



Imaging Physics

Recommendations for Routine

Testing and Quality Control

for

Diagnostic Imaging Equipment

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CancerCare Manitoba
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IMAGING PHYSICS

Performance Test Procedures

This report is intended as a guide to routine Quality Control (QC) procedures and recommends the tests which should be performed on various pieces of diagnostic Imaging Equipment. This includes daily, weekly, monthly QC procedures performed by the technologist in the Department, as well as annual performance checks performed by the Physicist. Some of the annual tests may be performed by a Physicist or Physics Associate in association with the Radiation Protection Officer, as part of the annual X-ray safety program.

It is recommended that there should be a Quality Assurance Committee at each site, which oversees the quality control programme and ensures that quality issues are acted upon promptly.

Quality control procedures:

Each Department should have documentation describing how the quality control procedures are performed. This may simply be a reference to the manufacturer's recommended quality control procedures, but should be sufficiently detailed to ensure consistent collection of the quality control data.

Records:

A record should be kept of all tests performed, along with the results. If possible, numerical results should be plotted so that trends can be easily observed. A log book close to the equipment and organised in columns, allows quick and easy recording of information. The logbook should also record action taken as a result of unsatisfactory test results.

Action Levels:

The documentation should also include expected results and the range of values which are considered acceptable. Details should be given on what action should be taken in the event of results falling outside these levels. These action levels may be set by the manufacturer, or may be set following acceptance, or baseline, testing performed after the installation of the equipment.

Test procedures and frequencies have been based on recommendations from Professional Associations including:

Canadian Association of Radiologists

American College of Radiology

American Association of Physicists in Medicine
Institute of Physics and Engineering in Medicine
British Institute of Radiology
American Institute of Ultrasound in Medicine
National Electrical Manufacturers Association

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Computed Radiography Equipment.

Daily (*Technologist*)

1. Inspection:
Inspect operational aspects of the system, including reader, ID terminals and viewing monitor.
2. Cleaning:
Remove dust, especially from the cassette slot.
3. Sensitometry:
Create laser-generated sensitometry strip and measure film densities
4. Film Supply:
Check film supply.
5. Artefacts:
Randomly select a cassette, erase and view it. Look for image artefacts. Log the ID number and results.

Weekly (*Technologist*)

1. Cleaning:
Clean filters and vents on system and processors.
2. Non-circulating Plates:
Erase all little-used, or non-circulating imaging plates in the inventory.
3. Sensitometry:
Create flash sensitometry strip for the processor only, and measure film densities.
4. Monitor Calibration:
Verify monitor calibration for soft copy review workstations using the SMPTE pattern, contrast/brightness settings to visualize 0%-5% patch and 95%-100% patch simultaneously.
5. Inspection of Plates:
Inspect cassettes and imaging plates. Clean as necessary according to the manufacturers instructions.
6. Phantom Images:
Acquire test phantom images and catalog results in computer database.

Monthly (*Technologist*)

1. Perform qualitative and quantitative QC phantom analysis (low contrast, spatial resolution, signal to noise ratio “spot-checks”).
2. Review film retake rate, overview exposure indices, determine causes of unacceptable images.
3. Review QC database; determine cause of problems and implement corrective action.

Semi-Annually and Annually (*Physicist and Technologist*)

1. Perform linearity/sensitivity tests of imaging plate inventory.
2. Inspect/evaluate image quality; spot check image processing algorithms for appropriateness.
3. Undertake acceptance test procedures to verify and/or re-establish baseline values.
4. Review retake activity, patient exposure trends, QC records and service history of the equipment.

References:

AAPM. Report of Task Group No. 10. 1998

Conventional Fluoroscopic Equipment.

All tests should be repeated after a tube change or any other major service to the unit.

Daily (*Technologist*)

1. Daily testing is not required unless a specific imaging quality problem has arisen. Use a phantom which can monitor detail/contrast as a minimum for tracking image quality.
2. Brightness and Contrast Levels:
Use a step wedge phantom to track display brightness and contrast levels.

Weekly (*Technologist*)

1. System functionality :
Image a detail/contrast phantom and record the maximum detail and lowest contrast levels observed as a function of kV and mA.

Annually (*Physicist/Radiation Protection Officer*)

1. Surface entrance exposure rates:
Measure the exposure rates for typical exams at all magnifications in phantoms of varying thicknesses, mimicking human anatomy using automatic brightness mode.
2. Maximum exposure rates:
Cover the Image Intensifier with lead to drive the kV and mA to its maximum.
Measure at the table top for under-table x-ray tubes.
3. Spatial resolution:
Use a line pair test pattern, and a copper plate at the collimator to sharpen the beam and yield the best possible image.
4. Low contrast detectability:
Use a contrast phantom, such as an aluminum plate which has an array of varying diameter circles with different thicknesses.
5. Half value layer:
For radiographic/fluoroscopic systems the HVL, and therefore the beam quality is not the same. The HVL has to be determined separately for the fluoroscopic mode.
6. Anti-scatter grid:
Remove the grid and image it using a detail film/screen system.
7. Collimation alignment:
Align the centre of the x-ray beam with the centre of the video image. Image for all magnification modes. Edges should align within 2% of the SID.

8. Image intensifier input exposure rate (IIER):
Place the ionization chamber between the entrance plane and the grid with the ABC driving the system to about 80kV. Measure for every pulsed fluoro, continuous, and high contrast fluoro rates, and each magnification mode.

References:

ACR Standard for Diagnostic Medical Physics Performance Monitoring of Radiographic and Fluoroscopic Equipment. 1997

Conventional Radiographic Equipment.

All tests should be repeated after a tube change or any other major service to the unit.

Daily (*Technologist*)

1. Visual Check:
Visually check the cables, interlocks, edges, etc to ensure patient safety.
2. Functionality:
Verify that the equipment is functional. At a minimum, check that generator turns on and programming protocols are accessible.

Weekly (*Technologist*)

1. Contrast-detail:
Image the contrast-detail phantom at a set protocol to ensure consistency of imaging. Log the image details, minimum contrast observed and highest detail achievable, for comparison and discussion at the monthly quality assurance meetings.

Quarterly (*Technologist*)

For older systems.

1. X-ray Beam and Bucky Alignment:
Align the centres of the x-ray beam and the bucky. There should be less than 2% SID variance between edges. This will prevent image cut-off.

For portables and wall buckys.

2. Grid Alignment and Timing:
Align the centre of the grid with the centre of the x-ray beam. Misalignment will result in cut-off artifacts, light film, or increased patient radiation.

Annually (*Physicist/Radiation Protection Officer*)

1. Half Value Layer:
Measure the half value layer to track beam quality.
2. Light Field and X-ray Field Congruence:
Check the light field and x-ray field congruence. If not aligned, this may lead to unnecessary exposures, or repeat exams.
3. Field Size Indicator:
The field size error should not be more than 2% of the SID (source-image-distance).
4. Focal Spot Size:
Use a slit camera to check the focal spot size. This will ensure proper performance of equipment.

5. X-ray Beam and Bucky Alignment:
Align the centres of the x-ray beam and the bucky. There should be less than 2% SID variance between edges. This will prevent image cut-off.
6. Kilovoltage Calibration and the kV Waveform:
The kilovoltage should not vary by more than 5% from stated value. Keep the waveform for yearly comparisons.
7. Exposure Timer Accuracy:
For those generators that indicate the time, 5% is acceptable for times greater than 10ms, with 10% for times less than 10ms.
8. Beam Quality:
Measure the mR/mAs for all focal spots and useful range of kVs and mA at a pre-determined SID. A 20% variation is allowed across the ranges.
9. Automatic Exposure Control (AEC):
The same optical density must be achieved regardless of the kV, mA or patient thickness.
10. AEC Density Control:
Optical density steps can manually override the base setting. Intervals should be checked against settings.
11. Grid Artifacts:
Image the grids to reveal any artifacts that could affect the patient diagnosis.
12. Grid Alignment and Timing:
Align the centre of the grid with the centre of the x-ray beam. Misalignment will result in cut-off artifacts, light film, or increased patient radiation.

CT Scanners

All vendors supply a phantom with their scanners. The technologist should perform the QA recommended by the manufacturer using the phantom supplied.

Physicists' tests are required following major changes, such as x-ray tube replacement.

Daily (*Technologist*)

An air calibration is automatically performed as part of the daily warmup procedure.

At Least Weekly (*Technologists*)

1. Imaging quality:
Scan the QC phantom provided by the vendor.
 - Examine the image for artifacts and non-uniformity at a constant window level and window width.
 - The mean value in the ROI is the CT number of water, the SD represents the image noise.
 - Significant artifacts or changes in mean CT number or SD may indicate a malfunctioning system.

Typical Values:

CT No. of water should be: 0 ± 3 .

Standard deviation at any position of the region of interest (ROI) should be in the range 2 to 7 but be constant for fixed technique and position on the phantom.

Quarterly (*Physicist/Technologist*)

1. Review QA log for system performance.
2. Review technique chart: investigate increased dose techniques.

Annually (*Physicist/Radiation Protection Officer*)

1. Beam Width profile:
Image slice widths, at several thicknesses, using Ready Pack film, in helical and axial modes. The FWHM of the profile gives the imaged slice thickness.
Measure the Scan Incrementation.

2. Radiation Dose and Scatter:
Position the CTDI head phantom at the isocentre. Acquire dose measurements at several kV's and slice widths.
With the CTDI positioned at the isocentre, position the Pancake probe 1m away at 45° from the gantry isocentre to obtain scatter measurements.
These measurements are useful in calculating dose to patients as well as monitoring the system.
Measure the dose in air at the isocentre.
3. Half Value Layer (HVL):
Park the tube. Measure the output for various thicknesses of aluminum. The HVL is a measure of tube performance.
4. Laser Beam Alignment:
Some vendors provide a phantom which can be used to check alignment. This is an important measurement for biopsies.
5. Uniformity and Noise:
Image the vendors QC phantom and look for areas of non uniformity. Use the ROI feature on the system to measure the noise.
6. Review of Current Protocols:
Investigate increased dose techniques.
7. High Contrast Spatial Resolution:
Use the vendor's phantom or the Catphan500 phantom . Acquire data at several kV's and mA's.
8. Low Contrast Detectability:
Use the vendor's phantom or the Catphan500 phantom. Acquire data at several kV's and mA's, using axial and helical modes.

References:

CAR Standards for Performing and Interpreting Diagnostic CT scans. 1994

AAPM Report 39 Specification and Acceptance Testing of Computed Tomography Scanners, 1993

AAPM Report No.74, Quality Control in Diagnostic Radiology, July 2002.

Digital Fluoroscopy Equipment (including Cath Lab).

All tests should be repeated after a tube change or any other major service to the unit.

Daily (*Technologist*)

1. Daily testing is not required unless a specific imaging quality problem has arisen. Use a phantom which can monitor detail/contrast as a minimum for tracking image quality.
2. Brightness and Contrast Levels:
Use a step wedge phantom to track display brightness and contrast levels.

Weekly (*Technologist*)

1. System functionality :
Image a detail/contrast phantom and record the maximum detail and lowest contrast levels observed as a function of kV and mA.

Annually (*Physicist/Radiation Protection Officer*)

1. Surface entrance exposure rates:
Measure the exposure rates for typical exams at all magnifications in phantoms of varying thicknesses, mimicking human anatomy using automatic brightness mode.
2. Maximum exposure rates:
Cover the Image Intensifier with lead to drive the kV and mA to its maximum.
Measure at the table top for under-table x-ray tubes.
3. Spatial resolution:
Use a line pair test pattern, and a copper plate at the collimator to sharpen the beam and yield the best possible image.
4. Low contrast detectability:
Use a contrast phantom, such as an aluminum plate which has an array of varying diameter circles with different thicknesses.
5. Half value layer:
For radiographic/fluoroscopic systems the HVL, and therefore the beam quality is not the same. The HVL has to be determined separately for the fluoroscopic mode.
6. Anti-scatter grid:
Remove the grid and image it using a detail film/screen system.

7. Collimation alignment:
Align the centre of the x-ray beam with the centre of the video image. Image for all magnification modes. Edges should align within 2% of the SID.

8. Image intensifier input exposure rate (IIER):
Place the ionization chamber between the entrance plane and the grid with the ABC driving the system to about 80kV. Measure for every pulsed fluoro, continuous, and high contrast fluoro rates, and each magnification mode.

References:

ACR Standard for Diagnostic Medical Physics Performance Monitoring of Radiographic and Fluoroscopic Equipment. 1997

AAPM Report 15: Performance Evaluation and Quality Assurance in Digital Subtraction Angiography

AAPM Report 70: Cardiac Catheterization Equipment Performance

Laser Printer.

In addition to the periodic testing, all inspections should be done on an “as needed” basis.

Daily (*Technologist*)

1. Sensitometry:
Print laser-generated sensitometry strip, measure and plot film densities.
2. Film Supply:
Check short-term film supply.
3. Contrast:
Print a gray image. Measure and record contrast levels from an average of values in each of four quadrants. The difference between any quadrant should not be greater than 0.2 OD. Horizontal banding should not be evident. Vertical banding contrast levels should not be greater than 0.02 OD.

Weekly (*Technologist*)

1. Film Supply:
Check longer-term film supply.
2. Contrast/Brightness:
Print SMPTE pattern, contrast/brightness settings to visualize 0%-5% patch and 95%-100% patch simultaneously and record values.

Monthly (*Technologist and Physicist*)

1. Retake Rate:
Review film retake rate, to determine causes of unacceptable images.
2. QC Database:
Review QC database; determine cause of problems and implement corrective action.

Semi-Annually and Annually (*Technologist and Physicist*)

1. Retake Rate:
Review retake activity, patient exposure trends, QC records and service history of the equipment.

References:

AAPM. Report of Task Group No. 10. 1998

Mammography

It is recommended that all mammography units seek accreditation by the Canadian Association of Radiologists.

To achieve and maintain this accreditation, QC records and annual testing are required. Annual tests must be performed by a Medical Physicist who has passed the Accreditation exam held by the Canadian College of Medical Physicists.

Daily (*Technologist*)

1. **Darkroom cleanliness:**
Before films are processed, wipe the horizontal surfaces in the darkroom with a lint-free cloth and an anti-static solution.
2. **Processor Quality Control:**
Visually inspect the processor and clean the surfaces. Take a sensitometry strip and plot the results.
3. **Screen cleanliness:** Clean the screens with a lint-free cloth and a cleaner recommended by the screen manufacturer. This will ensure images are free of dust artifacts.

Weekly (*Technologist*)

1. **Viewboxes and viewing conditions :**
Clean viewbox surfaces with a lint-free cloth and special cleaning solution. Remove sources of light glare from the viewing areas.
2. **Phantom images :**
Image an approved mammographic test phantom, eg RMI-156. Score the phantom image and plot the results. Retain the phantom image films for at least one full year.
3. **Processor chemistry :**
Check the specific gravity of the fixer and developer solutions.

Monthly (*Technologist*)

1. **Visual checklist :**
Visually inspect the interlocks, display lights, compression paddle condition and cable condition and record on a checklist.

Quarterly (*Technologist*)

1. Repeat analysis :
Analyse the reasons for rejected and repeated films to identify where improvements may be made.
2. Analysis of fixer retention in film :
Use hypo test solution to analyse fixer retention in the film. This ensures image stability.

Semi-annually (*Technologist*)

1. Darkroom fog :
This procedure ensures that the darkroom fog is kept sufficiently low, so as not to reduce contrast in mammographic films.
2. Screen-film contact :
A screen-film contact test tool is required. This test is to ensure optimum contact is maintained between the screen and the film in each cassette.
3. Compression:
Measure the breast compression force using bathroom scales. This will ensure adequate, but not excessive, breast compression force.

Annual Testing (*Physicist*)

1. Mammography unit assembly evaluation
2. Collimation assessment
3. Evaluation of focal spot size performance
4. kVp reproducibility and accuracy
5. Beam quality assessment (half-value layer)
6. Automatic exposure control system performance assessment
7. Uniformity of screen speed
8. Breast entrance exposure, average glandular dose, and AEC reproducibility
9. Image quality evaluation
10. Artifact evaluation
11. Inspection of mammography site's Quality Control program
12. Measurement of viewbox illuminance

References:

ACR. Mammography Quality Control Manual. 1999

Quebec Breast Cancer Screening Program. Mammography Quality Control Manual. 2001

MRI

The following quality control tests shall be performed and documented by an MR technologist knowledgeable in quality control procedures.

Daily (*Technologist*)

1. Frequency:
Measure the central frequency.

Weekly (*Technologist*)

1. Signal-to-Noise:
Measure the system signal-to-noise ratio on a standard head or body coil.

Annually (*Physicist*)

1. Review daily quality control testing records.
2. Measure image uniformity.
3. Measure spatial linearity.
4. Measure high contrast spatial resolution.
5. Measure slice thickness, locations and separations.
6. Assess image quality and image artifacts.
7. Eddy current compensation.
8. System shim.

References:

ACR Standard for Diagnostic Medical Physics Performance Monitoring of Magnetic Resonance Imaging Equipment. 1999

CAR Standards for Magnetic Resonance Imaging. 1999

Nuclear Medicine

Daily (*Technologist*)

1. Peak position and Flood field uniformity :
Use either
 - a) ^{99m}Tc point source with the collimator removed
 - or
 - b) ^{57}Co sheet source with a low-energy collimator installedCheck the position of the peak then acquire a flood image, typically about 10 million counts. Record the uniformity numbers, if available, or perform a visual inspection.
2. Attenuation correction imaging :
If there are attenuation correction sources, follow the manufacturers recommended daily quality control procedures.
3. Dose Calibrator :
Check the zero and the background reading. Measure the check source on all isotope settings which will be used that day. Record all these values.

Monthly (*Technologist*)

Follow the recommendations from the manufacturer. This will usually include:

1. High count uniformity :
Acquire an intrinsic or extrinsic flood with 50 to 200 million counts, perhaps including different radionuclides and different collimators.
2. Centre of rotation or non-circular orbit correction :
Prepare the sources and scan as recommended. This may be a check of the current Centre of Rotation correction or the acquisition of new data.
3. Attenuation Correction sources :
Follow the procedures and limits recommended.
4. Jaszczak Phantom :
Use a bone SPECT protocol for acquisition and processing. Make a visual comparison to previous scans. This is an overall check of the whole SPECT imaging procedure.

Annually (*Physicist*)

These tests will be performed according to the protocols described in the NEMA documents. The tests may include:

1. Intrinsic Energy Resolution.
2. Intrinsic Spatial Resolution:
Use a slit phantom to measure the resolution in mm.

3. Intrinsic linearity:
Use a slit phantom.
4. Intrinsic Count Rate Performance:
Measure the response of the camera to an increasing input count rate using copper plates to increase the input counts.
5. Multiple Window Registration:
Use Gallium-67 to check that the images formed by the different energy peaks are accurately aligned.
6. System Spatial Resolution:
Measure the system resolution in air using the LEHR collimator.
7. System Planar Sensitivity:
Measure the system response to a known amount of radioactivity in a thin round phantom.
8. SPECT Reconstructed Resolution:
Using the cylindrical phantom containing three line sources, acquire and reconstruct SPECT data. Calculate the FWHM of the resulting point images.
9. Whole Body Count Rate Variation on Scanning:
Using a cobalt sheet source placed on the lower detector, acquire a scanned image for the full length of the bed. Use line profiles to check the uniformity of the image.

References:

ACR Nuclear Medicine Accreditation Program Overview. 2003

NEMA NU 1. Performance Measurements of Scintillation Cameras, 1994 and 2001

IPEM Report 86. Quality Control of Gamma Camera Systems. 2003

Ultrasound

Daily (*Technologist*)

1. Scan Head Elements:
Check for dead scan head elements

Weekly (*Technologist*)

1. Image Quality:
If desired, the technologist can scan themselves at low power. Use the same presets.
Most important is the quality of spectral & colour Doppler.

Monthly (*Technologist*)

1. Artefacts:
Check for loose matching layer (beam former artefacts)
2. Noise increase or reduction in penetration:
Acquire a B-mode image of a standard phantom using standardized settings.
3. Image comparison:
Scan the phantom and check for a decrease in contrast of vessels in phantom

Annually (*Physicist*).

1. Dead scan head elements
2. Beam former artefacts
3. Noise measurements
4. Spatial resolution:
Image of a string in a water bath
5. Spectral & colour Doppler sensitivity and accuracy (if phantoms are available)

References:

ACR the Standard for Diagnostic Medical Physics Performance Monitoring of Real Time B-mode Ultrasound Equipment. 1998

CAR Standards for Performing and Interpreting Diagnostic Ultrasound examinations. 1996

AIUM standards committee. Standards methods for measuring performance of pulse-echo ultrasound imaging equipment. 1991 AIUM Laurel MD.

AIUM methods for measuring performance of pulse echo of sound imaging equipment Part II: digital methods stage 1. 1995a AIUM Laurel MD.

AIUM standards committee. AIUM quality assurance manual for greyscale ultrasound scanners: stage 2. 1995b AIUM Laurel MD.

AIUM technical standards committee. Methods for specifying acoustic properties of tissue mimicking phantoms and objects: stage 1. 1995c AIUM Laurel MD.

AIUM standards committee. Performance criteria and measurements were Doppler ultrasound devices. 1993 AIUM Laurel MD.

Real-time B-mode ultrasound quality control test procedures Report of a AAPM Ultrasound Task Group No 1. Med. Phys. 25: 1385-1 406; 1998.

IPSM Report No 70. Testing of Doppler ultrasound equipment. 1994

IPSM report No 71. Routine Quality Assurance of Ultrasound Imaging Systems. 1995.