

# Procedure Guideline for General Imaging: 1.0

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**Key Words:** practice guidelines; nuclear medicine imaging

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## PART 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. See the *Society of Nuclear Medicine Procedure Guideline for PET Imaging* (to be developed) for recommendations common to most PET imaging procedures.

## PART 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 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.
- B. 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.
- C. Nuclear medicine computer systems collect, quantitate, analyze and display the imaging information.

## PART 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 pregnancy test is not required prior to performing most diagnostic

imaging procedures. A pregnancy test should be performed in all women physically capable of becoming pregnant when the effective dose to a fetus potentially exceeds 5 rems. An example of such a test is whole-body imaging following a 5 mCi dose of <sup>131</sup>I.

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.
  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 which 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 and the proper disposal of radioactive biological waste.
  2. Adverse reactions associated with radiopharmaceutical administration should be reported to the Society of Nuclear Medicine/USP Drug Problem Reporting Program.
  3. In general, precautions taken to avoid the biological hazards from patient excreta is more than sufficient to avoid the often much smaller radiation hazard.
  4. Instructions should be provided on methods of lowering radiation exposure to the patient's family and to the general public where appropriate.
  5. Weight and size tolerances of equipment should be observed when imaging large patients.
  6. 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.
- D. Quality Control
1. A procedure manual should exist, containing the following:

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Note: All 26 SNM-approved procedure guidelines are available on the SNM home page. We encourage you to download these documents via the Internet at [www.snm.org](http://www.snm.org). If you would like information on the development process of this guideline or require additional copies of this or other SNM-approved guidelines, please contact Joanna Wilson, Society of Nuclear Medicine, 703-708-9000 or via email at [jwilson@snm.org](mailto:jwilson@snm.org).

- a. A step-by-step procedure for each exam including: radiopharmaceutical and dosage, other pharmaceuticals and doses, patient preparation, views, type of collimator, timing, instrument set-up, acquisition parameters and data processing.
  - b. A detailed description of the quality control procedures for all instruments. This must include the testing frequency, imaging or data format, 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. 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 must be maintained and all problems must 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 must be maintained in appropriate files for each instrument.

#### **PART IV: SINGLE-PHOTON SCINTILLATION CAMERAS**

##### **A. Planar Imaging**

##### **1. Image Acquisition**

##### **a. Peaking**

The scintillation camera must 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 are desirable for a range of energies.

##### **b. 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 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. A collimator that will offer adequate resolution for the most energetic photons must be used.

##### **c. Dual Radionuclides**

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

In principle, it is possible to use multiple energy windows to image two radionuclides simultaneously. However, such a technique involves many pitfalls, 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). The digital appearance of smaller matrix sizes can be reduced by interpolation to large matrices for display. Statistical fluctuation in large matrix sizes can be reduced by smoothing, but spatial resolution will decrease.

##### **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, somewhat longer times are generally used in order to provide sufficient imaging statistics for each frame.

For computer acquired images, a matrix size of  $64 \times 64$  or  $128 \times 128$  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, deadtime effects may be important. In such cases, count rate loss should be ascertained by deadtime measurements.

##### **g. 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  $64 \times 64$  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**

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 (2–3 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  $256 \times 256$  or  $128 \times 128$  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 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.
  3. Quality Control
    - a. Scintillation Camera
      1. The pulse-height analyzer is set appropriately for the radioisotope to be used.
      2. The CRT dot size should be adjusted for minimum size and astigmatism.
      3. Field uniformity must 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 (five 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 M counts, large-field circular, 2.5 M counts and large rectangular field cameras, 4 M counts. Alternatively, the manufacturer's recommendations can be used. All imaging parameters and the technologist's initials should be recorded.
    4. Spatial resolution and linearity (distortion) must 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 must be designed for  $^{99m}\text{Tc}$ .
 

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.
    5. All collimators except the pinhole should be tested annually for damage. This can be done with 5 to 10 M count images.
    6. Several additional tests should be performed periodically. These include tests of deadtime, uniformity for nuclides other than  $^{99m}\text{Tc}$  and multiple window spatial registration.
    7. The imaging system must 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 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.
  - c. Film Processors
    1. Perform daily temperature and sensitometric checks.
    2. Perform periodic cleaning and maintenance.
    3. The chemicals must 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  $64 \times 64$ . For multihead cameras the matrix size will be  $64 \times 64$  or  $128 \times 128$  for higher resolution studies. The manufacturer's processing protocols should be consulted for compatibility with specific data acquisitions.
      - b. As counting statistics are very important in the reconstruction process, long imaging times are typical. 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 (64) for single-head cameras when acquiring a  $360^\circ$  acquisition. At least 30 (32) views should be obtained for  $180^\circ$  imaging. For high-resolution images, 120 (128) views would be used for a  $360^\circ$  acquisition, and 60 (64) views would be used for  $180^\circ$  acquisition.
    2. Processing
 

Projection data are smoothed and then reconstructed with a ramp filter, which is usually modified by an appropriate window filter.

      - a. 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.
- b. Reconstruction
1. Filtered Backprojection  
A ramp filter is always used in the 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") since it is possible to produce artifacts.
  2. Iterative Reconstruction  
With the increasing power and memory of computer hardware, iterative reconstruction of SPECT studies is moving from the research lab to the clinical environment. This methodology 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.
  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 must define the boundaries of the body prior to 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 must be performed on SPECT imaging systems.
  - b. Center of rotation calibrations must 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 M counts are used for  $64 \times 64$  matrices and 120 M for  $128 \times 128$  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. 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 for assessing the geometrical and electronic alignment of all detectors with respect to each other should be followed.

## PART 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, deadtime correction, depth of interaction correction, sensitivity correction) and (e) digital position computation.

#### 2. Interface

- a. Two general types of interface exist being: 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 two basic modes:
  1. Frame mode: complete images or matrices are available to the attached computer.
  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 also be 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 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.

#### 3. Processing system

The processing system is 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 (floppy) 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 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 display tables.

- b. Hardcopy

A hardcopy device is normally 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), print time.

5. Archive

A storage device for archiving old studies is normally provided.

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 or TIFF.

- B. Acquisition

1. The types of acquisition are described in Part 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  $64 \times 64$ ,  $128 \times 128$ ,  $256 \times 256$  and  $512 \times 512$ . Nonsquare matrix sizes also exist, for example for whole-body studies.
- b. Each pixel is a single byte (pixel values ranging from 0 events up to 255 events) or 16 bit words (pixel values ranging up to a maximum of 32K or 64K).
- c. Overflow occurs when the number of events recorded at some given position (in some given pixel) exceeds the capacity of the system. 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 data base containing the full patient information.
- b. Normally, the patient name and unique identification is stored with the study, plus other information such as date of birth, sex, referring clinical, type of study, provisional diagnosis, etc.

- C. Processing

- Regions of interest

The accuracy of regions of interest should be confirmed by viewing a 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, 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 truth. 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 dataset 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: (a) correct timing of a gated study acquisition, (b) correct handling of bad beats, (c) accuracy of the definition of a region of interest, (d) correct values determined for a time-activity curve, (e) correct computation of ejection fraction from a time-activity curve and (f) 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.

#### PART VI: DISCLAIMER

The Society of Nuclear Medicine has written and approved guidelines to promote the cost-effective use of high quality nuclear medicine procedures. These generic recommendations cannot be applied to all patients in all practice settings. The guidelines should not be deemed inclusive of all proper procedures or exclusive of other procedures reasonably directed to obtaining the same results. The spectrum of patients seen in a specialized practice setting may be quite different than the spectrum of patients seen in a more general practice setting. The appropriateness of a procedure will depend in part on the prevalence of disease in the patient population. In addition, the resources available to care for patients may vary greatly from one medical facility to another. For these reasons, guidelines cannot be rigidly applied.

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

#### PART VII: ISSUES REQUIRING FURTHER CLARIFICATION

A guideline for general PET imaging needs to be developed.

#### PART VIII: CONCISE BIBLIOGRAPHY

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#### PART IX: LAST HOUSE OF DELEGATES APPROVAL DATE

January 14, 1996

#### PART X: NEXT ANTICIPATED APPROVAL DATE

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## Procedure Guideline for Imaging with Radiopharmaceuticals: 1.0

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#### PART I: PURPOSE

This guideline was developed by the Society of Nuclear Medicine to describe important factors common to most scintigraphic studies. It is intended to guide nuclear medicine

practitioners in establishing policies and procedures for the use of radiopharmaceuticals in clinical practice. This guideline is intended to be concordant with the regulations of the Nuclear Regulatory Commission (NRC) and other state and federal government agencies.

#### PART II: BACKGROUND INFORMATION AND DEFINITIONS

- A. Diagnostic radiopharmaceuticals (also known as radioactive drugs) are substances that contain radionuclides that emit penetrating radiation(s). The distribution of the radiopharmaceutical within the body is determined by the physiochemical properties of the drug, the stability of the label, the purity of the radiopharmaceutical preparation, the pathophysiological state of the patient and the presence or absence of interfering drugs. Dynamic and static images of the distribution of the radiopharmaceutical within the body

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