Quality Assurance and Accreditation in Nuclear Medicine

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Disclosure

• No disclosures
Objectives

• Review the elements of a quality assurance program for nuclear medicine including PET
• Review Quality Assurance (QA) programs that are a part of accreditation
• Discuss the role of the medical physicist in Quality Assurance and the accreditation process
• Describe what a medical physicist does in the nuclear medicine department
My Nuclear Medicine Coverage

• Medical physicist at a university hospital
• Accredited by The Joint Commission (TJC)
  • 2 PET/CT
  • 1 SPECT/CT
  • 3 SPECT
  • 1 Planar gamma camera
• We provide consulting medical services to other organizations throughout the state
  • 3 PET/CT scanners that are ACR accredited for both PET and CT
  • 1 SPECT scanner that is accredited by Intersocietal Accreditation Commission (IAC)
Quality Assurance and Quality Control

• Quality Assurance – What is it?
  • Quality Assurance (QA) is a system wide program in which data is used to establish confidence that the product or service being delivered meets a high standard of quality
  • The service we deliver is patient care

• Quality Control (QC) is a single component of QA
  • Quality Control encompasses the specific testing that we use to ensure that our instruments are working properly

• QA/QC includes the two things a medical physicist is always concerned with:
  • Image quality
  • Patient dose
Why do we do QA and QC?

• At perhaps the most basic level we do QC because it is legally required
• Does meeting the legal requirements set by law constitute a quality assurance program?
  • The answer is “no”
• The regulations are primarily concerned with radiation safety
• Federal regulations do not address image quality
• Agreement state regulations vary
• Legally mandated QC is not enough to assure that the institution is producing quality images and quality patient care
History - MIPPA

• In 2008, Congress passed the Medicare Improvements for Patients and Providers Act (MIPPA)

• One part of MIPPA dealt with advanced diagnostic imaging which was defined as Nuclear Medicine, PET, MR and CT

• To receive payment for imaging services provided to a patient covered by Medicare, MIPPA required that suppliers that provide the technical component of advanced diagnostic imaging be accredited by a designated organization

• Centers for Medicare and Medicaid Services (CMS) is part of the Department of Health and Human Services (HHS)

• The Secretary of Health and Human Services was tasked with designate the accrediting organizations
Why do we do QA and QC?

- Accreditation “Quasi-mandated” by the need to do business and receive reimbursement from Medicare
- Three original organizations chosen to accredit diagnostic imaging facilities
  - American College of Radiology (ACR)
  - The Joint Commission (TJC)
  - Intersocietal Commission on Accreditation of Nuclear Laboratories (ICANL)
CMS Approved Accrediting Organizations in Nuclear Medicine

At this time, CMS considers the following accrediting organizations to meet MIPPA requirements for reimbursement:

- The Joint Commission (TJC)
- American College of Radiology (ACR)
- Intersocietal Accreditation Commission (IAC) formerly ICANL
- RadSite
TJC and ACR

• Hospitals were exempt from MIPPA requirements
• Hospitals that are TJC accredited must meet TJC requirements for Diagnostic Imaging
• The latest set of TJC requirements for Diagnostic Imaging went into effect July 1, 2015
• The TJC requirements are similar to the standards used by the ACR and other accrediting bodies
Common Elements Among Accrediting Organizations

• Some common elements of quality standards of the accrediting bodies:
  • Three-year cycle for accreditation
  • Random site visits and site audits
  • Review of:
    • Qualifications of medical personnel
    • Continuing education
    • Safety of patients and personnel
    • Written procedures for the tasks necessary for a nuclear medicine department
    • *Equipment performance including review of phantom images*
    • *Quality control and quality assurance program*
Medical Physicist – QA/QC

• Part of the physicists job is to do the research necessary to find an appropriate test that measures the value of interest

• Does this in a timely fashion

• Establish pass/fail criteria
  • Baseline measurements
  • Manufacturer’s specifications
  • Accepted standards (ACR pass/fail criteria)

• Establish testing frequency

• Annual survey w phantom imaging
Medical Physicist – QA/QC

• All four accrediting bodies have very similar requirements
• All provide a list of tests that are required but not much regarding pass/fail criteria
• All have phantom imaging requirements that can be met by using the ACR phantom testing instructions and ACR pass/fail criteria
• Other resources include:
  • AAPM – American Association of Physicists in Medicine – Publishes methods of testing camera sensitivity, count rate performance and other tests
  • Manufacturer’s will often provide performance data
Gamma Camera Testing

The Joint Commission

A 21. At least annually, a diagnostic medical physicist or nuclear medicine physicist conducts a performance evaluation of all nuclear medicine imaging equipment. The evaluation results, along with recommendations for correcting any problems identified, are documented. The evaluations are conducted for all of the image types produced clinically by each NM scanner (for example, planar and/or tomographic) and include the use of phantoms to assess the following imaging metrics:

- Image uniformity/system uniformity
- High-contrast resolution/system spatial resolution
- Sensitivity
- Energy resolution
- Count-rate performance
- Artifact evaluation

Note 1: The following test is recommended, but not required: Low-contrast resolution or detectability for non-planar acquisitions.

Note 2: The medical physicist or nuclear medicine physicist is accountable for these activities. He or she may be assisted with the testing and evaluation of equipment performance by individuals who have the required training and skills, as determined by the medical physicist or nuclear medicine physicist. (See also HR 01.02.01, EP 1; HR 01.02.05, EP 20; HR 01.02.07, EPs 1 and 2; HR 01.06.01, EP 1; and LD 03.06.01, EP 4)

RadSite

7.2.3 Nuclear Medicine Testing

7.2.3.1 Gamma Camera Imaging

A. Physics Testing

1. Annual Physics Evaluation of Nuclear Medicine modalities means testing that is performed on the Nuclear Medicine system by a qualified medical physicist and that includes at least the following factors:

   - Intrinsic Uniformity
   - System Uniformity
   - Intrinsic Spatial Resolution
   - System Spatial Resolution
   - Count Rate Sensitivity
   - Visual Inspection of Camera

2. The Imaging providers must submit the following to meet the Gamma Camera physics review requirements:

   - The Nuclear Medicine system’s Annual Physics Evaluation is performed by a qualified medical physicist.
   - All Sites have completed the Site’s Nuclear Medicine Protocol Review Sheet for the procedures specified.
   - Tc-99m or Co-57 intrinsic or extrinsic uniformity images of 10 million counts for each camera head. If Ti-201 is utilized by the facility, Ti-201 uniformity images are also required for each camera head.

7.2.3.2 Single Photon Emission Computed Tomography (SPECT) Images

A. Physics Testing

1. Annual Physics Evaluation of Nuclear Medicine modalities means testing that is performed on the Nuclear Medicine unit by a qualified medical physicist and that includes at least the following factors:

   - Intrinsic Uniformity
   - System Uniformity
   - Intrinsic Spatial Resolution
   - System Spatial Resolution
   - Count Rate Sensitivity
   - Visual Inspection of Camera
   - Center of Rotation

   Review of Nuclear Medicine Technologist’s Quality Control Tests
Gamma Camera Testing

ACR

Nuclear Medicine Performance Tests - At Least Annually:

1. Intrinsic Uniformity - Performed to ensure that the intrinsic detector integral and differential uniformity is sufficient to minimize the production of artifacts and ensure that patient abnormalities can be visualized without interference from the imaging system. These tests also monitor a scintillation unit for electronic problems and crystal deterioration (hydration).

2. System Uniformity - Performed to check all commonly used collimators for defects that might produce artifacts in planar and tomographic studies.

3. Intrinsic or System Spatial Resolution - Performed to ensure that the detector resolution is sufficient to provide satisfactory lesion detectability and delineate detail in clinical images.

4. Relative Sensitivity - Performed to verify that count rate per unit activity is satisfactory to maintain image quality and preserve the integrity of quantitative studies.

5. Energy Resolution - Performed to verify that scatter rejection is sufficient to provide optimal contrast in clinical studies. Note: On some unit systems, precise measurements of energy resolution are very difficult to make.

6. Count Rate Parameters - Performed to ensure that the time to process an event is sufficient to maintain spatial resolution and uniformity in clinical images acquired at high-count rates.

7. Formatter/Video Display - Performed to ensure that systems used to produce hard copy and monitors that are used for interpretation of clinical studies provide satisfactory image quality in terms of uniformity and spatial resolution.

8. Overall System Performance for SPECT Systems - Performed to quantitatively verify that SPECT systems provide satisfactory tomographic uniformity, contrast and spatial resolution.

9. System Interlocks - Performed to verify that all system interlocks are operating as designed and that the system is safe and reliable for the nuclear medicine technologist to operate and for imaging patients.

IAC

1.3.1B Gamma Camera

(See Guidelines on Page 35 for further recommendations.)

1.3.1.1B Energy peaking to verify that the photopake is centered in the set photopake energy window must be performed, if applicable (documentation not required). Frequency: Daily (prior to use)

1.3.1.2B Intrinsic or extrinsic uniformity calculation of integral and/or differential uniformity values must be performed on all gamma cameras (e.g., 3-5%). Frequency: Daily (prior to use)

1.3.1.3B Spatial resolution/spatial linearity with resolution phantom (e.g., bars) must be performed on all gamma cameras. Frequency: Weekly

1.3.1.4B Center-of-rotation (COR) must be performed to ensure mechanical and electrical alignment of the center of field of view. Frequency: Monthly

1.3.1.5B High count flood for uniformity correction, performed to correct for residual detector and collimator non-uniformity, must be performed. Frequency: Per manufacturer’s recommendation

1.3.1.6B Preventive maintenance (PM) of all gamma cameras must be performed. Frequency: Every six months

1.3.1B Gamma Camera:

Overall system performance may be evaluated using a fillable phantom containing non-radioactive (cold) inserts of different sizes and visually inspecting the resulting images.

Collimator integrity, comparing the extrinsic and intrinsic uniformity flood along with visual inspection of collimator for damage, should be performed. Frequency: Annually
Gamma Camera - Planar

- All image types used clinically must be tested i.e. planar and tomographic

- Planar tests:
  - Intrinsic and extrinsic uniformity (floods)
  - Spatial resolution (bars)
  - Sensitivity
  - Energy resolution
  - Count rate performance
  - Artifact evaluation

**Note 1:** The following test is recommended, but not required: Low-contrast resolution or detectability for non-planar acquisitions.

**Note 2:** The medical physicist or nuclear medicine physicist is accountable for these activities. He or she may be assisted with the testing and evaluation of equipment performance by individuals who have the required training and skills, as determined by the medical physicist or nuclear medicine physicist. (See also HR.01.02.01, EP 1; HR.01.02.05, EP 20; HR.01.02.07, EPs 1 and 2; HR.01.06.01, EP 1; and LD.03.06.01, EP 4)
Nuclear Medicine Camera Quality Control

• Periodic testing of gamma cameras usually being performed by nuclear medicine technologist

• Planar imaging
  • Uniformity - daily
  • Spatial resolution - weekly
  • Spatial linearity – weekly

• SPECT
  • Uniformity correction map - monthly
  • Center of rotation (COR) correction – monthly

• I review the test results and perform my own tests
Gamma Camera: Planar

- Intrinsic and extrinsic uniformity floods
- Evaluate ability of system to produce a uniform image of a uniform field of radiation
- Artifacts
- Problems with the crystal
- PMT problems
- Evaluate collimators for damage

Early and Sodee, *Principles and Practice of Nuclear Medicine 2nd ed.*
Gamma Camera: Planar

• Spatial Resolution and Linearity
• Test that the system can provide adequate spatial resolution
• Measures the ability to visualize small objects
• Linearity checks that the system is not producing spatially distorted images

Nuclear Medicine Planar Only Images:
(4-quadrant bar phantom)

Te99m or Co57:

Intrinsic spatial resolution images:
Satisfactory: 2.5 to 2.9 mm bars are resolved in one quadrant of a four quadrant pattern and they have low contrast
Marginal: 3.0 to 3.4 mm bars resolved in one quadrant of a four quadrant pattern

System spatial resolution images:
Satisfactory: 3.0 to 3.4 mm bars are resolved in one quadrant of a four quadrant pattern
Marginal: 3.5 to 3.9 mm bars resolved in one quadrant of a four quadrant pattern
Gamma Camera: Planar

• Sensitivity – measured count rate with known amount of activity in a flat container
• Measure cpm/uCi
• Compare to manufacturer’s claims and/or baseline values

Early and Sodee, Principles and Practice of Nuclear Medicine 2nd ed.
Gamma Camera: Planar

- Energy resolution is measured using spectrometer (MCA) function on modern gamma camera
- This ensures that the camera is measuring the correct gamma photon energy
- Also verifies that the camera is rejecting scattered photons. This reduces image noise

A 21. © At least annually, a diagnostic medical physicist or nuclear medicine physicist conducts a performance evaluation of all nuclear medicine imaging equipment. The evaluation results, along with recommendations for correcting any problems identified, are documented. The evaluations are conducted for all of the image types produced clinically by each NM scanner (for example, planar and/or tomographic) and include the use of phantoms to assess the following imaging metrics:

- Image uniformity/system uniformity
- High-contrast resolution/system spatial resolution
- Sensitivity
- Energy resolution
- Count-rate performance
- Artifact evaluation

Note 1: The following test is recommended, but not required: Low-contrast resolution or detectability for non-planar acquisitions.

Note 2: The medical physicist or nuclear medicine physicist is accountable for these activities. He or she may be assisted with the testing and evaluation of equipment performance by individuals who have the required training and skills, as determined by the medical physicist or nuclear medicine physicist. (See also HR.01.02.01, EP 1; HR.01.02.05, EP 20, HR.01.02.07, EPs 1 and 2; HR.01.08.01, EP 1; and LD.03.06.01, EP 4)
Gamma Camera: Planar

- Count rate performance is measured using two-source method
- Compare results to established baselines for older cameras
- Manufacturer’s performance claims

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Count Rate Performance

- When a gamma photon interacts with a detector, it takes a finite amount of time for the detector to respond to this event.
- The “resolving time” or “dead time” is how long it takes a detector to recover after detecting an event.
- The detector will not count another event during the dead time.
- At high count rates, the system will not count some events.

Knoll, Radiation Detection and Measurement.
Count Rate Performance

- As a result of dead time, the observed count rate will be less than the true count rate
- This can impact quantification studies in which data is obtained at high count rates
  - Rapid data acquisition
  - Large activity

**Figure 11-15.** Observed ($R_o$) versus true ($R_t$) counting rate curves for paralyzable and nonparalyzable systems having the same dead time value, $\tau$. 
Gamma Camera: Tomographic

- Tomographic tests:
- SPECT uniformity/artifact evaluation
- SPECT high-contrast resolution
- SPECT low-contrast resolution

Note 1: The following test is recommended, but not required: Low-contrast resolution or detectability for non-planar acquisitions.

Note 2: The medical physicist or nuclear medicine physicist is accountable for these activities. He or she may be assisted with the testing and evaluation of equipment performance by individuals who have the required training and skills, as determined by the medical physicist or nuclear medicine physicist. (See also HR.01.02.01, EP 1; HR.01.02.05, EP 20, HR.01.02.07, EPS 1 and 2; HR.01.06.01, EP 1; and LD.03.06.01, EP 4)
Gamma Camera: Tomographic

- ACR provides detailed phantom testing instructions with pass/fail criteria
- SPECT QC involves imaging an ACR SPECT phantom also known as a Jaszczak phantom
Gamma Camera: Tomographic

- The phantom is filled with water
- Approximately 10-20 mCi of Tc-99m is mixed with the water
- A SPECT scan of the phantom is performed
**Flangeless Deluxe Jaszczak Phantom™**

**Model ECT/FL-DLX/P**

**Main Features:**
- Deluxe ECT phantom without protruding flange

**Main Applications:**
- For use with high spatial resolution SPECT and PET systems
- System performance evaluation (collimator, artifacts, calibration, reconstruction parameters)
- Acceptance testing
- Routine quality assurance and control
- Evaluation of center-of-rotation error
- Evaluation of non-uniformity artifact
- Evaluation of changes of radius-of-rotation on spatial resolution
- Evaluation of reconstruction filters on spatial resolution
- Evaluation of attenuation and scatter compensation
- Research
- ACR recommended phantom

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**Specifications of Cylinder:**
- Cylinder inside diameter: 20.4 cm
- Cylinder inside height: 18.6 cm
- Cylinder wall thickness: 6.4 mm

**Specifications of Insert and Spheres:**
- Rod diameters: 4.8, 6.4, 7.9, 9.5, 11.1 and 12.7 mm
- Height of rods: 8.8 cm
- Solid sphere diameters: 9.5, 12.7, 15.9, 19.1, 25.4 and 31.8 mm
- Height of center of spheres from base plate: 12.7 cm
ACR SPECT Phantom

• The top region is free of objects and is used to evaluate uniformity

• The middle region contains spheres of different sizes. This region is used to evaluate contrast

• The bottom region contains rods of different sizes. These are used to evaluate resolution
Gamma Camera: Tomographic

- ACR provides detailed phantom testing instructions with pass/fail criteria

### Nuclear Medicine SPECT Phantom:

**(Deluxe Phantom)**

(If a phantom receives 2 scores of Marginal this equals a FAIL)

**Tc99m SPECT:**

**Uniformity (GP and HR):**

- Satisfactory [3]: Artifacts are seen in only a few slices of the complete set but are not thought to be clinically significant.
- Marginal [2]: Significant artifacts visualized in one or more slices but they probably would not affect the interpretation of clinical studies.
- Fail [1]: Strong artifacts visualized in one or more slices of such magnitude that they probably will affect the interpretation of clinical studies and the instrument should not be used for clinical studies.

**Spatial Resolution (GP and HR):**

- Satisfactory: 11.1 mm rods resolved with low contrast
- Marginal: 12.7 mm rods resolved with high contrast

**Contrast (GP and HR):**

- Satisfactory: 19.1 mm and larger spheres resolved with high contrast
- Marginal: 25.4 mm and larger spheres resolved with low contrast

### Specifications of Insert and Spheres:

- Rod diameters: 4.8, 6.4, 7.9, 9.5, 11.1 and 12.7 mm
- Height of rods: 8.8 cm
- Solid sphere diameters: 9.5, 12.7, 15.9, 19.1, 25.4 and 31.8 mm
- Height of center of spheres from base plate: 12.7 cm

### Specifications of Cylinder:

- Cylinder inside diameter: 20.4 cm
- Cylinder inside height: 18.6 cm
- Cylinder wall thickness: 6.4 mm
Uniformity

• The results of phantom imaging are rich in information
• Uniformity requirements for SPECT are more stringent than for planar imaging
• A nonuniformity that may not be noticeable on planar images may produce a visible artifact on images of the SPECT phantom
• Common causes of non-uniformities include:
  • Different sensitivities of the PMTs (unbalanced PMTs or the PMTs are not ‘tuned’)
  • Damaged collimator
  • Activity contamination on camera
  • Out of date uniformity map
Non-Uniformity Artifact

- **Figure 09-38.** Uniformity artifacts are formed when there is an area of decreased sensitivity on the camera face. **A,** A quality control phantom is filled with uniform tracer solution. An area of decreased sensitivity resulted in a uniformity defect in the activity profiles of the two planar projections shown. **B,** When back-projected, these areas originate from the same pixels in each projection. **C,** The intersections of the uniformity defects from each of the projections scribes a circular defect in the transaxial image.

Christian and Waterstram-Rich, Nuclear Medicine and PET/CT, 7th ed.
Center of Rotation (COR)

- The center of rotation is an imaginary axis about which the camera heads rotate.
- Each detector matrix needs to be in near perfect alignment with the COR.
- Offset errors of even a fraction of a pixel can produce artifacts and negatively affect the spatial resolution of SPECT images.
Effects of COR Offset Error

3.3.2. Example: Simulations of a phantom reconstructed with different COR offset errors — no statistical noise

Simulations with different COR offsets of a reconstructed transverse slice through the rods of a Data Spectrum ECT phantom (Jaszczak phantom). Acquisition: No statistical noise, 37 cm FOV with 1.5 zoom, 64×64 matrix, 360° total angle of rotation, 64 projection angles. Reconstruction into transverse slices using a ramp filter and FBP, no attenuation correction. No correction was made for the COR offset error. Pixel size 3.85 mm.

L: 0 pixel offset (perfect data).
M: 0.25 pixel offset error.
R: 0.5 pixel offset error.

IAEA Quality Control Atlas for Scintillation Camera Systems
Effects of COR Offset Error

3.3.4. Example: Phantom reconstructed with and without COR offset error (real data)

A

B

Single-head SPECT system, Data Spectrum ECT phantom (Jaszczak phantom) imaged with and without COR offset correction where the offset was 3 pixels. 360° total angle of rotation. Reconstruction with FBP and a Hann filter. The left image in both A and B shows the transverse image (6 mm thick slice) at the level shown as a horizontal line on the raw image data (right images).

A: Uncorrected for a COR offset of 3 pixels.
B: Corrected for COR offset.
PET Camera Testing

The Joint Commission

A. 22. At least annually, a diagnostic medical physicist conducts a performance evaluation of all position emission tomography (PET) imaging equipment. The evaluation results, along with recommendations for correcting any problems identified, are documented. The evaluations are conducted for all of the image types produced clinically by each PET scanner (for example, planar and/or tomographic) and include the use of phantoms to assess the following imaging metrics:

- Image uniformity/system uniformity
- High-contrast resolution/system spatial resolution
- Low-contrast resolution or detectability (not applicable for planar acquisitions)
- Artifact evaluation

**Note 1:** The following tests are recommended, but not required, for PET scanner testing: sensitivity, energy resolution, and count-rate performance.

**Note 2:** Medical physicists are accountable for these activities. They may be assisted with the testing and evaluation of equipment performance by individuals who have the required training and skills, as determined by the medical physicist. (See also HR.01.02.01, EP 1; HR.01.02.02, EP 2; HR.01.02.07, EPs 1 and 2; HR.01.06.01, EP 1, and LD.03.06.01, EP 4)

RadSite

7.2.3.3 Positron Emission Tomography (PET) Images

A. Physics Testing

1. Annual *Medical Physics* Evaluation of *Nuclear Medicine* modalities means testing that is performed on the PET unit by a qualified medical physicist and that includes at a minimum the following factors:
   a. Spatial Resolution
   b. Uniformity
   c. Contrast Resolution
   d. SUV Evaluation
   e. Review of *Nuclear Medicine* Technologist’s Quality Control Tests
PET Camera Testing

ACR

- ACR-approved Phantom - Testing of each PET system with an appropriate phantom as described below
- Dose Calibrators - Performed annually to verify that readings from this instrument are accurate (accuracy test). All basic measurements of performance must be done at the time of installation and repeated after major repair. This test must be done according to protocols accepted by the appropriate state regulatory agencies or the NRC.
  - Linearity
  - Accuracy with NIST traceable standard

IAC

1.3.2B PET Scanner

1.3.2.1B A blank scan, performed by uniform irradiation of the detector elements to assess detector response, must be performed.
Frequency: Daily

1.3.2.2B Tomographic uniformity using a cylinder phantom (as applicable for procedures performed per regulations)
Frequency: Per manufacturer’s recommendation

1.3.2.3B Bed position alignment (as applicable for procedures performed per regulations)
Frequency: Per manufacturer’s recommendation

1.3.2.4B Normalization calibration to measure the efficiency of all the detector projections in the system must be performed.
Frequency: After a hardware change or per manufacturer’s recommendations

1.3.2.5B Absolute activity calibration (as applicable for procedures performed per regulations)
Frequency: After a hardware change or per manufacturer’s recommendations

1.3.2.6B Preventive maintenance of all PET and PET/CT scanners must be performed.
Frequency: Every six months

Comment: If imaging equipment is physically moved from site to site, the QC tests must be repeated after each move and prior to equipment use.

1.3.3B SPECT/CT and PET/CT Scanner

1.3.3.1B Accuracy of image registration (as applicable for procedures performed per regulations)
Frequency: Monthly or per manufacturer’s recommendation

1.3.3.2B Accuracy of CT-based attenuation correction (as applicable for procedures performed per regulations)
Frequency: Monthly or per manufacturer’s recommendation
ACR PET Phantom

• The ACR SPECT phantom can be converted to ACR PET phantom
• The spheres are removed a special lid is added
• The lid has several containers that are filled with a solution of F-18
• The ability of the camera to perform quantitative (SUV) studies is evaluated with the phantom

Data Spectrum Corp.

ACR PET Phantom Instructions
PET Camera Testing

• The quantitative capability of the camera system can be evaluated by following a “recipe” provided in the ACR PET Phantom Instructions

• The following are specified:
  • Activity
  • Injection start time
  • Patient weight

APPENDIX: PET Phantom Activation Based on Patient Dose

From the left column on the Chart below, select the administered FDG whole-body dose for your site. The corresponding phantom Doses A and B are along the same row as the Patient dose. Be sure to adjust the “zero” and “background” settings on your dose calibrator. Follow the directions below to measure (± 10%) the doses and activate the PET phantom. Scanning begins 1 hr after Dose A is measured. (Please record all information on the “Phantom Dilution Worksheet” found on page 12.)

### Phantom Dose Chart

<table>
<thead>
<tr>
<th>Patient Dose</th>
<th>Dose A mCi</th>
<th>Dose B mCi</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 mCi</td>
<td>0.14</td>
<td>0.33</td>
</tr>
<tr>
<td>6 mCi</td>
<td>0.21</td>
<td>0.50</td>
</tr>
<tr>
<td>8 mCi</td>
<td>0.28</td>
<td>0.66</td>
</tr>
<tr>
<td>10 mCi</td>
<td>0.35</td>
<td>0.83</td>
</tr>
<tr>
<td>12 mCi</td>
<td>0.42</td>
<td>0.99</td>
</tr>
<tr>
<td>14 mCi</td>
<td>0.49</td>
<td>1.15</td>
</tr>
<tr>
<td>16 mCi</td>
<td>0.56</td>
<td>1.32</td>
</tr>
<tr>
<td>18 mCi</td>
<td>0.63</td>
<td>1.48</td>
</tr>
<tr>
<td>20 mCi</td>
<td>0.70</td>
<td>1.65</td>
</tr>
</tbody>
</table>

Directions for Activating Phantom and Vials

Protocol Summary for the Two Required Doses (from Chart)
• **Dose A** will be added to 1000 ml bag (or bottle) to diluted activity for the 4 test vials.
• **Dose B** will be added to the phantom as background activity.

1) Measurement of Doses A and B
   Measure and record the activity of **Dose A** and **Dose B** (tuberculin syringes) with time on the work sheet (next page). Scanning begins 1 hr after the Dose A measurement time.

2) Activation of Test Vials on Phantom Cover
   Add **Dose A** to the 1000 ml bag or bottle and mix well. Then with the first 60 ml syringe withdraw 60 ml — this is test **Dose #1** (set aside, see Step 4). Next, using the second 60 ml syringe withdraw 40 ml from the bag and fill the 4 appropriate chambers in the phantom top.

3) Activation of the Phantom
   Thoroughly mix **Dose B** into the main chamber of the PET phantom (a bubble of air will help ensure a well-mixed solution). After mixing, using the third 60 ml syringe, withdraw 60 ml from the phantom — this is test **Dose #2** (set aside, see Step 4).

4) Test Dose Measurement with Time
   Measure the activity of test **Dose #1** and **Dose #2** and record. Then, inject **Dose #2** back into the phantom. Fill any remaining air-space in the phantom with water and mix again. Scan at the specified time. Dispose of syringes appropriately.
PET Camera Testing

- Quantitative results
- Regions of interest are drawn around the different containers and SUV values are calculated for each container

ACR PET Phantom Instructions

**Evaluation of SUV Analysis Worksheet**

*****NEW 2010 PASS/FAIL CRITERIA for SUV Values (revised December 2, 2009):*****

- Mean Bkgd: 0.85 – 1.15
- 25 mm cylinder: >1.8 - <2.8
- 16/25 ratio: >.7
PET Phantom Criteria

• Annual imaging tests required by TJC can be met with the ACR PET phantom
• ACR has pass/fail criteria for phantom images

ACR PET Phantom Instructions

PET Phantom:
(If a phantom receives 2 scores of Marginal this equals a FAIL)
Contrast:
Satisfactory: 12 mm vial is resolved with low contrast; larger vials resolved with high contrast
Marginal: 16 mm vial is resolved with acceptable contrast; larger vials resolved with high contrast
Spatial Resolution:
Satisfactory: 9.5 mm rods are resolved with low contrast; larger rods are resolved with high contrast
Marginal: 11.1 mm rods are resolved with low contrast; larger rods are resolved with high contrast
Uniformity:
Satisfactory: Artifacts are seen in only a few slices of the complete set but are not thought to be clinically significant.
Marginal: Strong artifacts are seen in a small number of slices.

NEW 2010 PASS/FAIL CRITERIA for SUV Values (effective July 1, 2010):
Mean Bkgd: 0.85 – 1.15
25 mm cylinder: >1.8 <2.8
16/25 ratio: >0.7

A phantom acquisition with two or more marginal scores for any category will be failed.
Computed Tomography

• CT is a necessary compliment of PET imaging and is being widely used with SPECT
• Consult for organizations that have 3 PET/CTs
• Our hospital has 2 PET/CTs and one SPECT/CT
• All of these CT perform diagnostic imaging
• I spend a significant amount of time dealing with CT systems located in nuclear medicine departments
Computed Tomography

• The Joint Commission has Diagnostic Imaging Requirements that went into effect July 1, 2015
• These requirements are for Nuclear medicine, PET, CT and MRI
• Note that the TJC requirements for diagnostic imaging do not apply to “dental cone beam CT radiographic imaging studies performed for diagnosis of conditions affecting the maxillofacial region or to obtain guidance for the treatment of such conditions”
• The TJC requirements for diagnostic imaging do not apply to CT systems used for calculating attenuation coefficients for nuclear medicine studies
• PET/CT and SPECT/CT systems are used to perform diagnostic CT in TJC accredited facilities must meet TJC requirements for CT
TJC/ACR CT

- CT annual survey is required
- TJC lists the tests that need to be done
- Does not have specifics
- We follow ACR CT manual
- The testing outlined in the ACR manual satisfies the testing requirements for TJC

**Standard EC.02.04.03**
The organization inspects, tests, and maintains medical equipment.

A 19. For diagnostic computed tomography (CT)

- **services:** At least annually, a diagnostic medical physicist conducts a performance evaluation of all CT imaging equipment. The evaluation results, along with recommendations for correcting any problems identified, are documented. The evaluation includes the use of phantoms to assess the following imaging metrics:
  - Image uniformity
  - Slice thickness accuracy
  - Slice position accuracy (when prescribed from a scout image)
  - Alignment light accuracy
  - Table travel accuracy
  - Radiation beam width
  - High-contrast resolution
  - Low-contrast resolution
  - Geometric or distance accuracy
  - CT number accuracy and uniformity
  - Artifact evaluation

**Note 1:** This element of performance does not apply to dental cone beam CT radiographic imaging studies performed for diagnosis of conditions affecting the maxillofacial region or to obtain guidance for the treatment of such conditions.

**Note 2:** Medical physicists are accountable for these activities. They may be assisted with the testing and evaluation of equipment performance by individuals who have the required training and skills, as determined by the physicist. (See also HR 01.02.01, EP 1: HR 01.02.01, EP 20; HR 01.02.07, EPs 1 and 2; HR 01.06.01, EP 1; and LR 03.06.01, EP 4)
Computed Tomography

RadSite

7.2 Standard - Physics Quality Evaluation

7.2.1 Computed Tomography (CT)

7.2.1.1 CT Physics Testing

A. Annual physics evaluation of CT imaging modalities means testing that is performed on the CT imaging system by a qualified medical physicist and that includes at a minimum the following factors:

1. CT number accuracy
2. Slice thickness verification
3. CT number uniformity
4. CT noise measurement
5. High contrast spatial resolution
6. Low contrast detectability
7. Review of the site’s CT quality assurance program.
8. Patient radiation dose for clinically utilized scans

B. Imaging providers must submit the following to meet the CT physics review requirements:

1. Submission of the most recent medical physics report for each imaging system under accreditation review (must be within the past 12 months).
2. Completed site CT protocol data for each imaging system for the procedures specified, containing the patient radiation dose information, especially dose length product (DLP) and CT dose index (CTDI) information necessary for medical physicist’s dose evaluation of site’s protocols.
3. Phantom images used for the annual physics report.
   a. Phantom imaged with the typical adult abdomen protocol.
   b. Phantom imaged with the typical adult head protocol.
   c. Phantom imaged with the typical pediatric abdomen protocol.
   d. Phantom imaged with the typical pediatric head protocol.
4. Examples of the examinations of an anatomic part specified by RadSite through a random selection process.
5. The protocol the applicant used to produce the submitted images must match the site’s actual CT protocol review sheet.
6. The patient radiation dose report for each exam.

RadSite MAP Accreditation Standards Version 2
Computed Tomography

• The tests described in the ACR CT manual satisfy the requirements for IAC and RadSite annual CT testing

1.3.4.B Annual system performance by a medical physicist or qualified expert must be evaluated using an appropriate phantom(s) (as applicable for procedures performed per regulations):
   i. Contrast scale
      Frequency: Annual or per manufacturer’s recommendation
   ii. Mean CT number of water and reference material
      Frequency: Annual or per manufacturer’s recommendation
   iii. Linearity
      Frequency: Annual or per manufacturer’s recommendation
   iv. Internal and external laser light alignment
      Frequency: Annual or per manufacturer’s recommendation
   v. Gantry tilt (tilt gantry systems only)
      Frequency: Annual or per manufacturer’s recommendation
   vi. Slice localization
      Frequency: Annual or per manufacturer’s recommendation
   vii. Table incrementation accuracy
      Frequency: Annual or per manufacturer’s recommendation
   viii. Slice thickness
      Frequency: Annual or per manufacturer’s recommendation
   ix. Image quality
      Frequency: Annual or per manufacturer’s recommendation
   x. Image display and storage devices
      Frequency: Annual or per manufacturer’s recommendation

1.3.3.B SPECT/CT and PET/CT Scanner
   1.3.3.1.B Accuracy of image registration (as applicable for procedures performed per regulations)
      Frequency: Monthly or per manufacturer’s recommendation
   1.3.3.2.B Accuracy of CT-based attenuation correction (as applicable for procedures performed per regulations)
      Frequency: Monthly or per manufacturer’s recommendation

1.3.4.B CT-Specific Quality Control
   1.3.4.1.B CT system acceptance testing must be performed.
      Frequency: Installation and following major upgrade
   1.3.4.2.B Measurement and assessment of patient radiation dose for representative examinations must be performed by a medical physicist or qualified expert.
      Frequency: Annually
   1.3.4.3.B Routine (daily and periodic) QC tests must be conducted as outlined by the manufacturer. Federal standards require CT manufacturers provide QC testing instructions, recommended testing frequency, a QC test phantom appropriate for the scanner and acceptable variations in parameter measurements.
      Frequency: Annually
      Daily QC tests (as applicable for procedures performed per regulations):
Computed Tomography – Image Quality

• The ACR manual has image quality tests with pass/fail criteria
Computed Tomography – Dosimetry

**Figure 10-33** For axial (or sequential) CT imaging with contiguous spacing, (A) while the table increment results in contiguous images, because the x-ray beam is slightly wider than the beam width (n7), there is overlap of the x-ray beam (B) between locations that increases the radiation dose to the patient in these regions.

A. contiguous axial imaging  
B. dose overlap between scans
The computed tomography dose index (CTDI) is measured using either a 16-cm or 32-cm-diameter polymethyl methacrylate (PMMA) phantom. The dosimeter is placed serially in the center hole and the peripheral hole, and the measurements are combined to produce the weighted CTDI, as described in the text.

Figure 6: CTDI phantom, pencil ionization chamber, and electrometer
TJC and ACR require that the medical physicist measures the CTDI\textsubscript{vol} produced by diagnostic CT for four protocols:

- Adult head
- Adult abdomen
- Pediatric head
- Pediatric abdomen

The ACR requires the measured CTDI\textsubscript{vol} to be less than the pass/fail criteria.
TJC CT

• The CTDI<sub>vol</sub> must be recorded for each exam as well

• For the machines that I deal with, this is automatically done

### Table

<table>
<thead>
<tr>
<th>Patient Position</th>
<th>Scan</th>
<th>KV</th>
<th>mAs</th>
<th>ref.</th>
<th>CTDI&lt;sub&gt;vol&lt;/sub&gt;</th>
<th>DLP</th>
<th>Ti</th>
<th>cSL</th>
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</thead>
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<tr>
<td>Topogram H-SP</td>
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<td>120</td>
<td>37</td>
<td>mA</td>
<td>68.56</td>
<td>1056</td>
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<td>0.6</td>
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<td>Brain 200</td>
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<td></td>
<td>68.56</td>
<td>1056</td>
<td>2.0</td>
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<tr>
<td>Last scan no.</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
TJC/ACR CT

• TJC and ACR require that MP measures the CTDI$_{vol}$ produced by diagnostic CT for four protocols:
  • Adult head
  • Adult abdomen
  • Pediatric head
  • Pediatric abdomen

• The measured CTDI$_{vol}$ must agree with the scanner reported CTDI$_{vol}$ to within 20%

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**Standard EC.02.04.03**
The organization inspects, tests, and maintains medical equipment.

- Verifies that the radiation dose (in the form of CTDI$_{vol}$) produced and measured for each protocol tested is within 20 percent of the CTDI$_{vol}$ displayed on the CT console. The dates, results, and verifications of these measurements are documented.
TJC CT

• We have dose tracking software installed that can flag exams

Standard PI.02.01.01

The organization compiles and analyzes data.

Element of Performance for PI.02.01.01

A.6. The organization reviews and analyzes incidents where the radiation dose index (CTDvol, DLP, or size-specific dose estimate [SSDE]) from diagnostic CT examinations exceeded expected dose index ranges identified in imaging protocols. These incidents are then compared to external benchmarks.

Note 1: While the CTDvol, DLP, and SSDE are useful indicators for monitoring radiation dose indices from the CT machine, they do not represent the patient’s radiation dose.

Note 2: This element of performance does not apply to dental cone beam CT radiographic imaging studies performed for diagnosis of conditions affecting the maxillofacial region or to obtain guidance for the treatment of such conditions.

Here we have a requirement from the TJC for input from interpreting radiologist, medical physicist and lead imaging technologist to review the CT protocols.

The time frame is up to the organization.

**Standard PC.01.03.01**

The organization plans the patient’s care.

A 26. Diagnostic computed tomography (CT) imaging protocols are reviewed and kept current with input from an interpreting radiologist, medical physicist, and lead imaging technologist to make certain that they adhere to current standards of practice and account for changes in CT imaging equipment. These reviews are conducted at time frames identified by the organization.

Note: This element of performance does not apply to dental cone beam CT radiographic imaging studies performed for diagnosis of conditions affecting the maxillofacial region or to obtain guidance for the treatment of such conditions.
TJC/ACR CT

• TJC is requiring that protocols are age appropriate
• Nuclear medicine – we usually have methods to reduce activity based on patient’s age
• CT – must have pediatric protocols

Standard PC.01.02.15
The organization provides for diagnostic testing.

A.12. For organizations that provide diagnostic computed tomography (CT), magnetic resonance imaging (MRI), positron emission tomography (PET), or nuclear medicine (NM) services: The organization considers the patient’s age and recent imaging exams when deciding on the most appropriate type of imaging exam.

Note 1: Knowledge of a patient’s recent imaging exams can help to prevent unnecessary duplication of these examinations.

Note 2: This element of performance does not apply to dental cone beam CT radiographic imaging studies performed for diagnosis of conditions affecting the maxillofacial region or to obtain guidance for the treatment of such conditions.

Standard PC.01.03.01
The organization plans the patient’s care.

Elements of Performance for PC.01.03.01

A.25. The organization establishes or adopts diagnostic computed tomography (CT) imaging protocols based on current standards of practice, which address key criteria including clinical indication, contrast administration, age (to indicate whether the patient is pediatric or an adult), patient size and body habitus, and the expected radiation dose index range.

Note: This element of performance does not apply to dental cone beam CT radiographic imaging studies performed for diagnosis of conditions affecting the maxillofacial region or to obtain guidance for the treatment of such conditions.
TJC/ACR CT

- CT has own set of requirements for morning QC
- At our TJC accredited facility, we follow the morning QC spelled out in ACR CT manual
- Medical physics establishes baselines and reviews daily QC records
Establish Quality Control Activities

- Identify the QC activities, pass/fail criteria, action plans, and the testing intervals
- Potential problems:
  - The written procedure does not reflect what is actually being done for QC
  - QC activity is described but is missing pass/fail criteria
  - No action plan in the event of failure
  - Not following testing frequency
  - Test dates missed

**Standard EC.02.04.01**
The organization manages medical equipment risks.

**Element of Performance for EC.02.04.01**
A7.10. The organization identifies quality control and maintenance activities to maintain the quality of the diagnostic computed tomography (CT), positron emission tomography (PET), magnetic resonance imaging (MRI), and nuclear medicine (NM) images produced. The organization identifies how often these activities should be conducted. (See also EC.02.04.03, EP 15).
TJC Shielding Evaluation

• The requirements for diagnostic imaging effective July 1, 2015 has two requirements for shielding

• The first requires that the shielding design is assessed by a medical physicist or health physicist prior to installation of new imaging equipment, replacement of existing imaging equipment or modification of rooms where ionizing radiation will be emitted or radioactive material stored

• This includes hot labs

Standard EC.02.06.05
The organization manages its space during demolition, renovation, or new construction.

Note: These elements of performance are applicable to all occupancy types.

Elements of Performance for EC.02.06.05
A 4. For computed tomography (CT), positron emission tomography (PET), or nuclear medicine (NM) services: Prior to installation of new imaging equipment, replacement of existing imaging equipment, or modification to rooms where ionizing radiation will be emitted or radioactive materials will be stored (such as scan rooms or hot labs), a medical physicist or health physicist conducts a structural shielding design assessment to specify required radiation shielding.

Note: This element of performance does not apply to dental cone beam CT radiographic imaging studies performed for diagnosis of conditions affecting the maxillofacial region or to obtain guidance for the treatment of such conditions.

* For additional guidance on shielding designs and radiation protection surveys, see National Council on Radiation Protection and Measurements Report No. 147 (NCRP-147).
TJC Shielding Survey

• After the installation or modification, the adequacy of the shielding is evaluated by a medical physicist or health physicist
• Must be done prior to clinical use

Standard EC.02.06.05
The organization manages its space during demolition, renovation, or new construction.

Note: These elements of performance are applicable to all occupancy types.

A 6. For computed tomography (CT), positron emission tomography (PET), or nuclear medicine (NM) services: After installation of imaging equipment or construction in rooms where ionizing radiation will be emitted or radioactive materials will be stored, a medical physicist or health physicist conducts a radiation protection survey to verify the adequacy of installed shielding. * This survey is conducted prior to clinical use of the room.

Note: This element of performance does not apply to dental cone beam CT radiographic imaging studies performed for diagnosis of conditions affecting the maxillofacial region or to obtain guidance for the treatment of such conditions.

* For additional guidance on shielding designs and radiation protection surveys, see National Council on Radiation Protection and Measurements Report No. 147 (NCRP-147).
TJC Shielding Evaluation

General Electric
Audits

• Audits are an important tool/element in a QA program
• All four of the accrediting bodies reserve the right to inspect or audit a facility
• We perform our own internal audit
• Feedback and self-assessment
• I would rather find errors and potential problems before inspection by accrediting body
• This requires time and effort
Beyond CMS

• Scanner Validation for Research
  • SNMMI-CTN
  • ACRIN

• Quantification validation for multi-center studies

• Phantom imaging for quantification validation

• Dose calibrator accuracy for F-18 using a NIST traceable Ge-68/Ga-68 source
Beyond CMS

• Calculation of patient dose from research scans – necessary for IRB review and consent forms
• Calculations for patients that request dose estimate
• Dosimetry calculations for unusual cases
  • I-131 ablation therapy in a patient on dialysis
  • I-131 therapy in patient with extensive metastatic disease in the lungs
Beyond CMS

• Acceptance Testing of new equipment or after major repair
• No accrediting body specifies the tests required for acceptance testing
• There is guidance in the literature
• The extent of the acceptance testing is dictated by the amount of time that is allotted for the testing
Conclusions

• Accreditation is necessary part of doing business
• Quality assurance program is necessary for accreditation and is essential for providing high-quality patient care
• Medical physics support is necessary for Quality Control and a Quality Assurance program
Bibliography

- Early, Paul and Sodee, D.Bruce, *Principles and Practice of Nuclear Medicine*, 2nd ed. Mosby, St. Louis MO, 1995