Continuing Education Series

Quality Control in SPECT

Kim Greer, Ronald Jaszczak, Craig Harris, and R. Edward Coleman

Duke University Medical Center, Durham, North Carolina

This is the second in a series of continuing education articles on SPECT. After studying this article, the reader should be able to: (1) describe quality assurance procedures; (2) discuss the importance of each procedure and time interval of performance; and (3) describe the pitfalls in QA failure.

Performance testing in single photon emission computed tomography (SPECT) imaging can occur at several times: acceptance (installation), routine (daily, weekly), and extended (monthly and at upgrades). Certain tests must become part of a regular effort to achieve the best possible results with a SPECT system. The final responsibility for optimal images lies with the nuclear medicine department rather than the vendor. The authors offer some suggestions for monitoring the imaging ability of SPECT camera-based systems. The main goals in performance testing are: (a) to ascertain minimum performance specifications as stated by the manufacturer; (b) to identify and correct losses of performance; and (c) to identify and correct the introduction of degradation with changes in hardware, software, and operators.

Achieving and maintaining the best possible imaging results from a SPECT system can be obtained through the appropriate use of performance testing. Most procedures involved in performance testing are generic and independent of the computer and manufacturer. Many of these procedures may be performed by nuclear medicine technologists acquainted with the basic operating procedure for the system in question. One may incorporate these and other tests into a continuing schedule of quality assurance.

Not every test described herein is possible with every system. Most of the procedures may be performed with a given system with little variation in the technique. The basic premise is that routine testing may pinpoint deficiencies ultimately resulting in improved patient studies. Artifacts from improperly operated systems and the basis for various compensations (flood, offset, etc.) have been well documented elsewhere (*1–9*).

For reprints contact: Kim L. Greer, Imaging Division, PO Box 3949, Duke University Medical Center, Durham, NC 27710.

INSTALLATION AND ACCEPTANCE TESTING

The tests performed at the time of instrument installation and acceptance should be carefully performed because they will establish the initial performance characteristics of the SPECT system. Problems may still need to be corrected by the manufacturer, either with the basic scintillation camera and associated computer or with the machines as an integrated functional unit. *Only* after proving that the camera meets the minimum specifications for a planar imaging device should SPECT performance be considered. Because SPECT images result from a series of planar images, anything that degrades the planar capabilities will affect the SPECT reconstruction.

INITIAL PLANAR ADJUSTMENTS

X-Y Centering

X-Y centering of the camera to computer is the first adjustment to make. Coarse adjustments may have already been performed by the service engineers at installation. The source holder supplied by many manufacturers for adjusting photomultiplier tubes can also be used for the X-Y centering adjustment (Fig. 1). Otherwise, a collimated beam source can be made by placing a millicurie of activity in a lead cylinder that has a 1–2-mm hole drilled in the bottom. Carefully place the cylinder on the uncollimated detector surface. Align the hole in the lead cylinder with the exact center of the detector surface. Most cameras have photomultiplier tube locations drawn on this surface, allowing for accurate placement. Adjust the offset voltage controls on the analog-digital converter (ADC) while monitoring the location of the point source on the computer monitor. A series of test acquisitions will then allow profiles to be drawn and a location established. For example, the point should fall in between channels (or pixels) 64 and 65 in a matrix that is 128 pixels wide. This applies to both X and Y dimensions. Less than one pixel error in either plane should be obtained. Many manufacturers currently allow in their software an "offset" calibration value that is acquired before or after patient studies.

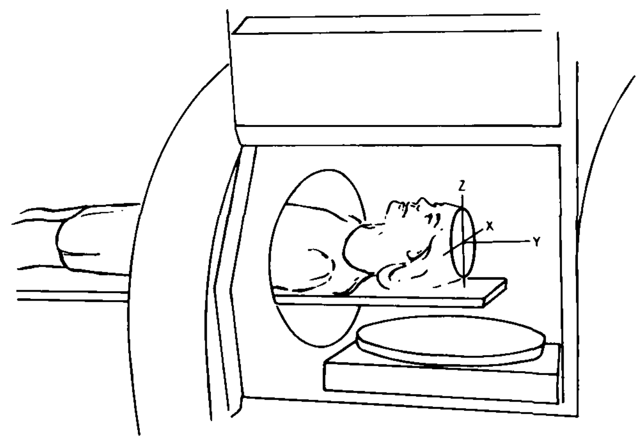


FIG. 1. Coordinate scheme as used in later references. Line "Y," not necessarily in center of patient, corresponds to axis of rotation (AOR).

X-Y Gain

Coarse adjustments to X and Y positioning signal gain on the ADC or line amplifier may be done while imaging a flood source over the collimated detector. Vary the gain to equalize the height and width of the image (Fig. 2). Then on a piece of paper or thin cardboard, draw a cross with a pencil. At equal distances from the intersection of the lines, just inside the field of view of the camera, place a drop of Tc-99m on each line. Try to keep the drop size small (about 2-mm diameter). Also place a drop at the intersection. Take appropriate measures to avoid contamination. Locate the central point source over the center of the camera, making fine adjustments in location similar to the X-Y centering routine just previously accomplished. Orient the sources so that they are aligned parallel and perpendicular to the X and Y axes (i.e., at the top, sides, and bottom of an image). Minor adjustments on the ADC or line amplifier voltages in conjunction with test acquisitions and profile analysis will allow for equalizing the size of the input signals. The horizontally aligned points should be the same number of pixels apart and in approximately the same profile locations as the vertically aligned points. Afterwards, assuming a circular field of view camera, a collimated flood source should appear circular and symmetrical, but only if the display device (persistence scope or video) is properly adjusted.

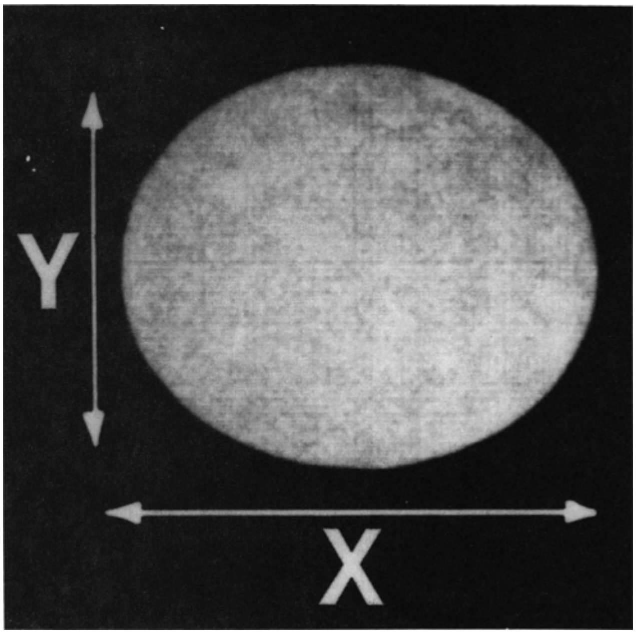


FIG. 2. Exaggerated inequality in the X- vs. the Y-gain for this flood image taken with a circular field of view gamma camera. The gains should be equal for both directions, measurable with point sources at specific locations on the camera face (see text).

Collimator

The collimators should be inspected by visual, scintigraphic, or radiographic methods. Surfaces should be free of dents and other obvious defects (Fig. 3). Radiographing the collimators can demonstrate defects such as separation of septa or nonsymmetrical penetration of off-axis radiation at septal interfaces. A 128 × 128 matrix flood acquisition of at least 20 million events can demonstrate otherwise unnoticed irregularities.

The tightness of fit of the collimator can affect the ability of the flood correction software to properly compensate for nonuniformities in the collimator. For cameras with spatial distortion correction, the collimator is the major factor in nonuniform field response, particularly the high frequency components. Therefore, if the collimator slides within its mounting, which is more likely for insert-type collimators, the correction matrix will not correspond in X-Y coordinates for the data acquired as the detector moves about the patient during a SPECT acquisition. The collimator should not move when side pressure is applied by hand.

Uniformity

Once uniformity in the planar mode meets specifications, several SPECT-related tests of uniformity should be performed. One early problem in SPECT detectors was related to both magnetic field and gravitational effects on uniform detector response as a function of detector angle or orientation. With the collimator off, take a series of flood images every 30° or so, making sure the point source is at the same distance and that the camera is not exposed to extraneous sources (i.e., other rooms and hallways). A 10-million count image can demonstrate that obvious problems exist if the counts per second or overall image pattern changes from angle to angle.

SPECT-related uniformity may be further tested by imaging a cylindrical phantom (at least 20-cm diameter) with a large number of events (approximately 15 million) per slice in the reconstructed images. Without flood correction, the slices should be nearly uniform throughout, but may have a few minor ring artifacts. These ring artifacts should disappear after flood-correcting the data (Fig. 4). If they do not, acquire a new flood image with approximately 40 million events with a 128 × 128 matrix or the equivalent counts per pixel if using a different size matrix. When problems persist, one should

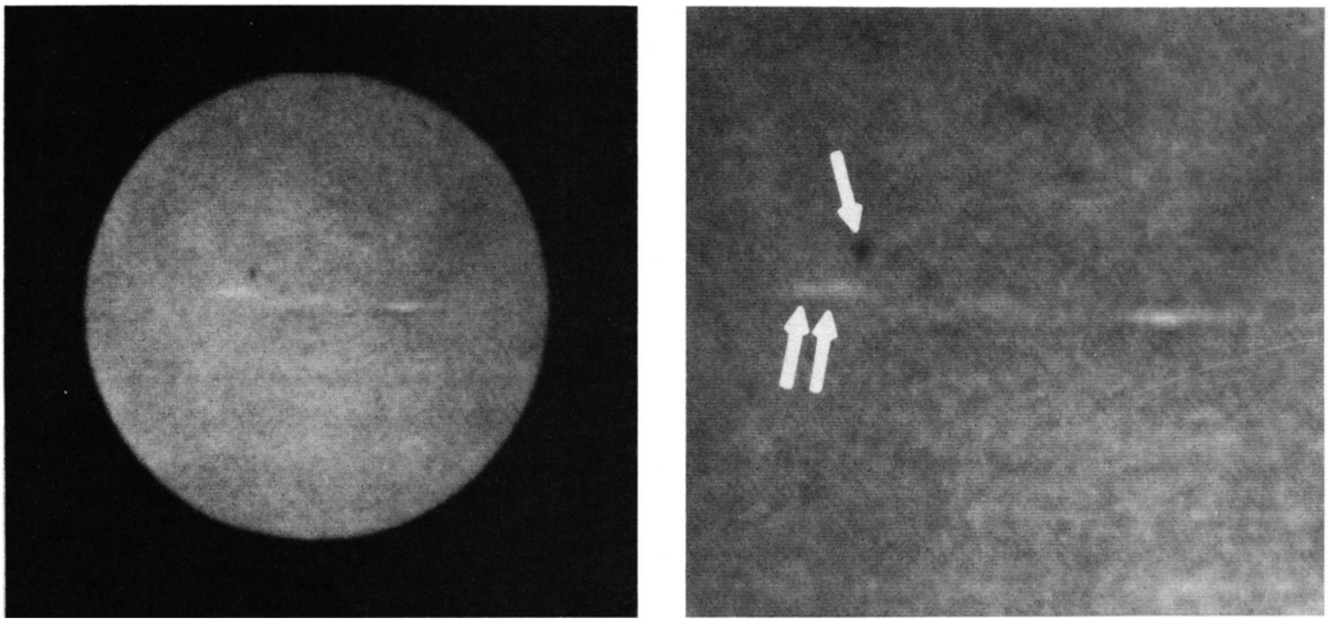


FIG. 3. Flood image (approximately 61 million counts) taken with imperfect collimator. Note structures of greater and lesser intensity, brighter and darker, respectively, that must be compensated for to avoid circular artifacts. Enlargement (right) demonstrates areas of apparent separation of septal interfaces (bright streaks, double arrows) and a dent in the collimator (dark area, single arrow).

contact the manufacturer. The reason for the large number of counts in this and other tests is that statistical uncertainty can mask or create artifacts. Providing reliable data allows for evaluating the system for its true abilities under optimal conditions. If it does not perform adequately under ideal conditions, it certainly is not going to do so under clinical conditions.

While late model cameras now exhibit impressive intrinsic uniformity, some radionuclides may still render a different response than others, notably Ga-67 and I-123 as compared to Tc-99m or Co-57. To be certain of the effect these different responses will have on any individual system, acquire flood data from various radionuclides to serve as correction matrices for uniform activity cylinder data acquired from different radionuclides.

Spatial Linearity

The left side of the camera may have different gain than the right side. It is currently difficult to make meaningful measurements of local distortions, but one should be aware of their presence, as well as global distortions. Because the

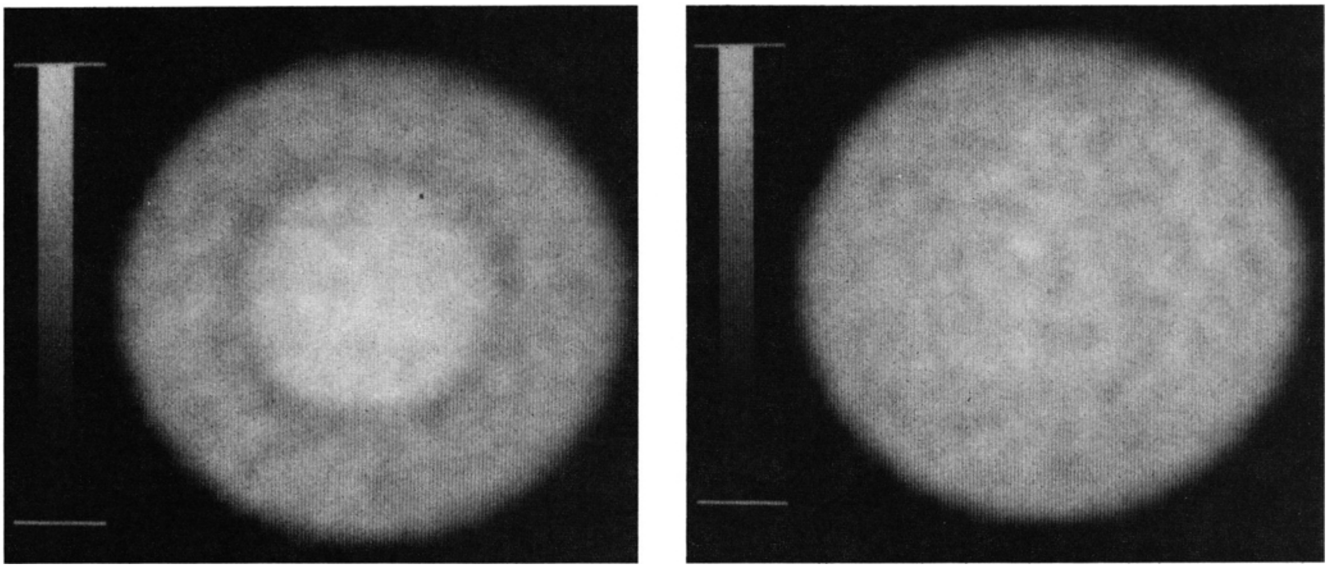


FIG. 4. Same slice through a water-filled cylinder containing uniform activity of Tc-99m, reconstructed with (right) and without (left) compensation for nonuniformities in camera response. Slice contains about 6.4 million counts.

user cannot normally adjust this parameter, the linearity test might better fit into the protocol carried out for use as a conventional planar camera. Spatial linearity for a SPECT camera should at least equal the performance of that camera in the planar mode. Changes in linearity can result in degradation of SPECT phantom images.

INITIAL SPECT ADJUSTMENTS

Center of Rotation

This calibration is concerned with determining the common reference point, the center of the camera respective to the computer matrix, so that the reconstruction software may compensate for errors in camera-computer relationship (Fig. 5). Commercial systems now available usually accomplish this by scanning a line or point source in air, mounted approximately parallel to, and slightly away from, the axis of rotation. Various diagnostic calculations are available to the operator depending on the specific system, once the scan is complete. Besides calculating the average error for later use in the reconstruction process, some systems print out the full width at half maximum (FWHM) and full width at tenth maximum (FWTM) determined from reconstruction of the line source (*10*). A sinogram curve-fitting routine is available from one vendor to provide additional information to the operator. Recording these data can provide a valuable reference source when problems arise. Each collimator that is expected to be used must have an offset calibration performed for it.

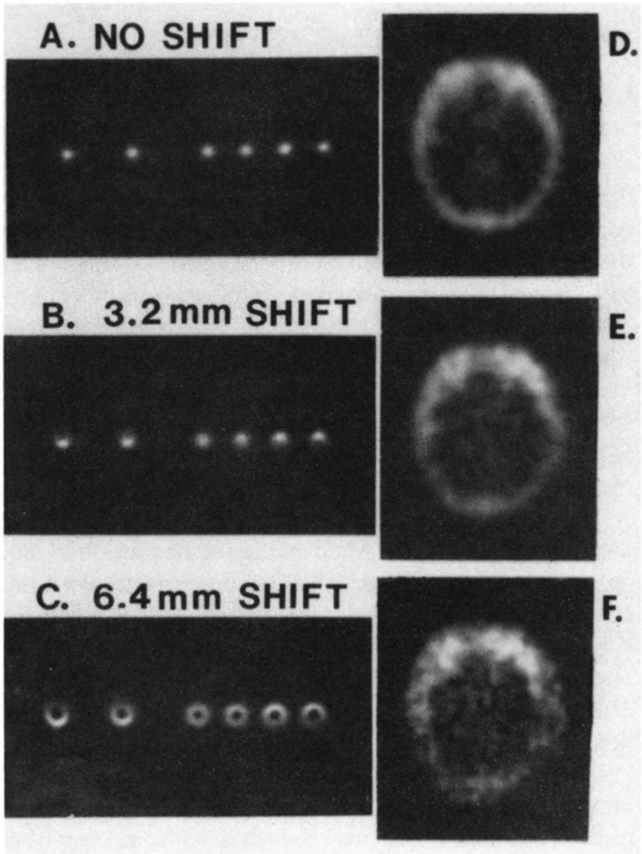


FIG. 5. Top figures depict reconstructions from unaltered data for 7 line sources (A) and a slice from a brain scan (D). Centering error for A and D measured as less than one millimeter. Figures B and E show the effect of a 3.2-mm error in offset determination, accomplished by shifting the same projection data from A and D by one pixel (3.2 mm) prior to reconstruction. Note rapid deterioration of resolution and introduction of circular artifacts in B as compared to A. Figures C and F: as in B and E, except data were shifted 6.2 mm from original.

Resolution

If SPECT image resolution measurements such as FWHM and FWTM are not possible, then line sources (Appendix A), rods, spheres, and other test phantoms may be scanned to determine approximate system resolution.

When it is possible to calculate FWHM and FWTM, one may compare line source measurements in air and water for SPECT and planar modes. Scan a line or point source, located near the axis of rotation (AOR), first in air, and then in a water-filled cylinder (approximately 20-cm diameter). Align the line source approximately parallel to the AOR. Note the radius of rotation. Acquire planar images of the lines at the same distance as the radius of rotation, in air and in water. After reconstruction with a ramp filter, the SPECT images should provide resolution values (FWHM and FWTM) nearly equal to those values obtained with planar imaging. Current available systems typically have resolution values (FWHM) that are 1 to 2 mm larger than planar values.

Phantoms*[†] designed for SPECT evaluation (Fig. 6) may be scanned with high counts (15–20 million) per slice. To obtain these count densities, it may be necessary to increase the slice thickness, or alternatively, to add several thinner slices together. With this high-counts-per-pixel, low-noise situation a resolving ability in the SPECT mode similar to the vendor's claims should be obtained. A large slice thickness (8 cm) is appropriate for hot or cold rod-like structures parallel to the AOR (Fig. 7A). Thinner slices (1 cm) will better demonstrate spheres, since partial volume effects will be eliminated (Fig. 7B). The trade-off is the increase in acquisition time or activity required to achieve 15 million counts per slice. In addition to high count studies, a scan of the rods or spheres at counts-

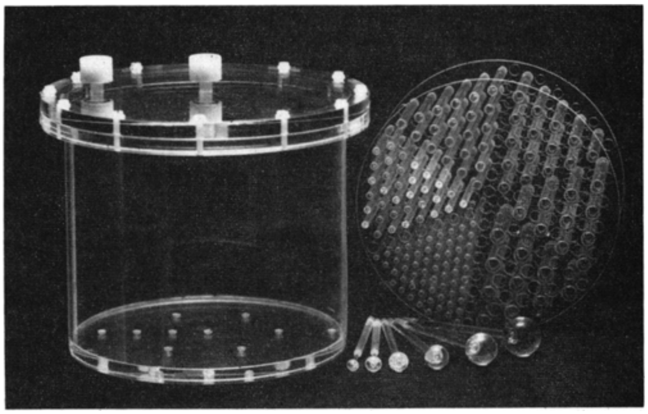
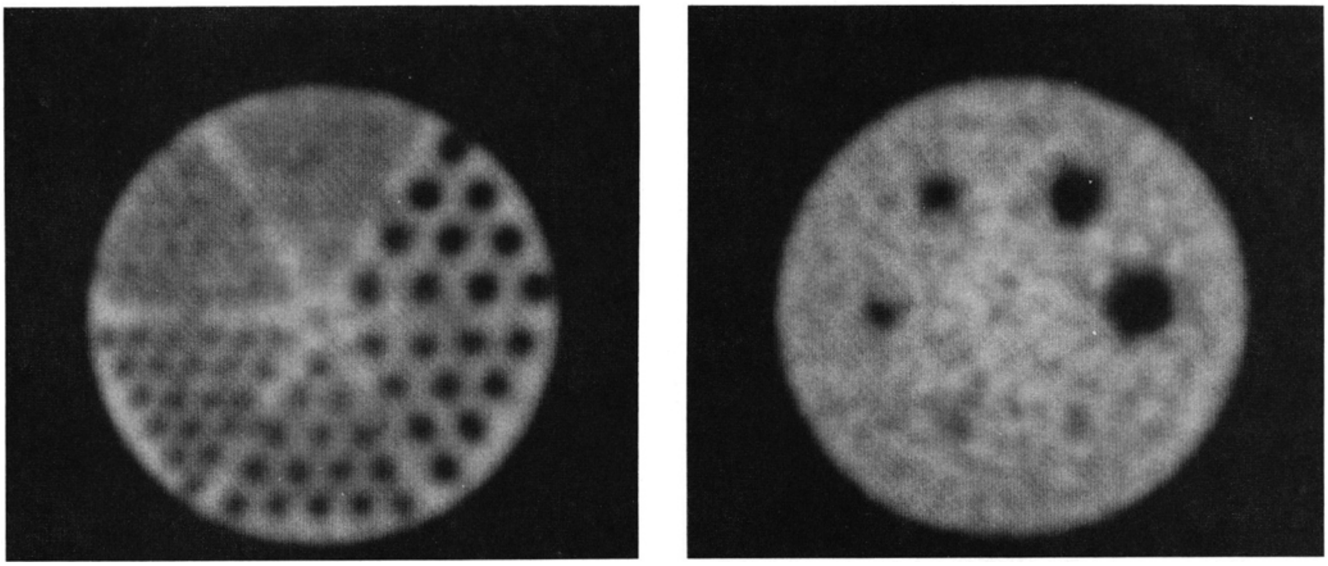


FIG. 6. A commercially available SPECT phantom, consisting of 22-cm diameter cylinder and inserts that may be used to measure system performance.



A B

FIG. 7. Scans of "cold" rods (A) and "cold" spheres (B) in a background of uniform activity. Rods are 4.8, 6.4, 7.9, 9.5, 11.1, and 12.7 mm in diameter. Spheres are 9.5, 12.7, 15.9, 19.1, 25.4, and 31.8 mm in diameter.

per-slice levels similar to that expected from patient scans is recommended to better estimate the clinical reality of fewer counts/slice (thus increased noise). The counts per slice for the phantom image is comparable to the noise level in the patient scan, because the phantom cross-sectional area is typically much larger than the active cross-sectional area of a patient's organ (e.g., liver and spleen). Thus, more counts are required for the phantom scan. Nonemitting (cold) spheres similar in size to the system resolution are much more difficult to visualize than radioactive ones in a cold background. Maintain a consistent size radius of rotation from study to study. High resolution phantoms (small rod and sphere diameters) require high resolution collimation and small radii of rotation. Lower resolution inserts (large diameter rods and spheres) may be imaged with lower resolution collimators and/or larger radii of rotation.

Sensitivity

A properly designed SPECT system should not exhibit decreased sensitivity in the SPECT mode compared to the planar mode. Measure a point, line, or symmetrical volume source with a planar acquisition, noting the counts/second per microcurie. Determine from a few projections of the SPECT data what count rate is shown. "Step and shoot" acquisition modes will necessarily have a significant amount of time that is not actually used in acquisition of data; therefore, calculate the sensitivity only when the computer is actively acquiring events.

Once parameterized, the values for the tests mentioned above should be confirmed against the claims of the manufacturer. Variations $> \pm 10\%$ should be questioned, particularly in regard to sensitivity and resolution. Exact, or even approximate values cannot be quoted here due to the large number of permutations of specific cameras, collimators, energy window width, and distances that one may have available.

ROUTINE TESTING

Center of Rotation

Some systems may be stable enough to require a new center of rotation ("offset") calibration acquisition on a weekly rather than a daily basis, provided the same collimator is being used. This kind of stability must be determined for the specific machine in question based on experimentation with a phantom, carried out over a period of several weeks with periodic comparisons of reconstructions made with new axis of rotation files. Perform the procedure in accordance with the manufacturer's recommendations and the above-mentioned concepts in mind. No more than a 2-mm error from the center of the matrix (approximately 0.6 pixels in a 128 pixel-wide matrix or 0.3 pixels in a 64 wide matrix) should be accepted. A 2-mm error determined from one projection is offset 2 mm in the opposite direction when looking at the projection 180° opposed to the original one. This amounts to a total of a 4-mm error, resulting in significant loss of contrast and resolution (Fig. 5). Axis of rotation information should be saved for two reasons: (a) It provides long term characterization of the system drift; and (b) It is usually required to reconstruct archived patient studies from weeks or months past. Do not use centering calibration data from one collimator with another collimator. The validity of the offset data and the associated reconstruction algorithm may be considered competent when the FWHM and FWTM of line sources approximates the values specified by the manufacturer under specific conditions (collimator, radius of orbit, etc). Refer to Appendix A for notes regarding the preparation of line sources for the offset calibration.

Flood Acquisition

Flood images may be valid for nonuniformity compensa-

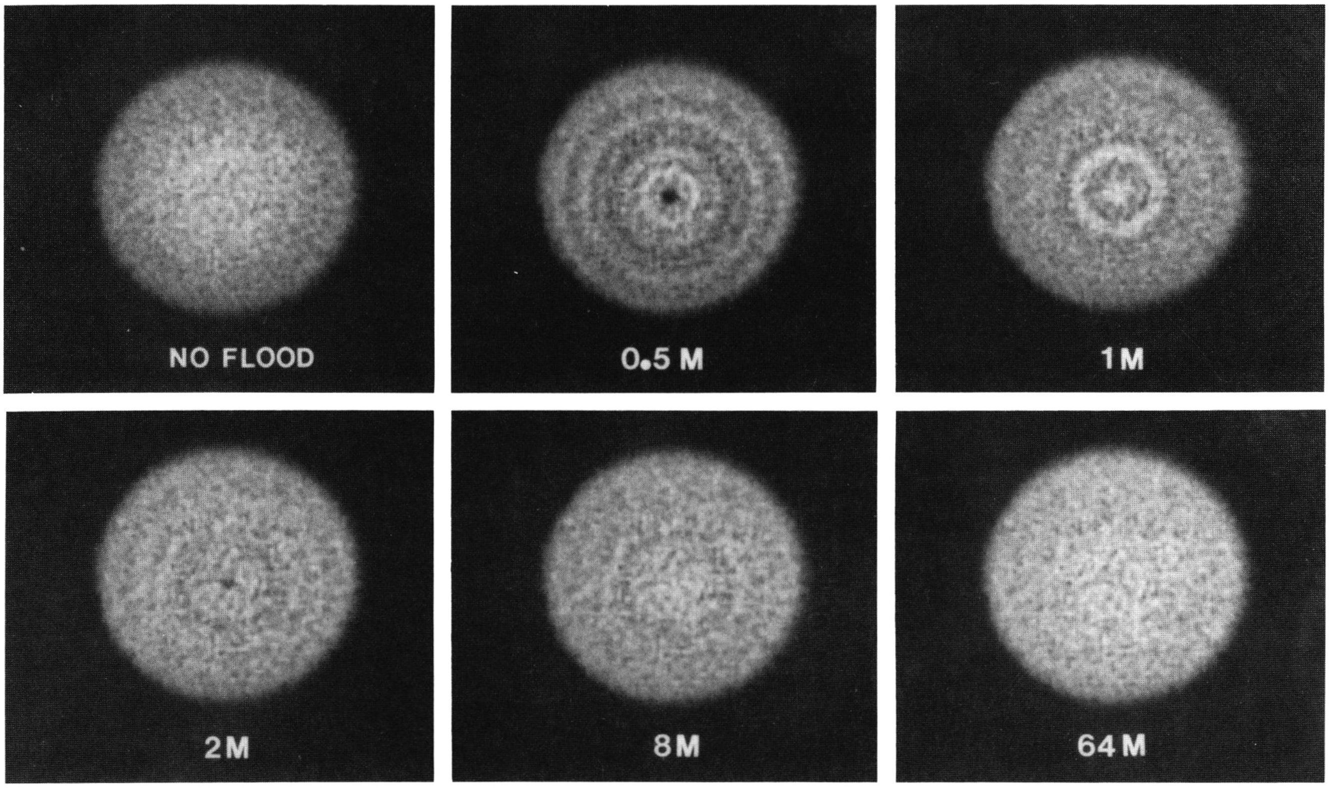


FIG. 8. Same slice of uniform activity cylinder reconstructed without flood compensation (top left) and then reconstructed with flood compensation with flood images containing the number of counts indicated. Statistically invalid flood input images (0.5, 1, 2, and 8 million counts) introduce more errors than are present without performing any flood correction. A 32-million flood image (reconstruction not shown) and the 64-million flood input image (bottom right) indicate that artifacts will not be introduced once a statistically valid flood input image is available to correct imperfections in system response.

tion for several weeks. The stability of the flood correction must be determined for the individual machine. Appendix B offers a suggested method of flood source preparation. A statistically valid image (128 × 128) must contain at least approximately 35 million counts (Fig. 8). Additional counts may be required if the flood compensation algorithm is relatively uncomplicated. Because every collimator is unique, a flood for each collimator that is to be used in SPECT scans should be acquired. Some modern cameras can easily handle 2 million counts per minute with little deadtime losses, even without enabling special high count rate circuits. Therefore, it is possible to acquire a 40 million count flood image in approximately 20 min. Note the activity and length of time required to acquire the image and compare with previous results. Investigate acute or chronic changes in counts/second per microcurie values. Visually compare the image with previous images, noting the occurrence of dents or changes in general uniformity. Archive the flood images if possible, for the same reasons as noting the offset information, and initiate flood compensation programs if operator intervention is required. The flood compensation may be considered adequate when the procedure removes circular artifacts present with noncompensated, high-count density images, while introducing no new artifacts.

A scattering medium is placed between the sheet source and the detector at some institutions. While this practice may be necessary on some systems to achieve pleasing results, the authors have not found it necessary to use any scattering media on either of the two SPECT cameras or systems in current use at their institutions.

Record Keeping

Record pertinent acquisition and reconstruction information on forms to be kept with the patient file folder. These parameters include matrix size, number of angles acquired, step and shoot versus continuous gantry motion, reconstruction filters, and attenuation correction. Note if any special problems arise with the detectors, software, or patient movement. These data sheets can provide a long-term perspective of problems that may develop. Appendix C provides a sample form that is useful in recording the relevant data from a clinical SPECT scan. Similar forms should also be maintained for phantom and calibration studies.

General Image Inspection

For phantom and patient studies, the operator should make certain that no obvious, gross artifacts are present. Errors can still be made by the operator and the computer software even after all the daily or weekly testing is performed. Hardware can deteriorate in short time frames, resulting in artifact-laden images. Contaminated collimators can generate intense circle artifacts, and numerous other problems can occur.

EXTENDED (MONTHLY/BIMONTHLY) TESTING

This category of testing requires many, but not all, of the examinations performed at the time of installation. User discretion is advised to determine what parameters should be remeasured for each unique SPECT system. It is probably unnecessary to redetermine if Tc-99m will flood correct Ga-67 images or if there are angle-dependent responses in field uniformity. Simple resolution measurements, high-count intrinsic flood images, and test phantoms should be scanned at least once every 2 months. The test phantoms should include hot or cold rods of known size, spheres, or the equivalent, to compare with initial installation measurements made with the system.

Equipment service or software/hardware upgrades can cause or accentuate existing problems. Count losses may go unnoticed if specific testing for this is not done. Resolution may suddenly drop due to changes in offset calculation or ADC instability.

MISCELLANEOUS CONCERNS

A few special concerns should be considered with the introduction of a SPECT system. These concerns involve the physical relationship of the camera to the axis of rotation and the matching of multiple detectors one to another.

The availability of multiple-detector systems, having two (*3*) and even three (*11*) camera heads will require the additional task of matching the outputs of one camera to another. Image sizing, collimator matching, sensitivity, and resolution performance will present new problems in quality assurance. The overall effect of averaging one camera performing very well with one having mediocre performance will be something less than very good. To prevent "wasting" the output of a very good camera by adding in the output of a lesser performing camera, one should maintain a high degree of camera tuning and X- and Y-axis gain matching.

Most SPECT systems allow for manual tilting of the camera with respect to the axis of rotation. To prevent artifacts and achieve maximum resolution, the camera face should always be parallel to the axis of rotation. The user must depend on some leveling device, either a built-in electronic readout or a bubble-level placed on the camera. The user should verify digital readouts at periodic intervals, perhaps once a month, using a bubble-level. Allowable error will depend on collimator and radius of rotation as well as other factors. Therefore, use phantom measurements to determine how the error affects a specific system.

CONCLUSIONS

High quality SPECT studies may be performed with commercially available systems. It is the user's responsibility to determine if the system is providing the maximum information possible. Knowing the expected system response, one may determine if the facility meets the stated specifications, and if not, appropriate measures should be taken to remedy the situation. To aid in achieving this goal, the authors offer a few closing suggestions:

- Specify at least one person in the department who is intimately familiar with the system and who is available to other users when problems arise.
- Establish a routine that is practical and meaningful (see Appendix D).
- Obtain offset and flood correction data for each individual collimator that is used.
- Record acquisition parameters for patients and experiments to help avoid confusion and maintain consistent quality studies (see Appendix C).
- Maintain records of resolution and sensitivity measurements and refer to them during future performance analysis.

ACKNOWLEDGMENTS

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FOOTNOTES

* Data Spectrum Corporation, 2307 Honeysuckle Rd., Chapel Hill, NC 27514

† Victoreen Nuclear Associates, 100 Voice Rd., Carle Place, NY 11514

APPENDIX A
Preparation of Line Sources

Line sources for SPECT applications may be purchased* or prepared on site from any one of several materials, one of which is glass capillary tubing. Glass capillary tubes† may be purchased in bulk, in lengths up to several feet per tube, and cut to the desired length. They are easy to fill and use.

The necessary materials are:

a. glass capillary tubing, approx. 1-2 mm diameter, 6-10 in long
b. small, triangular steel file
c. putty to seal tube ("Seal-Ease")**
d. rubber gloves
e. desired radionuclide, in approx. 0.4 ml of fluid, in 3-cc syringe

Cutting glass capillary tubes is best done with a small triangular file. Carefully score the tube with the file at the desired length. Use a corner of the file, rather than the flat surface of it. With the tube on a flat surface, make only one etch mark with just enough pressure to scratch the surface of the glass. Do not try to saw the tube in two. Hold the tube with the scratch mark between the thumbs and forefingers of each hand. The scratch mark should be away from the body. Gentle pressure will usually cause a clean break. Be careful of minute glass particles that may break away. Avoid using tubes with jagged ends. The tube is now ready to be filled.

Wearing rubber gloves, hold the tube in one hand while holding a 3-cc syringe containing about 0.4 ml of pertechnetate in the other hand. The needle should not be on the syringe. With the tube and the syringe nearly horizontal, insert the tube into the syringe. The fluid should begin to flow into the tube after tilting the opposite end down slightly. When the desired amount of fluid is in the tube, stop the flow by placing a fingertip over the exposed end of the tube. Continue to hold the finger over the end of the tube. The tube can then be removed from the syringe and sealed.

Seal the tube with a commercially available putty designed for sealing micro-hematocrit tubes. Use just enough pressure to force the end of the tube into the putty. The tubes are fragile and can be easily broken at this time. It is suggested that the other end then be forced into the putty to be sealed as well. Should the tube break later on, this half of the tube would otherwise drain, whereas the remaining half with a sealed end would retain nearly all of its original volume. Wash the tube off under the faucet of a "hot sink" and dry with a paper towel. The tube is now ready to scan.

Capillary tube line sources are quick to prepare after a little experience. Practice filling mock line sources with nonradioactive liquids. The fragility and radioactive nature of these line sources require careful handling to avoid possible contamination if they are broken.

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* Data Spectrum Corporation, Chapel Hill, NC 27514

† Kimbell Division, Owens-Illinois, Inc., Toledo, OH, 53666, Article No 46485.

** Clay Adams, Parsippany NJ 07054, Cat. No. 1015.

APPENDIX B
Preparation of Flood Sources

Special care must be taken with flood sources to ensure proper flood data acquisition for correction of SPECT images. One must address two issues in particular, namely uniformity of source radionuclide distribution and sufficient photon flux to provide adequate statistical accuracy levels in the flood data. A liquid-filled source of Tc-99m ("slab tank") is the preferred source. A plastic sheet source of Co-57 can be acceptable, if its uniformity is everywhere within $\pm$ 2% of the mean distribution. However, currently available sources are claimed to have better than $\pm$ 4% uniformity, and the necessary activity levels are sometimes too low or too high to use with a specific collimator. The weekly filling of a Tc-99m source is often the optimal choice in flood sources.

The following filling protocol will maximize source uniformity of Tc-99m slab tanks:

1. Determine the actual volume of the tank by calculating its diameter and inside thickness. This is done because the tank will bow outward when filled with water. The volume is calculated as $3.1416 \times r \times r \times d$, where r is the radius in cm and d is the depth in cm (seen in an edgewise view).

2. Fill the tank with the calculated volume of clean, mineral free water. Distilled water or "sterile water for irrigation" is inexpensive and readily available. Scribe a line on the side of the tank indicating the level of the water. A relatively large amount of air will still remain in the tank.

3. Add the Tc-99m by injecting directly into the water and *not against the inside walls* of the tank. The Tc-99m should be in the form of sodium pertechnetate. Avoid using sulfur colloid or albumin formulations, as they tend to clump and stick to the walls of the tank. Replace the screw back into the filling port.

Approximate activity levels for various collimators:
- Low energy all purpose: 5-7 mCi
- High resolution: 10-14 mCi
- Ultra-High resolution: 20-30 mCi

4. Mix the solution thoroughly, using the large remaining bubble.

5. Remove the screw from the filling port and expell the bubble. Procede carefully to avoid spraying the solution out of the port. A fixture can be made, in the manner of a large "C-clamp," to easily control bubble removal.

Further considerations are as follows:

a. Use appropriate radiation shielding whenever possible.
b. Wear rubber gloves; avoid personal and machine contamination.
c. Drain, disinfect, and refill the tank when bacterial growth is evident. This will prevent nonuniform deposition of Tc-99m and spread of infectious diseases.
d. Coloring agents are not recommended because they can lead to particulate formation.
e. Many cameras can process about 2 million counts per minute with acceptable deadtime losses. Try to keep source activity high, but avoid deadtime losses of greater than 10-15%.

APPENDIX C
Sample Patient Data Acquisition Form
Name of Institution
Divison of Nuclear Medicine

Patient Name ______________________

History Number ______________________

Date of Scan ______________________

Study Name ______________________

Radiopharmaceutical ______________________

Dose ______________________ mCi

Organ/Region Scanned	______
Time When Injected	______
Time When Scanned	______
Arms Overhead?	Yes/No/NA
Patient Position	Supine/Prone
Physician	______
Technologist's Initials	______

Energy Analyzer 1 Centerline __ keV and width __ %
Energy Analyzer 2 Centerline __ keV and width __ %
Energy Analyzer 3 Centerline __ keV and width __ %
High Count Rate? ______ Yes/No ______

Collimator	LEAP HRES UHRS MEDE
Matrix Size	128^2 64^2 128^2 Zoom 64^2 Zoom
Start Position	______ degrees
Rotation	CW/CCW 180°/360°
Flood Data File Date	______
Offset Data File Date	______
Views per Scan	30 45 60 90 180
Slice thickness (transverse)	______ mm
Radius of rotation	______ cm

Continuous Mode
Min/Scan ______

Step and Shoot Mode
Stop Conditions
Sec/View ______
or
Counts/View ______

APPENDIX D
Sample Protocols

DAILY

Flood*	5-million count acquisition visual inspection† photography (NOTE: *not* for use as flood correction data)

DAILY to WEEKLY

Offset Information**	acquisition of line source processing statistical information (inspection/recording)
Uniformity Correction Flood Image**	30–60 million count acquisition processing statistical information (inspection/recording) photography visual inspection†
Patient Studies	acquisition reconstruction/processing photography archival/deletion appropriate paperwork/data recording

WEEKLY

	standardized phantom and acquisition and reconstruction methods (e.g., lines, rods, or spheres, and uniform cylinder) visual inspection† check head tilt

EXTENDED (every 2 months)‡

Resolution	FWHM of planar vs. SPECT of line source
Uniformity	intrinsic and with collimators (high counts) visual comparison with previous images scan of uniform activity cylinder with and without flood correction of reconstructions
Orbit Eccentricity	sine wave curve fit of line source in air
X-Y Gain Symmetry	adjust ADCs to be absolutely equal, from left to right and top to bottom, if needed
X-Y Centering	adjust image to center of computer matrix, if needed
Sensitivity	compare planar vs. SPECT compare to previous measurements check energy windows

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* Not performed if uniformity correction image (30–60 million counts) has been acquired.

† Includes image inspection, noting changes in statistical workups, appearance of artifacts, uniformity changes in flood, decrease in apparent resolution, etc.

** Must be performed for each collimator that will be used. Also must be performed after any system repair, tuning, or maintenance.

‡ Should be performed after major system repair or upgrade.

REFERENCES

1. Keyes JW. Perspectives on tomography. *J Nucl Med* 1982;23:633-40.

2. Greer KL, Jaszczak RJ, Coleman RE. An overview of a camera-based SPECT system. *Med Phys* 1982;9:455-63.

3. Jaszczak RJ, Chang LT, Stein NA, et al. Whole-body single-photon emission computed tomography using dual, large-field-of-view scintillation cameras. *Phys Med Biol* 1979;24:1123-43.

4. Budinger TF. Physical attributes of single-photon tomography. *J Nucl Med* 1980;21:579-92.

5. Jaszczak RJ, Coleman RE, Whitehead FR. Physical factors affecting quantitative measurements using camera-based single photon emission computed tomography (SPECT). *IEEE Trans Nuc Sci*, 1981;28:69-80.

6. Rogers WL, Clinthorne NH, Harkness BA, et al. Field-flood requirements for emission computed tomography with an Anger camera. *J Nucl Med* 1982;23:162-68.

7. Todd-Pokropek A, Zurowski S, Soussaline F. Non-uniformity and artifact creation in emission tomography. *J Nucl Med* 1980;21:P38.

8. Jaszczak RJ, Greer KL, Coleman RE. SPECT system mis-alignment: Comparison of phantom and patient images. In *Emission Computed Tomography: Current Trends*, Esser PD, ed, New York: Society of Nuclear Medicine, 1983:57-70.

9. Lim CB, Han KS, Hawman EG, et al. Image noise, resolution and lesion detectability in single photon emission CT. *IEEE Trans Nuc Sci* 1982;29:500-05.

10. Jaszczak RJ, Greer KL, Coleman RE, et al. SPECT Instrumentation: Evaluation of system performance. Proceedings of Southeast Chapter, Society of Nuclear Medicine, Lexington, KY, November 1984, viii-1—viii-14.

11. Lim CB, Gottschalk S, Walker R, et al. Triangular SPECT system for 3-D total imaging: Design concept and preliminary imaging results. *IEEE Trans Nuc Sci* 1985;741-47.