QC Imaging - Challenges

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  • Supervisor, Nuclear Medicine
  • University of New Mexico Hospital
Disclosure

• No disclosures
Objectives

• Define image Quality Assurance (QA) and Quality Control (QC)
• Discuss the motivation for maintaining a QA/QC program
• Review the elements of a QA/QC program for nuclear medicine imaging
• Identify sources that contribute to loss of image quality
• Describe tips and recommendations to improve image quality – lessons learned
Image Quality

- Image quality can be broken down into the following components
- Uniformity
- Noise
- Artifacts
- Spatial Resolution
- Spatial Distortion
- Contrast
- Quantitation (activity/volume)
- Registration with CT
- The components of image quality can be tested in a QC program
Quality Control and Quality Assurance

• I found a description in “Quality and Safety in Radiology” by Abujudeh and Bruno that I thought was good:

• Quality Control (QC) are tests that produce data points and have pass/fail criteria.

• An analogy is an apple farmer who discards apples that have defects. Thus, the apples that go to the market pass QC and meet a minimum set of requirements.

• The apple farmer who evaluates apple quality and works on the apple trees in an attempt to create a better product has a Quality Assurance (QA) program.
Motivation

• Reasons to do QA/QC in Radiology:
  • Imaging is a component of patient care. Clinical decisions are made based on imaging results. The physicians need confidence that the imaging is accurate
  • Regulations primarily address radiation safety. However, image quality is included.
  • A QA/QC program is required by accrediting organizations
History - MIPPA

• In 2008, Congress passed the Medicare Improvements for Patients and Providers Act (MIPPA)
• The MIPPA act enforces QA/QC for facilities that desire reimbursement for advanced imaging of patients covered by Medicare and Medicaid
• Advanced diagnostic imaging is defined in MIPPA as Nuclear Medicine, PET, MR and CT
• MIPPA requires that suppliers 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 the Department of HHS was tasked with designating the accrediting organizations
Accrediting Organizations

- 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)
- ICANL is now the Intersocietal Accreditation Commission (IAC)
- There is now a fourth accrediting agency named RadSite
Accrediting Organizations

- All of the accrediting bodies require a review of:
- Initial qualifications of medical personnel (physicians, technologists and medical physicist)
- Continuing education
- Written procedures for the tasks necessary for a nuclear medicine department
- Equipment performance including review of phantom images
- Quality control and quality assurance program
QA and QC Motivation

- The need to obtain and maintain accreditation has created a strong monetary motivation to schedule and perform QA/QC
- All parties involved now must make time and spend the money necessary to perform QA/QC
- It is a necessary cost of doing business
Elements of QC

- Each accrediting body has a list of required QC tests
- The list of required testing is similar among the accrediting organizations

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**Nuclear Medicine Technologist’s Quality Control Tests**

1. **Intrinsic or System Uniformity** (each day of use) - Performed to verify that components are properly functioning and provide a uniform image in response to a uniform flux of radiation.

2. **Intrinsic or System Spatial Resolution** (weekly) - Performed to quantitatively verify that detector spatial resolution is satisfactory for clinical imaging.*

3. **Center-of-Rotation** (monthly) - Performed to maintain ability to resolve details in clinical SPECT studies.

4. **High-Count Floods For Uniformity Correction** (frequency as recommended by a qualified medical physicist) - Performed to correct for residual detector and collimator non-uniformity and to minimize the production of artifacts in clinical studies.

5. **Overall System Performance for SPECT Systems** (semiannually, quarterly recommended) - Performed to qualitatively verify that the system has maintained its capabilities with respect to tomographic uniformity, contrast, and spatial resolution that maximize the benefit in clinical studies. Technetium must be done at least semiannually; other radionuclides may be tested on alternate quarters.

6. **Dose Calibrators** (daily, quarterly, and semiannual)
   - **Daily** - Tests are performed to verify that the calibrator is accurate and reliable for the assay of doses administered to patients.
   - **Quarterly** - A linearity test must be performed to document that accurate readings are provided through the entire range of activities used clinically. Other qualified personnel may do these tests.
   - **Semiannual** - All non-exempt radionuclide sources must be tested to verify that radioactivity is not leaking from the sources. Other qualified personnel may also do these tests.

7. **Thyroid Uptake and Counting Systems** (each day of use) - Standards are measured to verify energy calibration and sensitivity for the measurement of organ function and the assay of patient samples.
Gamma Camera Testing by Technologist

**ACR**

**Nuclear Medicine Technologist’s Quality Control Tests**

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**IAC**

1.3.1B **Gamma Camera**

*(See Guidelines on Page 35 for further recommendations.)*

1.3.1.1B Energy peaking to verify that the photopeak is centered in the set photopeak 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 value 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.
- **Frequency:** Annually

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

• There is the “core” list for all accrediting organizations of the tests usually performed by nuclear medicine technologists

• Planar imaging
  • Daily uniformity (flood)
  • Weekly spatial resolution and spatial linearity (bars)

• SPECT
  • Monthly uniformity correction map – high count flood
  • Monthly center of rotation (COR)
Gamma Camera QC

- Intrinsic and extrinsic uniformity floods
- Evaluate ability of the camera to produce a uniform image of a uniform field of radiation
- Artifacts
- Problems with the crystal, PMTs, or other component of the imaging chain

2.2.8.5. Example: Clinical bone scan — defective PM tube

Bone scan of patient using $^{99m}$Tc phosphonate, 15% energy window.

Sokole E. IAEA Quality Control Atlas for Scintillation Camera Systems. Page 86
Gamma Camera QC

- Spatial Resolution and Linearity
- The spatial resolution test measures the ability of the camera to image closely-spaced, small objects
- Linearity checks that the system is not producing spatially distorted images

ACR criteria

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

**Tc99m 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 QC

- Technologist typically perform high count floods on a camera used for SPECT
- The camera system uses these to map out or compensate for non-uniformities
- This eliminates subtle non-uniformities that would otherwise produce artifacts in SPECT images
Gamma Camera QC

- Technologist will typically perform center of rotation (COR) on a camera used for SPECT.
- The center of rotation is an imaginary axis about which the camera heads rotate.
- The pixel matrix of each detector head needs to be in 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.

Christian and Waterstram-Rich, Nuclear Medicine and PET/CT, 7th ed.
Elements of QC

• Testing by the Medical Physicist:

• Acceptance testing after installation
  • Verify that the camera system meets designed capabilities and is functioning properly
  • Establish baseline measurements
  • Establish pass/fail criteria

• Annual survey which is required by accrediting body

• Survey after repair or calibration
Acceptance Testing

- After installation and prior to applications training, the physicist should perform acceptance testing on new equipment.
- Accrediting bodies such as TJC and ACR require acceptance testing that is equal to or exceeds the annual survey.
- At our institution, acceptance testing includes verification that the purchased software and hardware has been delivered and is functional.
Annual QC Testing of Gamma Camera by Medical Physicist

• Planar and/or Tomographic Tests:
  • Intrinsic and extrinsic uniformity (floods)
  • Spatial resolution and distortion
  • Sensitivity
  • Energy resolution
  • Count rate performance
  • Artifact evaluation

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)
Annual QC Testing by Medical Physicist

- Similar testing as done by technologist
- Uniformity flood
- Spatial resolution
Annual QC Testing by Medical Physicist

- Sensitivity test
- Carefully measure an amount of activity
- Image the source
- Draw ROI and measure counts from source
- Calculate cpm/µCi
- Compare to manufacturer’s claims and baseline values
- For a dual-headed gamma camera, the ACR recommends that the relative sensitivity of the detector heads agree to within 5%

Fig. 13.25: NEMA procedure for system sensitivity. (From NEMA standard for performance measurement of scintillation cameras, Pub. No. NU-1-1986, National Electrical Manufacturers’ Association, 1986, NEMA. Courtesy Picker International, Cleveland, Ohio.)

Early and Sodee, Principles and Practice of Nuclear Medicine 2nd ed.

System Planar Sensitivity with LEHR Collimator at 10 cm:
Absolute
202 cpm/µCi
Annual QC Testing by Medical Physicist

- Energy resolution
- Measured using the spectrometer (MCA) function on the gamma camera
- This ensures that the camera is measuring the correct gamma photon energy and that the “spread” of the photopeak is within limits
- An excessive amount of spread would indicate a possible problem in the imaging chain
- Compared to manufacturer’s values and baseline values
Annual QC Testing by Medical Physicist

• Count Rate Performance
• When a gamma photon interacts with a detector, it takes a finite amount of time for the detector to respond and to recover from this event
• The detector needs to recover before it is able to record another event
• The time it takes a detector recover is called the “dead time”
• At high count rates, the dead time will accumulate, and paralyze the system
Annual QC Testing by Medical Physicist

- Paralyzable systems such as gamma cameras will have a maximum count rate
- One way to measure maximum count rate is to move a source towards the camera while noting the count rate
- As the source approaches a detector, the count rate will peak and then begin to decrease
- The maximum count rate can be compared to baseline values

SPECT Performance

- ACR provides detailed phantom testing instructions with pass/fail criteria
- ACR SPECT phantom is also known as a Jaszczak phantom
- SPECT uniformity
- SPECT spatial resolution
- SPECT contrast
SPECT Performance

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

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

• The bottom region contains rods of different sizes used to evaluate resolution
SPECT Performance

• The phantom is filled with water and approximately 10 mCi to 20 mCi of Tc-99m
• Scan parameters such as number of counts, number of views, reconstructed slice thickness etc. is provided in the phantom testing instructions
• There is a video on SPECT phantom imaging posted on the ACR nuclear medicine accreditation website
SPECT Performance

- The phantom is scored per ACR instructions
- The scores are compared to the ACR pass/fail criteria

**Nuclear Medicine SPECT Phantom:**
*(Detector Phantom)*
*(If a phantom receives 2 scores of Marginal this equals a FAIL)*

**Te99m 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
SPECT Performance

- 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 significant on planar images may produce a visible artifact on images of the SPECT phantom
- Possible causes of non-uniformities include:
  - Activity contamination on camera
  - Out of date uniformity map
  - Damaged collimator, PMT, crystal or other component in the imaging chain
Non-Uniformity Artifact

- Non-uniformity will produce a ring in 360 degree acquisitions

Christian and Waterstram-Rich, Nuclear Medicine and PET/CT, 7th ed.
Non-Uniformity Artifact

• Simulate a damaged collimator by taping a piece of lead to the collimator
SPECT Spatial Resolution

- A loss of spatial resolution could possibly be due to Center of Rotation offset error.
SPECT COR Offset Errors

• COR offset errors can produce clinically significant artifacts

3.3.9. Example: Clinical brain blood flow SPECT - effect of different COR offsets

Single head SPECT system, normal. $^{123}$I IMP brain perfusion SPECT study, 360° total angle of rotation, 64 x 64 matrix. Data were collected and reconstructed by FBP into a single reconstructed transverse slice with four different COR offsets.

TL: 0 pixel offset.
TR: 0.5 pixel offset.
BL: 1.0 pixel offset.
BR: 2.5 pixel offset.

Results: As the COR offset increases, the images become more blurred and distorted. One can easily recognize poor quality in the fourth image (BR), but in routine practice the second and third images made with COR offsets of 0.5 and 1.0 pixel could mistakenly be passed as acceptable (since no comparable data are available).

Comments: Determining the optimum image quality possible in clinical SPECT images is difficult. Degradation of images due to a COR offset can be overlooked. A regular QC check of the integrity of the COR offset calibration and correction is essential.

3.3.8. Example: Clinical study with large COR offset error

Clinical SPECT transaxial images of the liver using $^{99m}$Tc sulphur colloid. The camera had just been installed and the COR calibration had not been done correctly.

Results: Because the COR calibration was done incorrectly, there was a very large COR error. The images were so distorted that the organ could not be recognized.

Comments: When acceptance tests are performed on a new system, tomography should be performed with a line or point source and the images reconstructed with a ramp filter. The spatial resolution ($r\text{FWHM}$) in the tomographic images should be compared with a planar image at the same distance as the average radius of rotation. The loss of resolution in tomographic studies should not exceed 10%.
PET Camera Testing

PET Phantom Instructions for Evaluation of PET Image Quality

ACR Nuclear Medicine Accreditation Program

PET Module

- 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

Flangeless Esser PET Phantom™
ACR PET Phantom

• The ACR SPECT phantom can be converted to ACR PET phantom
• The spheres are removed and a special lid is added
• The lid has several cylinders that are filled with a “hot” solution of F-18
• There are “cold” cylinders as well
PET Camera Testing - Quantitative

- The hot cylinders and the bulk fluid in the phantom are filled according to a “recipe” provided in the ACR PET Phantom Instructions.
- The following are specified for the phantom:
  - Activity
  - Injection start time
  - Patient weight
- Results in SUV values similar to high-uptake tumors in a liver.

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.)

<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 Doses #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

- Regions of interest are drawn around the different cylinders and in the bulk fluid
- SUV values are calculated for each cylinder
- The SUV values are compared to pass/fail criteria

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 Image Quality

- The spatial resolution, uniformity and contrast can be scored
- ACR has pass/fail criteria for these parameters

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

**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: >.7

A phantom acquisition with two or more marginal scores for any category will be failed.
Standard Uptake Value

• The Standard Uptake Value (SUV) is a ratio of activity concentrations

• Requires good data on:
  • body weight
  • administered activity
  • time of administration (scanner clock and lab clock)

• Requires agreement between dose calibrator and PET camera

\[
\text{SUV} = \frac{\text{Mean ROI activity (mCi/mL)}}{\text{Administered activity per body weight (mCi/g)}}
\]
SUV

• To check if the dose calibrator and PET scanner are in agreement:
• Measure activity and Inject into water-filled phantom, mix well
• Set “patient weight” to the mass of water
• The SUV should equal 1.0

Activity concentration in the region of interest – measured by PET scanner

\[
SUV = \frac{\text{Mean ROI activity (mCi/mL)}}{\text{Administered activity per body weight (mCi/g)}}
\]

1 mL ≈ 1 gram
Units cancel out

Activity concentration in the phantom – measured in dose calibrator
Cross Calibration

- The PET scanner is calibrated with a source of known activity
- For Siemens scanners a Ge-68/Ga-68 check source is used
- This source has a calibration date and activity that is entered into the PET scanner system
- Ge-68/Ga-68 source is short-lived
- Source gets exchanged every year
Cross Calibration

• When the Ge-68/Ga-68 calibration source is exchanged, the cross calibration should be performed to bring the PET scanner and dose calibrator into agreement

• Consequences of not doing cross calibration
  • An unexpected, sudden change in SUV values after the source is replaced
  • Failure of ACR PET annual survey. SUV ends up too high or too low
  • SUV values do not agree among different scanners

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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
Cross Calibration

• In my experience, cross calibration between the PET scanner and dose calibrator seems to be the test that is missed the most

• This has happened even though the test is listed in the manufacturer’s users manual
Computed Tomography

• CT usually has its own accreditation and QA/QC testing
• Important to maintain CT image quality
• CT is used for attenuation correction
• CT artifacts that affect HU values may introduce artifacts into PET images
• CT is fused with nuclear medicine images for anatomic localization of activity
• Registration is important and should be checked on SPECT/CT and PET/CT systems
Non-Imaging Equipment QC

- Dose calibrators and well counters
- Non-imaging instrumentation can affect the accuracy of the patient dose/administered activity
- This can affect image quality especially quantitation
Dose Calibrators

- Regarding the federal regulations for dose calibrators
- 10 CFR 35.60(c) “A licensee shall calibrate the instrumentation ... in accordance with nationally recognized standards or the manufacturer’s instructions”
- Agreement state regulations can be as strict or stricter than federal regulations
- Use the strictest regulation

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Subpart C--General Technical Requirements

§ 35.60 Possession, use, and calibration of instruments used to measure the activity of unsealed byproduct material

(a) For direct measurements performed in accordance with § 35.63, a licensee shall possess and use instrumentation to measure the activity of unsealed byproduct material before it is administered to each patient or human research subject.

(b) A licensee shall calibrate the instrumentation required in paragraph (a) of this section in accordance with nationally recognized standards or the manufacturer’s instructions.

(c) A licensee shall retain a record of each instrument calibration required by this section in accordance with § 35.2060.
Non-Imaging Equipment QC

• Constancy
  • Regulations may require that constancy is checked each day of use. This includes weekends and holidays if radiopharmaceuticals are administered during these times

• Linearity
  • Range of activity to be assayed should start above the maximum activity to be administered and measurements continue until the activity is below the minimum activity to be assayed
  • The lowest activity that needs to be assayed should be stated in a state regulation, manufacturer’s recommendation or is a condition of your license
  • I have seen several instances where the lowest measured activity was not less than minimum activity
  • This includes the linearity tubes
Non-Imaging Equipment QC

• Accuracy
  • The requirements for the sources can be very specific. Be careful that you are meeting the requirements
  • For example, New Mexico requires two sources one of which has a primary photon energy between 100 keV and 500 keV. The activity of the sources must be determined by the manufacturer to be within 5% of the stated activity and the source activity must be greater than 50 µCi. (NMAC 20.3.7.703 A(1)(b))

• Geometry
  • Make sure you can find a record of geometry testing
Non-Imaging Equipment QC

• Well-counters and thyroid probes are covered under state law in New Mexico
• May be the same in your state
• NMAC 20.3.7.703 D: “At a minimum, quality control procedures and their frequencies shall be those recommended by the equipment manufacturer”
• Need to dig in and see what the manufacturer recommends
  • Daily calibration to determine operating voltage or amplifier gain
  • Constancy - A long-lived source of known activity is measured daily to evaluate constancy
  • Background
  • Detector efficiency
  • Chi-square test
  • Minimum Detectable Activity (MDA)
  • Energy resolution
Recommendations

• We’ve looked at the elements typically found in a Nuclear Medicine QA/QC program

• The following slides present different ideas, tips, and recommendations

• These are based on experience at UNMH and other facilities throughout New Mexico

• These fall under the umbrella of having a well-maintained QA/QC program
Recommendations

• Possible consequences of not having a well-maintained QC program:
  • Sub-optimal patient care
  • Unexpected down time instead of scheduled down time
    • Unexpected down time means having to reschedule patients
    • Service and parts can be on-site during a scheduled down time
  • Regulatory fines or citations
  • More repeat scans
  • Problems maintaining accreditation which may results problems with reimbursement from CMS
  • Accreditation testing goes smoothly on a camera that is working properly
  • Repeating the accreditation testing will cost time and money
Recommendations

• Assignment of QC responsibilities
• Eliminates “single-point” failure
• Big board in hot lab that has daily, weekly and monthly QC
• One person has a goal of keeping the board up-to-date
• Technologists perform the QC when time permits and the room is available
• We are planning to move to QC tracking software
• This will send email alerts if QC is not complete or if equipment fails a test
Recommendations

• The technologists should review the results of QC
• Does the results of the testing look ok?
• If a test fails, take some type of action. Do not simply continue.
• The action that should be taken in the event of a failure should be in the department procedure
• It is good to have a soft fail before a hard fail
Recommendations

- Schedule audits of the QC program
- We do self-audits every six months in mammography
- We have some success in implementing self-audits in nuclear medicine
- Finding time to do review the large amount of records has been a challenge
- It can be an ongoing process instead of all-at-once
  - Schedule regular meeting
  - Base checklist on last inspection
- Review necessary documentation for inspections
- Review the QC program procedures
- Self-audits are a good way to find problems before the inspectors do
- Self-audits provide feedback regarding the effectiveness of QA/QC
Recommendations

- Self-audits of the QC program policies and procedures
- Things to look out for:
  - Policies that are out of date
  - Multiple instances of the same test
    - The same test is mentioned in different policies and procedures and each instance has different pass/fail criteria
- Your procedures should describe what you are actually doing for QC
Recommendations

• There are three primary sources of information that should be considered while reviewing a QC program

• Regulations: Agreement State or Federal regulations

• Accrediting Body: Joint Commission, ACR, IAC, RadSite will have similar QC requirements. The specific tests and schedules are different

• Manufacturer: The manufacturer will also have recommendations on specific tests, pass/fail criteria and testing schedule
Recommendations

• Actually read the regulations. Don’t take anyone else’s word for what is in the regulations. Look up and read the actual regulations.
• Regulations change over time
• Find the relevant, most recent regulations
• Search engines such as Google or Bing are good tools for finding Federal and State regulations
• Ask your medical physicist or radiation safety team for clarification
Recommendations

• Know the requirements of your accrediting body
• As an example, ACR requires two phantom scans per year for the SPECT accreditation program
• The ACR PET accreditation program also requires two phantom scans per year
• I’ve seen this surprise people who have had ACR accreditation for awhile

Quality Control

PET Performance Tests

It is recommended that the quality control testing be performed in accordance with the ACR Technical Standard for Medical Nuclear Physics Performance Monitoring of PET Imaging Equipment, as applicable. Data will continue to be collected regarding the quality control tests performed by the facility. Based on this data, the ACR Committee on Nuclear Medicine Accreditation may establish QC requirements at the time of renewal. At this time, the ACR strongly recommends quarterly testing of each PET system with an appropriate phantom such as described below in addition to other tests recommended by the vendor. At a minimum, testing with the appropriate phantom must be performed semi-annually, but strongly recommends quarterly.
Recommendations

• Read the manual provided by the manufacturer
• If the manual is not available, get it from the manufacturer or send out email to fellow techs
• It is difficult to follow manufacturer’s recommendations if you do not have the manual
• If no one reviews the manual, a QC test can be missed
Recommendations

• Strategy: Review the imaging protocols
• There should be a process to review, revise and create protocols
• The physician, technologist and medical physicist should all be involved in the process
• Look at image quality and dose to the patient
• Is the protocol doing what the physicians need it to do?
• Are the revised protocols being deployed on the scanner correctly?
Recommendations

• Consider patient intervention a part of imaging QC
• If a patient shows for an exam and they have not prepped correctly this can lead to having to reschedule.
• Wasted radiopharmaceutical, wasted time
• Review the protocols and and the information given to the schedulers. We have seen disconnects between the protocol that the techs have and the information that the schedulers have
• Review scheduling templates
  • Restrictions: NPO, no caffeine, medication restrictions
  • Rooms: Some scans can only be done on certain cameras
  • Other: Chemotherapy or radiation therapy timing
• Skillful communication is a key factor in minimizing patient-induced imaging problems
Conclusions

• Provide enough time to do testing and evaluate the testing
  • Nuclear medicine technologist and medical physicist
  • This includes self-audits

• Know the testing requirements
  • Accrediting body
  • Regulations
  • Manufacturer’s recommendations

• Patients
  • Communication is the key

• No easy solutions, a well-maintained QA/QC program takes time, money and work
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