flatness	Manufacturer's specification	
ML14	Beam symmetry	2.00%	3.00%
ML15	Relative Dosimetry Photons and Electrons	2.00%	3.00%
ML16	Records	Complete	-
Quarterly			
Q1	Central axis depth dose reproducibility	1%/2 mm	2%/3 mm
Annually			
AL1	Accessories: Integrity and centring	Functional	-
AL2	Accessories: Latching and interlocks	Functional	-
AL3	Optical distance indicator	1 mm	2 mm
AL4	Light/radiation coincidence with gantry angle	1 mm	2 mm
AL5	Field size indicator with gantry angle	1 mm	2 mm
AL6	Reference dosimetry – TRS398	1.00%	2.00%
AL7	Relative output factor reproducibility	1.00%	2.00%
AL8	Wedge transmission factor/profile reproducibility	1.00%/1 mm	2.00%/2 mm
AL9	Accessory transmission factor reproducibility	1.00%	2.00%
AL10	Output reproducibility versus gantry angle	1.00%	2.00%
AL11	Beam symmetry reproducibility versus gantry angle	2.00%	3.00%
	or	or	or
	Off-axis factor constancy versus gantry angle	1.00%	2.00%
AL12	Monitor chamber linearity	1.00%	2.00%
AL13	End monitor effect	0.1 MU	0.2 MU
AL14	Collimator rotation isocentre	1 mm	2 mm
AL15	Gantry rotation isocentre	1 mm	2
AL16	Couch rotation isocentre	1 mm	2 mm
AL17	Coincidence of collimator, gantry, couch axes and lasers	1 mm	2 mm
AL18	Independent quality control review	Complete	-

Notes: Please see full reference list of this article https://doi.org/10.4102/sajo.v9i0.329 for more information.

DL1–7 The configuration of these tests will depend on the design of the facility and equipment. Safety is the concern and tests should be designed accordingly. As a minimum, manufacturer's recommendations and applicable regulations must be followed.

DL8–9 All energies in use on the particular treatment day. Standard local geometry as reference.

ML1 Proper functioning of the emergency stop buttons, indicators and emergency circuits.

ML2 Alignment of crosswires and appropriate lasers for collimator angle 0°, gantry angles 0°, 90° and 270° at isocentre.

ML3 Gantry angle 0° and at the isocentre and at 10 cm below isocentre, or a similar range.

ML4 Gantry angle 0°, 100 cm SAD and multiple field sizes (e.g. 5 × 5, 10 × 10, 20 × 20 and max cm^2)

ML5 Virtual or dynamic wedge factors for at least one wedge angle to be verified, relative to open beam outputs, for each photon energy.

ML6 Mechanical and digital gantry angle readouts must be verified using a spirit level or other appropriate levelling device, for at least 0°, 90°, 180° and 270°.

ML7 Mechanical and digital collimator angle readouts must be verified using a spirit level or other appropriate levelling device, for at least 0°, 90° and 270°.

ML8 Mechanical and digital couch position readouts must be verified over an appropriate clinical range in the directions of the three cardinal axes.

ML9 Rotation of the couch about the optical collimator rotation axis must be verified.

ML10 The couch rotation angle must be verified over an appropriate clinical range.

ML11 Collimator rotation isocentre measured at appropriate SSD for angles of 0°, 90°, 180°, 270° or checked over one full rotation. Tolerances and Action Levels refer to the optical isocentre measured.

ML12 Geometric alignment of the radiation and optical field edges must be established at a clinically relevant field size at a gantry angle 0°. The field size and energy employed should be varied monthly.

ML13–14 Flatness or non-flatness (for FFF) and symmetry are compared with those measured at acceptance and should be within the specifications as defined by the linac manufacturer. A single, convenient gantry angle may be chosen.

ML15 Dosimetry using an ionisation chamber in a solid phantom or water phantom referenced to an annual absolute dosimetry measurement.

ML16 Documentation relating to the daily quality control checks, preventive maintenance, service calls and subsequent checks must be complete, legible and the operator identified.

Q1 Measurements at two depths in an appropriate phantom serve to confirm that depth dose has not changed since commissioning the unit. Tolerances and Action Levels are specified in percentage for photon beams and mm for electron beams. Clinically relevant depths are used for these measurements.

AL1 Physical integrity and centring of accessories, including physical wedges, trays and cones.

AL2 Latching and interlocks of accessories, including physical wedges, trays and cones.

AL3 The optical distance indicator should be checked over a clinically relevant range of SSD and gantry angle. The tolerance and action level may be twice as large (i.e. 2 mm and 4 mm) as the clinical limits of the optical distance indicator's range.

AL4 Geometric alignment of the radiation and optical field edges must be established over a range of field sizes at gantry angles 0°, 90° and 270°. Representative half blocked fields must be included if available. Tolerances and Action Levels apply to each edge of a rectangular field.

AL5 Compliance of the optical field sizes with the indicated dimensions must be established over a range of field sizes at gantry angles 0°, 90° and 270°. Jaw sizes at six representative sizes, for example 0,5, 10, 20, 30, max cm.

AL6 A full TRS-398 calibration is performed annually using a local primary standard. The output of all available beams is then measured using the local secondary standard, to provide a reference for daily readings.

AL7–9 These tests confirm that essential parameters used for treatment time calculations have not changed. All accessories available in the treatment room must be checked.

AL8 Wedge factors to be checked for all physical wedges, for all photon energies. For non-physical wedges (dynamic and virtual), a profile reproducibility check is recommended and should be measured for at least four wedge angles.

AL10 An ion chamber with build-up cap may be used in air for these measurements. The chamber may be positioned at the isocentre or may be mounted on the head of the unit. In the latter case, effects because of head sag will not be observed.

AL11 Gantry angles of 0°, 90° and 270°, should be used.

AL12–13 From a series of radiation measurements with different monitor units the linearity and the end monitor effect are determined for each energy.

AL14–16 Using film, star or spoke patterns are produced and the three radiation axes of rotation are determined. Alternatively, a Winston-Lutz test can be performed. Tolerances and Action Levels refer to the diameters so measured.

AL17 By referencing the films/Winston-Lutz in 14–16 above, the relative locations of the three axes of rotation at the isocentre may be determined and should coincide. The external isocentre reference (i.e. lasers) should also coincide with the determined radiation isocentre.

AL18 To ensure redundancy and adequate monitoring, a second qualified medical physicist must independently verify the implementation, analysis and interpretation of the quality control tests at least annually.

Multileaf collimators

TABLE 25: Quality assurance tests for Multileaf Collimators (MLCs).

Designator	Test	Performance	
		Tolerance	Action
Monthly			
MM1	Light and radiation field coincidence	1 mm	2 mm
MM2	Leaf positions for standard field template	1 mm	2 mm
Annual			
AM1	Leaf transmission (all energies)	Reproducibility	-
AM2	Leakage between leaves (all energies)	Reproducibility	-
AM3*	Transmission through abutting leaves	Reproducibility	-
AM4	Stability with gantry rotation	Reproducibility	-
AM5	Alignment with jaws	-	1°/1 mm
AM6	Records	Complete	-
AM7	Independent quality control review	Complete	-

*May not apply to all MLC designs.

Notes:

MM1 For MLCs with rounded leaf edges, the optical field may be smaller than the radiation field. A standard irregularly shaped field can be verified using film.

MM2 Light projection of an irregular MLC-shaped field involving all leaves onto a standard printed template. Note: The geometrical accuracy of the printout should be verified.

AM1,2,3 Average and maximal transmission should be reported and compared to TPS values. Differences from commissioning or baseline values should be less than 2%.

AM4 With the gantry at 90 or 270 degrees exposures should be made with the leaves' vertical and the collimator rotated ± 60 degrees. It is recommended to use a picket fence pattern acquired at a gantry angle at 90 or 270 degrees. Leaf position repeatability within 1 mm is expected.

AM5 Use a large field with one leaf from each leaf bank protruding well into the field. The parallelism with the collimator edge is checked.

AM6 Documentation relating to the daily quality control checks, preventive maintenance, service calls and subsequent checks must be complete, legible and the operator identified.

AM7 To ensure redundancy and adequate monitoring, a second qualified medical physicist must independently verify the implementation, analysis and interpretation of the quality control tests at least annually.

Radiation protection

TABLE 26: Quality assurance tests for radiation protection in oncology.

Designator	Test	Performance	
		Tolerance	Action
Commissioning Linac			
CRP1	Skyshine	SAHPRA Licensing Limits	
CRP2	Wall penetration	SAHPRA Licensing Limits	
CRP3	Roof penetration	SAHPRA Licensing Limits	
CRP4	Door/maze penetration (neutron)	SAHPRA Licensing Limits	
CRP5	Door/maze penetration (x-rays)	SAHPRA Licensing Limits	
CRP6	Radiation warning signs in place	Functional	
Commissioning Cobalt/CT/simulator/contact/HDR			
CRP7	Wall penetration	SAHPRA Licensing Limits	
CRP8	Roof penetration	SAHPRA Licensing Limits	
CRP9	Door/maze penetration	SAHPRA Licensing Limits	
CRP10	Radiation warning signs in place	Functional	
CRP11	Room area monitor calibration (HDR)	Performed	
Daily			
DRP1	Room area monitor (where required)	Functional	
DRP2	Radiation ON lights	Functional	
Weekly			
WRP1	Pregnant personnel monitored with direct read digital dosimeter	DoH Licensing Limits	
Monthly			
MRP1	Radiation worker monitoring	DoH Licensing Limits	
Annually			
ARP1	Lead apron (where required) intact	Physical	
ARP2	Lead apron (where required) image	X Ray	
ARP3	Wipe test of all sealed radionuclides	Magnitude equal to local background	
ARP4	Documentation	Complete	
Biennially (Every 2 years)			
BRP1	Room area monitor calibration verification	Performed	
BRP2	Survey meter calibration	Performed	
BRP3	Electronic Personal Dosimeter	Performed	
New installations/major renovations			
NRP1	CRP1–11, DRP1–2, MRP2, ARP1–4, BRP1–3	-	

SAHPRA, South African Health Products Regulatory Authority.

Relevant references:[19,20,21]

Notes: Please see full reference list of this article https://doi.org/10.4102/sajo.v9i0.329 for more information.

CRP1–5,7–9 SAHPRA Licensing Conditions and Dose Limits. The shielding of an external beam radiation therapy facility shall be designed according to the recommendations of United States (US) National Council on Radiation Protection and Measurements (NCRP, Report No. 151 of 2005). Calculated based on room usage, beam output, classification of individuals at risk of exposure etc. such that controlled areas ≤ 5 mSv/year and uncontrolled areas ≤ 1 mSv/year.

CRP11 Calibration performed by SSDL or through documented cross calibration with meter calibrated by SSDL. Room area monitors are generally only required at Co-60 units and HDR units.

WRP1 Additional restrictions apply to the above-mentioned occupational dose limit of pregnant women. When pregnancy has been diagnosed, the conceptus must be protected by applying a supplementary equivalent dose limit to the surface of the woman's abdomen (lower trunk) of 2 mSv for the remainder of the pregnancy (see *South African Hazardous Substances Act, 1973 (Act No. 15 of 1973)* and Regulations Relating to Group IV Hazardous Substances No. R. 247).

MRP1 The occupational effective dose shall be limited to 20 mSv per annum such that no more than 100 mSv accumulates over a 5-year period (with no more than 50 mSv in any 1 year).

ARP1–2 Lead apron should be imaged using kV X rays to check integrity upon failure of a physical check.

ARP3 Adherence to the relevant licensing conditions.

ARP4 Documentation should include radiation survey readings, radiation worker medical reports, monthly radiation worker readings, pregnant worker monitoring and swipe test results.

BRP1 Calibration of the room area monitor verified against a survey meter calibrated by SSDL.

BRP2 Calibration performed by SSDL or through documented cross calibration with meter calibrated by SSDL.

BRP3 Calibration performed by SSDL or through documented cross calibration with meter calibrated by SSDL.

NRP1 Tests performed as relevant to equipment being commissioned

Therapeutic radioisotope administration

TABLE 27: Quality assurance tests for therapeutic radionuclides.

Designator	Test	Performance	
		Tolerance	Action
Commissioning			
CRI1	Check source calibrated	Certified	-
CRI2	Chamber calibrated (well-type or other)	2%	3%
CRI3	Linearity of system	5%	10%
Patient Specific			
PRI1	Isotope activity verified	5%	10%
PRI2	Isotope type verified	Correct	-
PRI3	Measure radiation exposure from patient	< 25 µSv/h for removal from isolation	
PRI4	Measure waste and discard if safe	< 6 µSv/h	-
PRI5	Measure linen and room, use normal if safe	< 6 µSv/h	-
PRI6	Records	Complete	-
Daily			
DRI1	Measurement system check	Functional	-
DRI2	Accuracy check	5%	10%
Quarterly			
QRI1	Records	Complete	-
Annually			
ARI1	Linearity of system	5%	10%
ARI2	Review emergency response procedures	Complete	-
ARI3	Independent quality control review	Complete	-
Biennially (Every 2 years)			
BIRI1	Calibrate check source	Certified	-

Notes: Please see full reference list of this article https://doi.org/10.4102/sajo.v9i0.329 for more information.

CRI1 Check source calibrated by accredited dosimetry institution.

CRI2 Source calibrator (well-type) chamber calibrated by accredited dosimetry institution.

CRI3 Test linearity of chamber, from low activity to high, in useful range of isotope activities.

PRI1 Measure activity of isotope prescribed to patient.

PRI2 Verify patient's name and prescribed isotope and activity on container.

PRI3 Measure radiation exposure form patient @ 1 m until < 25 µSv/h and safe for removal from isolation.

PRI4,5 Measure radioactive waste from patient room, discard per normal if surface dose < 6 µSv/h.

PRI6 Documentation relating to patient dose, patient discharge form isolation, waste, room safety. and linen must be complete, legible and the operator identified.

DRI1 Check that source chamber is functional and system undamaged.

DRI2 Check accuracy of measurement with check source.

QRI1 Documentation relating to the daily quality control checks, preventive maintenance, service calls and subsequent checks must be complete, legible and the operator identified.

ARI1 Test linearity of chamber, from low activity to high, in useful range of isotope activities.

ARI2 The configuration of these tests will depend on the design of the facility and staffing. Review of the emergency procedures with reference to when a patient vomits, become incontinent, or dies.

ARI3 To ensure redundancy and adequate monitoring, a second qualified medical physicist must independently verify the implementation, analysis and interpretation of the quality control tests at least annually.

BRI1 Check that source calibration certificate by accredited dosimetry institution is still valid and records available.

Record and verify systems

TABLE 28: Quality assurance tests for Record and Verify (R&V) systems.

Designator	Test	Performance	
		Tolerance	Action
Commissioning			
CRV1	Enter site details, assign user rights to users and groups	Documented	-
CRV2	Verification of treatment parameters	Correct	-
CRV3	Light field tests	Correct	-
CRV4	Imaging System	Correct	-
Patient Specific			
IPRV1	Verification of treatment parameters	Correct	-
IPRV2	Verification of dose recording	Correct	-
Weekly			
WRV1	Back-ups	Successful	-

Relevant references:[22]

Notes: Please see full reference list of this article https://doi.org/10.4102/sajo.v9i0.329 for more information.

CRV1 For safety purposes, assign appropriate user rights to individuals and staff groups.

CRV2 Export treatment plans to R&V system and to treatment system to check correct transport of treatment parameters. The minimum parameters to be checked should be monitor units, couch angle, gantry angle, collimator angle, position of X and Y jaws, energy, start and stop angles for arcs (if applicable).

CRV3 The light field test needs to be performed by sending fields/collimator files via an R&V system to the linac testing the complete treatment transfer chain. Test for conformal beam, conformal arc, dynamic conformal arc, IMRT beam. Test orientation.

CRV4 Check Imaging system corresponds to R&V System by simulating patient setup and images are saved back.

Patient-Specific tests should be performed at least at the first fraction, but ideally at every fraction

IPRV1 Verify treatment parameters, for example, monitor units, couch angle, gantry angle, collimator angle, position of X and Y jaws, energy, start and stop angles for arcs (if applicable) matches treatment plan.

IPRV2 Verify Total dose, dose/fractionation, number of fractions matches prescription and what has been treated.

WRV1 Independent back-ups of the patient database must be performed at least weekly.

Conventional radiotherapy simulators

TABLE 29: Quality assurance tests for radiotherapy simulators.

Designator	Test	Performance	
		Tolerance	Action
Daily			
DS1	Door interlock	Functional	-
DS2	Beam status indicators	Functional	-
DS3	Lasers/cross-wires	1 mm	2 mm
DS4	Optical distance indicator	1 mm	2 mm
DS5	Cross-wires/Reticle/Block tray	1 mm	2 mm
DS6	Field size indicators	1 mm	2 mm
Monthly			
MS1	Motion interlock	Functional	-
MS2	Emergency off buttons	Functional	-
MS3	Collision avoidance	Functional	-
MS4	Gantry angle readouts	0.5°	1°
MS5	Collimator angle readouts	0.5°	1°
MS6	Couch position readouts	1 mm	2 mm
MS7	Alignment of FAD movement	1 mm	2 mm
MS8	Couch isocentre	2 mm	3 mm
MS9	Couch parallelism	1 mm	2 mm
MS10	Couch angle	0.5°	1°
MS11	Laser/crosswire isocentricity	1 mm	2 mm
MS12	Optical distance indicator	1 mm	2 mm
MS13	Crosswire centring	1 mm	2 mm
MS14	Light/radiation coincidence	1 mm	2 mm
MS15	Field size indicators	1 mm	2 mm
MS16	Records	Complete	-
Annual			
AS1	Light/radiation coincidence versus Gantry angle	1 mm	2 mm
AS2	Field size indicators versus Gantry angle	1 mm	2 mm
AS3	Redefine isocentre	1 mm	2 mm
AS4	Couch deflection	3 mm	5 mm
AS5	Alignment of focal spots	0.5 mm	1 mm
AS6	Independent quality control review	Complete	-
Annual fluoroscopic and radiographic checks			
AS7	Lead apron	Functional	
AS8	kVp	5%	10%
AS9	Reference dosimetry	5%	10%
AS10	Beam quality (HVL)	5%	10%
AS11	Automatic exposure control	5%	10%
AS12	Focal spot	Reproducible	-
AS13	Contrast	Reproducible	-
AS14	Resolution	Reproducible	-
AS15	Fluoroscopic timer	5%	10%

Relevant references:[1,2]

Notes: Please see full reference list of this article https://doi.org/10.4102/sajo.v9i0.329 for more information.

DS1,2 The configuration of these tests will depend on the design of the facility and equipment. Safety is the concern and tests should be designed accordingly. As a minimum, the manufacturer's recommendations and applicable regulations must be followed.

DS3 Alignment of cross-wires and appropriate lasers for collimator angle 0°, gantry angles 0°, 90° and 270° at an SSD of 85 cm.

DS4 Gantry angle 0° and at isocentre.

DS5 Coincidence of cross-wires and/or reticle and/or block tray axes for collimator angle 0°, gantry angle 0° and SSD 85 cm.

DS6 The optical field defining wires for a 10 × 10 cm^2 field with gantry angle 0°, collimator angle 0° and SSD 100 cm should agree with the electronically indicated field borders.

MS1,2,3 The configuration of these tests will depend on the design of the facility and equipment. Safety is the concern, and tests should be designed accordingly. As a minimum, the manufacturer's recommendations and applicable regulations must be followed.

MS4 Mechanical and digital gantry angle readouts must be verified using a spirit level, or other appropriate levelling devices, for at least 0°, 90°, 180° and 270°.

MS5 Mechanical and digital collimator angle readouts must be verified using a spirit level, or other appropriate levelling devices, for at least 0°, 90° and 270°.

MS6 Mechanical and digital couch position readouts must be verified over an appropriate clinical range in the directions of the three cardinal axes.

MS7 Automatic setting of the Focus-Axis-Distance must be checked, if relevant, using mechanical devices.

MS8 The couch isocentricity must be checked over a range of couch angles from 90° to 270°.

MS9 With a couch angle 0°, couch motions must parallel the cardinal axes of the simulator geometry over an appropriate clinical range.

MS10 The couch rotation angle must be verified over an appropriate clinical range.

MS11 The radiation isocentre is established radiologically using the real-time imaging device. Alignment of the optical and mechanical systems at the isocentre is then confirmed for gantry angles of 0°, 90° and 270°.

MS12 A mechanical device, calibrated against the true radiation isocentre, is used to provide the base reading for the check of the optical distance indicator. The standards stated in the Table apply at the isocentre. The optical distance indicator should be checked over a clinically relevant range of SSD and gantry angle. The tolerance and action level may be twice as large (i.e. 2 mm and 4 mm) as the clinical limits of the optical distance indicator's range.

MS13 The coincidence of both the optical and radiological images of the cross-wires is measured with respect to the radiological isocentre at 100 cm SSD for collimator angles of 0°, 90° and 270°. Tolerances and Action Levels refer to the coincidence with the radiation isocentre.

MS14 Geometric alignment of the x-ray and optical images of the field-defining wires must be established over a range of clinically relevant field sizes at gantry angle 0°.

MS15 Compliance of the x-ray and optical images of the field-defining wires with the indicated dimensions must be established over a range of clinically relevant field sizes at gantry angle 0°.

MS16 Documentation relating to the daily quality control checks, preventive maintenance, service calls and subsequent checks must be complete, legible and the operator identified.

AS1 Geometric alignment of the x-ray and optical images of the field-defining wires must be established over a range of field sizes from 5 × 5 cm^2 to 35 × 35 cm^2 at gantry angles 0°, 90° and 270°. Representative half-blocked fields must be included. A minimum of six field sizes will be required for this test. Tolerances and Action Levels apply to each edge of a rectangular field.

AS2 Compliance of the x-ray and optical images of the field-defining wires with the indicated dimensions must be established over a range of field sizes from 5 × 5cm^2 to 35 × 35 cm^2 at gantry angles 0°, 90° and 270°. Representative half-blocked fields must be included. A minimum of six field sizes will be required for this test. Different field sizes may be examined at different gantry angles if appropriate and efficient. Tolerances and Action Levels apply to each edge of a rectangular field.

AS3 The mechanical, optical and radiation isocentre should be redefined and optical and mechanical systems re-aligned.

AS4 Couch deflection is measured with 70 kg at the end with the couch extended to the isocentre.

AS5 Typical exposure factors are used.

AS6 To ensure redundancy and adequate monitoring, a second qualified medical physicist must independently verify the implementation, analysis and interpretation of the quality control tests at least annually.

AS7 Any available lead aprons, gloves and other protective wear should be visually and radiologically inspected for cracks, and appropriate action taken should cracks be found.

AS8 kVp should be measured in at least three settings over the range from 60 to 120 kVp. When measured non-invasively, Tolerances and Action Levels refer to baseline values established at acceptance and referenced to invasive measurements.

AS9 Tolerance and Action Levels refer to the coefficient of variation of 10 measurements of relative exposure at a typical set of operating parameters. These tests should be performed with and without Automatic Exposure Control.

AS10 Half value layer is to be compared at three kVp values with the baseline values established at acceptance.

AS11 Where more than one detector can be used for Automatic Exposure Control, consistency between the exposures delivered should be established.

AS12,13,14 A variety of equipment is available for performing these tests. Generally, the tests are subjective, and the results are observer-dependent. Tolerances and Action Levels will need to be developed locally depending on the equipment available and the performance variability of the observers. Routine monitoring of these parameters should be based on performance at installation.

AS15 The limit on fluoroscopy time is verified.

Stereotactic radiosurgery/ radiotherapy – Gamma knife based

TABLE 30: Quality assurance tests for Gamma Knife units.

Designator	Test	Performance	
		Tolerance	Action
Daily			
DSG1	Door interlock/radiation on lights	Functional	-
DSG2	Audio and visual contact with the patient	Functional	-
DSG3	System Alarm test	Functional	-
DSG4	Machine interlocks (side protection bars, Docking device) and Mattress adjustment features function as specified.	Functional	-
DSG5	Frame/Mask adaptor docking and angle interlock	Functional	-
DSG6	Treatment initiate/timer terminate	Functional	-
DSG7	System status indicator on console	Functional	-
DSG8	Treatment pause and resume	Functional	-
DSG9	Imaging Quality Assessment	Variable1	-
DSG10	Dose rate on specified date	Correct	-
DSG11	TPS Treatment time Calculation (Independent check)	3%	5%
DSG12	Focus Precision Test	≤ 0.4 mm (Radial)	-
DSG13	CBCT Precision	≤ 0.4 mm	-
DSG14	HDMM system check	Functional	-
DSG15	Emergency Procedure	Posted	-
DSG16	Radiation Survey meter	Available and functional	-
DSG17	Relative Output Factors (ROFs)	Correct	-
Weekly			
-	If Daily quality assurance (QA) has not been performed within the last 7 days, perform all Daily QA tests.	-	-
Monthly			
MSG1	Extended alarm test	Functional	-
MSG2	UPS battery check	Functional	-
MSG3	Timer linearity	1%	2%
MSG4	Timer constancy	1%	3%
MSG5	Shutter correction/Timer Error	0.01 min.	0.02 min
MSG6	Timer accuracy	0.1%	0.2%
MSG7	Radiation output (Dose rate)	1.5%	2%
MSG8	Thermometer, barometer, ion chamber QA	SASQART standards	-
MSG9	Emergency stop and reset	Functional	-
MSG10	Couch out (Couch emergency release)	Functional	-
MSG11	Clearance test tool check	Functional	-
MSG12	CBCT Image quality:	-	-
	Spatial Resolution	> 6 lp/mm	-
	Contrast-to-noise ratio (CNR)	> 0.5 (low dose 2.5 mGy) > 0.8 (High dose 6.3 mGy)	-
	Image Uniformity	< 21%	-
MSG13	Documentation	Complete	-
Biannual			
BSG1	Sector Alignment	Specified by vendor	-
BSG2	RFP Location Accuracy	Specified by vendor	-
BSG3	Frame Integrity	Specified by vendor	-
BSG4	Wipe Tests [Beta/Gamma and Alpha]	0.4 Bq /cm^2 and 0.04 Bq/cm^2	-
Annually			
ASG1	Acceptance functional tests	Functional	-
ASG2	Calibration – IAEA TRS 398 and 483	1%	2%
ASG3	Dose profiles	1 mm at 50%	-
ASG4	Relative Output Factors	5%	7%
ASG5	Radiation/mechanical isocentre coincidence	0.5 mm	-
	Δx, Δy, Δz	< 0.3 mm	-
	Δr	< 0.4 mm	-
ASG6	End-to-end test	±5% (Point dose measurement)	-
	Distance to Agreement (DTA)	≤ 1.5 mm	≤ 3 mm
ASG7	CBCT dosimetry	±35% from nominal stated value	-
ASG8	Transit dose	3 cGy/shot (≤ 0.01 Gy)	(≤ 0.02 Gy) TG178
ASG9	Independent Quality Control Review	Complete	-

Table 30 continues →

TABLE 30 (Continues...): Quality assurance tests for Gamma Knife units.

Designator	Test	Performance	
		Tolerance	Action
Acceptance and commissioning			
CSG1	Relative Output Factors (ROFs)	±5% of value in TPS	±7% of value in TPS
CSG2	End – to End Test	±5% (Point dose measurement)	
	Distance to Agreement (DTA)	≤1.5 mm	≤3 mm
CSG3	Radiation Survey	Value within Regulatory requirements	-
CSG4	Confirmation of existence of all ^{60}Co sources	Performed by vendor and confirmed by MP.	-
Tests pertaining to TPS			
CSG5	Dose rate on specified date	Correct	-
CSG6	Treatment time calculation at representative points in spherical phantom	± 1% near centre; ±5% near periphery	±2% near centre; ± 10% near periphery
CSG7	Profiles	Full-width-at-Half-maximum (FWHM) within +/-1 mm of TPS value	Full-width-at-Half-maximum (FWHM) within ±1.2 mm of TPS value
CSG8	Electronic Transfer of treatment delivery parameters	Correct	-

Tolerances should reflect the dose being delivered and the eloquence of the treatment site.

Notes: Please see full reference list of this article https://doi.org/10.4102/sajo.v9i0.329 for more information.

DSG1,2	The configuration of these tests will depend on the design of the facility and equipment. Safety is the concern and tests should be designed accordingly. As a minimum, manufacturer's recommendations and applicable regulations must be followed.
DSG3	Perform test as described in the GK User Manual (GK® User Manual).
DSG4	Initiate conditions for the interlock to occur. Ensure that the treatment cannot commence when the interlock is active and ensure that mattress adjustment features function as specified by manufacturer.
DSG5	Ensure that the frame/mask adaptor is mounted correctly, and the relevant angle is indicated, ensure that selecting the incorrect angle generates an error message.
DSG6	When no interlocks are engaged the treatment starts; the treatment stops once the requested time has elapsed.
DSG7	The system status indicator on the computer monitor is correct.
DSG8	Perform Test function as described in the GK User Manual (GK® User Manual).
DSG9	Imaging quality assurance will vary between institutions. Ensure the appropriate images (Appropriate magnetic resonance imaging [MRI] sequences, CT and Angiograms) are used for treatment planning to ensure accurate delivery of treatment.
DSG10	Review the displayed decayed daily dose rate and confirm that it is correct.
DSG11	Check performed and signed by the physicist.
DSG12	Verify the radiological focus position in relation to the Leksell coordinates. Test is preloaded on machine, follow instructions in GK User Manual. Manufacturer requires that it be performed monthly so that the institution can assess and decide.
DSG13	To make sure that the CBCT precision is satisfactory. Test is available on the system and procedure available in the GK User manual. Required to be performed monthly but manufacturer recommends daily.
DSG14	Check the functionality of the HDMM system on days it will be in use.
DSG15	Ensure that details of emergency procedures are posted and easily available when needed.
DSG16	Ensure that a functional radiation survey meters are always available.
DSG17	Check that the values of the ROFs as stated on a sample treatment plan are correct.
MSG1	Verify that the mute button only silences the audible alarm for ~2 min.
MSG2	Perform the following tests: UPS test as described in the GK User Manual (GK® User Manual) for both office and medical UPS.
MSG3	Ensure that ion chamber measurements performed over the range of times expected during actual treatments vary linearly with treatment time.
MSG4	Ensure that successive ion chamber measurements for the same treatment time are reproducible.
MSG5	Ensure that the shutter correction does not exceed the stated tolerances. The control system of the Leksell Gamma Knife Icon compensates for the shutter dose in the planned shot position so that the delivered dose becomes correct.
MSG6	Check the timer accuracy for the range of treatment times in test MSG4 using a stopwatch, the physicist should use a timed run long enough to render the effects of human reflexes negligible. The manufacturer-stated accuracy of the Leksell Gamma Knife Perfexion and Icon timers is 0.2%. If the primary and secondary timers differ more than 0.1 min or 10% (whichever is reached first), the treatment is terminated. The system then compares the primary, secondary and a third backup timer. Refer to Table 2 for the error measured in dose.
MSG7	Ensure that the radiation output, corrected for decay agrees with the calibration value.
MSG8	Test the accuracy of the thermometer, barometer and ion chamber using established institutional procedures. Refer to SASQART standard for dosimetry equipment and quality assurance devices.
MSG9, 10	Test function of the Emergency Stop button and the Emergency Exit sequence as well as the couch release, as described in the GK User Manual. This test can be performed more often (e.g. bimonthly) at the discretion of the department and as per the manufacturer's recommendations.
MSG11	Verify the accuracy of the clearance test tool. Refer to GK user manual for instructions. Also, check after possible damage to the tool.
MSG12	Make sure the CBCT image quality is satisfactory. Refer to GK Manual for procedure and specifications.
MSG13	Documentation relating to the daily quality control checks, preventive maintenance, service calls and subsequent checks must be complete, legible and the operator identified.
BSG1	Vendor confirms that, within tolerances limits, each sector moves correctly to each sector position.
BSG2	Vendor confirms that the location of the RFP, with respect to the table position, is within specifications using measurements conducted in an off-centred position.
BSG3	Vendor checks all frames used clinically using a specifically designed tool.
BSG4	Performed on outer surface of the collimator cap and on the sector drive shafts for the PFX and Icon. Manufacturer specifies tolerances per measured component, for example, Beta/Gamma then Alpha component.
ASG1	Repeat all functional tests which are not performed during daily, weekly or monthly quality assurance.
ASG2	Calibrate the Gamma Knife.
ASG3	Measure the dose profiles using the procedure described in the GK User Manual as a guideline.
ASG4	Measure Relative Output factors with GAFchromic film or small field ionisation chamber.
ASG5	Measure the isocentre coincidence using the procedure described in the GK User Manual as a guideline.
ASG6	An end-to-end phantom test is performed including frame placement, imaging, treatment planning, treatment and verification that the intended treatment was delivered with the stated dose and positioning accuracy.
ASG7	Measure the Computed Tomography dose index (CTDI) for each CBCT preset to ensure it is within manufacturer specifications. Refer to the GK manual for procedure and specifications.
ASG8	Measure the transit dose for largest collimator.
ASG9	To ensure redundancy and adequate monitoring, a second qualified medical physicist must independently verify the implementation, analysis and interpretation of the quality control tests at least annually.
CSG1	Check that relative output factors are within specification of those in the TPS.
CSG2	An end-to-end phantom test must be performed to check positioning and dose delivery accuracy.
CSG3	Ensure Radiation survey results are within regulations specifications.
CSG4	Ensure that all sources are in existence.
CSG5	Review the displayed decayed dose rate and confirm that it is correct.
CSG6	Check the treatment time at different points within the spherical phantom.
CSG7	Irradiate and analyse films to confirm that dose profiles for all collimators agree with those calculated by the TPS.
CSG8	Check and confirm that values transferred from the TPS to the treatment unit are correct.

Stereotactic radiosurgery/ radiotherapy – Linac based

TABLE 31: Quality assurance tests for linac-based Stereotactic Radiosurgery/Stereotactic Radiotherapy.

Designator	Test	Performance	
		Tolerance	Action
Daily			
DSL1	Patient monitoring system	Functional	-
DSL2	SRS/SRT-specific machine interlocks	Functional	-
DSL3	IGRT matching and positioning accuracy	1 mm	1 mm
DSL4	Laser and optical isocentre alignment	1 mm	1 mm
Patient-Specific*			
PSL1	Collision/clearance tests	Functional	-
PSL2	Reference imaging and calculation parameter check	Appropriate	-
PSL3	Measurement/Independent MU calculation	3%/1 mm	5%/1.5 mm
PSL4**	Couch/Pedestal Locking	Functional	-
PSL5**	Field collimating device alignment (if applicable)	0.5 mm	1 mm
PSL6	Field shape check	Correct	-
PSL7	Head Frame motion (if applicable)	1 mm	1 mm
PSL8**	Gantry, couch, collimator radiation isocentre wobble (radius)	0.7 mm	1 mm
PSL9**	Average MV isocentre and IGRT axis coincidence	0.5 mm	1 mm
PSL10	Checklist/Records	Complete	-
Annually			
ASL1	Acceptance functional tests	Functional	-
ASL2	Percentage depth dose	1%	2%
ASL3	Dose profiles (FWHM)	1 mm	1 mm
ASL4	Output factors	2%	3%
ASL5	Gantry, couch, collimator radiation isocentre wobble (radius)	0.7 mm	1.0 mm
ASL6	Gantry, couch, collimator radiation, laser and IGRT isocentre axis coincidence	0.5 mm	1.0 mm
ASL7	End-to-end test	3%/1 mm	5%/1.5 mm
ASL8	CT localisation performance	0.5 mm	1.0 mm
ASL9	MRI localisation performance	1.0 mm	2.0 mm
ASL10	Angiography localisation performance	1 mm	1 mm

SRS, Stereotactic Radiosurgery; SRT, Stereotactic Radiotherapy; IGRT, Image-guided Radiation Therapy; CT, Computed Tomography; MRI, Magnetic Resonance Imaging.

Relevant references:[23,24,25,26,27]

Notes: Please see full reference list of this article https://doi.org/10.4102/sajo.v9i0.329 for more information.

In this document, SRS is used to describe single-fraction–high-dose–high-precision techniques and SRT as a collective substitute for all fractionated high-dose–high-precision techniques (≥ 5 Gy/fraction and ≤ 5 fractions) for both intracranial and extra-cranial stereotactic treatments.

It is assumed in this document that SRS and SRT programmes have IGRT modalities available, as sole laser/localiser-based positioning methods are no longer considered acceptable standards of care. Additionally, SGRT modalities alone are insufficient for SRS/SRT and need to be used in conjunction with internal IGRT modalities.

*Patient-specific tests are to be carried out for every SRS and SRT patient subject to the notes below:

For SRS, all patient-specific tests need to be performed before the fraction. For SRT, tests PSL4, PSL5 and PSL7 are before every fraction; tests PSL1, PSL2 and PSL3 before the first fraction and tests PSL6, PSL8, PSL9 and PSL10 on a weekly basis. PSL10 can be reduced to only the first fraction if a record and verify system is used for dose delivery and tracking.

**Denotes patient-specific tests that can be carried out once on the day of treatment if treating more than one patient per day provided that the SRS apparatus is not moved/removed between patients.

Daily tests are only required on days when SRS is performed

DSL1 The camera and audio intercom system must be functional. This is to ensure that the patient can be seen and heard at all times.

DSL2 Test the functioning of machine interlocks that are affected by the SRS delivery (e.g. interlock that stops irradiation at the end of an arc or if an add-on is not properly attached).

DSL3 Acquire online images of a phantom with known offsets using the standard acquisition process. Verify that the couch corrections are calculated and applied correctly. For IGRT systems with recorded stability, this test can be performed weekly.

DSL4 A common method of checking laser alignment to the linac isocentre at different gantry angles is using an imaging phantom, a Winston-Lutz pointer or the projection onto the cross-hairs. For laser systems with recorded stability, this test can be performed weekly. For frameless-based treatments the laser system is the first tool to align the target at isocentre position. Fine-tuning of that position will be performed with online imaging. Although optimal alignment of the laser system seems less relevant, realise that the laser system is probably used as the base for calibrating the imaging system.

PSL1 Test that all gantry/couch motions to be activated remotely can actually occur without colliding with the patient. This is particularly of concern with Cones and micro-MLC systems and static fields where some planned fields may result in patient collisions.

PSL2 Ensure that imaging parameters (such as imaging modality and slice thickness) are appropriate to the site being treated. Calculation grid size and imaging slice thickness ≤ 2 mm are recommended.

PSL3 Check performed and signed by physicist. A gamma analysis is recommended with a pass rate ≥ 95% with the %DD and DTA tolerance and action levels mentioned. Deviations of 3% or less are usually achievable with secondary MU check programmes, but up to 5% dose difference is acceptable if checked with manual calculations and measurements (to include equipment and setup uncertainties).

For IMRT and VMAT-based SRS/SRT/SBRT a relative dose measurement and an independent MU check must be performed as per SASQART IMRT/VMAT. An absolute calibrated dose measurement must be performed if an independent MU check is not available as per SASQART IMRT/VMAT.

PSL4 This is a functional test to ensure that any locking mechanisms on the couch or pedestal mount are working properly to prevent unwanted couch translations during patient treatment.

PSL5 Relevant if the cone or micro-MLC position is not fixed with respect to the collimator axis. Can be performed using film at opposing angles, for example.

PSL6 This test is intended for field shapes that are defined by add-on systems, such as custom blocks or mMLC. The test can be performed by checking projections against a printout of field projections from the treatment planning system at a given distance or the digital MLC projection on the treatment console.

PSL7 Head frame motion can be assessed using a depth helmet that measures SSD at different entry points and compares to CT-determined SSDs or SSDs previously measured using the depth helmet. Other methods can also be found in the literature or may be suggested by the vendor. This test is not applicable in SRT provided a suitable PTV margin (> tolerance) is being used in the treatment planning process. It can also be omitted for SRS if it is determined during commissioning that head frame slippage is well below the suggested tolerance for the given frame.

PSL8–9	The optimal radiation isocentres of the gantry, collimator and couch should be within a 1 mm radius of each other; according to relevant patient-specific treatment beam angles. The most common method of checking alignment to the radiation isocentre at different gantry, couch and collimator angles is that suggested by Winston and Lutz (1998); the use of modern phantoms and analysis software which contain multiple radiographic markers and advanced off-axis results are acceptable. See also ASL5 and ASL6. The tolerance suggested is from manufacturer installation values – if these tolerances are not achievable by the routine QA equipment, then the use of additional PTV margins needs to be discussed with the treating physicians. Verify that the IGRT isocentre coincides with the radiation isocentre. If long-term stability of the imaging and treatment isocentres cannot be assured, a quick check protocol should be in place to assure the accuracy just before treatment.
PSL10	All results of the QA procedures and appropriate signatures of checks and tasks completed should be included in the patient's documentation.
ASL1	Repeat all functional acceptance tests which are not performed during daily quality assurance.
ASL2	PDD measured using a suitable detector for a representative small-field (cones or standard micro-MLC sizes).
ASL3	Dose profiles measured with a suitable small detector and compared to TPS baseline data. Tolerance and action levels refer to the difference in width of the 50% isodose line (where central axis = 100%).
ASL4	Factors relating output for a given cone size or micro-MLC field with a reference field size (e.g. 10×10 cm^2). Compared with values in the TPS. Special care and consideration need to be taken for small-field dosimetry used in SRS and SRT ($< 4 \times 4$ cm^2).
ASL5	The radiation isocentre centroid* test for all three motions (collimator, couch, gantry), within a sphere of radius ≤ 1 mm. *The smallest sphere through which the central ray of the radiation beam runs. Generally performed with a Winston-Lutz test, but film spoke-shots and phantoms with multiple radiographic markers may also be used.
ASL6	A complete set of isocentre coincidence tests including radiation isocentre and laser coincidence for all three motions (collimator, couch, gantry). For example, the completion of Winston-Lutz isocentre testing will result in the steel ball being accurately aligned to the linac MV isocentre. This ball alignment allows a convenient opportunity to verify the alignment of the IGRT isocentre compared to the MV isocentre.
ASL7	Can be assessed by CT scanning a known small target object, planning a treatment and verifying that the coordinates determined correspond to the target. Subsequently, use the IGRT system to position the phantom with the internal object at isocentre and image those markers with the MV beam. Compare the expected position and shifts with the actual position and shifts. The plan is delivered and the resulting measurement is compared with the predicted value. The phantom and dose detection system should have a high spatial resolution and a high accuracy in dose detection in the high-dose region. The phantom used should be comprehensive as different inserts may be required for scanning on different imaging devices (MRI, CT) to investigate the data transfer process and the geometric distortions from the imaging system. Investigate the dose distribution around target and critical regions. Secondly, investigate the absolute dose delivery.
ASL8	The CT scanner used for imaging should allow for exact localisation through well-defined anatomical landmarks. Use the TPS measurement tools to ensure the known landmarks in the phantom are of the correct shape, dimension and position and no distortion has occurred. This can be performed during ASL 7.
ASL9	Similar to ASL8 but for MRI. If MRI is used through an image fusion process only (no fiducials on the MRI) for clinical cases, then in addition to this annual test, MRI fusion must be evaluated and approved by the physician on a per-patient basis.
ASL10	Similar to ASL9 but for angiography.

Treatment planning systems

TABLE 32: Quality assurance tests for TPS.

Designator	Test	Performance	
		Tolerance	Action
Patient-specific			
PTPS1	Patient-related data	Data verified	-
PTPS2	Beam geometry	Data verified	-
PTPS3	Dose distribution	Data verified	-
PTPS4	MU/time per beam	2 MU/2%	3 MU/3%
PTPS5	Plan data transfer	Data verified	
Weekly			
WTPS1	Back-ups	Successful	-
Quarterly			
QTPS1	Digitiser (if used clinically)	2 mm	3 mm
QTPS2	Electronic plan transfer	Data verified	-
QTPS3	Plan details	Data verified	-
QTPS4	Plotter/Printer (if used clinically)	2 mm	3 mm
Semi-Annual (Every 6 months)			
STPS1	CT geometry/density	2 mm/0.02 RED	3 mm/0.03 RED
Annual			
ATPS1	Revalidation	2%	3%
Commissioning and Validation after major upgrades			
UTPS1	End-to-end	2%	3%
CTPS1	Independent quality control review	Complete	-

Notes: Please see full reference list of this article https://doi.org/10.4102/sajo.v9i0.329 for more information.

PTPS1 Anatomical and contour data are current and for the correct patient; correct orientation; target and organ at risk (OAR) contours look reasonable; appropriate couch/immobilisation device contours included and densities applied.

PTPS2 Wedges correctly oriented; compensators and bolus included as appropriate; tertiary blocking/MLC correctly oriented; plan normalisation point in an appropriate position, intended fractionation applied.

PTPS3 Dose distribution looks reasonable for the beam geometry; beam configuration achievable; plan objectives and constraints met as closely as possible. Clearly the plan has to be consistent with the prescription and receive documented approval by the Radiation Oncologist.

PTPS4 Independent check of MU or time per beam either manually or by an independent computer programme. Local tolerance and action levels may need to be developed for complex geometries such as IMRT, thoracic and tangential breast irradiation.

PTPS5 Prior to the first treatment, the treatment machine settings must be compared with those used to generate the dose distribution.

WTPS1 Independent back-ups of the patient database must be performed at least weekly.

QTPS1 Using the on-screen ruler check that a known contour has been digitised accurately.

QTPS2 Using a standard set of at least three clinical plans covering a range of treatment configurations (e.g. photons, electrons, brachytherapy), confirm that the data are accurately transferred from the TPS to the therapy machine.

QTPS3 Using a standard set of at least three clinical plans covering a range of treatment configurations, confirm that the data are accurately transferred from the TPS to hard copy or digital copy for paperless environments.

QTPS4 Check the dimensions on the printout against the input contour and previous plots.

STPS1 Check that the CT geometry and the relationship between CT number and density have not changed. Alternate between scan protocols every 6 months. Tolerances and Action Levels are specified in mm/relative electron density.

ATPS1 Check the constancy of dose calculations using a standard set of at least four clinical plans covering a range of treatment configurations and geometries to include the most extreme scenarios likely to be encountered clinically. As part of the constancy check, the repeatability of the calculated dose-volume histogram (DVH) shall be reviewed, as well as MU/time per field, maximum dose and dose to isocentre.

UTPS1 Perform end-to-end tests including dosimetric verification to ensure that the entire treatment chain (including the connectivity with other systems and CT transfer protocols) still functions as it should. Make sure that the clinical workflow is followed and use dummy patients representing typical clinical cases. Alternate between the different techniques available in your clinic for every run of this test. If no or only minor changes were made to the dose calculation, DICOM export and optimisation/segmentation algorithms, the dosimetric verifications can be limited to a few cases. Tests should include, but are not limited to, those specified in QTPS1–4, STPS1 and ATPS1. Evaluation is performed by comparing the results in the current clinical version of the TPS and in the version to be installed.

CTPS1 To ensure redundancy and adequate monitoring, a second qualified medical physicist must independently verify the implementation, analysis and interpretation of the quality control tests.

Treatment planning system auxiliary equipment

TABLE 33: Quality assurance tests for auxiliary Treatment Planning System (TPS) equipment.

Designator	Test	Performance	
		Tolerance	Action
Printers/Plotters			
Commissioning			
CAUP1	Patient Image Reproducibility (Scaling 1:1)	Correct	2 mm
CAUP2	Patient Image Reproducibility (Scaling 1:2)	Correct	3 mm
CAUP3	Patient Image Reproducibility (Scaling 2:1)	Correct	3 mm
CAUP4	Image Orientation	Correct	-
CAUP5	Beam Modifiers Reproducibility	Correct	2 mm
Daily			
DAUP1	Output	Functional	-
Annually			
AAUP1	Reproducibility (Scaling 1:1)	Correct	2 mm
AAUP2	Reproducibility (Scaling 1:2)	Correct	3 mm
AAUP3	Reproducibility (Scaling 2:1)	Correct	3 mm
AAUP4	Image Orientation	Correct	
AAUP5	Beam Modifiers Reproducibility	Correct	2 mm
Light Tables/Digitiser			
Commissioning			
CAUD1	Reproducibility (Scaling 1:1)	Correct	2 mm
CAUD2	Reproducibility (Scaling 1:2)	Correct	3 mm
CAUD3	Reproducibility (Scaling 2:1)	Correct	3 mm
CAUD4	Image Orientation	Correct	-
Annually			
AAUD1	Reproducibility (Scaling 1:1)	Correct	2 mm
AAUD2	Reproducibility (Scaling 1:2)	Correct	3 mm
AAUD3	Reproducibility (Scaling 2:1)	Correct	3 mm
AAUD4	Image Orientation	Correct	

Notes: Please see full reference list of this article https://doi.org/10.4102/sajo.v9i0.329 for more information.

C/AAUP1–3 Print a known phantom size on the specific scaling and measure printout.

C/AAUP4 Image orientation markers placed correctly on output.

C/AAUP5 Beam modifiers scaled correctly (MLC beams-eye view (BEV) or Cut-outs as utilised).

C/AAUL1–3 Digitise a known phantom size on the specific scaling and measure input.

C/AAUL4 Image orientation markers placed correctly on input.

Bore based medical linear accelerators (such as halcyon, tomotherapy and MRI-linacs)

TABLE 34: Quality assurance tests for bore-based linacs.

Designator	Test	Performance	
		Tolerance	Action
Daily			
DL1	Door interlock/last person out	Functional	-
DL2	Beam status indicators	Functional	-
DL3	Patient audio-visual monitors	Functional	-
DL4	Motion interlock	Functional	-
DL5	Couch brakes	Functional	-
DL6	Room radiation monitors (where available)	Functional	-
DL7	Beam interrupt/counters	Functional	-
DL8	Output constancy – photons	2.00%	3.00%
DL9	Imaging and treatment isocentre coincidence	< 1 mm	< 2 mm
DL10	Collision interlock – bore	Functional	-
Monthly			
ML1	Lasers and isocentre coincidence	1 mm	2 mm
ML2	Couch position readouts	1 mm	2 mm
ML3	Beam (un)flatness/off-axis-intensity	Manufacturer's specification	
ML4	Beam symmetry	2.00%	3.00%
ML5	Reference dosimetry – TRS398	1.00%	2.00%
ML6	MLC (if applicable)	-	-
ML7	MV and kV planar imaging (if applicable)	-	-
ML8	CBCT (if applicable)	-	-
ML9	Records	Complete	-
Quarterly			
QL1	Emergency off	Functional	-
QL2	Beam quality/energy	2.00%	3.00%
Annually			
AL1	Relative output factor reproducibility	1.00%	2.00%
AL2	Output reproducibility versus gantry angle	1.00%	2.00%
AL3	Output reproducibility versus dose rate	1.00%	2.00%
AL4	Beam symmetry versus gantry angle	2.00%	3.00%
	or	or	or
	Off-axis intensity versus gantry angle	1.00%	2.00%
AL5	Monitor chamber linearity	1.00%	2.00%
AL6	End monitor effect	0.1 MU	0.2 MU
AL7	Collimator rotation isocentre	1 mm	2 mm
AL8	Gantry rotation isocentre	1 mm	2 mm
AL9	Coincidence of collimator and gantry axes	1 mm	2 mm
AL10	MLC (if applicable)	-	-
AL11	MV and kV planar imaging (if applicable)	-	-
AL12	CBCT (if applicable)	-	-
AL13	Independent quality control review	Complete	-

Notes: Please see full reference list of this article https://doi.org/10.4102/sajo.v9i0.329 for more information.

DL1–7 The configuration of these tests will depend on the design of the facility and equipment. Safety is the concern and tests should be designed accordingly. As a minimum, manufacturer's recommendations and applicable regulations must be followed.

DL8 All energies in use on the particular treatment day. Standard local reference and measuring device.

DL9 Imaging using a known phantom and geometry, matching using provided tools to give results of known translations or deviation from isocentre.

DL10 When activated the interlock for collision with the bore prevents any further motions.

ML1 Alignment of lasers for collimator angle 0°, gantry angles 0°, 90° and 270° at isocentre. A phantom can be imaged to determine the correct position of lasers.

ML2 Couch position readouts must be verified over an appropriate clinical range in the directions of the three cardinal axes.

ML3–4 (Un)flatness and symmetry are compared with those measured at acceptance. A single, convenient gantry angle may be chosen.

ML5 A full TRS-398 calibration is performed using a local primary standard. The output of all available beams is then measured using the local secondary standard, to provide a reference for daily readings.

ML6 Varied MLC tests according to MLC SASQART including accuracy of leaf position; travel leaf speed and shape setting versus radiation field. Certain test, like light-rad coincidence, might not be applicable.

ML7 Varied testing according to EPID SASQART and IGRT SASQART including image and treatment coordinate coincidence; scaling; contrast; uniformity and noise. Certain tests, like panel positioning, might not be applicable.

ML8 Varied testing according to IGRT SASQART including geometric distortion; spatial resolution; contract; HU constancy; uniformity and noise.

ML9 Updated documentation relating to the daily/monthly/quarterly quality control checks, preventive maintenance, service calls and subsequent checks must be complete, legible and the operator identified.

QL1 Proper functioning of the emergency stop buttons, indicators and emergency circuits. Alternate between the available buttons. This must be documented.

QL2 Verification of the beam quality and its deviation from TPS baseline values.

AL1 These tests confirm that essential parameters used for treatment time calculations have not changed.

AL2–3 An ion chamber with build-up cap may be used in air for these measurements. A rotational detector or ionisation in a geometrically uniform phantom may be used. The detector may be positioned at the isocentre or may be mounted on the head of the unit. In the latter case, effects because of head sag will not be observed.

AL4 Beam profiles at other gantry angles (e.g. 90° and 270°) should be comparable to those at gantry 0°.

AL5–6 From a series of radiation measurements with different monitor units the linearity and the end monitor effect are determined.

AL7–8 Using film, star or spoke patterns are produced and the two radiation axes of rotation are determined. Tolerances and Action Levels refer to the diameters so measured.

AL9 By referencing the films in AL7–8 above and the laser system, or using a phantom with an imbedded radio-opaque marker, the relative locations of the axes of rotation at the isocentre may be determined.

AL10 Varied annual MLC tests according to MLC SASQART including accuracy of leaf position; travel leaf speed and shape setting versus radiation field.

AL11 Varied annual testing according to EPID SASQART and IGRT SASQART including image and treatment coordinate coincidence; scaling; contrast; uniformity and noise.

AL12 Varied annual testing according to IGRT SASQART including geometric distortion; spatial resolution; contract; HU constancy; uniformity and noise.

AL13 To ensure redundancy and adequate monitoring, a second qualified medical physicist must independently verify the implementation, analysis and interpretation of the quality control tests at least annually.

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Competing interests

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Authors' contributions

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References

1. Institute of Physics and Engineering in Medicine. Physics aspects of quality control in radiotherapy. York: Institute of Physics and Engineering in Medicine; 1999.
2. American Association of Physicists in Medicine. Report 46: Comprehensive QA for radiation oncology. Med Phys. 1994;21(4):581–618.
3. Canadian Partnership for Quality Radiotherapy. Technical quality control guidelines for computed tomography simulators. Québec: CPQR; 2017.
4. American Association of Physicists in Medicine. TG-66: Quality assurance for computed-tomography simulators and the computed tomography-simulation process. Med Phys. 2003;30(10):2762–2792.
5. American Association of Physicists in Medicine. TG-233: Performance evaluation of computed tomography systems. Alexandria: American Association of Physicists in Medicine; 2019.
6. American College of Radiology. Computed tomogrpahy quality control manual. Reston: American College of Radiology; 2017.
7. International Atomic Energy Agency. HHS-19: Quality assurance programme for computed tomography: Diagnostic and therapy applications. Vienna: International Atomic Energy Agency; 2012.
8. South African Health Products Regulatory Authority. Guidelines on requirements for licence holders with respect to quality control tests for diagnostic X-ray imaging systems. Johannesburg: South African Health Products Regulatory Authority; 2022.
9. American Association of Physicists in Medicine. TG-142 report: Quality assurance of medical accelerators. Med Phys. 2009;36:4197–4212.
10. American Association of Physicists in Medicine. TG-179: Quality assurance for image-guided radiation therapy utilizing CT-based technologies. Med Phys. 2012;39(4):1946–1963.
11. American Association of Physicists in Medicine. AAPM medical physics practice guideline 2.a: Commissioning and quality assurance of X-ray–based image-guided radiotherapy systems. J Appl Clin Med Phys. 2014;15(1):3–13.
12. Canadian Partnership for Quality Radiotherapy. Technical quality control guidelines for accelerator-integrated cone-beam systems for verification imaging. Toronto: Canadian Partnership for Quality Radiotherapy; 2015.
13. American College of Radiology – American Society for Radiation Oncology. ACR–ASTRO practice parameter for image-guided radiation therapy (IGRT). Am J Clin Oncol. 2020;43(7):459–468. https://doi.org/10.1097/COC.0000000000000697
14. Nederlandse Commissie Voor Stralingsdosimetrie. Report 32: Quality assurance of cone-beam CT for radiotherapy. Delft: NCS; 2019.
15. Van Esch A, Huyskens DP, Behrens CF, et al. Implementing RapidArc into clinical routine: A comprehensive program from machine QA to TPS validation and patient QA. Med Phys. 2011;38(9):5146–5166.
16. Bedford JL, Warrington AP. Commissioning of volumetric modulated Arc therapy (VMAT). Int J Radiat Oncol Biol Phys. 2009;73(2):537–545. https://doi.org/10.1016/j.ijrobp.2008.08.055
17. American Association of Physicists in Medicine. TG 218: Tolerance limits and methodologies for IMRT measurement-based verification QA. Med Phys. 2018;45(4):e53–e83.
18. Boonzaier WP. A multi-institutional quantitative survey of multi-leaf collimator accuracy using a digital picket fence test with sub-millimeter detection capabilities. Stellenbosch: Stellenbosch University; 2022.
19. NCRP. Report 147: Structual shielding design for medical X-ray imaging facilities. Bethesda: NCRP; 2004.
20. NCRP. Report 151: Structural shielding design and evaluation for megavoltage X- and gamma-ray radiotherapy facilities. 2005.
21. South African Health Products Regulatory Authority. Guidelines for users of electronic therapeutic devices emitting ionizing radiation. Pretoria: SAHPRA; 2023.
22. American Association of Physicists in Medicine. TG 275: Strategies for effective physics plan and chart review in radiation therapy. Med Phys. 2020;47(6):e236–e272.
23. Mack A, Mack G, Scheib S, et al. Quality assurance in stereotactic radiosurgery/radiotherapy according to DIN 6875-1. Stereotactic Funct Neurosurg. 2005;82:235–243. https://doi.org/10.1159/000083175
24. Canadian Association of Provincial Cancer Agencies. Stereotactic radiosurgery/radiotherapy – Standards for quality control at Canadian Radiation Treatment Centres. Toronto: CAPCA; 2006.
25. Benedict SH, Yenice KM, Followill D, et al. Stereotactic body radiation therapy: The report of AAPM Task Group 101. Med Phys. 2010;37(8):4078–4101.
26. Klein EE, Hanley J, Baymouth J, et al. Task Group 142 report: Quality assurance of medical accelerators. Med Phys. 2009;36(9):4197–4212.
27. Netherlands Commission on Radiation Dosimetry. Process management and quality assurance for intracranial stereotactic treatment: Report 25. Delft: NCS; 2015.