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ACPSEM guideline: recommendations for a fluoroscopic system quality assurance program

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Abstract

Fluoroscopic systems are increasingly used for complex image-guided procedures across medical disciplines in Australia and New Zealand. The associated radiation exposure risks to patients and staff necessitate robust quality assurance (QA) programs. However, no national guidance has previously existed for a standardised fluoroscopy QA program in the Australia and New Zealand context. To provide evidence-informed recommendations for the quality assurance of fluoroscopic systems in Australia and New Zealand, addressing the absence of national standards and supporting consistent, high-quality clinical practice. This guideline was developed by the ACPSEM Fluoroscopy QA Working Group, established in February 2019 by the ACPSEM Radiology Specialty Group. Recommendations were informed by an expert-driven review of international standards and protocols, including those from the AAPM, IAEA, EFOMP, and IEC, adapted for Australia and New Zealand practice through working-group discussions and reviews. The draft guideline underwent stakeholder consultation, including circulation to ACPSEM members and relevant professional organisations. The guideline outlines recommended QA tests for medical physicists at acceptance, commissioning, and periodic intervals, along with routine quality control procedures for radiographers. Key areas include radiation dose output assessment, automatic dose rate control verification, image quality evaluation, personal protective equipment integrity testing, and clinical dose audits. A quality review meeting framework is also provided. This guideline establishes a nationally consistent framework for fluoroscopy QA that complements local regulatory requirements. Its adoption will support patient safety, staff radiation protection, and optimal equipment performance across healthcare facilities in Australia and New Zealand.

Keywords ACPSEM · Fluoroscopy · Quality assurance · Quality control · Digital imaging · C-arm

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Abbreviations

AAPM	American association of physicists in medicine
ACPSEM	Australasian college of physical scientists and engineers in medicine
ADRC	Automatic dose rate control
AK_{ref}	Reference air kerma
ALARA	As low as reasonably achievable
ARPANSA	Australian radiation protection and nuclear safety agency
ASMIRT	Australian society of medical imaging and radiation therapy
CAK_{ref}	Cumulative reference air kerma
CBCT	Cone beam computed tomography
CNR	Contrast-to-noise ratio
CoV	Coefficient of variation
CR	Computed radiography
CT	Computed tomography
Cu	Copper
DAP	Dose area product
del	Detector element
DIASAC	Diagnostic imaging accreditation scheme advisory committee
DICOM	Digital imaging and communications in medicine
DRL	Diagnostic reference level
DSA	Digital subtraction angiography
EFOMP	European federation of organisations for medical physics
ESTRO	European society for radiotherapy and oncology
FOV	Field of view
FRL	Facility reference level
FSD	Focus-to-skin distance
FWHM	Full width at half maximum
GRADE	Grading of recommendations assessment, development and evaluation
HCR	High contrast resolution
HU	Hounsfield units
HVL	Half-value layer
IAEA	International atomic energy agency
ICRP	International commission on radiological protection
IEC	International electrotechnical commission
IQ	Image quality
KAP	Kerma area product
MTF	Modulation transfer function
NEMA	National electrical manufacturers association
NHMRC	National health and medical research council
PACS	Picture archiving and communication system
PMMA	Polymethylmethacrylate
PPE	Personal protective equipment
PSD	Peak skin dose
QA	Quality assurance
QC	Quality control
QMPS	Qualified medical physics specialist
RANZCR	Royal Australian and New Zealand college of radiologists
RDSR	Radiation dose structured report
ROI	Region of interest
SID	Source-to-image distance
SNR	Signal-to-noise ratio

Introduction

Background

Fluoroscopic systems are X-ray units capable of real-time imaging and are traditionally found in fixed fluoroscopy rooms, angiography/interventional suites, and catheterisation laboratories. Due to the expansion of the modality across various medical disciplines, mobile fluoroscopic systems have continued to see increased use in operating theatres and other surgical locations [1]. Additionally, advances in medicine have enabled more complex procedures to be performed under the guidance of fluoroscopic imaging. This has consequently increased the radiation dose burden on patients and staff from these systems. The risks of radiation exposure in this setting, particularly during complex procedures, are well-documented [2]. Routine quality control (QC) testing is essential for evaluating equipment safety and performance. It supports the optimisation of radiation exposure by ensuring equipment stability, maintaining image quality (IQ), and reducing radiation dose to patients and staff [3]. A comprehensive quality assurance (QA) program for fluoroscopic systems spans the entire equipment lifecycle. This includes procurement, acceptance testing, commissioning, routine facility-based QC procedures, manufacturer-specified preventive maintenance, and regulatory radiation safety testing.

No national guidance exists for a standardised QA program for fluoroscopic systems in Australia or New Zealand. Thus, the Australasian College of Physical Scientists and Engineers in Medicine (ACPSEM) tasked the Fluoroscopy QA working group with establishing recommendations for a QA program relevant to Australian and New Zealand practice. National and international QA programs, as well as local experience, have informed the advice in this guideline [4–7]. This document does not intend to replace local regulatory requirements but to detail a professionally considered approach to equipment QA. Therefore, the tests listed in this guideline should be used in conjunction with local

regulatory requirements to monitor equipment performance, safety, and compliance throughout a system's lifespan.

The development of nationally consistent QA guidance for fluoroscopy is of strategic importance to the ACPSEM and the medical physics profession. Without standardised recommendations, variability in QA practices across facilities may compromise patient safety and equipment performance. This guideline addresses this gap by providing a structured framework that supports consistent, high-quality QA practice across Australia and New Zealand.

Scope of this document

This guideline recommends a QA program for fluoroscopic systems within Australia and New Zealand. Although it outlines a comprehensive QA framework, implementation should be context sensitive. The program must be established, maintained, and regularly reviewed by a multidisciplinary team comprising radiological medical practitioners, operators, and service engineers, with appropriate oversight from a Qualified Medical Physics Specialist (QMPS).

While key QA tests are identified, flexibility in their frequency is essential. Implementation should be tailored to local factors such as clinical use, system age, and the scope of preventive maintenance contracts. This adaptability is a core responsibility of the multidisciplinary team, ensuring the QA program remains both practical and effective.

The document focuses on guiding QA activities that help maintain optimal equipment performance following installation. As noted, regulatory radiation safety testing is not covered; readers should consult their respective regulatory authorities for those requirements.

This document does not address tests conducted in radiographic mode. Where a system offers a true radiographic mode, the reader should refer to the ACPSEM Recommendations for a General X-ray Quality Assurance Program [7]. Similarly, although this guideline does not comprehensively address cone-beam computed tomography (CBCT) performed with rotational fluoroscopy, it includes limited guidance. Additional details may be found in the literature, including the EFOMP-ESTRO-IAEA protocol on CBCT quality control [8] and the American Association of Physicists in Medicine (AAPM) Task Group Report 261 [9].

This guideline provides:

- A summary of the roles and responsibilities of the medical physicist in fluoroscopic QA.
- Recommendations for performance evaluation of digital fluoroscopic imaging systems:
  - Performed by a medical physicist at acceptance/commissioning or equipment upgrade,
  - Routinely performed by a medical physicist, and
  - Routinely performed by a radiographer or other facility staff.

The role of the medical physicist

A Qualified Medical Physics Specialist (QMPS) is a medical physicist listed on the ACPSEM professional register with expertise in Radiological Physics. Although an unregistered medical physicist may conduct tests, the QMPS oversees the QA program for fluoroscopic systems, which involves a multidisciplinary team [10]. This may include defining the QA program, training, and reviewing results from tasks performed by other staff, such as unregistered medical physicists, medical physics registrars, trainees, and radiographers. The involvement of non-QMPS staff will vary depending on local resources and regional regulatory differences.

The primary role of the QMPS within this multidisciplinary team is to ensure the safe use of radiation whilst maintaining optimal equipment performance. It is the position of the ACPSEM that to fulfil this role, the QMPS must have the following responsibilities within the QA program:

- Provide expert technical advice concerning equipment procurement, radiation safety, system performance and how it relates to clinical practice.
- Conduct acceptance tests and commission new equipment to confirm that the system is fit for clinical use and establish appropriate QC baselines.
- Confirm that all local regulatory radiation safety requirements are satisfied.
- Establish requirements of routine QC performance testing.
- Oversee and review facility QC procedures.
- Provide recommendations that may improve radiation dose optimisation, clinical IQ and guide improvements in clinical practice.
- Maintain records of data collection for analysis and review.

The term "medical physicist" is used throughout this guideline to indicate the role of a QMPS, except where the specific status of QMPS registration is being emphasised.

Terminology

This guideline uses the following two-tier classification to categorise the components of the QA program:

- Recommended: Tests that should be performed at the specified frequency as core components of the QA

program. These tests are considered essential for maintaining equipment performance and patient safety within this framework.
- Optional: Tests that serve primarily as troubleshooting tools or are applicable under specific clinical or system circumstances. These tests should be performed as needed, at the discretion of the medical physicist, based on the objectives of the QA program, clinical context, and observed system performance.

The frequency of recommended tests may be adjusted under the guidance of a medical physicist based on local requirements, system age, clinical use patterns, and observed performance variability over the system's lifetime. Tables 5 and 6 (Appendix) indicate the classification of each test.

Table 1 lists the recommended components of a fluoroscopic QA program, including testing frequency and the person responsible for performing the test. For this document, Facility Staff will be referred to as Radiographers. This designation does not preclude other appropriately trained and licensed personnel from conducting a subset of these tests, provided they are working within their scope of practice and under the supervision of a qualified professional.

Methodology

Working group composition

The Fluoroscopy Quality Assurance Working Group was established in February 2019 by the ACPSEM Radiology Specialty Group to develop recommendations for a quality assurance program for fluoroscopy and angiography systems. The working group comprised members with expertise spanning diagnostic radiology and medical physics, drawn from multiple institutions across Australia and New Zealand. This multi-institutional and cross-jurisdictional representation ensured that the recommendations reflect the diversity of clinical practice and regulatory environments across Australia and New Zealand.

Literature review strategy

An expert-driven review of international standards and protocols was conducted to inform the recommendations in this guideline. Key source documents included the AAPM Task Group Report 272 [4], the International Atomic Energy Agency (IAEA) Handbook of Basic Quality Control Tests for Diagnostic Radiology [5], the European Federation of Organisations for Medical Physics (EFOMP) Quality Control of Dynamic X-ray Imaging Systems Protocol [6], and the ACPSEM Recommendations for a Digital General X-ray Quality Assurance Program [7]. Additional guidance was drawn from the EFOMP-ESTRO-IAEA protocol on CBCT quality control [8], AAPM Task Group Report 261 [9], and relevant International Electrotechnical Commission (IEC) standards [11–13]. Local regulatory requirements, including the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) Code for Radiation Protection in Medical Exposure [10], were also reviewed to ensure the recommendations are consistent with the Australia and New Zealand regulatory framework.

Evidence appraisal

Recommendations in this guideline are based on expert consensus informed by international best practice. No formal evidence grading framework (e.g., GRADE or NHMRC levels of evidence) was applied. The working group assessed the applicability and relevance of international recommendations to the Australia and New Zealand context.

GRADE and similar evidence-grading frameworks are primarily designed to evaluate clinical-effectiveness evidence, whereas fluoroscopy quality assurance guidance is predominantly drawn from regulatory standards (e.g., IEC), professional-society publications (AAPM, IAEA, EFOMP), and consensus best-practice documents. For this reason, a

Table 1 Components of the quality assurance program

Test type	Frequency	Performed by	Purpose
Acceptance testing	Post installation	Medical physicist	Acceptance testing includes verifying that a piece of equipment (including software and peripheral equipment) has been supplied as specified during procurement. It also includes verifying that the system meets minimum safety and regulatory standards
Commissioning	Before clinical use	Medical physicist	Verify that equipment has been installed, configured, and calibrated in a manner fit for clinical use. During the commissioning process, performance baselines for future routine testing are also established. Commissioning is typically performed after installation, manufacturers' internal tests, and acceptance testing, but before clinical use
Routine quality control	Periodically (infrequently e.g. annually)	Medical physicist	Tests to ensure that the performance of a system remains within acceptable criteria The testing frequency depends on the potential clinical implications and the likelihood of affecting system performance
Performance checks	Periodically (frequently e.g. monthly)	Facility staff	A small subset of potentially simplified Routine Quality Control tests is undertaken more frequently than routine QC. These checks are intended to be simple and quick, but they serve as indicators of important system performance or functional changes

consensus-of-experts approach informed by international standards and best practice was considered the most appropriate methodology for developing the recommendations in this guideline.

Consensus process

Consensus on the content and recommendations was reached through iterative working-group discussions and reviews. Each section was initially drafted by designated working group members with relevant expertise, then reviewed, discussed, and refined through multiple rounds of group review until agreement was achieved. The final manuscript was reviewed and approved by all working group members.

Stakeholder consultation

Following the working group consensus, the draft guideline was circulated for stakeholder consultation. This included distribution to ACPSEM members and relevant professional organisations, including the Australian Society of Medical Imaging and Radiation Therapy (ASMIRT) and the Diagnostic Imaging Accreditation Scheme Advisory Committee (DIASAC). Feedback was received from ASMIRT and DIASAC, and a number of individual expert reviewers. All comments were formally documented and addressed through a structured response-to-feedback process. The consultation period was conducted from 5 July 2024 to 9 August 2024. A summary of the stakeholder feedback and the working group's responses is provided as supplementary material.

Peer review

The guideline was submitted to the ACPSEM Head of Specialties and presented at an ACPSEM Board meeting for endorsement. External peer review was conducted through the Physical and Engineering Sciences in Medicine (PESM) journal submission process.

Medical physics testing and equipment performance

Introduction

Medical physics testing before clinical use and periodically thereafter is essential for the optimal and safe use of fluoroscopic systems. Acceptance testing and commissioning are significantly more thorough and occur at installation and before initial clinical use. They aim to validate the manufacturer's specifications and establish performance benchmarks or baselines for future periodic testing.

Since fluoroscopic systems can be configured and operated in various clinical contexts, the ACPSEM recommends that testing reflect their intended clinical use. The medical physicist should determine the most regularly used clinical protocols before testing begins.

During procurement, input should be sought from key stakeholders, including clinical users, radiographers, medical physicists, and biomedical engineers, where appropriate. Following procurement, the manufacturer's User QA and preventive maintenance program should be reviewed to inform the development of the facility's QA program. This enables integration of automated features and helps avoid unnecessary duplication of QA tests.

If protocol adjustments are made by applications specialists, system "Super-users", or during repair or servicing by service engineers, the medical physicist should be informed and must confirm whether the changes affect critical system behaviour or baseline measurements.

Similarly, where maintenance actions are required to correct a failure, appropriate validation tests must be undertaken before the system returns to clinical use. Once an acceptable result has been achieved, a note in the records indicating the actions taken demonstrates that the initial failure has been resolved and may assist in the future should a similar failure occur.

If the unit being tested is a bi-plane system, both X-ray tubes and image receptors must be assessed against the requirements below and demonstrate matched performance within the system's design constraints. For example, the lateral plane may utilise a different tube focus-to-isocentre distance or field size than the frontal plane, leading to subtle differences in typical entrance air kerma rates.

Acceptance and commissioning test recommendations

Table 5 lists the acceptance and commissioning tests for the medical physicist; the Classification column indicates whether each test is Recommended (core component) or Optional (performed at the medical physicist's discretion based on clinical context). The following sections detail the methodology and tolerance thresholds for each test. All Recommended tests for periodic testing must also be included during commissioning. The medical physicist must establish the necessary baselines for Radiographer QC during this testing stage.

Because of their impact on system performance, acceptance and commissioning tests should be repeated following significant system changes, such as an X-ray tube or image receptor replacement, software upgrades, or service interventions that affect dose and/or IQ. Additionally, protocol adjustments made by application specialists or

"Super-Users" that affect system performance or clinical output should trigger a review of baselines and the repetition of relevant QA tests.

Verification of distances (displayed and fixed)

The medical physicist must confirm that the focal spot position is indicated externally on the tube housing. As the focal spot position is sometimes marked inside the housing, it may need to be indicated externally by a service engineer or medical physicist at installation. A service engineer can remove the housing to locate the marking, or a medical physicist can use triangulation with two objects (e.g., coins or two copper (Cu) sheets, one half the size of the other) on the table and image receptor to determine the focal spot position.

The accuracy of displayed equipment geometry distances, such as source-to-image distance (SID) and table position, must be verified to be within ± 1 cm during acceptance testing.

In addition, the system must have a means to ensure a minimum achievable focus-to-skin distance (FSD) that meets the following requirements:

- Fixed fluoroscopic systems must achieve an FSD of at least 300 mm.
- Mobile fluoroscopic systems must achieve an FSD of at least 200 mm.
- Mobile extremity fluoroscopic systems (Mini C-arm), typically operating with tube currents ≤ 0.2 mA, are exempt from this requirement.

Where engineering controls do not automatically maintain the required FSD, additional engineering solutions such as spacer devices or patient positioning aids should be used. If these are not feasible, administrative controls may be implemented to help ensure consistent FSD during clinical use. These requirements aim to reduce patient skin dose. Additional system assembly checks are included in Sect. "Fluoroscopic system assembly evaluation".

Radiation protection of the operator

Provisions must be made to protect the operator from scattered radiation. For fixed systems, this may be achieved by operating the system remotely from behind structural shielding, such as a control room wall or window, or by utilising the system or ceiling-mounted radiation shields combined with Personal Protective Equipment (PPE) when operation is required from within the exam room, as commonly implemented in interventional settings [14].

For mobile systems, operators must wear PPE and operate the system from a minimum distance of 2 m from the X-ray beam or focal spot, using a hand or foot switch [11], or another control method validated by a medical physicist.

For mobile extremity systems, also known as Mini C-arms, that lack a hand-switch operation, safe operation can be confirmed by placing a suitable patient-equivalent phantom, such as a 5 cm polymethylmethacrylate (PMMA) phantom for extremity imaging [15], in the X-ray beam path and performing screening. At the operator's hand or foot position, the dose rate should not exceed 10 µGy/min.

If a real-time staff dose monitoring system is integrated with the fluoroscopy system, its suitability and calibration must also be rigorously evaluated, given its critical role in informing staff members about their radiation exposure. Medical physicists are responsible for ensuring that this dose-monitoring system operates as intended and that the readouts accurately reflect the expected exposure levels. It is essential to emphasise that these real-time monitors are supplementary and should not replace the mandatory, traceable personal dose monitoring system for staff members, particularly those who may exceed the public dose limit of 1 mSv/year.

Fluoroscopic system-related items used for staff radiation protection should be checked before clinical use to ensure correct installation, suitability for the task, and that the manufacturer's specifications are met. This includes but is not limited to ceiling-mounted shields, mobile shields, and table drapes/skirts. PPE is addressed more fully in the following section.

Radioprotective personal protective equipment (PPE)

Due to the substantial scattered radiation present during fluoroscopic procedures, PPE must be worn by procedural staff to ensure that dose limits are not exceeded and that exposure remains as low as reasonably achievable (ALARA). PPE should meet the minimum design criteria outlined in IEC 61331-3 [16]. Whether to use 0.25 mm, 0.35 mm, or 0.5 mm lead equivalent protective clothing is context-dependent. The medical physicist should provide advice based on an assessment of typical dose rates from the fluoroscopic examinations being performed, the locations and times when staff are present during procedures, and the presence of any additional protective devices, including system- or ceiling-mounted radiation shields. However, consideration should be given to standardising PPE specifications across a facility or department to avoid the risk of garments of different specifications being used in areas where they were not originally specified.

At acceptance, all garments are to be checked for integrity using the procedures detailed in "Radioprotective personal

protective equipment (PPE)" Section. It is highly advised that fabrics be tested to verify their attenuation properties, ideally following the methods specified in IEC 61331-1 [17]. Garments that fail to meet the established design criteria, integrity checks, or the minimum lead equivalence required must not be permitted. Additionally, the lead equivalence of protective eyewear should be verified to identify any manufacturing defects. Particular attention should be given to shielding coverage, especially around the sides of the eyewear, to ensure adequate protection for staff members frequently exposed to radiation on the sides of their heads.

Beam quality (half-value layer)

A beam quality measurement is essential to confirm that the fluoroscopic system produces diagnostic images with appropriate filtration, minimising unnecessary patient radiation exposure from low-energy photons, while also minimising the negative impact on image contrast should photon energies be too high. Modern interventional systems often use variable, vendor-specific filtration. To assess the minimum beam quality, this test should be performed without any selectable added filtration in the X-ray beam, as this represents the least penetrating beam the system can deliver. It may be necessary to use a mode designed for imaging larger patients, an acquisition mode or enter service mode to disable added filtration to make this measurement.

The half-value layer (HVL) is the recommended metric for evaluating beam quality, as it provides a direct, reproducible, and standardised measure of the X-ray beam's penetration. HVL should be measured at the same tube voltage settings used during the tube voltage accuracy assessment (see "Tube voltage accuracy" Section). The minimum acceptable HVL values are adopted from IEC 60601-1-3 [12] and are summarised in Table 2.

Table 2 Minimum permissible half-value layer for fluoroscopic systems [12]

X-ray tube voltage (kVp)	Minimum permissible first half-value layer (mm Al)*
50	1.8
60	2.2
70	2.5
80	2.9
90	3.2
100	3.6
110	3.9
120	4.3
130	4.7
140	5.0
150	5.4

*Half-value layers for other voltages must be obtained by linear interpolation or extrapolation

Modern dose meters can automatically determine the HVL without requiring additional filters. If this functionality is unavailable or filtration levels fall outside acceptable parameters for the particular dose meter, the HVL can still be calculated using first-principles methods [5, 18].

This test should be conducted when new equipment is accepted, after replacing the X-ray tube, or after significant repairs.

Tube voltage accuracy

Tube voltage is clinically relevant as it directly affects image contrast. It is particularly important when contrast agents, such as those containing iodine or barium, are used in systems that allow manual selection of tube voltage in clinical modes. The tube voltage should be assessed using a suitable non-invasive kVp meter and measured across the available operating range, e.g. between 50 kVp and 120 kVp in 10 kVp intervals.

For systems that vary the tube voltage under ADRC, place the kVp meter as required by the operator's manual and add Cu or other attenuating material to the image receptor side of the kVp meter to achieve different tube voltages. Alternatively, guidance from the service engineer or application specialist may help determine whether ADRC can be disabled or a suitable service mode can be used for measurement via manual kVp adjustment.

Measured tube voltages should be within ± 5% of the indicated values. Deviations exceeding ± 10% require the system to be withdrawn from clinical use until rectified.

This test should be conducted when new equipment is accepted, after replacing the X-ray tube, or after significant repairs.

Leakage radiation

Leakage radiation transmitted through the protective housing of the X-ray tube and collimator, including scattered radiation produced within the source assembly, can result in unnecessarily high patient or operator doses.

The leakage radiation from the tube housing assembly must be ≤ 1 mGy/h, averaged over 100 cm^2 (with no linear dimension exceeding 20 cm), at 1 m with the highest rated tube voltage and maximum rated continuous tube current [12]. The collimators must be closed entirely, or additional lead shielding must be placed in front of the collimator to ensure that only leakage X-rays from the tube assembly are detected.

Leakage radiation must be tested during acceptance of new equipment and tube replacement, or when impact damage is visible on the tube housing.

Automatic dose rate control (ADRC) functionality

Automatic Dose Rate Control (ADRC), also known as Automatic Brightness Control or Automatic Exposure Rate Control, is a key feature in fluoroscopic systems designed to maintain IQ while delivering optimised patient dose. It adjusts parameters such as tube voltage, current, pulse width, filtration, and focal spot size based on patient attenuation, field of view (FOV) and selected fluoroscopic or radioscopic protocol. Understanding and verifying ADRC behaviour is essential for optimising clinical protocols and maintaining consistency in dose and IQ.

During commissioning, ADRC functionality should be evaluated using standardised tissue-equivalent phantoms, typically polymethyl methacrylate (PMMA). A common approach involves incrementally increasing the phantom thickness from zero to 40 cm in 2.5 cm increments to simulate a range of patient sizes [19]. The phantom's entrance point should be positioned at the interventional reference point defined by the system, typically 15 cm from the isocentre towards the tube [13], for consistency. The dose rate should be measured at the same location, either with the dosimeter placed outside the sensitive area of the ADRC system or with a radiolucent dosimeter that does not activate the ADRC system. Where possible, tests should be performed in the default clinical fluoroscopy modes (e.g. normal, low, and high dose) and field sizes, using typical pulse rates and beam filtration.

The following parameters should be measured or recorded for each phantom thickness and clinical mode:

- Tube voltage (kVp)
- Tube current (mA) and pulse width (ms)
- Filtration (automatically selected filters, where applicable)
- Incident Air Kerma Rate (mGy/min), measured at the reference point
- Image Receptor entrance dose (if the system provides or allows estimation)

The system's response should be consistent and gradual as phantom thickness increases. Sudden changes in technique parameters, failure to adjust appropriately, or failure to stabilise quickly may indicate calibration or logic issues with the ADRC.

The measured ADRC response should be used to establish a performance baseline for each clinical mode. This can be compared to manufacturer-provided dose curves or assessed against expected clinical performance. Parameters such as image receptor dose per frame and air kerma rate should support the IQ required for clinical tasks (e.g., catheter tracking in large patients or fine-detail contrast in paediatric modes). If multiple dose modes are available (e.g. low, normal, high), the relative changes in dose and IQ should be verified to reflect the intended clinical trade-offs.

In addition to testing with PMMA, it is recommended that a subset of baseline measurements also be acquired using a 2 mm Cu filter placed in the beam. This approach facilitates the establishment of reproducible reference values for simplified dose constancy checks during routine radiographer-led quality assurance (see "Dose rate constancy" Section). At a minimum, one common clinical protocol and field size should be measured using the 2 mm Cu setup during commissioning to enable future comparisons and tracking of system performance over time.

For systems with pedestal tables, attention should be given to potential variations in attenuation along the long axis of the patient couch, as this design feature may influence dose constancy measurements. Care should be taken to minimise such effects during setup and data acquisition.

IQ metrics such as signal-to-noise ratio (SNR) and low-contrast detectability, measured using a standard phantom, can support the optimisation of ADRC settings. These tests can also assist in selecting or customising protocols for specific populations (e.g. paediatric vs. adult imaging). Temporal resolution, using appropriate phantoms such as the rotating spoke assembly NEMA XR21, should also be included in a range of these tests to reflect clinical requirements.

If the system allows direct configuration of image receptor dose per pulse or frame, these values should be validated across the available range, with attention to linearity, accuracy, and their relationship to IQ in clinical use.

ADRC functionality should also be re-evaluated following major software updates, protocol changes made by applications specialists or "Super-users," or when clinical concerns are raised regarding image quality or dose.

Table and mattress attenuation

As recommended in AAPM Report 357 [20], attenuation and forward scatter of the tabletop and mattress should be considered for patient skin dose estimates. These factors are energy and geometry-dependent and can result in a typical reduction of 15–25%, with the entrance air kerma reduced to approximately 75–85% of its initial value. The medical physicist may undertake a set of measurements to quantify the extent of beam attenuation for the actual equipment used, taking into account changes in table thickness in the

z-direction, potential variations in mattress thickness, and any differences in beam quality resulting from ADRC control (kVp and filtration). These measurements, combined with information from the radiation dose structured report (RDSR) on kVp and filtration, will improve the accuracy of skin dose estimation.

Radiation dose structured report (RDSR)

An RDSR records procedural information, including institution and patient details, acquisition parameters, and radiation dose data. It is an essential part of the patient's medical record. Additionally, the RDSR can facilitate automated or semi-automated methods for establishing or reviewing facility reference levels (FRLs) and performing patient and population dosimetry.

It is recommended that procurement tenders for fluoroscopic X-ray systems specify conformance to at least the "Basic" dose documentation level of IEC 61910-1 [21] and that fixed systems, as used for complex interventional cases, conform to the "Extended" dose documentation level. This can usually be clarified by examining the vendor's conformance statement.

The accuracy of the RDSR needs to be verified at acceptance and, as necessitated, after any software changes to ensure it meets clinical dose audit requirements. Verification should also confirm that the RDSR can be correctly transmitted to and received by the PACS or relevant archiving system.

Distance calliper accuracy

Verification of system distance callipers is essential to maintain the accuracy of distance measurements in fluoroscopic systems. Precise distance measurements are crucial for various diagnostic and therapeutic procedures, and ensuring the accuracy of distance callipers guarantees that the imaging system operates within acceptable tolerances.

Verification can be accomplished by imaging in the same plane as the image receptor, using steel rulers or other objects with known dimensions, positioned both parallel and perpendicular (at 90 degrees) to the long axis of the patient table. Direct measurements should be taken from the image using console tools. Distance measurements should also be performed at the reporting workstation to confirm that there are no issues when transferring dimensions to PACS. If this is not feasible, images should be exported to another workstation and assessed using a DICOM viewer. When performing these assessments, the magnification effect must be taken into account to ensure an accurate evaluation.

It is essential to validate the accuracy of clinically used image-measuring functions at the time of system acceptance and after any software updates or upgrades that could affect their calculations. Accuracy should ideally be within a tolerance of ± 2%, but must at least meet the manufacturer's specified tolerances. These tolerances should be determined by examining the system's technical documentation or aligning with the clinical requirements for the specific metric in question.

Display monitor assessment

Display monitors should be assessed at acceptance following the procedures specified in AAPM Report 270 [22] and, at a minimum, meet the specifications provided in the Royal Australian and New Zealand College of Radiology (RANZCR) Standards of Practice for Clinical Radiology [23]. All live and reference monitors used in the examination and control rooms must meet the standards for secondary monitors.

Periodic testing recommendations

Table 5 lists the periodic tests for the medical physicist; the Classification column indicates whether each test is Recommended or Optional. The sections below provide further discussion of the procedures and tolerances for each test. A subset of tests is usually required after significant equipment or software upgrades or repairs, such as X-ray tube or image receptor replacement, automatic dose-rate control and IQ adjustment, or any other change that may affect IQ or patient dose. The nature of the upgrade dictates which specific tests should be performed before the equipment can be used clinically. All routine periodic tests are conducted at least annually under the guidance of the medical physicist. However, the frequency may be increased, depending on local requirements and resources, in consultation with the medical physicist overseeing the QA program.

Fluoroscopic system assembly evaluation

A thorough mechanical inspection of the fluoroscopic system and its related components must be undertaken at each regular testing interval to ensure that no hazardous, misaligned, or inoperative safety features (e.g., warning lights and signs) are present. The correct function and condition of all motorised components, anti-collision devices, emergency cut-off switches, deadman switches, warning lights, timers, indicators, displays, cables, interlocks, and any other miscellaneous safety-related issues, such as system motion stability, should be confirmed.

Collimation and alignment

X-ray field/image receptor alignment It is essential to ensure that the X-ray beam is limited to the image receptor and that patient tissue outside the FOV is not exposed to the primary X-ray beam. The collimator must automatically limit the X-ray beam to the image receptor area at all field sizes and across the system's range of focus-to-image-receptor distances. The simplest way to ensure this is to adjust the collimator blades so that the edges are just visible within the imaged region, even at the widest selectable setting. If the X-rayed edges of the blades are not visible within the imaged area, X-ray field image receptor alignment must be assessed. This is not to be confused with electronic cropping of the displayed field, which can be unintentionally set within the X-ray field.

There are different methods for performing this test if an alignment measurement is required. An alignment device comprising movable attenuating material can be used in conjunction with an auxiliary imaging technique, such as a computed radiography (CR) cassette or self-developing film. Alternatively, a fluorescent screen can be used to establish the X-ray field's edges before manually measuring the deviation from the visible image boundary. At a minimum, all field sizes should be assessed at a single SID during periodic testing or following the replacement of collimators, tubes, or image receptors.

If the X-ray beam is rectangular, and the image receptor is circular, the length and width of the X-ray beam must fall within the image receptor area. In all other circumstances, the discrepancy between any edge of the X-ray beam and the corresponding visible edge of the image (or collimator edge, if visible) must not exceed 1% of the focal spot-to-image receptor distance (SID).

Collimation tracking with source to image distance (SID) Systems with variable SID functionality require that any changes to the focus-to-image receptor distance be accompanied by an automatic collimator adjustment to maintain the selected beam area. This is because if the collimators are open to the widest position and extend to the edge of the image receptor when positioned at a short SID, the X-ray beam would extend beyond the receptor at a long SID if there is no collimation tracking to maintain appropriate X-ray field/image receptor alignment.

The image receptor should be brought close to the X-ray tube with the collimators open. Screening will be performed by increasing the SID from the minimum to the maximum focus-to-image-receptor distance [24]. An automatic adjustment of the collimators should accompany any changes to the SID.

If there is any reason to suspect poor tracking, then the methodology and tolerances outlined in 3.3.2.1 can be used to assess performance at different SIDs.

Table 3 Acceptable and maximum deviation limits for displayed dose metrics [11]

Metric	Specified range	Acceptable deviation (%)	Maximum deviation (%)
AK_{ref} rate	6 mGy/min to maximum value	20	35
AK_{ref}	100 mGy to maximum value	20	35
Cumulative KAP	> 0.05 Gy.cm2	20	35

Accuracy of displayed dose metrics

The accuracy and display of radiation dose information are essential in managing patient and staff doses. Thresholds for tissue reactions to high skin doses are significant for managing side effects from prolonged interventional cases. Modern interventional fluoroscopic systems should be capable of displaying cumulative Reference Air Kerma (CAK_{ref}) and Reference Air Kerma Rate (AK_{ref} rate), as well as the Kerma Area Product (KAP), commonly referred to as the Dose Area Product (DAP). Some systems may also display real-time dose mapping using metrics related to peak skin dose. System-reported dose mapping provides valuable feedback that prompts real-time adjustments to examination techniques, helping avoid tissue reactions and facilitating post-procedure patient follow-up without the need for complex dosimetry. However, with no standardised definition for this metric, uncertainties in its calculation must be understood.

The accuracy of the displayed dose metrics should be assessed under the manufacturer's calibration conditions. This might involve controlling variables such as kVp, patient table and cushion positions (in/out of the beam), measurement location, and field size. If the conditions are not specified, the measurement procedure detailed in AAPM Report 190 [25] should be followed.

Where manufacturer tolerances are not specified, the tolerances in Table 3 should be used.

When additional dose values, such as peak skin dose or its analogues, are provided, it is essential to understand the methods and assumptions the manufacturer used in their calculations. These should be verified during acceptance testing or after any software updates that may affect these calculations.

Radiation dose output

Typical incident air kerma rate For ongoing periodic testing, it is recommended that 20 cm PMMA be used to test a representative subset of dose rate modes established during commissioning. This includes at least the three most common clinical protocols and, for one dose mode, measures the typical entrance air kerma rate at all selectable FOVs. Table 4 provides the measurement location for this test.

Periodic test results should be within ± 20% of the baseline values. Additionally, the medical physicist must confirm that the dose rate varies appropriately with field size and dose rate settings, for example, by comparing it with the specifications provided in the Instructions for Use. The dose rate should decrease with lower dose-rate modes and larger field sizes. New baseline values must be established following any changes to protocols or systems (hardware, software, or configuration) that may affect radiation output or the ADRC system.

Maximum incident air kerma rate Australia and New Zealand have legislated limits on the maximum incident air kerma rate during fluoroscopic screening in Normal Mode, measured at a specified reference position. While some jurisdictions permit outputs of up to 100 mGy/min in this mode, the International Electrotechnical Commission (IEC) recommends a more conservative threshold of 88 mGy/min as a safety measure [11]. Local regulations must be followed, with the lower threshold applied where required.

Specific fluoroscopic modes, such as High-Level Control or Boost mode, allow operation at higher dose rates than those permitted in Normal Mode. Due to the increased radiation risk associated with these modes, their use requires continuous activation and an audible warning signal. These higher-dose modes are also subject to strict maximum air kerma rate limits, that cannot be exceeded. In many systems, these limits are set at approximately twice the level applied to Normal Mode.

While the above restrictions provide a degree of protection against tissue effects, they may result in an image receptor input dose rate that is insufficient for particular clinical scenarios, such as imaging bariatric patients or anatomical regions with substantial effective thickness. In such cases, strict enforcement of maximum dose rate limits can lead to increased image noise and reduced clinical IQ. This may necessitate prolonged exposure times or greater reliance on acquisition modes, potentially offsetting the intended benefits of these restrictions.

To address this, the medical physicist, in collaboration with interventional and radiographic staff, must ensure compliance with local regulatory requirements and optimise the image receptor input dose rate for the specific clinical task, as detailed in "Image receptor incident air kerma rate" Section.

ADRC reproducibility Under consistent test conditions, the air kerma rate should be reproducible during consecutive exposures and between regular testing periods. Using the same setup as in "Typical incident air kerma rate" Section, five successive measurements should be taken with a single clinical protocol, and the air kerma rate should be recorded. The air kerma rate is not recorded until the ADRC stabilises the tube voltage, current, pulse width, and filtration (where relevant). This typically takes 2 s. During this test, the exact setup conditions must be accurately recorded so that the test can be reproduced in the future.

The coefficient of variation (CoV) must not exceed 0.05 for five consecutive measurements of air kerma rate.

Image receptor incident air kerma rate The dose rate measured at the image receptor relates to the trade-off between image noise and patient dose. Therefore, it should be optimised for the specific clinical task.

Image Receptor Incident Air Kerma Rate is measured by adding approximately 2 mm Cu filtration as close as possible to the tube exit port to obtain a tube voltage of

Table 4 Nominal patient entrance reference point locations for different fluoroscopic system types [13]

System type*	Reference point location
Vertical orientation fixed C-arm system	15 cm from the isocentre toward the X-ray source along the centreline of the X-ray beam
Horizontal orientation fixed C-arm, L-arm, or lateral system	15 cm from the isocentre of the X-ray table and in the direction of the X-ray source, with the end of the beam-limiting device or spacer positioned as closely as possible to the point of measurement
Under table X-ray tube	1 cm above the tabletop or cradle
Over table X-ray tube	30 cm above the tabletop with the end of the beam-limiting device or spacer positioned as closely as possible to the point of measurement
Mobile C-arm	30 cm from the entrance surface of the image receptor toward the X-ray source along the centreline of the X-ray beam
Mini C-arm	Typically located 3–6 cm from the image receptor toward the X-ray source along the centreline of the X-ray beam.

*Manufacturer-specified reference point should be used for hybrid OR / robotic gantry systems

*The manufacturer must specify the patient entrance reference point for fluoroscopic systems not listed above

approximately 80 kVp, consistent with AAPM TG-272 [4]. The dose rate should be measured at the surface of the image receptor for fluoroscopic screening and radiographic acquisitions across a range of commonly used clinical protocols. The clinical protocol determines the input receptor dose rates, the selection of the dose rate settings, the fluoroscopic pulse rates, and the acquisition frame rates. All exposure factors determined through the ADRC system should be recorded, including tube voltage and current, pulse width, additional filtration, varying pulse and frame rates, and focal spot size.

The dose rates are to be measured at the input surface of the image receptor with the grid removed. If the grid cannot be removed, a grid correction factor provided by the manufacturer can be applied. The measurements should be made using all clinically relevant field sizes and protocols with open collimators. Measurements should be compared with manufacturer specifications and system-reported values. Typically, the fluoroscopy dose rate is expressed in units of nGy/s, and the acquisition dose per frame is measured in μGy/frame. When the acquisition frame rate varies during exposure, the cumulative dose and the total number of frames can be used to calculate the average dose per frame. Measurements can be used as baselines for future quality control testing.

At system commissioning, baseline measurements must be established for the air kerma rate at the image receptor. These measurements must fall within the manufacturer's stated tolerance and comply with all applicable local regulatory requirements. Subsequent periodic test results should remain within ±20% of this established baseline. Furthermore, for optimisation, measured dose rates for similar clinical tasks should be compared across all comparable fluoroscopic systems at the site. Attention should be paid to prevent inadvertent activation of the ADRC system by the measuring device. The measuring device should be positioned outside the active area. If this is not feasible, exposure settings should be determined without using the measuring device. Following this, the dose rate should be measured in manual mode using these pre-established settings. Alternatively, a radiolucent dosimeter may be used to avoid triggering the ADRC system while allowing measurements in clinical mode. Establishing and maintaining these baselines aids in the optimisation process and ensures consistency, quality, and safety across the clinical site.

For safety reasons, some fluoroscopic systems include a feature that automatically halts fluoroscopic exposures when the dose rate to the image receptor falls below a manufacturer-defined threshold for acceptable image quality. Where this functionality is present, it should be confirmed during testing.

This feature may complicate the measurement of the maximum incident air kerma rate, as the system may terminate exposure before reaching the desired measurement point. In such cases, measurements should be taken at the point just before the safety feature interrupts fluoroscopy.

Image quality (IQ)

Objective and subjective IQ measurements help monitor a system's performance throughout its working life. Providing that constant measurement conditions are maintained, any significant change in performance should be evident in the test results. Many test objects or phantoms are available for this purpose, and the ACPSEM does not recommend any particular phantom. However, the chosen phantoms should be used to assess the system's high-contrast spatial resolution, low-contrast resolution, and image uniformity. Additionally, image distortion must be evaluated using a square grid pattern or a similar tool for systems that use image intensifiers.

All test objects should be positioned as close as possible to the entrance surface of the image receptor to minimise the effects of geometric unsharpness. To reduce the influence of the heel effect and variations in effective focal spot size, the test object should be centred within the X-ray field. Unless otherwise specified, all tests should be performed under ADRC, with sufficient attenuating material added to simulate typical clinical exposure conditions for an average patient, or as specified by the test object manufacturer (e.g., additional Cu placed near the X-ray tube exit port). Ambient lighting should match the level used during clinical procedures. The collimation should be fully open, and the anti-scatter grid should be used unless it is not employed during clinical imaging.

Recording the parameters and exposure techniques employed for all tests is crucial. This practice ensures reproducible results and facilitates troubleshooting in the event of performance deviations. This guideline does not specify IQ performance criteria. Therefore, the equipment should be evaluated against the vendor's specifications and local IQ requirements pertinent to the clinical task. Once baseline values are established, the IQ should be consistent throughout the equipment's lifetime, ensuring no deterioration in performance.

Image uniformity Sheets of Cu or PMMA can be used qualitatively or quantitatively, using region-of-interest statistics, to assess gross non-uniformities and identify any clinically

significant artefacts. This assessment can be performed simultaneously during output measurements.

A selection of PMMA slabs can be placed near the image receptor, or Cu sheets can be placed on the X-ray tube exit port. The image can be visually inspected, or a quantitative evaluation of the mean pixel values can be employed. If mean pixel values are not measured at the modality, images can be exported for assessment using third-party software. AAPM Report 272 recommends performing the uniformity test at various SIDs, including both the minimum and maximum SIDs, with consideration of grid cut-off effects. It is essential to ensure that images are free from distortions and clinically relevant artifacts [4].

High contrast (spatial) resolution High contrast (spatial) resolution (HCR) must be evaluated. There are many suitable test objects available on the market for this purpose. HCR must be assessed for each combination of detector element (del) binning associated with the various FOVs and defined image matrix sizes, to establish a baseline for future assessments using the same clinical exposure protocol. Careful consideration must also be given to the orientation of the test object to avoid aliasing with the del matrix alignment, for example, placing the test object at a 45-degree angle to the edge of the image receptor. The test object should be positioned as close as possible to the image receptor to reduce the effects of magnification and geometric unsharpness. The anti-scatter grid, if used during clinical imaging, should be removed for this test. The exposure settings used during the measurement can influence the results and should be recorded for future constancy testing. There should be no deterioration in the limiting HCR over time.

Low contrast resolution Low contrast resolution evaluation must be performed using the test object's reference values to establish baseline results for future assessments. An appropriate attenuator, such as Cu sheets, should be positioned in the X-ray beam near the tube exit port. As with high-contrast resolution testing, the exposure parameters used during evaluation can influence the results. Therefore, a detailed record of the test object's position and the exposure settings must be maintained to ensure consistency, reliability, and repeatability over time. If non-processed images are not available, a quantitative evaluation of signal-to-noise ratio (SNR) or contrast-to-noise ratio (CNR) may be used to establish baseline values and enable future comparisons. A recommended methodology is outlined in AAPM Report 272 [4]. Except for evaluation using the SNR/CNR method, this test relies on a subjective assessment of the test object used. Therefore, the medical physicist should determine the appropriate tolerance in conjunction with the clinical staff from the baseline value. The test should enable the identification of deterioration in low-contrast resolution.

Temporal resolution Temporal resolution should be evaluated using specialised phantoms, such as a rotating spoke pattern, to assess motion blur and the impact of frame averaging. Such assessments are valuable when collaborating with clinical staff to optimise post-processing and exposure settings. The acceptable tolerances for these evaluations should be determined based on the specific clinical tasks for which the fluoroscopy system is intended to be used.

Digital subtraction angiography (DSA) If used clinically, system performance under subtraction imaging should be assessed using appropriate phantoms. Several phantoms are available on the market, such as Leeds TO DSA, QUART DSA, and Diagnomatic Pro-RF DSA. These phantoms help evaluate system performance in terms of dynamic range, contrast sensitivity, spatial resolution, and the presence of image artifacts. Appropriate beam energies, such as 70 kVp, should be used during these assessments. Performance values should be documented and compared against baseline values throughout the equipment's lifespan. Any significant degradation in performance that could impact clinical outcomes must be escalated for further investigation.

Laser alignment

Where lasers are installed on a fluoroscopic system, they are primarily used to delineate a point, line, or plane in the x-y-z patient space; designs vary. They do not designate a beam-collimation area (as in collimator-light-beam diaphragm systems).

When assessing appropriate tolerances, the medical physicist must consider the clinical purpose for which the laser is intended and compare the actual alignment of the laser beam with the required point, line, or plane. Alignment tests are performed free-in-air to centre the entrance field of the image receptor and designate the entrance skin plane. These tests should not necessitate radiation exposure, as the entrance surface of the image receptor/grid and alignment to the X-ray focus serve as helpful reference points. Lasers typically exhibit a full-width half maximum (FWHM) beam cross-section of approximately 1 mm, hence the need to consider positional accuracy. It is essential to note that while achieving laser beam alignment with an accuracy better than ± 1 mm is not typically expected, lasers can usually attain alignment within ± 2 mm.

CBCT functionality

Many high-end interventional fluoroscopic systems offer CBCT functionality. The following section is not designed to be a comprehensive guide. Currently, there is no international standardisation for performance evaluation. However, there are several considerations when defining an appropriate QA regime to monitor CBCT performance, should it be routinely used.

Unless otherwise specified by the phantom manufacturer or required to replicate a specific clinical protocol, the phantom should be centred within the FOV to ensure consistency and minimise artefacts from off-axis positioning.

Geometrical precision C-arm sag can introduce significant spatial measurement errors in CBCT datasets. Measurement of isocentre accuracy of C-arm cone-beam systems can be made by scanning a suitable phantom, e.g., a small ball-bearing or manufacturer-specific phantom and measuring object drift from the isocentre as a function of gantry angle.

The relative spatial relationship of the imaged structures in each orthogonal direction can be assessed using a suitable phantom, e.g., a small cube of PMMA, Catphan, or a manufacturer-specific phantom. Distance accuracy in the orthogonal directions can then be established using available acquisition workstation tools or assessed offline with other software. Without manufacturer specifications, a tolerance of ± 2 mm should be applied unless the clinical context demands higher accuracy [8].

Uniformity and noise Subjective image uniformity and noise assessments can be made using a suitable phantom, e.g., a PMMA cylinder, Catphan, CT water phantom, or manufacturer-specific phantom. Basic assessment is made via observation under tight window/level conditions to identify non-uniformities or excessive noise that could negatively impact IQ.

Objective constancy measurements can be made per slice using raw voxel data or Hounsfield Units (HU) if the system provides this. For uniformity, each ROI's diameter is approximately 20% the diameter of the phantom and positioned at the centre, 12, 3, 6 and 9 o'clock locations (peripheral ROIs should be placed to avoid any edge effects). Uniformity can then be calculated as a percentage difference from the central ROI. Noise can be established using an ROI of approximately 40% of the diameter of the phantom positioned in the centre.

Without manufacturer methodology and tolerance, images should be created using the largest voxel size and highest tube current to maximise signal-to-noise ratio and allow sensitive uniformity and noise assessment. Care must be taken to avoid image receptor saturation.

Noise should be within 20% of the baseline. Where a system provides Hounsfield Units, uniformity should be within ± 10 HU [8].

High contrast (spatial) resolution Subjective assessment of limiting resolution can be established by observation of a suitable phantom that contains line pairs of high and low-density materials representing different spatial frequencies, e.g. Catphan. Objective assessment via evaluation of the modulation transfer function (MTF) can be complicated due to beam hardening from imaging an inclined wire (for oversampling) or another suitable test object. A phantom that reduces the likelihood of beam-hardening artifacts is recommended for this test, for instance, a phantom containing a wire suspended in air.

Without manufacturer tolerance, the MTF at 50% and 10% points should be within 20% of the baseline [8].

Voxel density This test assesses whether the system can accurately reproduce voxel density values for given materials. If the system uses the Hounsfield Unit scale, testing should confirm the accuracy of the HU values for specific materials. If the system does not use the HU scale, the testing should focus on constancy, ensuring that the values for certain materials do not significantly deviate from their established baseline values.

Without a manufacturer's methodology, a test phantom containing materials of varying densities commonly seen in clinical practice is required, i.e., covering at least air, water, and bone.

If the system can produce Hounsfield Units, an action level of ± 50 HU from the baseline should be applied. If the system does not use the Hounsfield Unit scale, the mean density for a specific material must not deviate from the baseline by more than 25% of the difference between the values for water and air [8]. For example, if the measured density value for water is 10 and air is 850, the acceptable deviation for the mean density of a specific material should not exceed ± 210.

CBCT dose CBCT dose constancy can be assessed by measuring the free-in-air dose from a CBCT acquisition using a CT pencil chamber positioned at the isocentre or by fixing a dosemeter to the front face of the image receptor. The location of the dosemeter must be recorded, as this affects the reading of the measured air kerma. Some systems may claim conformance to the test methodology outlined in IEC 60601-2-44 [26], others may present their measurement

conditions, and some provide no guidance. The measurement technique should be varied according to any documentation supplied concerning CBCT dose specifications.

A tolerance of within ±20% of the baseline should be applied if no manufacturer methodology is provided.

Note that where separate generator control systems are used for CBCT capture (compared with projection imaging), it is recommended that free-in-air measurements be made for all clinically used modes and repeated five times in one mode to establish dose output and reproducibility.

Clinical audits

Diagnostic reference levels (DRL) Monitoring typical entrance air kerma rates is crucial for assessing imaging system stability under specified conditions and benchmarking across different equipment. However, Diagnostic Reference Levels (DRLs) provide a clinically oriented tool for optimising patient protection during diagnostic and interventional procedures [27]. It is essential to understand that DRLs are not dose limits but benchmarks to challenge current clinical practice. At the time of writing, Australia and New Zealand's only nationallyoptimisation of fluoroscopic systems [27–31]. However, comparative conclusions must account for differences in clinical procedure methodology, imaging technology, patient demographics and other influencing factors.

A patient dose survey determines the median dose for routine procedures, using it to compare against DRLs or other reference values [27]. Dose metrics, such as KAP, AK_{ref} and system-determined skin dose estimates, should be collected. Data on fluoroscopy time, acquisition runs, patient size, clinician, and case complexity can also be collected to provide a more detailed understanding of clinical practice. Statistical resilience improves with larger data sets, and the typical values for at least the top five procedures should be calculated using a minimum of 30 patients. Annual reviews by a medical physicist are recommended. However, the frequency should mirror local regulatory requirements or align with measuring outcomes from local clinical practice interventions [27]. Automated or semi-automated data collection via query or retrieval of RDSRs or system logs can improve sample size, enhance data integrity, and minimise data cleansing compared to more manual techniques. Analysis can be conducted by various staff, including unregistered medical physicists, medical physics registrars, trainees, and radiographers. However, the overall interpretation of the results must be made by the medical physicist overseeing the QA program.

High-dose patients Thresholds exceeding 2 Gy in peak skin dose (PSD) have been shown to potentially result in tissue effects, such as erythema, epilation, and tissue necrosis [2]. Hospitals performing complex interventional procedures have the potential to surpass these thresholds. Procedures must be in place to ensure patient follow-up, notify a medical physicist, and meet local regulatory reporting requirements. These procedures should also establish clear guidelines for patient communication and designate responsibilities for follow-up.

A quarterly audit must be conducted to confirm that all procedures resulting in cumulative AK_{ref}above locally established notification levels have been actioned. This essential review process not only ensures high levels of patient care but also confirms any regulatory reporting requirements have been fulfilled and allows medical physics review of locally established notification levels through receiving feedback on experienced tissue effects.

Data review for quality improvement As a range of data, including patient, clinical, and imaging parameters, is routinely collected for governance purposes, the secondary use of this information can enhance the effectiveness of routine QA programs. Many facilities now have access to electronic procedural data, including protocol parameters, dose metrics, patient demographics, and clinical indications. These datasets can be used for near real-time analysis, supporting a broader radiation risk management approach and facilitating quality improvement by identifying trends in system performance, variations related to specific imaging platforms, users, or protocols, and highlighting individual case outliers for review [32].

By implementing structured data monitoring processes, unusual patient dose levels, whether elevated or unexpectedly low, can be flagged for investigation. Persistent changes in system performance may also be identified more reliably than through user detection alone. While phantom-based checks and other regular quality control tests, as recommended in this guideline, are essential for evaluating equipment performance, the addition of automated monitoring using statistical process control methods, such as control charts, provides greater sensitivity to subtle or discrete changes in overall system function [32]. These changes may be due to equipment drift, unintended protocol modifications, or other operational variations.

Importantly, this approach also allows the identification of errors related to system use that might otherwise go unnoticed. When implemented as part of a broader monitoring program, it enables direct assessment of patient dose changes following a protocol update, confirming whether

the intended outcome has been achieved without compromising clinical performance. This contributes to a more robust and comprehensive risk management framework. Regular review of the collected data, conducted monthly, quarterly, or following any intended system or protocol change, adds a layer of oversight and may detect system issues more rapidly than routine compliance testing alone.

Radiographer quality control

Introduction

Radiographer QC procedures are essential in the ongoing QC program to ensure the fluoroscopic equipment's continued safe and optimal performance. These QC checks are intended to supplement the routine periodic medical physicist QC tests outlined above and help identify variations in system performance between medical physics QC tests, including unintended changes that may occur following preventative maintenance. At the discretion of the medical physicist overseeing the QA program, and depending on the metric and type of repair, radiographer QC procedures may also be of utility following certain system repairs to validate performance before returning the system to clinical use. It is vital that the tests are performed correctly and recorded accurately to allow for comparison with previous test results or baselines set at commissioning by the medical physicist. All personnel responsible for performing QC tests must receive initial training appropriate to their level of responsibility. Periodic re-training and mentoring by a medical physicist should be provided as required.

The tester must be capable of performing the QC test and identifying any procedural mistakes they may have made. Where out-of-tolerance results have been established, corrective action should involve seeking the advice of a medical physicist, who may perform further tests to ensure the system is acceptable for clinical use.

The medical physicist should periodically review the radiographer QC test records to identify system trends that may lead to future out-of-tolerance results (trend analysis), assist in identifying radiographer training needs, and rectify or re-establish baselines or procedural corrections as necessary. Results should be stored for the lifetime of the equipment.

If the unit being tested is a bi-plane system, both X-ray tubes and image receptors must be assessed against the requirements below and demonstrate matched performance within the system's design constraints. For tests compared to baseline, the consistent reproduction of system settings and exact alignment of phantom geometry are paramount.

Table 6 provides a comprehensive list of tests the radiographers must perform.

Periodic test procedure recommendations

Visual inspection

While observed and considered daily, radiographers should intentionally perform and record an overall mechanical inspection of the fluoroscopy system quarterly to ensure that no hazardous, inoperative, out-of-alignment, or improperly operating items are present on the system. The visual check should include:

- Check that all cables are free from breaks, kinks, or knots. Cables should not be under other heavy equipment or in a 'stressed' position.
- Ensure that there are no oil leaks around the X-ray tube and generator and that these are free from dust.
- Verify that anti-collision systems and brakes are working correctly.
- Ensure that the table, image receptor and tube move smoothly.
- Confirm the X-ray tube housing remains stationary during exposure unless intended to move.
- Ensure that all radiation warning signs are visible and that illuminated lights are functional.
- Verify that table- and ceiling-mounted shields are operable and fit for purpose.

Radioprotective personal protective equipment (PPE)

Fluoroscopic environments require a significant quantity of PPE due to the large number of staff involved in these procedures. Therefore, it is essential to ensure that the facility includes periodic checking of the integrity of these items as part of the QA program. Radioprotective PPE items, including aprons, eyewear, and thyroid collars, must be visually inspected before each use.

Checking for faults, holes, or material deterioration using fluoroscopy screening or a similar method [33, 34] should occur at acceptance, annually, and following any suspicion of damage or cracking to the protective material. To allow adequate contrast, testing can be performed using fluoroscopic X-ray equipment, ideally with a floating table, at approximately 60 kVp. Other screening methods that do not utilise ionising radiation may be used, but they need validation by a medical physicist.

For radioprotective aprons, any defect must not be > 15 mm^2 in area or 20 mm in length if the location is near a critical organ. If the area is away from critical organs, the defect must not be > 670 mm^2 in area or 50 mm in length. In cases

where the defect is not located over a critical organ and does not exceed the rejection criteria, the location of the defect must be marked on the radioprotective apron. For thyroid collars, any defect must not be > 11 mm^2 in area or 20 mm in length [35–37].

The integrity of shielding for radioprotective eyewear can be inspected visually. It must be rejected if there are any cracks or damage to the lens that is visible to the operator. Side shielding must remain attached to the eyewear in a location likely to intercept radiation towards the operator's eye lens.

Display monitor

Softcopy interpretation of medical image data is paramount to ensure high levels of patient care in fluoroscopic applications. It follows that regular assessment of the quality and accuracy of display technologies is required, as faults in display technology can mask or lead to misinterpretation of the produced image data. Several suitable test patterns [22] can be reviewed on live and reference monitors within the fluoroscopic suite and control room. Quarterly assessment by a radiographer should include an evaluation that:

- The pattern is centred in the active area, and borders are visible.
- Any ramp bars should appear continuous without any contour lines.
- Squares of different shades from black to white are distinct at a defined window and level setting. Note: assessment will depend on available test patterns. However, most will provide 5% and 95%-pixel value squares on 0% and 100% backgrounds. Higher-level assessments may include:
  - AAPM TG18-QC pattern - verification that all 16 luminance patches and corner patches are distinctly visible, or the number of letters visible in the phrase "Quality Control" for the dark, mid-grey and light renditions is at least eleven.
- No disturbing artefacts are visible, and.
- Non-uniformities, artefacts (including defective pixels) or ghosting, especially at black-to-white transitions, are not present.

These tests should be performed on a clean monitor after it has been powered on for 20 min to stabilise, and are to be conducted before other system IQ tests.

Dose rate constancy

In an ADRC mode, fluoroscopic systems should consistently produce the same response to a given stimulus. Any deviation from this baseline, established during commissioning, may indicate a system change potentially impacting the anticipated IQ and patient dose behaviours. Radiographers should conduct a monthly dose rate constancy check by employing a standardised system geometry with a uniform attenuator (such as a 2 mm Cu filter) that intercepts the X-ray beam. An exposure is made under ADRC conditions for the primary clinical protocols. Once the exposure rate has stabilised, the AK_{ref}rate (mGy/min) displayed by the system (or, if unavailable, the exposure technique kVp/mA/pulse duration) can be a suitable surrogate. The process is repeated for the primary clinical protocols' most commonly used field sizes. This test depends on the displayed AK_{ref}rate being accurate; calibration of the displayed dose metric is verified annually under Accuracy of displayed dose metrics. Where significant drift is identified at annual testing, prior radiographer constancy results should be reviewed retrospectively.

The displayed AK_{ref}rate (mGy/min) should be within ±20% of the baseline value.

Due to the variability of table thickness on some fixed fluoroscopic systems, specifying a fixed location along the z-axis helps ensure reproducible attenuation.

Image quality constancy

When in an ADRC mode, fluoroscopic systems should produce the same response to a given stimulus. The same constancy applies not only to dose rate but to IQ. The system's low-contrast detectability and high-contrast spatial resolution characteristics for a given ADRC mode should not change unexpectedly over time. Monitoring ensures that any deviation from expected behaviour is investigated and addressed quickly. Several fluoroscopic image-quality phantoms are available on the market. One that allows monitoring at least low contrast detectability and spatial resolution can be combined with the uniform attenuator used in the dose rate constancy testing ("Dose rate constancy" Section), providing a simple method to identify any concerning drift in IQ.

This process is to be conducted monthly on the most commonly used clinical protocol and field sizes. The overall appearance of the Dose Rate Constancy image should be assessed to identify any non-uniformities that may disrupt diagnosis, for example, areas of high attenuation due to mechanical damage to the grid and image receptor hydration artefacts. The subjective IQ of the phantom image must not differ from baseline values.

On systems with CBCT functionality, CBCT image quality should also be assessed monthly—including a visual check for undesirable artefacts and, optionally, low-contrast resolution constancy testing. Performance must not differ from baseline values.

Fluoroscopy quality review meeting

Fluoroscopy quality review meetings should be conducted, with documented minutes to ensure adequate follow-up and ensure that all necessary actions are taken. These meetings aim to review system performance, address quality issues, and support continuous improvement in patient care. Where feasible, these meetings should report to (or function as a subcommittee of) the hospital's Radiation Safety Committee, ensuring alignment with the hospital's overarching radiation safety objectives.

Where feasible, the following personnel should attend the quality review meetings:

- Administrator (e.g., chief radiographer or appropriate delegate)
- Senior radiographer
- Clinical representative (e.g., radiologist or radiology registrar)
- Technical representative (e.g., service engineer or maintenance contract manager)
- Medical physics representative (e.g., QMPS)
- Radiation safety representative (e.g., Radiation Safety Officer)

The agenda for each meeting should include the following points:

- Review of facility QC results
- Review of any relevant incidents or deviations
- Review of cases exceeding tissue reaction thresholds
- Discussion of IQ concerns from clinical images
- Review of audits and trend analysis
- Assessment of protocol management and updates

Additionally, the meeting should aim to identify atypical performance trends and explore opportunities for QA improvements.

The meeting should be chaired by a designated lead (typically the QMPS) and held at least quarterly, with the frequency reviewed annually based on the volume of fluoroscopic activity, the complexity of the equipment fleet, and the rate at which findings or incidents are identified. A quorum should be specified locally; at minimum, the medical physics representative, a clinical representative, and either the senior radiographer or radiation safety representative should be present.

Each meeting should produce documented minutes that capture decisions, agreed actions, owners, and due dates. Actions should be maintained in a persistent action register that is reviewed at the start of every subsequent meeting to track progress and close out items.

Implementation considerations

Resource and workforce implications

Implementation of this guideline requires access to appropriately qualified personnel and equipment. A QMPS is essential for establishing and overseeing the QA program, conducting acceptance and commissioning tests, and performing periodic medical physics assessments. Facilities in rural or regional areas may face challenges in accessing QMPS services, and strategies such as shared service arrangements or remote consultation should be considered to address this gap.

Equipment required for comprehensive fluoroscopy QA testing includes calibrated dosimetry instruments, image quality phantoms (for both fluoroscopy and, where applicable, CBCT), beam quality measurement tools, and appropriate attenuating materials (e.g., PMMA slabs and Cu filters). The cost of acquiring and maintaining this equipment should be factored into departmental budgets.

Radiographer-led quality control procedures require initial training and periodic re-training by a medical physicist. Adequate time must be allocated within clinical schedules to perform the recommended QC tests without compromising patient care. The level of training required will depend on the complexity of the tests and the radiographer's experience.

Resource requirements will vary depending on facility size, the number and complexity of fluoroscopic systems, clinical workload, and the scope of existing preventive maintenance contracts. Facilities should assess their specific needs and develop implementation plans that balance the recommendations of this guideline with practical constraints.

Regulatory or accreditation relevance

This guideline is designed to complement, not replace, local regulatory requirements for radiation safety and equipment compliance. In Australia, the ARPANSA Code for Radiation Protection in Medical Exposure [10] establishes the overarching regulatory framework, while specific requirements are administered by state and territory radiation

safety authorities. In New Zealand, radiation safety is regulated under the Radiation Safety Act 2016 and administered by the Ministry of Health.

The recommendations in this guideline are consistent with the RANZCR Standards of Practice for Clinical Radiology [23] and may assist facilities seeking accreditation or compliance with these standards. Facilities should ensure their QA programs satisfy both the recommendations of this guideline and all applicable regulatory requirements. Where the two differ, the more stringent requirement applies.

Monitoring and quality improvement strategies

Facilities should monitor the implementation and effectiveness of their QA program through several mechanisms. The fluoroscopy quality review meeting described in "Fluoroscopy quality review meeting" provides a regular forum for reviewing system performance, quality control results, and clinical dose audit data.

Trend analysis of quality control data, including dose rate constancy, image quality metrics, and equipment performance records, should be used to identify gradual performance changes that may not be apparent from individual test results. Statistical process control methods, such as control charts, can enhance the sensitivity of monitoring programs to detect subtle or discrete changes in system function [32].

Regular clinical dose audits, including comparison against diagnostic reference levels where available, support ongoing optimisation of fluoroscopic practice and patient radiation protection.

Limitations and barriers to adoption

Several potential barriers to the adoption of this guideline are acknowledged:

- Workforce availability: Access to a QMPS may be limited in some regions, particularly rural and remote areas. The guideline's recommendation for QMPS oversight of all QA programs may present challenges for facilities without established medical physics services.
- Equipment and cost: The phantoms, dosimeters, and test objects required for comprehensive QA testing represent a significant investment. Facilities with limited budgets may need to prioritise acquisition based on the recommended test categories in this guideline.
- Regulatory variation: Differences in radiation safety regulations between Australian states and territories, and between Australia and New Zealand, mean that facilities must reconcile guideline recommendations with their specific regulatory obligations.
- Vendor-specific differences: Fluoroscopic systems from different manufacturers may implement ADRC, service modes, and dose reporting features differently, which can affect the applicability of specific test procedures. Access to service modes for some measurements may require vendor cooperation.
- Clinical workflow: Allocating equipment downtime for QA testing in busy clinical environments remains a practical challenge. The flexibility built into testing frequencies (under QMPS guidance) is intended to help address this barrier.

Review and endorsement statement

This document was approved by the ACPSEM Board on 31 July 2026. It will be reviewed no later than 31 July 3031 by the ACPSEM Fluoroscopy QA Working Group or a working group established under the ACPSEM Radiology Specialty Group. An earlier review may be initiated if prompted by significant changes in evidence, technology, regulatory requirements, or professional standards.

This is the first edition of this guideline.

Conclusion

This guideline presents a framework for the QA of fluoroscopic systems in the Australian and New Zealand context, drawing upon international best practices and local expertise. The recommendations outlined, spanning from acceptance testing to routine quality control and radiographer QC procedures, are essential to ensure that the equipment consistently performs as expected over time, thereby maintaining patient safety and radiation protection of staff. The guideline should be implemented in the context of local regulatory requirements and institutional resources, and its recommendations should be adapted to the specific clinical and operational circumstances of each facility. This guideline will be reviewed within five years of publication, or sooner if significant developments in technology, evidence, or regulatory requirements warrant revision. The ACPSEM strongly encourages the adoption of these practices and emphasises the importance of collaboration with a medical physicist to tailor certain aspects to local needs and update procedures between subsequent republications.

Appendix

See Tables 5 and 6 .

Table 5 Summary of recommendations for medical physics testing of fluoroscopic units

Item	Test	Classification	Performance requirements	Brief method	Frequency
3.2.1	Verification of distances (displayed and fixed)	Recommended	The focal spot must be marked externally on the tube housing Confirm geometry distances, such as SID and table position, are within ± 1 cm. The focus-to-skin distance must be ≥ 300 mm for fixed fluoroscopic systems, ≥ 200 mm for mobile systems, and does not apply to mini-C-arms	Visually determine if housing is removed by an engineer or use triangulation with two different-sized objects	At acceptance or a significant upgrade
3.2.2	Radiation protection of the operator	Recommended	For fixed systems, confirm that appropriate radiation protection for the operator, including but not limited to ceiling-mounted shields, table drapes/skirts, and distance of operation, is installed correctly and suitable for the clinical use of the room For mobile systems, wearing PPE in combination with operation from a sufficient distance, greater than 2 m from the focal spot or X-ray beam, using a hand or footswitch on a cable, or any other means validated by a medical physicist is required For extremity systems (Mini C-arms) without a hand or foot switch on an extendable cable, the dose rate should not exceed 10 µGy/min at the operator's hand/foot position If a real-time staff dose monitoring system is integrated with the fluoroscopic system, its suitability and calibration must be evaluated. These systems supplement, but do not replace, traceable personal dosimetry	For fixed systems, assess the appropriateness of radiation protection for the operator For mobile systems, confirm that operation from a distance greater than 2 m from the focal spot or X-ray beam can be achieved For extremity systems (Mini C-arms) without a hand or foot switch on an extendable cable, determine the dose rate with 5 cm PMMA in the X-ray beam Assess the suitability and calibration requirements of any real-time staff dose monitoring system	At acceptance only
3.2.3	Radioprotective personal protective equipment (PPE)	Recommended	PPE should meet minimum design criteria as outlined in IEC 61331-3 [16], and it is recommended that attenuation properties are determined with consideration to clinical use to provide optimised protection to wearers	Assess PPE requirements depending on the workload and radiation scatter contexts. Test the attenuation properties of specific fabrics according to IEC 61331-1 [17]	At purchase. At PPE Acceptance
3.2.4	Beam quality (HVL)	Recommended	The total filtration must be such that the half-value layer of the primary beam for a given X-ray tube and collimator is not less than the values specified in this document.	Determine the HVL at the kV_p increments used in the kV_p accuracy test.	At acceptance, tube change, or significant repair
3.2.5	Tube voltage accuracy	Recommended	Measured tube voltages should be within ± 5% of the indicated values (action level). Deviations exceeding ± 10% require the system to be withdrawn from clinical use until rectified	Obtain a series of measurements from the lowest kV_p to the maximum kV_p in increments of 10 kV_p steps	At acceptance or significant repair
3.2.6	Leakage radiation	Recommended	The maximum leakage radiation must not exceed 1 mGy/hr averaged over 100 cm^2 (with no linear dimension more than 20 cm) at 1 m with the X-ray tube operating at the maximum kV_p and mA	Determine the dose rate at various points around the tube housing with the collimators completely closed or with additional lead shielding placed at the exit of the collimator to ensure that only stray X-rays from the assembly are detected	At acceptance, tube change, or if damage is visible on the tube housing
3.2.7	ADRC functionality	Recommended	The ADRC should be characterised for the primary clinical protocols (fluoroscopic and acquisition) intended for that fluoroscopic unit, including the most commonly used FOV	Characterise the ADRC functionality using manufacturer procedures or the methodology outlined by AAPM Task Group 125 [19]	Commissioning

Table 5 (continued)

Item	Test	Classification	Performance requirements	Brief method	Frequency
3.2.8	Table and mattress attenuation	Optional	The table and mattress attenuation should be categorised for a range of kV_p	Undertake a set of measurements to quantify the extent of attenuation of the beam for the actual equipment used, being aware of table thickness in the *z*-direction, possible changes in mattress thickness, and any different beam qualities achieved through the ADRC control (kV_p and filtration)	At acceptance
3.2.9	RDSR	Recommended	Confirm the RDSR's conformance with the Basic dose documentation level of IEC 61910-1 [21] or the Extended dose documentation level for fixed systems used for complex cases Confirm the accuracy of the RDSR metrics	Compare RDSR-recorded values against measured air kerma values; confirm correct transmission to and storage in PACS	At procurement, acceptance, and relevant software changes
3.2.10	Distance calliper accuracy	Recommended	Distance calliper accuracy should ideally be within a tolerance of ± 2% but must at least meet the manufacturer's specified tolerances	In the same plane as the image receptor, image steel rulers or other objects with known dimensions parallel to and at a 90° angle to the long axis of the patient table. Direct measurements should be taken from the image using console tools. Distance measurements should also be performed at the reporting workstation to confirm no issues when transferring dimensions to PACS. If this is not feasible, images should be exported to another workstation and assessed with a DICOM viewer. Magnification effects need to be considered	At acceptance and relevant software changes
3.2.11	Display monitor assessment	Recommended	Monitors must meet the RANZCR Standards of Practice [23] and may be assessed against AAPM Report 270 [22] All live and reference monitors used in the examination and control rooms must meet the standards of a secondary monitor	Assess all live and reference monitors in examination and control rooms following procedures specified in AAPM Report 270 [22]	At acceptance
3.3.1	Fluoroscopic system assembly evaluation	Recommended	A full mechanical inspection of the fluoroscopic system and related components ensures no hazardous, misaligned, or inoperative features on the system	Confirm the function and condition of all motorised components, anti-collision devices, emergency cut-off switches, deadman switches, warning lights, timers, indicators, displays, cables, interlocks and any miscellaneous safety-related issues (e.g. system motion stability)	At acceptance and routine periodic testing
3.3.2	Collimation and alignment	Recommended	If the X-ray beam is rectangular, and the image receptor is circular, the length and width of the X-ray beam must fall within the image receptor area. In all other circumstances, the discrepancy between any edge of the X-ray beam and the corresponding visible edge of the image (or collimator edge, if visible) must not exceed 1% of the focal spot-to-image receptor distance (SID) For systems with variable SID functionality, the collimator must automatically track changes in SID to maintain consistent alignment between the X-ray field and the image receptor	Assess the alignment for all available field sizes and at a single focal spot to image receptor distance (at a minimum) Observe automatic collimator adjustment while screening as the SID is increased	At acceptance, routine periodic testing, tube, or collimator change and image receptor replacement

Table 5 (continued)

Item	Test	Classification	Performance requirements	Brief method	Frequency
3.3.3	Accuracy of displayed dose metrics	Recommended	Must meet manufacturer-specified tolerances or displayed AK_{ref} rate, AK_{ref}, and Cumulative KAP should be within ± 20% and must be within ± 35%	The accuracy of the displayed dose metrics should be assessed under the manufacturer's calibration conditions. This might involve controlling variables like kV_p, patient table and mattress in or out of the beam, measurement location and field size. If the conditions are not specified, the measurement procedure detailed in AAPM Report 190 [25] should be followed	At acceptance and routine periodic testing
3.3.4	Radiation dose output	Recommended	The air kerma rate should be within ± 20% of the baseline values High-Level Control / Boost modes that exceed Normal-mode air kerma rate limits must require continuous activation and an audible warning signal The coefficient of variation must not exceed 0.05 for five consecutive measurements of air kerma rate	1. The maximum SID should be selected, and the dosimeter should be placed on the X-ray tube side of 20 cm of PMMA at the reference point (Table 3). The test is to be conducted for at least the three most common protocols and one dose mode for all FOVs 2. Confirm that a continuous audible alarm is triggered when the dose rate at the image receptor surpasses 88 mGy/min 3. Obtain at least 5 consecutive radiation output measurements under the same testing conditions as step 1. 4. Determine the typical air kerma rate at the input surface of the image receptor for clinically relevant protocols	At acceptance, commissioning and routine periodic testing During commissioning, additional measurements should be taken to determine the typical entrance dose rates for the most commonly used protocols using a patient-equivalent phantom of varying thickness
3.3.5	Image quality	Recommended	Images should be free from distortions and clinically relevant artefacts. Image uniformity, high-contrast (spatial) resolution, low-contrast resolution, and temporal resolution should each be evaluated against baseline. DSA performance must also be assessed if used clinically. Limiting spatial resolution must not deteriorate over time, and low-contrast tolerances should be established with clinical staff	Assess the IQ of a range of clinically relevant protocols using a fluoroscopic IQ test object placed on the image receptor and an attenuator of Cu or equivalent in front of the collimator	At commissioning and routine periodic testing
3.3.6	Laser alignment	Optional	The medical physicist must consider the purpose of the laser being assessed. Achieving laser beam alignment better than ± 1 mm is not typically expected. Lasers can usually attain alignment within ± 2 mm	This test is to be performed free-in-air to centre the image receptor's entrance field and designate the entrance skin plane. These tests should not necessitate radiation exposure The image receptor's entrance surface/grid and X-ray focus serve as useful reference points	At acceptance and routine periodic testing

Table 5 (continued)

Item	Test	Classification	Performance requirements	Brief method	Frequency
3.3.7	CBCT functionality	Recommended	1. The geometric precision should be within ± 2 mm or stricter if clinical context demands higher accuracy 2. Subjective uniformity and noise should be assessed. Objective IQ should be within ± 20% or ± 10 HU of baseline 3. Subjective limiting spatial resolution should be assessed. Objective assessment of the 50% and 10% MTF values should be within ± 10% of baseline 4. The voxel density should not deviate by ± 50 HU from baseline or ± 25% of the difference between the values for water and air at baseline 5. Free-in-air dose from a CBCT acquisition should not deviate by ± 20% of baseline	1–4. Assessed using a suitable phantom placed at isocentre (e.g. Catphan®) and evaluated on the acquisition workstation using the displayed HU or pixel value or offline with other software 5. Assessed using a CT pencil chamber placed free-in-air for all clinically used modes	At acceptance, commissioning and routine periodic testing
3.3.8	Clinical audits	Recommended	DRLs: Review local typical values; clinical practice must be reviewed where a facility's typical value significantly exceeds (or falls far below) published DRLs High-dose patients: Procedures with cumulative AK_{ref} above locally established notification levels must be actioned, including patient follow-up and any required regulatory reporting Data review for QI: Routine monitoring of dose and protocol data should support trend analysis and identification of outlier cases, ideally using statistical process control methods	DRLs: Determine typical values for the top five most-performed procedures using a minimum of 30 patients each High-dose patients: Confirm all cases above local notification thresholds have been actioned and reviewed Data review for QI: Use RDSR queries or system logs to identify trends and outliers; review following protocol or system changes	Annual DRL review Quarterly high-dose patient audit Data review monthly, quarterly, or following protocol/system changes

Table 6 Summary of recommendations for radiographer testing of fluoroscopic units

Item	Test	Classification	Performance requirements	Brief method	Frequency
4.2.1	Visual inspection	Recommended	A full mechanical inspection of the fluoroscopic system and related components is needed to ensure no hazardous, misaligned, or inoperative features are present on the system	Confirm the function and condition of all motorised components, warning lights, displays, cables, interlocks, and any miscellaneous safety-related issues (e.g. system motion stability)	Quarterly
4.2.2	Radioprotective PPE	Recommended	Aprons: Defects near critical organs must not exceed 15 mm^2 in area or 20 mm in tear length. Defects away from critical organs must not exceed 670 mm^2 in area or 50 mm in tear length Thyroid collars: Defects must not exceed 11 mm^2 in area or 20 mm in tear length. Eyewear: Must be free from any cracks or damage within the operator's line of sight Side shielding must remain securely attached	Inspect all articles visually for function e.g. Velcro, clips and hanging loops and using a floating table or similar method screen in fluoroscopic mode to determine integrity. Note: while less efficient, radiographic exposures or CT scanograms offer an alternative to fluoroscopic assessment	Annually and on suspicion of damage or cracking of the protective material
4.2.3	Display monitor	Recommended	Criteria using a suitable test pattern (e.g. AAPM TG18-QC) must meet the following requirements: The pattern is centred in the active area, and borders are visible; Any ramp bars should appear continuous without contour lines; Squares of different shades from black to white are distinct at a defined window and level setting; No disturbing artefacts are visible; and Non-uniformities, artefacts (including defective pixels) or ghosting, especially at black-to-white transitions, are not present	Visually assess a suitable test pattern on live and reference monitors in the fluoroscopy suite and control room	Quarterly
4.2.4	Dose rate constancy	Recommended	The displayed AK_{ref}rate (mGy/min) must be within ± 20% of the baseline value. If the surrogate metric of kVp/mA is to be used, the medical physicist must determine the equivalent deviation values from baseline values	Using a uniform attenuator, such as 2 mm Cu, the displayed dose rate should be recorded and compared to the baseline for all field sizes on the most used protocol	Monthly
4.2.5	Image quality constancy	Recommended	The subjective image quality must not differ from baseline values. On systems with CBCT functionality, CBCT image quality should also be assessed monthly for undesirable artefacts and (optionally) low-contrast resolution constancy	Using a suitable IQ phantom, the subjective image quality should be assessed on the most used protocol and field size	Monthly

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