

Society of Nuclear Medicine Procedure Guideline for General Imaging

Version 3.0, approved May 30, 2004

Authors: J. Anthony Parker, MD, PhD (Beth Israel Hospital, Boston, MA); Margaret E. Daube-Witherspoon, PhD (University of Pennsylvania, Philadelphia, PA); L. Stephen Graham, PhD, FACR (West Los Angeles VA Medical Center/UCLA School of Medicine, Los Angeles, CA); Henry D. Royal, MD (Mallinckrodt Institute of Radiology, St. Louis, MO); Andrew E. Todd-Pokropek, PhD (University College of London, United Kingdom); and Michael V. Yester, PhD (University of Alabama at Birmingham, Birmingham, AL)

I. Purpose

The purpose of this document is to provide nuclear medicine practitioners with general guidelines on imaging in the practice of nuclear medicine. The guideline includes recommendations common to most nuclear medicine imaging procedures. Recommendations specific to individual procedures are included in their respective procedure guidelines. Among the many topics covered are:

III. Procedure

A. Patient Preparation

(including considerations for women of child-bearing age [III.A.2])

B. Information Pertinent to Performing the Procedure

C. Precautions (including radiation precautions [III.C.1–4])

D. Quality Control

IV. Single-Photon Scintillation Cameras

A. Planar Imaging

B. SPECT Imaging

V. Nuclear Medicine Computer Systems

VI. Reporting (including report contents [VI.D])

II. Background Information and Definitions

The strength of nuclear medicine lies in its ability to image and quantify regional physiologic biochemical processes. This information may complement anatomic information provided by other modalities.

A. Single-Photon Scintillation Cameras

Single-photon scintillation cameras provide static, dynamic, or gated images of the distribution of radiopharmaceuticals within the body. Single-photon emission computed tomographic (SPECT, also known as SPET) images may be obtained by reconstruction of a number of planar images taken at different angles. CT scanners have been combined with some single-photon cameras that have SPECT capability in order to provide attenuation correction capability as well as localizing information. Use of combined SPECT/CT scanners is likely to increase in the future.

B. Positron Cameras

Positron cameras provide static, dynamic, or gated images of the distribution of positron-emitting radionuclides within the body by detecting pairs of photons produced in coincidence by

The Society of Nuclear Medicine (SNM) has written and approved these guidelines as an educational tool designed to promote the cost-effective use of high-quality nuclear medicine procedures or in the conduct of research and to assist practitioners in providing appropriate care for patients. The guidelines should not be deemed inclusive of all proper procedures nor exclusive of other procedures reasonably directed to obtaining the same results. They are neither inflexible rules nor requirements of practice and are not intended nor should they be used to establish a legal standard of care. For these reasons, SNM cautions against the use of these guidelines in litigation in which the clinical decisions of a practitioner are called into question.

The ultimate judgment about the propriety of any specific procedure or course of action must be made by the physician when considering the circumstances presented. Thus, an approach that differs from the guidelines is not necessarily below the standard of care. A conscientious practitioner may responsibly adopt a course of action different from that set forth in the guidelines when, in his or her reasonable judgment, such course of action is indicated by the condition of the patient, limitations on available resources, or advances in knowledge or technology subsequent to publication of the guidelines.

All that should be expected is that the practitioner will follow a reasonable course of action based on current knowledge, available resources, and the needs of the patient to deliver effective and safe medical care. The sole purpose of these guidelines is to assist practitioners in achieving this objective.

Advances in medicine occur at a rapid rate. The date of a guideline should always be considered in determining its current applicability.

the annihilation of a positron and an electron. Positron-emission tomographic (PET) images are produced by reconstruction from the coincidence pair data. CT scanners have been combined with some positron cameras to provide attenuation correction capability as well as localizing information. Use of combined PET/CT scanners is rapidly increasing.

C. Nuclear Medicine Computer Systems

Nuclear medicine computer systems collect, quantitate, analyze, and display the imaging information.

III. Procedure

A. Patient Preparation

1. For many procedures, no patient preparation is necessary; however, when patient preparation is necessary for specific procedures, the preparation is outlined in the relevant guideline.
2. In women of childbearing age, pregnancy and lactation status should be determined.
 - a. Elective diagnostic nuclear medicine procedures should be delayed until a patient is no longer pregnant or breastfeeding.
 - b. Nonelective diagnostic procedures (e.g., ventilation perfusion imaging) usually can be modified to make a small fetal dose even smaller.
 - c. Care should be taken not to decrease the diagnostic accuracy of the study when modifications are made to reduce the radiation dose.
 - d. A few diagnostic nuclear medicine studies (e.g., ^{131}I whole-body imaging) may have severe consequences for the developing fetus. The risk of performing these studies in a pregnant woman should be weighed against the benefits.
 - e. When performing diagnostic studies that may have severe consequences for the developing fetus, a pregnancy test should be obtained in women with childbearing potential. Under exceptional circumstances, the pregnancy test may be omitted.
 - f. Breastfeeding should be interrupted for an amount of time appropriate for the radiopharmaceutical used. For a few diagnostic studies (e.g., ^{131}I whole-body imaging), breastfeeding must be stopped for 1–2 mo; therefore, it is impractical to resume breastfeeding for that child.
 - g. Current Nuclear Regulatory Commission regulations require that written instruction be given to breastfeeding women if the potential radiation dose to the infant is likely to exceed 5 mSv (500 mrem); oral instruc-

tions are required if the potential radiation dose to the infant is likely to exceed 1 mSv (100 mrem). Pathways for exposure include ingestion of tracer concentrated in breast milk and external exposure as a result of close contact during breastfeeding. There is considerable uncertainty about the actual dose to the infant since little data are available for excretion into breast milk for most radiopharmaceuticals.

- h. For a few diagnostic studies (e.g., ^{131}I whole-body imaging), the radiation dose to the lactating breast can be large (10 cSv [10 rem] or greater)—as much as 10 times the dose to the nonlactating breast. When possible it is best to delay these studies for at least 4 wk after breastfeeding has stopped.
3. Before the study is begun, the procedure should be explained to the patient and questions about the procedure should be answered.
4. When sedation is needed, appropriate procedures should be followed (e.g., Procedure Guideline for Pediatric Sedation in Nuclear Medicine).
5. Written informed consent is not required for standard diagnostic imaging procedures.

B. Information Pertinent to Performing the Procedure

The nuclear medicine practitioner and staff can provide the best results when fully integrated into the clinical management team. Pertinent information includes:

1. Indication.
2. Relevant history and physical findings, including medications and recent imaging with contrast-containing material.
3. History of prior administration of radiopharmaceuticals.
4. History of prior therapy, including surgery, that might affect radiopharmaceutical distribution.
5. Results of pertinent imaging studies and laboratory results.
6. In large or small patients, consideration should be given to adjustment of the administered activity.

C. Precautions

1. Medical personnel should be instructed in the proper care of patients after radioisotope administration. Generally, the hazard to personnel is small and measures taken to protect workers from biological hazards are sufficient to protect workers from radiological hazards. In general, radioactive human waste is disposed of in the same way as nonradioactive human waste.

2. In general, precautions taken to avoid biological hazards from patient excreta are more than sufficient to avoid the often much smaller radiation hazard.
3. Instructions should be provided on methods of minimizing radiation exposure to the patient's family and to the general public, where appropriate.
4. In general, there is no scientific or regulatory reason why a pregnant nurse cannot provide routine care to a patient who has had a diagnostic imaging study. The risk of caring for a patient receiving therapy is small; however, it may be prudent not to assign pregnant nurses to care for these patients.
5. Adverse reactions associated with radiopharmaceutical administration should be reported to the Society of Nuclear Medicine/U.S. Pharmacopeia Drug Problem Reporting Program.
6. Weight and size tolerances of equipment should be observed when imaging large patients.

D. Quality Control

1. A procedure manual should exist, containing the following:
 - a. A step-by-step procedure for each exam including: radiopharmaceutical and administered activity, other pharmaceuticals and doses, patient preparation, views, type of collimator, timing, instrument setup, acquisition parameters, and data processing.
 - b. A detailed description of the quality control procedures for all instruments. This should include the testing frequency, imaging or data format, and data analysis and action levels.
 - c. Detailed information on all aspects of radiation safety and emergency procedures.
2. Quality Control Records
 - a. Records of all quality control procedures should be maintained for the time specified by regulatory agencies. These should include all pertinent information relative to the acquisition of data and should include the identification of the person who acquired the data.
 - b. A log of all instrument problems should be maintained, and all problems should be reported to the chief technologist or supervisor. This information will serve to identify trends in instrument performance and to alert the clinical staff to factors that may affect interpretation of patient data.
 - c. All service records should be maintained in appropriate files for each instrument.

IV. Single-Photon Scintillation Cameras

A. Planar Imaging

1. Image Acquisition

a. Peaking

Scintillation camera should be peaked correctly for the energy (energies) to be used at least daily. A 15%–20% energy window is typically used. The window is placed symmetrically about the peak, or asymmetrically if an appropriate energy correction is available. A physicist can help in determining the limits of asymmetry that can be used for a range of energies.

b. Multiple Energy Windows

The use of multiple energy windows for radionuclides with more than 1 energy peak is advantageous. It is necessary to check the multiple window spatial registration for the combination of the windows. A physicist can help determine if the coregistration for all of the windows is proper in order to maintain the best spatial resolution and contrast. A collimator that will offer adequate resolution for the most energetic photons should be used. Intrinsic uniformity should be checked for imaging multiple energy windows for such radionuclides. A physicist can help determine the need for special uniformity corrections.

c. Dual Radionuclides

When using 2 radionuclides in a sequential study, images from the lowest energy radionuclide should be obtained first.

In principle, it is possible to use several energy windows to image two radionuclides simultaneously. Such a technique involves many pitfalls, however, and the results will depend on the equipment used and special quality control tests. The different energies will have different spatial resolutions. The procedure must account for the detection of scatter from the higher energy photons into the energy window used for lower energy photons. Such a procedure should be designed with care by an individual who has the necessary expertise.

d. Static Imaging

The specific imaging parameters for a given exam will vary depending on the desired clinical information.

For computer-acquired images, matrix size will vary depending upon the specific requirements of each type of study. Whole-body scans require large matrices.

When large matrices are used for smaller areas, higher resolution images can be obtained, but they have more statistical fluctuation (noise). Statistical fluctuation in large matrix sizes can be reduced by smoothing, but spatial resolution will decrease. The digital appearance of smaller matrix sizes can be reduced by interpolation to large matrices for display.

e. Whole-Body Imaging

Scan time varies depending on the count rate and count density required. Matrix size will vary depending on the radionuclide, number of counts, and resolution required. Because a whole-body image covers about 200 cm, the matrix dimension along the length of the patient should be at least 512 pixels. Acquisition times greater than about 30 min are not practical for routine use in unsedated ill patients.

f. Dynamic Imaging

The time per frame should be selected depending on the temporal resolution needed for the process being studied. For quantitative functional studies, shorter times are preferred, consistent with obtaining adequate statistics, in order to measure physiologic changes. For purposes of imaging alone, longer times are generally used in order to provide sufficient imaging statistics for each frame.

For computer-acquired images, a matrix size of 64×64 or 128×128 may be suitable, depending on the type of study. A particular point to note is that it may be necessary to choose between “word” and byte mode acquisitions. If there is any question, word mode should be used to avoid pixel saturation that may occur in byte mode.

For high-count-rate studies, dead time effects may be important. In such cases, count rate loss should be ascertained by dead time measurements.

g. Gated Imaging

- i. Electrocardiographic gating is used to synchronize image acquisition with the patient’s heart rate.
- ii. The number of frames per R-R interval should be no less than 16 for ejection fraction measurements and 32 for time-based measurements (filling rates, etc).
- iii. For gated cardiac blood pool imaging, electronic zoom generally should be used to magnify the field of view to approximately 25 cm. A matrix size of 64×64 is sufficient. Typically, a total

of at least 5 million counts in the entire study will provide sufficient statistics for quantitative and functional image processing.

h. Pinhole Imaging

- i. Pinhole imaging provides the spatial resolution that most closely approaches the intrinsic limit of the camera at the expense of counting sensitivity. The distance between the collimator and the patient determines both the degree of magnification and the sensitivity (or count rate). Smaller pinhole apertures (2–3 mm) provide better resolution but lower sensitivity. The largest pinhole in routine clinical use is 5 mm.
- ii. For typical collimators with a 25-cm diameter field of view, a matrix size of 256×256 or 128×128 is generally sufficient.

2. Processing

a. Windowing

To optimally evaluate clinical studies, it is often necessary to adjust the upper and lower threshold on a computer display in order to enhance the contrast of the pertinent parts of the image. A lesion with intense activity may make other lesions difficult to visualize. Similarly, small variations in activity of large organs may be seen more clearly if contrast is enhanced.

b. Cine

A cine (movie) can be used to improve the detection of abnormalities such as in gastrointestinal bleeding studies or cardiac wall motion studies. Cines are also useful in SPECT studies for visualizing spatial relationships and checking the projection data for patient motion.

3. Quality Control

a. Scintillation Camera

- i. The pulse height analyzer should be set appropriately for the radioisotope to be used.
- ii. Field uniformity should be tested each day a scintillation camera is used.
A solid- or liquid-filled uniform flood source can be used to evaluate system (collimator on) uniformity. An acceptable alternative is to remove the collimator and produce an image using a distant ($5 \times$ the maximum detector dimension) point source.

The point source must be on the central axis (an imaginary line extending out perpendicularly from the center of the detector). For planar imaging, the

general rule is that images for small-field cameras must contain at least 1.25 million counts; for large-field circular cameras, 2.5 million counts; and for large rectangular field cameras, 4 million counts. Alternatively, the manufacturer's recommendations can be used. All imaging parameters and the technologist's initials should be recorded.

- iii. Spatial resolution and linearity (distortion) should be tested at least once each week. This measurement can be made with the collimator on or off. However, if the collimator is on, it should have the highest resolution that is available and be designed for ^{99m}Tc . General-purpose collimators may show moiré patterns.

If the imaging system is digital, the finest matrix that is available should be used. A coarse matrix will produce images that appear to show a loss of spatial resolution and may also show moiré patterns. Medium- and high-energy collimators will produce moiré patterns even in analog imaging systems because of the interplay between the collimator holes and the resolution pattern. The count density should be the same as for uniformity images; thus, typically the bar pattern would be imaged for one-half the number of counts used for the uniformity images. All imaging parameters should be recorded.

- iv. All collimators except the pinhole should be tested annually for damage. This can be done with 5- to 10-million count images.
 - v. Several additional tests should be performed periodically. These include tests of dead time, uniformity for nuclides other than ^{99m}Tc , and multiple-window spatial registration.
 - vi. The imaging system should be inspected regularly for mechanical and electrical hazards. Minor problems should be corrected as soon as possible; hazardous situations must be corrected immediately. Interlocks should be tested on a regular basis as specified in the procedure manual.
- b. Monitors and Imaging Formatter

A Society of Motion Picture and Television Engineers (SMPTE) or similar test pattern may be used to ensure the faithful reproduction of images. Alternatively, im-

ages of a resolution test pattern can be placed in all positions of the formatter and a film carefully examined for uniformity and variation in intensity, spatial resolution, distortion, and the presence of artifacts. Monitor quality control may be a particular problem in the telenuclear medicine setting (see SNM Telenuclear Medicine Guideline).

- c. Film Processors
 - i. Perform daily temperature and sensitometric checks.
 - ii. Perform periodic cleaning and maintenance.
 - iii. The chemicals should be tested on a regular basis, as recommended by the manufacturer. Maintain a log of all measurements and maintenance.
- d. Printers

Inexpensive hardcopy printers can be used for distribution of demonstration quality images. Printers with 600 or more dots per inch (dpi) can provide images of reasonable quality.

B. SPECT Imaging

1. Image Acquisition

- a. The parameters employed will depend greatly on the number of detectors incorporated into the camera. For a single-head camera, the general matrix size will normally be 64×64 . For multihead cameras, the matrix size will be 64×64 or 128×128 for higher resolution studies. The manufacturer's processing protocols should be consulted for compatibility with specific data acquisitions.
- b. Because counting statistics are very important in the reconstruction process, long imaging times are sometimes needed. However, total imaging time should be less than 30–45 min to minimize problems from patient motion.
- c. SPECT data can be acquired using step-and-shoot, continuous motion, or a hybrid technique, depending on the camera design and the type of study to be performed. Continuous rotation will provide the most efficient image-gathering capability. If the stepping time between views is greater than 10% of the imaging time per stop, continuous motion is preferred.
- d. The number of stops or views should be equal to or greater than 60 for single-head cameras when acquiring a 360° acquisition. At least 30 views should be obtained for 180° imaging. For high-resolution images, 120 views would be used for a 360°

acquisition and 60 views would be used for a 180° acquisition.

2. Processing

a. Preprocessing

- i. Prefiltering of the projection data is appropriate in many SPECT studies, because smoothing in the axial direction may be included. When necessary, guidance on the choice of filter and filter parameters (cutoff and order) should be sought from experts.
- ii. Correction for patient motion may reduce reconstruction artifacts. The highest quality study will be obtained by minimizing patient motion.

b. Reconstruction

- i. Filtered Backprojection. A ramp filter is always used in filtered backprojection. It corrects for the smoothing caused by the backprojection process. Filters exist that “restore” some of the resolution lost in the reconstruction process. The particular filter that is used depends upon the imaging equipment, the depth of the organ of interest, and the radius of rotation. Care should be taken with image enhancement (“restoration”), because it may produce artifacts.
- ii. Iterative Reconstruction. With the increasing power and memory of computer hardware and with development of the more efficient ordered subsets expectation maximization (OSEM) algorithm, iterative reconstruction of SPECT studies is now common in the clinical environment. This method makes it possible to incorporate correction for many physical effects, such as nonuniform attenuation correction, scatter reduction or removal, variation of spatial resolution with distance, etc.
- iii. Attenuation Correction. Attenuation correction is used to correct for the fact that many photons that originate in the body are absorbed within the body before they are detected. Most vendors supply software for this operation, but the algorithms are fairly simple and only work correctly if the part of the body that is imaged is homogeneous. The operator may need to define the boundaries of the body before application of the algorithm.

Some vendors now offer software for nonuniform attenuation correction. They are based on the acquisition of a

transmission scan that is used to generate an image (map) of the attenuation factors for the patient. The attenuation factors are then applied to the reconstructed images.

c. Reformatting (Oblique Rotation)

Reformatting of SPECT images is used for organizing reconstructed images along the primary axis of specific organs, most commonly the heart and brain. Software is provided to guide the operator in the selection of the axis, for example, the long and short axis of the heart. This technique is also used to generate slices of the brain that are parallel to the orbital-meatal line.

3. Quality Control

- a. All quality control procedures described for planar cameras should be performed on SPECT imaging systems.
- b. Center-of-rotation calibrations should be performed according to the vendor’s recommendations.
- c. High-count floods should be acquired periodically and used to apply uniformity correction to SPECT projection data. The vendor’s recommendation should be followed. There are significant variations between vendors in terms of the number of counts and the matrix size that should be used. Typically, at least 30 million counts are used for 64×64 matrices, and 120 million for 128×128 matrices. For some cameras, the same isotope should be used for the flood and imaging.
- d. Periodically, a high-count SPECT study of a uniformly filled cylindrical phantom should be performed to assess tomographic uniformity. Tomographic uniformity should also be evaluated after major repair of the camera or installation of new or updated software. Some phantoms also contain structures that enable the user to evaluate contrast and spatial resolution.
- e. For multiple head cameras, the manufacturer’s or physicist’s recommendation should be followed for assessing the geometrical and electronic alignment of all detectors with respect to each other.

V. Nuclear Medicine Computer System

A. Components

1. Camera head

A substantial (and increasing) amount of processing normally takes place not in the nuclear medicine computer system itself but in

the camera head. However, such functions can sometimes be provided in the associated image processing system. These functions include: (a) image size, position, and zoom; (b) energy correction; (c) spatial distortion correction; (d) other corrections (scatter correction, dead time correction, depth of interaction correction, sensitivity correction); and (e) digital position computation.

2. Interface

- a. The 2 general types of interfaces are: (1) analog: the signals from the gamma camera are analog pulses and are digitized by analog-to-digital converters (ADCs) in the interface; and (2) digital: the signals passed from the camera head have already been digitized, and only digital signals are handled in the interface.
- b. The interface handles the data in 2 basic modes: (1) frame mode: complete images or matrices are available to the attached computer; and (2) list mode: data are passed on to the attached computer as a list of event x, y coordinates, to which time information and energy information may be also attached.
- c. The interface also handles some special functions. Dynamic study acquisitions are commonly multiple images acquired at different times and frame rates. The timing of such studies needs to be controlled by the acquisition system and interface.

For cardiac studies in particular, time lapse averaging is required, such that each image acquired at some specific time within the cardiac cycle is added to others acquired at similar times. This operation is handled by the acquisition system and interface, which must also handle the corrections needed when ectopic beats occur.

3. Processing system

The processing system is a computer comprised of: (a) 1 or more central processing units (CPUs); (b) computer memory (random access memory [RAM]); (c) backup storage, such as hard disk drives; and (d) peripherals, such as removable disk drives.

4. Display

The display is an important component of a medical imaging system and may be specifically designed for this purpose.

a. Monitors

Monitors typically display color and are large enough to display several images simultaneously. Important parameters include the display matrix size, number of

display levels, number of overlays, number of lookup, and display tables.

b. Hardcopy

A hardcopy device may be provided for output of images onto paper or film. The method of generating such displays can be analog (video) or purely digital. Important parameters include print size, print resolution (number of points per unit of surface, number of gray levels or colors per point), and print time.

c. Labeling

Monitor or hardcopy display should include patient name, patient identifier such as a medical record number, date, and type of study so that the displayed data can be uniquely identified. Other information such as the phase of the study, view and institution may facilitate interpretation, particularly when viewed out of the nuclear medicine department or at another institution.

5. Archive

A storage device with a database for lookup and backup capability may be used for saving studies.

6. Networks

It is common for the computers involved in processing nuclear medicine data to be linked together in the form of a network. Such a network is called a local area network (LAN) and may, in turn, be connected to other networks, for example, wide area networks (WAN) including the Internet. Formats for sending nuclear medicine data over such networks include: (a) manufacturer-specific formats, (b) INTERFILE, (c) DICOM, and (d) general purpose graphic formats such as GIF, JPEG, or TIFF.

B. Acquisition

1. The types of acquisitions are described in section IV.
2. Matrix size and number of bytes
 - a. The matrix size used for nuclear medicine studies is almost always a power of 2, typical values being 64×64 , 128×128 , 256×256 , and 512×512 . Nonsquare matrix sizes also exist, for example, for whole-body studies.
 - b. Each pixel can be represented with a single byte (pixel values ranging from 0 to 255 counts) or 16-bit words (pixel values ranging up to a maximum of 32,000 or 64,000).
 - c. Overflow occurs when the number of counts recorded at some given position (in some given pixel) exceeds the maximum

number of counts. Overflow is more likely to occur when using a byte matrix.

3. Patient information

- a. When an acquisition is performed, patient information must be associated with the information acquired. The minimal information would be a pointer to another database containing the full patient information.
- b. Normally, the patient name and unique identification are stored with the study, plus other information such as date of birth, sex, referring clinic, type of study, provisional diagnosis, etc.

C. Processing Regions of Interest

The accuracy of regions of interest should be confirmed by viewing cine with the regions of interest overlaid to make certain that the patient did not move.

Periodic reanalysis of studies should be done to measure intraobserver variability. When multiple individuals perform quantitative image analysis, periodic reanalysis of studies should be done to measure interobserver variability.

D. Quality Control

1. Trend analysis

A nuclear medicine computer system should be able to store and analyze the results of gamma camera quality control tests so that trend analysis (the change in performance as a function of time) can be analyzed and fault conditions predicted before they happen. When faults occur, an analysis can also be made to assist in the determination of the cause.

Some systems are assisted by a remote connection with the manufacturer. Many quality assurance functions can be performed remotely and the resulting data then analyzed.

2. Software quality control

a. Analysis of software code, line by line

The software code, more commonly the process of producing the code, is controlled by some process (e.g., as defined in the ISO9000 series of specifications). For complex software, analysis of the code itself cannot guarantee correct performance.

b. Phantom studies

Phantoms with given physical parameters are analyzed such that the computed results are compared with precisely known distributions of activity. Such studies are helpful in certain cases (e.g., the estimation of size) but, in most cases, lack clinical realism.

c. Simulated studies

Simulated data can be created with certain properties and the software assessed com-

pared against some truth. This assumes that the simulated software is also correct. This type of analysis is very helpful in certain cases (e.g., testing uniformity, computation of ejection fraction) but still does not reflect true clinical reality.

d. Use of reference patient data

Clinical studies are acquired from a variety of centers under careful control, and the results of clinical parameters computed by different software packages are compared. No independent reference standard exists, and normally only limited clinical groups (normal/abnormal) exist. Nonetheless, analysis of a standard data set is important in evaluating the precision of analysis software.

e. Clinical audit

The final judge of any analysis method is a clinical audit: the correctness and impact of the decisions made with respect to any method and process. Such methods are very slow, requiring many years to establish conclusions and are not entirely appropriate for software quality assurance, which normally requires much faster feedback.

Any useful quality assurance system must study both individual components and overall performance. This is common in the quality assurance of detectors but less common with respect to software. Thus a chain of tests is appropriate for studying in sequence: (1) correct timing of a gated study acquisition; (2) correct handling of bad beats; (3) accuracy of the definition of a region of interest; (4) correct values determined for a time activity curve; (5) correct computation of ejection fraction from a time activity curve; and (6) correct functioning of the complete clinical protocol.

Each of these, except for the last, is a single test with a well-defined input and output where correctness can be tested on known data with known values. The final test needs to be performed on many studies—normal, abnormal, and intermediate (if possible)—to establish the limits of performance of the complete system.

VI. Reporting

A. Goals of a Nuclear Medicine Report

1. Provide the referring physician with a timely answer to the clinical question within the limits of the test
2. Document the appropriateness, necessity, and performance of the procedure

3. Expedite and assure correct billing

B. Direct Communication

1. Findings likely to have a significant, immediate influence on patient care should be communicated to the requesting physician or an appropriate representative in a timely manner.
2. Actual or attempted communication should be documented as appropriate.
3. Significant discrepancies between an initial and final report should be promptly reconciled by direct communication.

C. Written Communication

1. Include the items in section D, Contents of a Nuclear Medicine Report, that are appropriate for a specific study.
2. Many items, such as patient identification or radiopharmaceutical information, can be transferred to the report automatically or entered by a technologist or secretary.
3. The final report should be proofread.
4. Electronic signature instead of a written signature is acceptable if access to the signature mechanism is secure.
5. Copies of the report should be sent to the requesting physician, made available to other identified health care workers, and archived for an appropriate period of time.

D. Contents of a Nuclear Medicine Report

1. Study Identification
 - a. Patient name.
 - b. Other information to uniquely identify the patient, such as sex, date of birth, social security number, medical record number, or universal patient code.
 - c. Requesting physician and other appropriate health care providers such as the primary care physician.
 - d. Type of study.
 - e. Date of study.
 - f. Time of study, if relevant.
 - g. Study accession number (in a well-integrated information system, the study accession number may not need to be visible).
 - h. Completion dates and times.
2. Clinical Information
 - a. Indication.
 - b. Other relevant history—see specific procedure guideline for details.
 - c. Information needed for billing such as referral number, patient status (e.g., inpatient/outpatient), or diagnostic codes (e.g., ICD-9-CM code).
 - i. Insurance carriers may not accept phrases such as “rule out” or “possible.”
 - ii. List the diagnosis to the highest level of specificity known at the time of bill-

ing or, if no diagnosis is known, the pertinent symptom or sign that led to the procedure.

3. Procedure Description
 - a. Radiopharmaceutical.
 - b. Administered dose.
 - c. Route of administration.
 - d. Timing of imaging relative to radiopharmaceutical administration.
 - e. Other drugs used, including name, dose, route, rate of administration, and timing relative to images.
 - f. Catheters or devices used.
 - g. Imaging technique, including alteration in normal procedure.
 - h. Complications or patient reactions.
4. Description of Findings
 - a. Significant positive findings as well as pertinent negative findings should be mentioned.
 - b. Image quality or other causes of study limitations (e.g., patient motion).
 - c. A reference range may be useful for quantitative values.
 - d. See individual guidelines for specifics.
5. Impression
 - a. A separate impression should be included for all but the shortest reports.
 - b. The impression should address the clinical indication for the scan.
 - c. Diagnoses, differential diagnoses, and judgments about the significance of the pertinent findings may be included in the impression.
6. Comments
 - a. Study limitations.
 - b. Recommendations for further procedures, if appropriate.
 - c. Documentation of direct communication of results including the name of the physician or physician designate and time/date of contact.
 - d. Comments may be included in the Impression section, especially when brief.

VII. Issues Requiring Further Clarification

A guideline for General PET Imaging including PET/CT should be developed.

VIII. Concise Bibliography

- A. American Association of Physicists in Medicine. *Rotating Scintillation Camera SPECT Acceptance Testing and Quality Control*. AAPM Report 42. Woodbury, NJ: American Institute of Physics; 1987.

- B. Basic sciences. In: Harbert JC, Eckelman WC, Neumann RD, eds. *Nuclear Medicine: Diagnosis and Therapy*. New York, NY: Thieme Medical Publishers; 1996:1–358.
- C. Hendel RC, Corbett JR, Cullom SJ, DePuey EG, Garcia EV, Bateman TM. The value and practice of attenuation correction for myocardial perfusion SPECT imaging: a joint position statement from the American Society of Nuclear Cardiology and the Society of Nuclear Medicine. *J Nucl Med*. 2002;43:273–280.
- D. Hutton BF. Basic sciences. In: Murray IPC, Ell PJ, eds. *Nuclear Medicine in Clinical Diagnosis and Treatment*. London, UK: Churchill Livingstone; 1994:1277–1388.
- E. *Performance Measurements of Positron Emission Tomographs*. NEMA Standards Publication NU 2-2001. Rosslyn, VA: National Electrical Manufacturers Association; 2001.
- F. Rosenthal MS, Cullom J, Hawkins W, et al. Quantitative SPECT imaging; a review and recommendations by the focus committee of the society of nuclear medicine computer and instrumentation council. *J Nucl Med*. 1995;36:1489–1513.