

Society of Nuclear Medicine (SNM) is an international scientific and professional organization founded in 1954 to promote the science, technology and practical application of nuclear medicine. Its 16,000 members are physicians, technologists and scientists specializing in the research and practice of nuclear medicine. In addition to publishing journals, newsletters and books, the Society also sponsors international meetings and workshops designed to increase the competencies of nuclear medicine practitioners and to promote new advances in the science of nuclear medicine.

The SNM will periodically define new procedure guidelines for nuclear medicine practice to help advance the science of nuclear medicine and to improve the quality of service to patients throughout the United States. Existing procedure guidelines will be reviewed for revision or renewal, as appropriate, on their fifth anniversary or sooner, if indicated.

Each procedure guideline, representing a policy statement by the Society, has undergone a thorough consensus process in which it has been subjected to extensive review, requiring the approval of the Procedure Guideline Committee, Health Policy and Practice Commission, and SNM Board of Directors. The SNM recognizes that the safe and effective use of diagnostic nuclear medicine imaging requires specific training, skills, and techniques, as described in each document. Reproduction or modification of the published procedure guideline by those entities not providing these services is not authorized.

Revised 2010

THE SNM PROCEDURE GUIDELINE FOR GENERAL IMAGING 6.0

PREAMBLE

These guidelines are an educational tool designed to assist practitioners in providing appropriate care for patients. They are not inflexible rules or requirements of practice and are not intended, nor should they be used, to establish a legal standard of care. For these reasons and those set forth below, the Society of Nuclear Medicine (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 regarding the propriety of any specific procedure or course of action must be made by the physician or medical physicist in light of all the circumstances presented. Thus, an approach that differs from the guidelines, standing alone, does not necessarily imply that the approach was below the standard of care. To the contrary, a conscientious practitioner may responsibly adopt a course of action different from that set forth in the guidelines when, in the reasonable judgment of the practitioner, such course of action is indicated by the condition of the patient, limitations of available resources, or advances in knowledge or technology subsequent to publication of the guidelines.

The practice of medicine involves not only the science, but also the art of dealing with the prevention, diagnosis, alleviation, and treatment of disease. The variety and complexity of human conditions make it impossible to always reach the most appropriate diagnosis or to predict with certainty a particular response to treatment. Therefore, it should be recognized that adherence to these guidelines will not assure an accurate diagnosis or a successful outcome. 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.

I. INTRODUCTION

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.

Nuclear medicine is the medical specialty that uses the tracer principle, most often with radiopharmaceuticals, to evaluate molecular, metabolic, physiologic and pathologic conditions of the body for the purposes of diagnosis, therapy and research.

The combination of anatomic information from other modalities may complement the information from tracers providing more information than the sum of the two separately.

II. GOALS

The goal of this guideline is to describe some of the elements common to many SNM procedures and therefore reduce repetition in other SNM guidelines.

III. DEFINITIONS

- A. Single Photon Scintillation Cameras provide static, dynamic or gated images of the distribution of radiopharmaceuticals within the body. Single photon emission computed tomographic (SPECT) images may be obtained by three dimensional reconstruction of a number of two dimensional planar images taken at different angles.
- B. Single Photon Emission Computed Tomography may be combined with Computed Tomography in a single system (SPECT/CT).
- C. 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 annihilation of a positron and an electron. Positron emission tomographic (PET) images are produced by reconstruction from the coincidence pair data.
- D. Positron Emission Tomography is generally combined with Computed Tomography in a single system (PET/CT).
- E. Nuclear Medicine Computer Systems collect, quantitate, analyze, and display the imaging information.

IV. COMMON CLINICAL INDICATIONS

- A. This section will include the introductory statement, “*Common indications for [INSERT PROCEDURE] include, but are not limited to the following:*”.
- B. This section should refer to appropriateness criteria when they do exist.

- C. If there are no existing appropriateness criteria, examples of clinical and research indications can be listed with specific references to the literature.
- D. Alternatively, the following sentence can be used: “ No appropriateness criteria have been developed for this procedure”

V. QUALIFICATIONS AND RESPONSIBILITIES OF PERSONNEL (in the United States)

Reference to this section should be made in all SNM procedure guidelines.

- A. More detailed qualifications are included in specific guidelines where appropriate.
- B. Physician

All Nuclear Medicine examinations should be performed under the supervision of and interpreted by a physician certified in Nuclear Medicine or Nuclear Radiology by the American Board of Nuclear Medicine, the American Board of Radiology, the Royal College of Physicians or Surgeons of Canada, Le College des Medecins du Quebec, or the equivalent. In addition, the physician should participate in maintenance of certification in the field of nuclear medicine.

- C. Medical Physicist

The medical physicist should be able to practice independently one or more of the subfields of medical physics. The SNM considers certification and continuing education in the appropriate subfield(s) to demonstrate an individual is competent. The SNM recommends that Medical Physicists be certified in the appropriate subfield(s) by the American Board of Science in Nuclear Medicine or by the American Board of Radiology, or the equivalent.

- D. Technologist

All nuclear medicine examinations should be performed by a Nuclear Medicine Technologist that is registered/certified in Nuclear Medicine by the Nuclear Medicine Technology Certification Board (NMTCB), American Registry of Radiologic Technologists (ARRT), or the Canadian Association of Medical Radiation Technologists (CAMRT) or the equivalent. The Nuclear Medicine Technologist works under the supervision of the Physician as outline above.

VI. PROCEDURE/SPECIFICATIONS OF THE EXAMINATION

- A. Nuclear Medicine study request

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, which might affect radiopharmaceutical distribution
5. Results of pertinent imaging studies and laboratory results
6. Patient weight (in large or small patients and in different ages, consideration should be given for adjustment of the administered activity).

B. Patient Preparation and Precautions

1. For many procedures, no patient preparation is necessary. 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.
 - b. Non-elective diagnostic procedures (e.g., ventilation perfusion imaging) usually can be modified to minimize the fetal dose.
 - c. Care should be taken to avoid decreasing the diagnostic accuracy of the study when modifications are made to reduce the radiation dose.
 - d. A few diagnostic nuclear medicine studies (e.g., I-131 whole body imaging) may expose the fetus to relatively large doses of radiation. 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 on the developing fetus, a pregnancy test should be obtained in women with childbearing potential. Under exceptional circumstances, the pregnancy test may be omitted.
 - f. Breast feeding should be interrupted for an amount of time appropriate for the radiopharmaceutical used. For a few diagnostic studies (e.g., I-131 whole body imaging), breast-feeding must be stopped for 1-2 months; therefore, it is impractical to resume breast-feeding for that child.

- g. Current NRC regulations require that written instruction be given to breast feeding women if the potential radiation dose to the infant is likely to exceed 5mSv (500 mrem); oral instructions are required if the potential radiation dose to the infant is likely to exceed 1 mSv (100 mrem). Pathways for exposure include ingestion of contaminated breast milk and external exposure due to close contact during breast-feeding. There is considerable uncertainty about the actual dose to the infant since little data is available for excretion into breast milk for most radiopharmaceuticals (10 CFR 35.75: <http://www.nrc.gov/reading-rm/doc-collections/cfr/part035/part035-0075.html>).
 - h. For a few diagnostic studies (e.g., I-131 whole body imaging) the radiation dose to the lactating breast can be large (100 mSv (10 rem) or greater) and ten times the dose to the non-lactating breast. When possible it is best to delay these studies for at least 4 weeks after breast-feeding 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.

C. Radiopharmaceuticals

See the SNM Procedure Guideline for Use of Radiopharmaceuticals

D. Protocol/Image acquisition

Recommendations specific to individual procedures are included in the respective procedure guidelines.

1. Single Photon Planar Imaging

a. Image Acquisition

i. Peaking

The scintillation camera should be peaked correctly for the energy (energies) to be used at least daily. A 15 or 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.

ii. Multiple Energy Windows

The use of multiple energy windows for radionuclides that have more than one 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 co-registration 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.

iii. Dual Radionuclides

When using two radionuclides in sequential studies, 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.

iv. 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 decline. The digital appearance of smaller matrix sizes can be reduced by interpolation to large matrices for display.

v. 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 centimeters, 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 unседated patients.

vi. 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 to measure rapidly changing physiologic parameters. Longer times are generally used when imaging statistics for each frame are being optimized.

For computer acquired images, a matrix size of 64 x 64 or 128 x 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” (often two-byte) 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.

vii. Gated Imaging

- (1) ECG gating is used to synchronize image acquisition with the patient’s heart rate.
- (2) 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).
- (3) 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 x 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.

viii. Pinhole Imaging

- (1) 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 to 3 mm) provide better resolution but lower sensitivity. The largest pinhole in routine clinical use is 5 mm.
- (2) For typical collimators with a 25 cm diameter field of view, a matrix size of 256 x 256 or 128 x 128 is generally sufficient.

b. Processing

i. 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.

ii. Cine

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

2. Single Photon Emission Computed Tomography (SPECT)

a. Image Acquisition

- i. 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 x 64. For multi-head cameras, the matrix size will be 64 x 64 or 128 x 128 for higher resolution studies. The manufacturer's processing protocols should be consulted for compatibility with specific data acquisitions.
- ii. As counting statistics are very important in the reconstruction process, long imaging times are typical. However, total imaging time should be less than 30 to 45 min to minimize problems from patient motion.
- iii. 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.
- iv. The number of stops or views should be equal to or greater than 60 (64) for single head cameras when acquiring a 360-degree acquisition. At least 30 (32) views should be obtained for 180 degree imaging. For high-resolution images, 120 (128) views would be used for a 360-degree acquisition and 60 (64) views would be used for 180-degree acquisition.

b. Processing

i. Preprocessing

- (1) 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.
- (2) Correction for patient motion may reduce reconstruction artifacts. The highest quality study will be obtained by minimizing patient motion.

ii. Reconstruction

(1) Filtered Back Projection

A ramp filter is always used in the filtered back projection. It corrects for the smoothing caused by the back projection 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”) since it is possible to produce artifacts.

(2) Iterative Reconstruction

With the increasing power and memory of computer hardware and with development of the more efficient OSEM algorithm, iterative reconstruction of SPECT studies is now common in the clinical environment. This methodology makes it possible to incorporate correction for many physical effects such as non-uniform attenuation correction, scatter reduction or removal, variation of spatial resolution with distance, etc.

(3) 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 prior to application of the algorithm.

Some vendors now offer software for non-uniform 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.

iii. **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. **SPECT/CT**

See SNM Procedure Guideline for SPECT/CT Imaging.

4. **PET/CT**

See SNM Procedure Guideline for Tumor Imaging with ¹⁸F-FDG PET/CT.

5. **Nuclear Medicine Computer System**

a. **Components**

i. **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.

ii. **Interface**

- (1) The interface handles the data in two 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.
- (2) 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 other 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.

iii. Processing system

The processing system is a computer comprised of: (a) one 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.

iv. Display

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

(1) 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.

(2) Hardcopy

Hardcopy devices are becoming less common. 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.

(3) 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.

v. Archive

A storage device for saving old studies is normally provided.

vi. 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.

b. Acquisition

i. The types of acquisitions are described in section IV.

ii. Matrix size and number of bytes

- (1) The matrix size used for nuclear medicine studies is almost always a power of 2, typical values being 64 x 64, 128 x 128, 256 x 256 and 512 x 512. Non-square matrix sizes also exist, for example for whole-body studies.
- (2) 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 32k or 64k).
- (3) 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.

iii. Patient information

- (1) 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.
- (2) Normally, the patient name and unique identification is 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 re-analysis of studies should be done to measure intra-observer variability. When multiple individuals perform quantitative image analysis, periodic re-analysis of studies should be done to measure inter-observer variability.

VI. E. Interpretation

Interpretive criteria for each procedure are given in the respective procedure guidelines.

VII. DOCUMENTATION/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

See also ACR Practice Guideline for Communication: Diagnostic Radiology

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, which are appropriate for a particular 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 gender, date of birth, 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 billing, 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. Correlation with other imaging studies should be documented in the report describing the date and type of the prior study. If other studies are not available for correlation, this should also be mentioned in the written report.
 - e. 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.

VIII. EQUIPMENT SPECIFICATION

Equipment specification for each procedure is given in the respective procedure guidelines.

IX. QUALITY CONTROL AND IMPROVEMENT, SAFETY, INFECTION CONTROL, AND PATIENT EDUCATION CONCERNS

Policies and procedures related to quality, patient education, infection control, and safety should be developed and implemented in accordance with the ACR Policy on Quality Control, and Patient Education Concerns appearing elsewhere in the ACR Practice Guidelines and Technical Standards book.

Physician quality control should also be done regularly to assure consistent, accurate physician interpretation of results. The ACR RadPeer system offers one method of achieving this goal; however, RadPeer is not mandatory and equivalent systems may be used.

Equipment performance monitoring should be in accordance with ACR Technical Standards for Medical Nuclear Physics Performance Monitoring of Computed Tomography (CT) and Nuclear Medicine Equipments

A. A procedure manual should exist, containing the following:

1. 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 set-up, acquisition parameters, and data processing.
2. 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.
3. Detailed information on all aspects of radiation safety and emergency procedures.

B. Quality Control Records

1. 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.
2. 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.
3. All service records should be maintained in appropriate files for each instrument.

C. Quality Control Scintillation Camera (1-5)

1. The pulse height analyzer should be set appropriately for the radioisotope to be used.

2. 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 1.25M counts, large-field circular, 2.5M counts and large rectangular field cameras, 4M counts. Alternatively, the manufacturer's recommendations can be used. All imaging parameters and the technologist's initials should be recorded.

3. 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 Tc-99m. 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.

4. All collimators except the pinhole should be tested annually for damage. This can be done with 5 to 10M count images.
5. Several additional tests should be performed periodically. These include tests of dead time, uniformity for nuclides other than Tc-99m and multiple window spatial registration.
6. 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.

D. Quality Control SPECT (1-5)

1. All quality control procedures described for planar cameras should be performed on SPECT imaging systems.
2. Center-of-rotation calibrations should be performed according to the vendor's recommendations.
3. 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 30M counts are used for 64 x 64 matrices, and 120M for 128 x 128 matrices. For some cameras, the same isotope should be used for the flood and imaging.
4. 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.
5. For multiple head cameras, the manufacturer or physicist's recommendation should be followed for assessing the geometrical and electronic alignment of all detectors with respect to each other.

E. Quality Control PET

See SNM procedure guidelines for tumor imaging using ^{18}F -FDG PET/CT

F. Quality Control CT

See also "Quality Control" sections of the American College of Radiology Practice Guideline for the Performance of Computed Tomography of the Extracranial Head and Neck in Adults and Children, the American College of Radiology Practice Guideline for the Performance of Pediatric and Adult Thoracic Computed Tomography (CT), and the American College of Radiology Practice Guideline for the Performance of Computed Tomography (CT) of the Abdomen and Computed Tomography (CT) of the Pelvis.

G. Quality Control Computer

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, the 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 compared against some standard. This assumes that the simulated software is also correct. This type of analysis is very helpful in certain cases, for example 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 very 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 QA of detectors, but less common with respect to software. Thus a chain of tests are 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, apart from 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.

H. Quality Control Monitors and Imaging Formatter

A SMPTE or similar test pattern may be used to ensure the faithful reproduction of images. Alternatively, images 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 Telenuclear Medicine Guideline).

I. Quality Control Film Processors

1. Perform daily temperature and sensitometric checks.
2. Perform periodic cleaning and maintenance.
3. The chemicals should be tested on a regular basis, as recommended by the manufacturer. Maintain a log of all measurements and maintenance.

J. Quality Control 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.

X. RADIATION SAFETY IN IMAGING

Nuclear medicine physicians, medical physicists, and technologists have a responsibility to minimize radiation dose to individual patients, to staff, and to society as a whole, while maintaining the necessary diagnostic image quality. This concept is known as “as low as reasonably achievable (ALARA).”

Policies should be in place to vary examination protocols to take into account patient body habitus, such as height and/or weight, body mass index or width

The dose reduction devices that are available on imaging equipment should be active; if not, manual techniques should be used to moderate the exposure while maintaining the necessary diagnostic image quality. In all patients, the lowest exposure factors should be chosen that would produce images of diagnostic quality.

It is the position of SNM that patient exposure to ionizing radiation should be at the minimum level consistent with obtaining a diagnostic examination. Reduction in patient radiation exposure may be accomplished by administering less radiopharmaceutical when the technique or equipment used for imaging can support such an action. Each patient procedure is unique and the methodology to achieve minimum exposure while maintaining diagnostic accuracy needs to be viewed in this light. Radiopharmaceutical dose ranges outlined in this document should be considered as a guide. Dose reduction techniques should be utilized when appropriate. The same principles should be applied when CT is used in a hybrid imaging procedure. CT acquisition protocols should be optimized to provide the information needed while minimizing patient radiation exposure. Minimizing radiation dose is especially important in children.

For example:

- A. Medical personnel should be instructed in the proper care of patients after radioisotope administration and in the proper disposal of radioactive biological waste.
- B. Adverse reactions associated with radiopharmaceutical administration should be reported to the Society of Nuclear Medicine/USP Drug Problem Reporting Program.
- C. In general, precautions taken to avoid the biological hazards from patient excreta is more than sufficient to avoid the often much smaller radiation hazard.
- D. Instructions should be provided on methods of minimizing radiation exposure to the patient's family and to the general public, where appropriate.
- E. Weight and size tolerances of equipment should be observed when imaging large patients.
- F. 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.
- G. All guidelines should include a table of dosimetry. (When indicated, a dosimetry table for children should be included.) The values for this table are usually readily available from the Society of Nuclear Medicine MIRD committee, ICRP 53, ICRP 62, ICRP 80 and ICRP 103. The source for these values should be referenced. The table should consist of four columns. An example from the SNM procedure guidelines for lung scintigraphy revised in 2010 is given below.
- H. All guidelines should include a table of fetal dosimetry, when indicated. The values for this table are usually readily available from: Russell JR, Stabin MG, Sparks RB, Watson E. Radiation absorbed dose to the embryo/fetus from radiopharmaceuticals. Health Phys. 1997;73:756-769. An example is given below.
- I. All guidelines should include recommendations for the breastfeeding patient. An example is given below.
- J. A wallet size card identifying the radionuclide, quantity, date of administration and

contact numbers may be helpful for patients receiving longer half-life radionuclides if they will be traveling to locations where radiation detectors are likely to be in use.

Radiation Dosimetry – Adults¹

Radiopharmaceutical	Administered Activity	Organ Receiving the Largest Radiation Dose	Effective Dose⁵
	MBq (mCi)	mGy/MBq (rad/mCi)	mSv/MBq (rem/mCi)
^{99m} Tc MAA ¹	40-150 (1.1-4.1)	0.067 Lung (0.25)	0.011 (0.041)
^{99m} Tc DTPA ²	20-40 (0.54-1.1)	0.047 Bladder (0.17)	0.0061 (0.023)
¹³³ Xe ³	200-750 (5.4-20)	0.0011 Lung (0.0041)	0.00071 (0.0026)
^{81m} Kr ⁴	40-400 (1.1-11)	0.00021 Lung (0.00078)	0.000027 (0.0001)

¹ ICRP 53, page 224

² ICRP 53, page 218

³ ICRP 53, page 345, rebreathing for 5 minutes

⁴ ICRP 53, page 160

⁵ ICRP Publication 80

International Commission on Radiological Protection. ICRP Publication 80, Radiation Dose to Patients from Radiopharmaceuticals: Addendum 2 to ICRP Publication 53, Ann. ICRP 28(3), 1998.

Radiation Dosimetry in Children

(5 year old)

Radiopharmaceutical	Administered Activity	Organ Receiving the Largest Radiation Dose	Effective Dose
	MBq/kg (mCi/kg)	mGy/MBq (rad/mCi)	mSv/MBq (rem/mCi)
^{99m} Tc MAA ¹	0.5-2 (0.014-0.054)	0.21 Lung (0.78)	0.038 (0.14)
^{99m} Tc DTPA ²	0.4-0.6 (0.011-0.016)	0.12 Bladder (0.44)	0.020 (0.074)

$^{133}\text{Xe}^3$	10-12 (0.27-0.32)	0.0037 Lung (0.014)	0.0027 (0.010)
$^{81\text{m}}\text{Kr}^4$	0.5-5 (0.014-0.14)	0.00068 Lung (0.0025)	0.000088 (0.00033)

¹ ICRP 53, page 224

² ICRP, page 218

³ ICRP, page 345, rebreathing for 5 minutes

⁴; ICRP 53, page 160

^{99m}Tc MAA: Dose estimates to the fetus were provided by Russell et al.(6). No information about possible placental crossover of this compound was available for use in estimating fetal doses.

Stage of Gestation	Fetal Dose mGy/MBq (rad/mCi)	Fetal Dose mGy (rad)
Early	0.0028 (0.010)	0.11-0.42 (0.011-0.042)
3 months	0.0040 (0.015)	0.16-0.60 (0.016-0.060)
6 months	0.0050 (0.018)	0.20-0.75 (0.020-0.075)
9 months	0.0040 (0.015)	0.16-0.60 (0.016-0.060)

^{99m}Tc DTPA aerosol: Dose estimates to the fetus were provided by Russell et al.(6). Information about possible placental crossover of this compound was available and was considered in estimates of fetal doses.

Stage of Gestation	Fetal Dose mGy/MBq (rad/mCi)	Fetal Dose mGy (rad)
Early	0.0058 (0.021)	0.12-0.23 (0.012-0.023)
3 months	0.0043 (0.016)	0.086-0.17 (0.0086-0.017)
6 months	0.0023 (0.0085)	0.046-0.092 (0.0046-0.0092)
9 months	0.0030 (0.011)	0.060-0.12 (0.0060-0.012)

^{133}Xe : Dose estimates to the fetus were provided by Russell et al. (6). No information about possible placental crossover of this compound was available for use in estimating fetal doses.

Stage of Gestation	Fetal Dose mGy/MBq	Fetal Dose mGy
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	(rad/mCi)	(rad)
Early	0.00025 (0.00092)	0.050-0.19 (0.0050-0.019)
3 months	0.000029 (0.00011)	0.0058-0.022 (0.00058-0.0022)
6 months	0.000021 (0.000078)	0.0042-0.016 (0.00042-0.0016)
9 months	0.000016 (0.000059)	0.0032-0.012 (0.00032-0.0012)

^{81m}Kr: No dose estimates to the fetus were provided by Russell et al. (6), but were estimated using kinetic data in ICRP 53. No information about possible placental crossover of this compound was available for use in estimating fetal doses.

Stage of Gestation	Fetal Dose	Fetal Dose
	mGy/MBq (rad/mCi)	mGy (rad)
Early	1.8×10^{-7} (6.7×10^{-7})	7.2×10^{-6} - 7.2×10^{-5} (7.2×10^{-5} - 7.2×10^{-6})
3 months	1.8×10^{-7} (6.7×10^{-7})	7.2×10^{-6} - 7.2×10^{-5} (7.2×10^{-5} - 7.2×10^{-6})
6 months	2.8×10^{-7} (1.0×10^{-6})	1.1×10^{-5} - 1.1×10^{-4} (1.1×10^{-6} - 1.1×10^{-5})
9 months	3.4×10^{-7} (1.3×10^{-6})	1.4×10^{-5} - 1.4×10^{-4} (1.4×10^{-6} - 1.4×10^{-5})

The Breastfeeding Patient

ICRP Publication 106, Appendix D suggests a 12 hour interruption of breast feeding for subjects receiving ^{99m}Tc MAA; it does not provide a recommendation about interruption of breastfeeding for ^{99m}Tc DTPA aerosols (but suggests that no interruption is needed for ^{99m}Tc DTPA intravenously administered or ^{99m}Tc technegas); the authors recommend that no interruption is needed for breastfeeding patients administered ¹³³Xe or ^{81m}Kr.

XI. ACKNOWLEDGEMENTS

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XII. BIBLIOGRAPHY/REFERENCES

All references need to be cited in numerical order in the format of the Journal of Nuclear Medicine

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XIII. BOARD OF DIRECTORS APPROVAL DATES:

Version 1.0 January 14, 1996

Version 2.0 February 7, 1999

Version 3.0 June 23, 2001

Version 4.0 January 30, 2010

Version 5.0 June 4, 2010

Version 6.0 September 12, 2010