Site Scanning Instructions for the ACR Nuclear Medicine Phantom

ACR Nuclear Medicine Accreditation Program

NUCLEAR MEDICINE ACCREDITATION PROGRAM

INSTRUCTIONS AND TEST IMAGE DATA SHEETS FOR SUBMISSION OF PHANTOM IMAGES

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I.   INTRODUCTION

This booklet is to be used by the facility applying for accreditation in nuclear medicine. One Site Scanning Data form should be completed for each camera system that is undergoing accreditation. The facility should make additional copies of the forms as needed.

Planar Imaging Only

If your facility performs only planar imaging and is only applying for accreditation in Module 1, General Nuclear Medicine (planar imaging), the number and complexity of the tests you are asked to perform, evaluate and submit for review are different than those required for a facility that performs SPECT. You must provide images documenting only the uniformity and spatial resolution of your camera detector(s). The resolution images will be acquired with the four-quadrant bar phantom that you should already own and use on a regular basis. A camera accredited for General Nuclear Medicine will have to be reaccredited if it is to be used later for SPECT.

SPECT and Planar Imaging

If your facility performs SPECT imaging and is applying for accreditation in Module 2 (SPECT) or Module 3 (Nuclear Cardiology), you must perform, evaluate and submit for review planar **and** SPECT information. Most of the planar and SPECT data are obtained with the ACR approved phantom (available from Data Spectrum). Submission of accreditation data from any other phantom without ACR permission will disqualify the site

The ACR approved phantom described below was chosen for the evaluation of tomographic systems because it is relatively easy to fill and set up for a SPECT study and can be used to measure planar resolution and tomographic uniformity, spatial resolution, and contrast. The wide variety of elements for evaluating spatial resolution and contrast are sufficient to enable the user to see relatively subtle differences in system performance.

In addition, Appendix A provides a sample calculation for determining the acquisition time per view based on 32M total counts.

Evaluation of the Images Submitted

Images will be submitted to a review panel of medical physicists for scoring. The committee has defined acceptable standards for uniformity, spatial resolution and contrast. The standards are based on results obtained from a variety of cameras that are operating satisfactorily.

Uniformity and noise are evaluated qualitatively by inspection of planar images and reconstructed tomographic sections. **Optimal density ranges should be comparable to those used for clinical images.** Planar spatial resolution is judged by identifying the smallest bars in a resolution phantom that can be visualized on cameras used for planar imaging only. For tomographic systems, the smallest "cold" rods in the ACR approved phantom are used. Collimator type (e.g. general purpose, high resolution) is considered in scoring the spatial resolution.

The reconstructed transaxial slices containing the cold spheres are used to visually evaluate image contrast based on the amount of image blur and identifying the smallest "cold" sphere. As with the evaluation of spatial resolution, collimator type is considered when the score for contrast is determined.

NOTE: Data must be collected and images prepared according to the instructions. The procedures may differ from those normally used by the applicant but were designed to minimize the variability in the images that are submitted. Despite the use of a specific protocol, it is understood that there will still be differences in the appearance of the images even when the data are collected on the same type and model of scintillation camera.

NOTE: Some cardiac SPECT systems cannot acquire a single set of projections over 360 degrees. For these systems, the phantom should be acquired with the maximum (128 or 64) allowable rotational steps for the standard rotational arc. For multi-head cameras, separate data sets for each head should not be submitted.

II.   PHANTOMS

All Modules (Planar Only or SPECT with Planar)

All applicants are required to submit a Tc-99m or Co-57 intrinsic or system flood field image, as well as a Tl-201 and/or a Ga-67/In-111 flood field image (if applicable). If both Tl-201 and Ga-67/In-111 are currently used, uniformity images are required for both isotopes.

Module 1(Planar Imaging Only)

If accreditation is requested for planar imaging only, intrinsic or system resolution images must be submitted. The phantom for this data is the four-quadrant bar phantom. **The smallest bars should be between 2 and 3 mm.** Planar images acquired with the ACR SPECT phantom are not required for applicants that are requesting accreditation for Module 1 only.

Module 2 and/or 3 (SPECT with Planar)

Applicants that are requesting accreditation for Module 2 or Module 3 must use the ACR approved phantom for evaluating planar and tomographic image quality. The ACR approved phantom is the Data Spectrum Deluxe phantom. The phantom is a cylinder with an internal diameter of 20.4 cm (flangeless phantom). Effective July 1, 2010, images from the Data Spectrum Standard phantom will no longer be accepted. The lower portion of the phantom contains 6 sets of acrylic rods arranged pie shaped pattern with the following diameters: 4.8, 6.4, 7.9, 9.5, 11.1, and 12.7 mm. The upper section contains six solid spheres with the following diameters: 9.5, 12.7, 15.9, 19.1, 25.4, and 31.8 mm. The spheres must be placed in order of increasing size (clockwise as viewed from the top) and the rod and sphere diameters must be the same as listed in the worksheets. The reviewers will use this information to properly score the images.

The recommended activities for the ACR approved phantoms are 10- 20 mCi Tc-99m, 4- 8 mCi of Tl-201, and 5-10 mCi Ga-67/In-111. Lower quantities of each isotope may be used but the imaging time will be proportionately longer. These activities are recommended to provide a good compromise between count rate limits, acquisition time, and cost.

Acquire and process the best possible images on your system within the guidelines provided - all settings must be documented.

The ACR strongly recommends quarterly testing of each SPECT system with an appropriate tomographic phantom, such as described above, in addition to other QC tests.

III. PLANAR ONLY PROTOCOL

If SPECT accreditation is desired (SPECT or Cardiology Module), skip to the next protocol. This protocol should be followed for camera systems seeking only accreditation for the Planar Module (General Nuclear Medicine). For systems with more than one detector (such as whole body scanners), an image must be submitted for each detector.

For each of the tests, plan the sequence so that the minimum time is required. For example, if you are acquiring a system flood field image using a fillable source, fill it with the shortest half-life isotope first (Tc-99m) and then with the longer half-life isotope (Tl-201 or Ga-67/In-111).

1. **Acquisition One** – Tc-99m or Co-57

    A. <u>Field Uniformity</u> (each detector)

    Set the acquisition for Tc-99m or Co-57 and acquire an intrinsic or system flood field image (whichever is routinely used) using a 256 x 256 matrix. For large rectangular field cameras (longest dimension > 32 cm), acquire 10 million counts. For large and small circular detectors and small rectangular field cameras (longest dimension ≤ 32 cm), 5 million counts are satisfactory.

    B. <u>Spatial Resolution</u> (four-quadrant bar phantom) *Tc-99m (preferred) or Co-57*

    Set the appropriate energy and acquire an intrinsic or system (whichever type is routinely used for quality control) resolution pattern image using a 512 x 512 matrix (or the finest matrix that is available). For large rectangular field cameras (longest dimension > 32 cm), acquire 5 million counts. For large and small circular detectors and small rectangular field cameras (longest dimension ≤ 32 cm), 3 million counts are satisfactory.

    (Tl-201 and Ga-67/In-111 are required if used currently or will be used on the unit).

2. **Acquisition Two** - Tl-201

    A. <u>Field Uniformity</u> (each detector)

    Set the camera for T1-201and acquire an intrinsic or system flood field image (whichever is routinely used) as described above for Tc-99m. Use the clinical analyzer window(s) settings.

    B. <u>Spatial Resolution</u> (four-quadrant bar phantom)

    Set the energy window for T1-201 and acquire an intrinsic or system resolution pattern image (whichever is routinely used) as described above for Tc-99m. Use the clinical analyzer window(s) settings.

3. **Acquisition Three** – Ga-67/In-111

    A. <u>Field Uniformity</u> (each detector)

    Set the camera for Ga-67 or In-111 and acquire an intrinsic or system flood field image (whichever is routinely used) as described above for Tc-99m. Use the clinical analyzer window(s) settings.

    B. <u>Spatial Resolution</u> (four-quadrant bar phantom)

    Set the energy window for Ga-67 or In-111 and acquire an intrinsic or system resolution pattern image (whichever is routinely used) as described above for Tc-99m. Use the clinical analyzer window(s) settings.

4. **Planar Images for Submission**

    For each of the acquisitions make a hard or soft copy image for submission to the ACR as follows:

    1. Individual planar images should be between six and nine cm in diameter. Other size images are difficult to read and may be returned to the facility without review.

    2. **Submit only gray scale images.**

    3. Use linear mapping of the display with the lower threshold set at 0 (or $\leq$ 5% of the maximum upper level) and the upper threshold set to the maximum count.

    4. Label hard copy with the ACR bar code and all pertinent imaging parameters. Digital submissions should also be appropriately labeled. Make sure the Site Scanning Data forms are filled out completely.

IV.   PLANAR AND SPECT PROTOCOL

For systems with more than one detector, planar images must be submitted for each detector.

Two SPECT Isotopes

If you use <u>two</u> different isotopes for SPECT imaging (Tc-99m plus a second isotope), you are required to submit planar uniformity and SPECT phantom studies, including planar resolution, using the ACR phantom for both isotopes.

Three or more SPECT isotopes

If you use <u>three or more </u>isotopes for SPECT imaging, you are required to submit SPECT phantom studies for only two of the isotopes as described above. For each of the additional isotopes not submitted as SPECT, you must include the following submissions:1) planar uniformity and 2) planar resolution with the four-quadrant phantom. Even though only 2 SPECT phantom studies are submitted, all the isotopes submitted may be used for clinical SPECT.

Note: If the additional isotopes include both Ga-67 and In-111, you only need one submission for Ga-67 <u>or</u> In-111):

Planar Images

1. **Acquisition One – Tc-99m or Co-57**

    A. <u>Planar Field Uniformity</u> (each detector)

        Set the acquisition for Tc-99m or Co-57 and acquire an intrinsic or system flood field image (whichever is routinely used) using a 256 x 256 matrix. For large rectangular field cameras (longest dimension > 32 cm), acquire 10 million counts. For large and small circular detectors and small rectangular field cameras (longest dimension ≤ 32 cm), 5 million counts are satisfactory.

    B. <u>Planar Spatial Resolution</u> (*with ACR phantom if SPECT phantom to be acquired*)

        Fill the phantom with an aqueous solution of Tc-99m, taking care to ensure that it is <u>thoroughly</u> mixed. It is advisable to perform the Tc-99m studies first, and then fill the phantom with T1-201 or Ga-67/In-111 after the Tc-99m has decayed. Place the bottom of the phantom (the flat bottom of the cylinder on the rod side) on top and in the center of the highest resolution low energy <u>parallel hole</u> collimator (LEHR collimator is preferred) that is used for the indicated radionuclide. The matrix size should be 256 x 256 and the count rate should not exceed 50 kcps.

        Set the acquisition for Tc-99m, no zoom, and acquire a 600,000 static image.

2. **Acquisition Two – Tl-201 (*required if used currently or will be used*)**

    A. <u>Planar Field Uniformity</u> (each detector)

Set the camera for T1-201and acquire an intrinsic flood field image as described above for Tc-99m. Use the clinical analyzer window(s) settings.

B. <u>Planar Spatial Resolution</u> (*with ACR phantom if SPECT phantom to be acquired*)
After the Tc-99m SPECT acquisition and refilling of the phantom with the second isotope, set the camera for Tl-201 and acquire a 600,000 static image with the window settings and collimator you use clinically (document settings).

3. Acquisition Three - Ga-67 or In-111 (*required if used currently or will be used*)

A. <u>Planar Field Uniformity</u> (each detector)

Set the camera for Ga-67 or In-111 and acquire an intrinsic flood field image as described above for Tc-99m. Use the clinical analyzer window(s) settings.

B. <u>Planar Spatial Resolution</u> (*with ACR phantom if SPECT phantom to be acquired*)

After the Tc-99m SPECT acquisition and refilling of the phantom with the second isotope, set the camera for Ga-67 or In-111 and acquire a 600,000 static image with the window settings and collimator you use clinically (document settings).

4. Planar Images for Submission

For each of the acquisitions make a hard or soft copy image for submission to the ACR as follows:

1. Individual planar images should be between six and nine cm in diameter. Other sizes images are difficult to read and may be returned to the facility without review.

2. Submit only gray scale images.

3. Use linear mapping of the display with the lower threshold set at 0 (or $\leq 5\%$ of the maximum upper level) and the upper threshold set to the maximum count.

4. Label hard copy with the ACR bar code and all pertinent imaging parameters digital submissions should also be appropriately labeled. Make sure the Site Scanning Data forms are filled out completely.

SPECT Images

A. <u>QC Information</u>

Center-of-rotation and flood uniformity calibrations are regularly performed on SPECT systems. Fill in the appropriate data fields based on the most recent calibrations.

B. SPECT Phantom Information

The ACR phantom that is used for the SPECT tests must be described on the Site Scanning Data Forms.

C. Acquisition One - Tc-99m

1. Positioning of ACR Phantom for tomography

   Place the phantom on the patient support (bed, chair, etc) so that it is positioned lengthwise, corresponding to the primary patient axis. The phantom's long axis must be parallel to the z-axis of the detector system with the phantom level and the uniformity section should be "head first" into the camera. Phantoms with flanges may require extra support for leveling. The phantom should be positioned in the center of the field of view of the detector(s), with the spheres placed in order of increasing size, clockwise as viewed from the top when a clockwise acquisition will be performed.

   Note: For a single detector camera which is only capable of rotating thru 180 degrees, rather than a complete 360 degrees, special caution must be exercised in the orientation of the spheres. The phantom must be positioned so that the largest sphere is at the center of the 180-degree sweep for frame 1. If a Dual head, fixed 90 degrees detector configuration that only has a 180-degree acquisition arc is being tested, the largest sphere must be positioned in the center of the leading detector for frame 1

   Failure to follow these directions will produce images with poor contrast in the cold spheres.

2. Collimator - Use the highest resolution low-energy parallel hole collimator that is routinely used for clinical studies

3. Acquisition – Select the appropriate isotope and acquire a SPECT study with the window setting, orbit shape, and detector motion (step-and-shoot or continuous) that is used clinically.

   Total counts - For SPECT acquisitions the total count for the sum of all images (for all heads on multiple detector systems) should be approximately 32 million counts (based on counts in the first view). See Appendix A for a sample calculation.

   Count rate should not exceed 50 kcps

   Use a 128 x 128 matrix with 120 (or 128) views over 360 degrees

   Radius of rotation should be as close as possible to 20 cm and the center of the phantom must be close to the axis-of-rotation so that the distance from the face of the

collimator(s) to the phantom does not change significantly during rotation (except in the case of non-circular orbits).

For an acquisition matrix of 128 x128, the pixel size should be near 2.8 to 3 mm. Some systems will require an acquisition zoom factor (up to a maximum of 1.6) to achieve the appropriate pixel size.

4. <u>Reconstruction</u>

The Butterworth filter is available on most commercial systems and it is strongly suggested that this filter be used in processing the phantom data. However, sites may substitute the clinical filter that they are currently using with the parameters optimized for the ACR Phantom. The filter and parameters must be documented on the site scanning data form. The substitute filter submission is expected to be equivalent to or surpass the Butterworth filter in the image quality of the contrast, resolution and uniformity transaxial slices generated from the ACR phantom data.

Reconstruct the entire phantom with a slice thickness as close to 0.6 cm as possible. For most large field-of-view cameras, summing 2 slices will generate the appropriate thickness. Thickness, filter and attenuation coefficient values must be entered into the parameter sheet. Most sites will reconstruct the <u>entire</u> phantom with filtered-back-projection and a Butterworth filter.

The Butterworth filter should be used with a slope of 6 and a cutoff of 0.55, which is optimal for many systems (for some vendors the cutoff will be close to 0.35). However, the <u>cutoff</u> can be adjusted to optimize contrast of the spheres and sharpness of the smallest visible rods in the transaxial slices.

Apply the attenuation correction so that a profile across the phantom is essentially flat. For most cameras, the linear attenuation coefficient for Tc-99m is 0.11 to 0.12/cm. Use the uniform part of the phantom to define the boundary for attenuation correction.

5. <u>SPECT Images for Submission</u>

Submit images of transaxial slices (0.6 cm thick) on 2 or 3 sheets of film or appropriate soft copy. Image size should be adjusted with the display zoom.

1. Individual images should be between three and six cm in diameter. Images other sizes are difficult to read and may be returned to the facility without review.

2. Submit only gray scale images.

3. Use linear mapping of the display with the lower threshold set at 0 (or $\leq 5\%$ of the maximum upper level) and the upper threshold set to the maximum count.

4. Label hard copy with ACR bar code and all pertinent imaging parameters - digital submissions should also be appropriately labeled. Make sure the Site Scanning Data forms are filled out completely.

D. <u>Acquisition Two</u> - Tl-201, Ga-67, or In-111 (if applicable)

1. <u>Positioning of ACR Phantom for tomography</u>

    Position the phantom as described for the Tc-99m acquisition.

2. <u>Collimator</u> - Mount the collimator used clinically for Tl-201, Ga-67, or In-111, as appropriate.

3. <u>Acquisition</u> - Acquire a SPECT study with the window settings and orbit used clinically for Tl-201 or Ga-67/In-111.

    Total counts - For SPECT acquisitions the total count for the sum of all images (for all heads on multiple detector systems) should be approximately 32 million counts (based on counts in the first view)

    Count rate should not exceed 50 kcps.

    Use 128 x 128 matrix with 120 (or 128) views over 360 degrees.

    Radius of rotation should be as close as possible to 20 cm and the center of the phantom must be close to the axis-of-rotation

    For an acquisition matrix of 128 x128 the pixel size should be near 2.8 to 3 mm. Some system will require an acquisition zoom factor (up to a maximum of 1.6) to achieve the appropriate pixel size.

4. <u>Reconstruct</u> as for Tc-99m except that the attenuation coefficient for the T1-201 and Ga-67/In-111 should be approximately 0.09/cm and the slice thickness should be as close to <u>0.9 cm</u> as possible. For most large field-of-view cameras, summing 3 slices will generate the appropriate thickness.

5. <u>SPECT Images for Submission</u> as for Tc-99m.

APPENDIX A

SAMPLE CALCULATION FOR SPECT ACQUISITION TIME

Calculation of the time per view to acquire approximately 32M counts in the SPECT study.

If the system you are using shows the count rate prior to starting the SPECT acquisition, use the procedure given below. If the count rate is not shown, just prior to starting the SPECT study, acquire a planar acquisition for 10 seconds (be sure the imaging table is not between the detector you are using and the phantom) and divide by 10 to get the rate in counts per second.

R = count rate in counts per second for one of the detectors

N = number of views (120 or 128, whichever is available or whichever you want to use if both are available)

T = time for the <u>first</u> view

Example:

$$T = \frac{32{,}000{,}000 \text{ total counts}}{N \times R}$$

Assume R = 28,000 counts per second

Assume N = 120 views

$$T = \frac{32{,}000{,}000 \text{ total counts}}{120 \times 28{,}000} = 9.52 \text{ seconds}$$

Round the time <u>up</u> to the next whole number if the fraction of a second is greater than 0.5.
Round the time <u>down</u> to the next whole number if the fraction of a second is less than 0.5.

T = 10 sec

If the system has two detectors the <u>total</u> acquisition time will be approximately one-half of the time for a single detector system. If the system has three detectors the <u>total</u> acquisition time will be approximately one-third of the time for a single detector system.

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