

Procedure Guideline for SPECT/CT Imaging 1.0*

Dominique Delbeke¹, R. Edward Coleman², Milton J. Guiberteau³, Manuel L. Brown⁴, Henry D. Royal⁵, Barry A. Siegel⁵, David W. Townsend⁶, Lincoln L. Berland⁷, J. Anthony Parker⁸, George Zubal⁹, and Valerie Cronin¹⁰

¹Vanderbilt University Medical Center, Nashville, Tennessee; ²Duke University Medical Center, Durham, North Carolina; ³Christus St. Joseph Hospital, Houston, Texas; ⁴Henry Ford Hospital, Detroit, Michigan; ⁵Mallinckrodt Institute of Radiology, St. Louis, Missouri; ⁶University of Tennessee, Knoxville, Tennessee; ⁷University of Alabama Hospital, Birmingham, Alabama; ⁸Beth Israel Deaconess Hospital, Boston, Massachusetts; ⁹Yale University, New Haven, Connecticut; and ¹⁰Mercy Hospital, Buffalo, New York

I. PURPOSE

The purpose of this Procedure Guideline is to assist physicians in recommending, performing, interpreting, and reporting the results of SPECT/CT for imaging of adult and pediatric patients.

II. BACKGROUND INFORMATION AND DEFINITIONS

SPECT is a tomographic scintigraphic technique in which a computer-generated image of local radioactive tracer distribution in tissues is produced through the detection of single-photon emissions from radionuclides introduced into the body. CT is a tomographic imaging technique that uses an external x-ray source to produce 3-dimensional anatomic image data. The first SPECT/CT system combined a dual-head γ -camera and an integrated x-ray transmission system mounted on the same gantry. The CT image is used for attenuation correction as well as anatomic imaging, and the CT and SPECT images are fused, with computer assistance, for display. More recently, additional integrated SPECT/CT devices have become available, including systems combining a state-of-the-art multihead γ -camera and multidetector CT scanner side by side with a common imaging table. Combined SPECT/CT devices provide both the functional information from SPECT and the anatomic information from CT in a single examination. Some studies have demonstrated that the information obtained by SPECT/CT is more accurate in evaluating patients than that obtained from either SPECT or CT alone.

SPECT and CT are proven diagnostic procedures. Although techniques for registration and fusion of images obtained from separate SPECT and CT scanners have been available for several years, the advantages of having SPECT and CT integrated into a single device have resulted in the development of this technology in the United States and elsewhere in the world. This Procedure Guideline pertains only to combined SPECT/CT devices.

Definitions

- A. A SPECT/CT scanner is an integrated device containing both a CT scanner and a SPECT γ -camera with a single patient table and therefore capable of obtaining a CT scan, a SPECT scan, or both. If the patient does not move on the bed between the scans, the reconstructed SPECT and CT images will be spatially registered.
- B. SPECT/CT registration is the process of aligning SPECT and CT images for the purposes of combined image display (fusion) and image analysis.
- C. SPECT/CT fusion is the combined display of registered SPECT and CT image sets. Superimposed data typically are displayed with the SPECT data color coded to the CT data in gray scale.
- D. SPECT/CT acquisitions can include the whole body, a limited portion of the body, or an organ.
- E. The method of attenuation correction is the use of CT transmission data with SPECT/CT scanners.

III. EXAMPLES OF CLINICAL OR RESEARCH APPLICATIONS

Indications for SPECT/CT include but are not limited to imaging of the following:

- A. Tumors
- B. Thyroid disorders
- C. Parathyroid disorders
- D. Skeleton disorders
- E. Inflammation or infection
- F. Lymphatic system
- G. Heart disorders
- H. Brain disorders
- I. Other organs

IV. PROCEDURE

A. Patient Preparation

1. Pregnancy and breast-feeding: See the Society of Nuclear Medicine Procedure Guideline for General Imaging.

Received May 11, 2006; revision accepted May 16, 2006.

For correspondence or reprints contact: Dominique Delbeke, MD, PhD, Vanderbilt University Medical Center, 21st Ave. S. and Garland, Nashville, TN 37232-2675.

E-mail: dominique.delbeke@vanderbilt.edu

*YOU CAN ACCESS THIS ACTIVITY THROUGH THE SNM WEB SITE (<http://www.snm.org/guidelines>).

COPYRIGHT © 2006 by the Society of Nuclear Medicine, Inc.

2. Before arrival: See the specific Society of Nuclear Medicine Procedure Guideline for the SPECT radiopharmaceutical used.
3. Before injection
 - a. See the specific Society of Nuclear Medicine Procedure Guideline for the SPECT radiopharmaceutical used.
 - b. For either a CT scan done for attenuation correction/anatomic localization (AC/AL) or a diagnostic CT scan of the abdomen or pelvis, an intravenous or intraluminal gastrointestinal contrast agent may be administered to provide adequate visualization of the gastrointestinal tract unless medically contraindicated or unnecessary for the clinical indication (see Section E.2.b).

B. Information Pertinent to Performing Procedure

See also the Society of Nuclear Medicine Procedure Guideline for General Imaging and the specific Society of Nuclear Medicine Procedure Guideline for the SPECT radiopharmaceutical used.

1. A focused relevant history related to the type of SPECT study performed
2. Patient's ability to lie still for the duration of the acquisition (15–45 min)
3. History of claustrophobia
4. Patient's ability to put his or her arms overhead, if applicable

C. Precautions

See the Society of Nuclear Medicine Procedure Guideline for General Imaging.

D. Radiopharmaceutical

See the specific Society of Nuclear Medicine Procedure Guideline for the radiopharmaceutical used.

With SPECT/CT, the radiation dose to the patient is the combination of the radiation dose from the SPECT radiopharmaceutical and the radiation dose from the CT portion of the study. Radiation dose in diagnostic CT has attracted considerable attention in recent years, in particular for pediatric examinations. It can be very misleading to state a “representative” dose for a CT scan because of the wide diversity of applications, protocols, and CT systems. This caveat also applies to the CT component of a SPECT/CT study. For example, a body scan may include various portions of the body and may use protocols aimed to reduce the radiation dose to the patient or aimed to optimize the CT scan for diagnostic purposes. The effective dose varies widely according to acquisition factors and can range from approximately 2 to 80 mSv (0.2–8.0 rems) for these options. It is therefore advisable to estimate the CT dose specific to the CT system and protocol being used.

Pediatric and adolescent patients should have their CT examinations performed at milliamperere-seconds settings appropriate for patient size, regardless of the CT protocol

used, because radiation dose to the patient increases significantly as the diameter of the patient decreases.

Radiopharmaceutical doses should also be adjusted for the size of the patient and the information required.

E. Image Acquisition

See also the specific Society of Nuclear Medicine Procedure Guidelines for various SPECT procedures, the Society of Nuclear Medicine Procedure Guideline for General Imaging, and the “Specifications of the Examination” and “Documentation” sections of the American College of Radiology (ACR) Practice Guideline for the Performance of Computed Tomography of the Extracranial Head and Neck in Adults and Children, the ACR Practice Guideline for the Performance of Pediatric and Adult Thoracic Computed Tomography (CT), and the ACR Practice Guideline for the Performance of Computed Tomography (CT) of the Abdomen and Computed Tomography (CT) of the Pelvis.

1. Field of view, positioning, and preacquisition preparation
 - a. See the specific Society of Nuclear Medicine Procedure Guideline for the pathophysiology being imaged.
 - b. Arms along the sides may produce artifacts over the torso. For optimal imaging of the body, the arms should be elevated over the head if tolerated by the patient. For optimal imaging of the head and neck, the arms should be positioned along the sides.
 - c. For radiopharmaceuticals excreted primarily by the kidneys, the patient should void the bladder before acquisition of the images.
 - d. Metallic objects should be removed from the patient whenever possible.
2. Protocol for CT imaging

The CT component of a SPECT/CT examination can be performed either for attenuation correction and AC/AL or as an optimized diagnostic CT scan. An AC/AL CT scan has not necessarily been optimized as a diagnostic CT examination, whereas for diagnostic CT, such optimization has been attempted. In some circumstances, both an initial CT acquisition for AC/AL (before the SPECT data acquisition) and diagnostic CT (after the SPECT data acquisition) are performed. Optimization of the CT technique used in SPECT/CT continues to evolve.

- a. If the CT scan is obtained for AC/AL, use of a low milliamperere-seconds setting is recommended to decrease the radiation dose to the patient.
- b. For an optimized diagnostic CT scan, standard CT milliamperere-seconds settings are recommended to optimize the spatial resolution of the CT scan. Tube current modulation may be used to minimize radiation dose to the patient. In some cases, intravenous or oral contrast material may be used. A separate

CT acquisition may be necessary to produce an optimized diagnostic CT scan that is requested for a particular region of the body. For many indications, the examination is performed with intravenous contrast material and appropriate injection techniques. High concentrations of intravenous contrast agents may cause an attenuation-correction artifact on the SPECT image, but the impact usually is modest. This artifact may be minimized on scanners by use of appropriate correction factors. The energy of the emission, typically lower for SPECT than for PET, may require different techniques according to the radionuclide used.

- c. For either a CT scan done for AC/AL or an optimized diagnostic CT scan of the abdomen or pelvis, an intraluminal gastrointestinal contrast agent may be administered to provide adequate visualization of the gastrointestinal tract unless medically contraindicated or unnecessary for the clinical indication. This agent may be a positive contrast agent (such as dilute barium or an oral iodinated contrast agent) or a negative contrast agent (such as water). Collections of highly concentrated barium or iodinated contrast agents may result in attenuation-correction artifacts. Other dilute positive and negative oral agents are less likely to affect SPECT image quality.
 - d. With regard to the breathing protocol for CT transmission scanning, in SPECT/CT, the position of the diaphragm on the SPECT emission scan should match as closely as possible that on the CT transmission images. Although a diagnostic CT scan of the chest typically is acquired during end-inspiration breath holding, this technique is not optimal for SPECT/CT because it may result in substantial respiratory motion misregistration on SPECT and CT images. Some facilities perform CT transmission scans during breath holding at mid-inspiration volume, and others prefer that the patient continue shallow breathing during the CT acquisition. The differences in respiratory cycles between CT and SPECT may result in inaccurate attenuation correction for SPECT data at the lung–liver interface. Respiratory motion results in inaccurate localization of lesions at the base and periphery of the lungs, at the dome of the liver, or near any lung–soft-tissue interface.
3. Protocol for SPECT emission imaging: See the specific Society of Nuclear Medicine Procedure Guideline for the organ being imaged.

F. Interventions

See the specific Society of Nuclear Medicine Procedure Guideline for the organ being imaged.

G. Processing

1. SPECT reconstruction: See the specific Society of Nuclear Medicine Procedure Guideline for the organ being imaged.
2. CT reconstruction: CT sinograms that are used for attenuation correction of SPECT emission data are reconstructed by filtered backprojection at the full field of view, whereas those that are used for CT interpretation are reconstructed separately, with appropriate zoom, slice thickness, slice overlap, and reconstruction algorithms for the particular region of the body scanned. The filtered backprojection can be either 2-dimensional after appropriate portions of the spiral CT data are collected into axial or tilted planes or fully 3-dimensional. In addition to the reconstruction kernel that adjusts in-plane features, such as spatial resolution and noise texture, longitudinal filtration (along the *z*-axis) is used to modify the *z*-resolution and the slice-sensitivity profiles. In addition, there are techniques to emphasize certain image features, for example, bone, lung, or brain algorithms. For attenuation correction, only the standard kernels are used. Because CT volumes today are nearly isotropic, reformatting such as coronal, sagittal, or even curved displays is often preferred. Advanced display techniques, such as volume rendering and maximum- or minimum-intensity projections applied to the complete volume or to thick, arbitrarily oriented sections, are often used. Organ- and task-specific automatic or semiautomatic segmentation algorithms and special evaluation algorithms also are in routine use.
3. Display: With an integrated SPECT/CT system, typically the software packages provide registered and aligned CT images, SPECT images, and fusion images in the axial, coronal, and sagittal planes as well as maximum-intensity-projection images for review in the 3-dimensional cine mode. SPECT images with and without attenuation correction should be available for review.

H. Interpretation Criteria

See the specific Society of Nuclear Medicine Procedure Guideline for the organ being imaged.

I. Reporting

See also the Society of Nuclear Medicine Procedure Guideline for General Imaging.

1. Study identification
2. Clinical information
 - a. Report the indication for the study.
 - b. Report any relevant history.
 - c. Provide information needed for billing.
3. Procedure description and imaging protocol
 - a. Radiopharmaceutical: Describe the choice of radiopharmaceutical, the administered activity, the route of administration, and the uptake time.

- b. Other drugs administered and procedures performed: These include placement of an intravenous line; hydration; insertion of a Foley catheter (size of catheter); administration of furosemide (dose, route, and time), muscle relaxants, or pain medications; and sedation procedures (choice of procedure, type of medication and time of sedation in relation to radiotracer injection, and patient's condition at the conclusion of the SPECT study).
 - c. Field of view and patient positioning: Specify whether imaging was of the whole body, from the skull base to mid thigh, or of a limited area, and describe the position of the arms.
 - d. CT transmission protocol: For AC/AL or diagnostic CT, describe whether the protocol included oral or intravenous contrast material and in what way the protocol was appropriate for the clinical scenario and body region of interest.
 - e. SPECT emission protocol: See the Society of Nuclear Medicine Procedure Guideline for General Imaging.
4. Description of findings
- a. Quality of the study: Describe, for example, whether the study was limited because of motion or because of an unusual distribution of the radiopharmaceutical.
 - b. Location, extent, and intensity of abnormal radiopharmaceutical uptake: Describe these findings in relation to uptake in normal comparable tissues and describe the relevant morphologic findings related to SPECT abnormalities on the CT images. An estimate of the intensity of uptake may be described as mild, moderate, or intense or in relation to a reference standard. The integrated SPECT/CT report should include any detected incidental findings on the CT scan that are relevant to patient care. If the CT scan was requested and performed as a diagnostic examination, then the CT component of the study may be reported separately, if necessary, to satisfy regulatory, administrative, or reimbursement requirements. In that case, the SPECT/CT report can refer to the diagnostic CT scan report for findings not related to the SPECT/CT combined findings.
 - c. Limitations: When appropriate, identify factors that can limit the sensitivity and specificity of the examination (e.g., small lesions).
 - d. Clinical issues: Address or answer any pertinent clinical questions raised in the request for the imaging examination.
 - e. Comparative data: Comparisons with previous examinations and reports, whenever possible, should be part of the radiologic consultation and report.
5. Impression (conclusion or diagnosis)
- a. Whenever possible, a precise diagnosis should be given.

- b. When appropriate, a differential diagnosis should be given.
- c. When appropriate, follow-up and additional diagnostic studies needed to clarify or confirm the impression should be recommended.

J. Quality Control

1. Radiopharmaceuticals: See the Society of Nuclear Medicine Procedure Guideline for Use of Radiopharmaceuticals.
 2. Instrumentation specifications: See also the Society of Nuclear Medicine Procedure Guideline for SPECT Imaging (to be developed) and the "Equipment Specifications" and "Quality Control" sections from the ACR Practice Guideline for the Performance of Computed Tomography of the Extracranial Head and Neck in Adults and Children, the ACR Practice Guideline for the Performance of Pediatric and Adult Thoracic Computed Tomography (CT), and the ACR Practice Guideline for the Performance of Computed Tomography (CT) of the Abdomen and Computed Tomography (CT) of the Pelvis.
- a. Equipment performance guidelines

A spectrum of integrated SPECT/CT systems is available commercially, and this technology is still evolving. The performance of these systems depends on the SPECT and CT components that are integrated.

The quality and resolution of the CT images depend on the performance of the CT system. The diagnostic information on the CT images may be limited by the capabilities of the system. On the low-end systems, the CT component has been designed primarily to provide attenuation maps with a minimal radiation dose to the patient, resulting in poor quality and poor resolution of the CT images. On the high-end systems, high-performance multidetector CT systems have been integrated with SPECT systems in order to perform high-resolution CT in combination with various SPECT radiopharmaceuticals and coronary CT angiography in combination with SPECT myocardial perfusion.

There is a spectrum of SPECT γ -cameras in these combined SPECT/CT systems as well, some optimized for body imaging and some for cardiac imaging.

A workstation with the capability to display CT, SPECT, and fused images with different percentages of CT and SPECT blending should be available. The workstation should allow multiplanar display with linked CT and SPECT cursors. Post-collection registration of the SPECT and CT datasets and registration with other imaging studies, including nonrigid registration, are desirable.

- b. Equipment quality control

SPECT performance monitoring should be in accordance with the Society of Nuclear Medicine Procedure Guideline for General Imaging.

CT monitoring should be in accordance with the ACR Technical Standard for Medical Physics Performance Monitoring of Computed Tomography (CT) Equipment.

The quality control procedures for SPECT/CT should incorporate both CT procedures and SPECT procedures according to the Society of Nuclear Medicine Procedure Guideline for General Imaging and ACR Technical Standards. The quality control procedures for CT should include air and water calibrations in Hounsfield units for a range of kilovolts. The quality control procedures for SPECT should include a calibration measurement of activity in a phantom containing a known concentration, generally as a function of axial position within the scanner field of view. A daily check on the stability of the individual detectors should also be performed to identify detector failures and drifts.

In addition, for SPECT/CT, a check on the alignment between the CT and SPECT scanners should be performed periodically. Such a gantry alignment check should determine any offset between the CT and SPECT scanners to be incorporated into the fused image display to ensure accurate image alignment.

3. Emergency procedures: An emergency cart containing appropriate medications and resuscitation equipment must be readily available to treat adverse contrast material reactions.

K. Sources of Error

See also the Society of Nuclear Medicine Procedure Guideline for the organ being imaged. Some of the technical sources of error seen with standard SPECT procedures are also present with SPECT/CT.

1. SPECT/CT image fusion errors
 - a. Movement in the interval between SPECT and CT data collection
 - Whole-body or extremity motion
 - Diaphragmatic motion with breathing
 - Bowel motility
 - Contrast motion or change in contrast concentration
 - Rapid filling of urinary bladder
 - b. Attenuation artifacts
 - Particularly dense materials such as dental work
 - Metallic implants
 - Lack of data for CT technique
 - c. Software misalignment of SPECT and CT data
2. Display errors
 - a. Inadequate windowing of SPECT or CT data on fused images

- b. Inadequate windowing of SPECT or CT data when viewed separately
- c. Cursor misalignment on SPECT and CT images
- d. Inappropriate color table selection for SPECT data

V. QUALIFICATION OF PERSONNEL

See also the Society of Nuclear Medicine Procedure Guideline for Tumor Imaging Using ¹⁸F-FDG PET/CT.

A. Physicians

The issue of training nuclear physicians to interpret the CT component of SPECT/CT is similar to that for PET/CT.

An article summarizing discussions regarding issues relating to imaging with PET, CT, and PET/CT was recently published by a collaborative working group with representatives from the ACR, the Society of Nuclear Medicine (SNM), and the Society of Computed Body Tomography and Magnetic Resonance (*J Nucl Med.* 2005;46:1225–1239). These organizations agree that only appropriately trained, qualified physicians should interpret PET/CT images. Traditionally, appropriate training has been quantified by the number of continuing medical education credits earned and the number of cases interpreted. The collaborative working group recommends that practicing nuclear physicians receive on-the-job CT training that includes earning 100 h of CT continuing medical education credit and interpreting 500 CT cases under the supervision of a diagnostic radiologist who is qualified as defined in the ACR Practice Guidelines for Performing and Interpreting Diagnostic Computed Tomography. The CT cases should include a reasonable distribution of those involving the head and neck, chest, abdomen, and pelvis. Alternative approaches, such as determining the accuracy of each physician's interpretation compared with that of his or her peers by use of a workstation simulator and a report generation and scoring system, may have equal or greater validity.

In the future, the requirements of radiology and nuclear medicine residency training programs will include training in the interpretation and supervision of integrated SPECT/CT studies. Certifying and recertifying examinations will include testing on CT, SPECT, and SPECT/CT. Eligibility for taking the recertification examinations will mandate participation in the maintenance-of-certification program and will include training in the interpretation of SPECT, CT, and SPECT/CT. Some components of the maintenance-of-certification program will include evaluation of the accuracy of each physician's interpretation of images compared with that of his or her peers by use of a workstation simulator and a report generation and scoring system. Performing and interpreting physicians should participate in and be able to show evidence of participation in continuing medical education on the techniques and interpretation related to the procedures discussed in this Procedure Guideline. Where maintenance-of-certification programs exist, physicians should be able to show evidence of participation.

B. Technologists

SPECT/CT and PET/CT technology present similar practice issues regarding the education, training, and certification of technologists to become appropriately qualified and competent to perform the CT portion of the study. Additional issues arise with regard to ensuring competency, standardizing the educational experience of these individuals, and barriers placed by licensure and regulation at the state level. The Society of Nuclear Medicine Technologist Section (SNM-TS) and the American Society of Radiologic Technologists (ASRT) have come together to develop a master plan and set into motion mechanisms to sort out the practice issues surrounding PET/CT. This master plan was crafted during a stakeholders' meeting—known as the PET/CT Consensus Conference—that was held in July 2002. The recommendations from this meeting can be found in a report of the PET/CT Consensus Conference (*J Nucl Med Technol.* 2002;30:201–204) and are also accessible on the SNM Web site (www.snm.org).

It is the responsibility of the professional associations to establish standards, delineate mechanisms for obtaining the training necessary to promote a qualified and competent workforce to perform these procedures, and collaborate with organizations that can assist in sorting out practice issues. To address educational needs, the ASRT and SNM-TS spearheaded the development of a PET/CT curriculum, which was endorsed by numerous professional organizations and distributed to the radiation control board of each state and to every program director in the United States; it is also posted on the SNM Web site (www.snm.org) and the ASRT Web site (www.asrt.org).

The American Registry of Radiologic Technologists (ARRT) has adapted its CT certification examination and has allowed certified or registered nuclear medicine technologists who have met the required prerequisites to take this examination. Eligibility criteria are located on the ARRT Web site (www.rrrt.org).

Licensure and regulation definitely are affecting the opportunities that nuclear medicine technologists have for obtaining the CT experience needed to take the ARRT CT examination. The SNM-TS is approaching these issues through both legislative and regulatory pathways. The SNM-TS has been promoting the Consumer Assurance of Radiologic Excellence bills pending before the U.S. Congress. These bills would establish minimum education and credentialing standards for those who perform medical imaging and therapeutic procedures. The second pathway recognizes the regulatory route in addressing these practice issues through a collaborative liaison relationship that has been established with the Conference of Radiation Control Program Directors (www.crcpd.org), the professional organization of state radiation regulators.

C. Qualified Medical Physicists

A qualified medical physicist is an individual who is competent 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 that an individual is competent to practice one or more of the subfield(s) of medical physics and to be a qualified medical physicist. The SNM recommends that the individual be certified in the appropriate subfield(s) by the American Board of Radiology (ABR) or the American Board of Science in Nuclear Medicine (ABSNM).

The appropriate subfields of medical physics are as follows: medical nuclear physics, with initially at least 15 h of continuing education credit in CT physics (ABR); diagnostic radiologic physics, with initially at least 15 h of continuing education credit in SPECT physics (ABR); and nuclear medicine physics and instrumentation, with initially at least 15 h of continuing education credit in CT physics (ABSNM).

A qualified medical physicist must have at least 40 h of practical experience providing physics support for both the SPECT and the CT components in an established SPECT/CT facility.

A qualified medical physicist's continuing education should be in accordance with the ACR Practice Guideline for Continuing Education and should include at least 15 h in SPECT and CT physics combined in a 3-y period.

A qualified medical physicist or other qualified scientist performing physics services in support of a SPECT/CT facility should meet all of the following criteria:

1. Advanced training directed at the specific area of responsibility (e.g., medical physics, health physics, or instrumentation)
2. Licensure, if required by state regulations
3. Documented regular participation in continuing education in the area of specific involvement to maintain competency
4. Knowledge of radiation safety and protection and of all rules and regulations applying to the area of practice

VI. ISSUES REQUIRING FURTHER CLARIFICATION

Use of AC/AL CT, optimized diagnostic CT, or both may depend on the indication.

VII. CONCISE BIBLIOGRAPHY

- A. Antoch G, Freudenberg LS, Statta J, et al. Whole-body positron emission tomography-CT: optimized CT using oral and IV contrast materials. *AJR.* 2002;179:1555–1560.
- B. Antoch G, Jentzen W, Freudenberg LS, et al. Effect of oral contrast agents on computed tomography-based positron emission tomography attenuation correction in dual-modality positron emission tomography/computed tomography imaging. *Invest Radiol.* 2003;38:784–789.
- C. Cohade C, Osman M, Nakamoto Y, et al. Initial experience with oral contrast in PET/CT: phantom and clinical studies. *J Nucl Med.* 2003;44:412–416.

- D. Coleman RE, Delbeke D, Guiberteau MJ, et al. Concurrent PET/CT with an integrated imaging system: intersociety dialogue from the joint working group of the American College of Radiology, the Society of Nuclear Medicine, and the Society of Computed Body Tomography and Magnetic Resonance. *J Nucl Med.* 2005;46:1225–1239.
- E. Czernin J, ed. PET/CT: imaging structure and function. *J Nucl Med.* 2004;45(suppl):1S–103S.
- F. Dizendorf E, Hany TF, Buck A, von Schulthess GK, Burger C. Cause and magnitude of the error induced by oral CT contrast agent in CT-based attenuation correction of PET emission studies. *J Nucl Med.* 2003;44:732–738.
- G. Donnelly LF. Lessons from history. *Pediatr Radiol.* 2002;32:287–292.
- H. Even-Sapir E, Lerman H, Lievshitz G, et al. Lymphoscintigraphy for sentinel node mapping using a hybrid SPECT/CT system. *J Nucl Med.* 2003;44:1413–1420.
- I. Fearon T, Vucich J. Pediatric patient exposures from CT examinations: GE CT/T 9800 scanner. *AJR.* 1985;144:805–809.
- J. Gayed IW, Kim EE, Broussard WF, et al. The value of ^{99m}Tc-sestamibi SPECT/CT over conventional SPECT in the evaluation of parathyroid adenomas or hyperplasia. *J Nucl Med.* 2005;46:248–252.
- K. Horger M, Eschmann SM, Pfannenbergl C, et al. Evaluation of combined transmission and emission tomography for classification of skeletal lesions. *AJR.* 2004;183:655–661.
- L. Keidar Z, Israel O, Krausz Y. SPECT/CT in tumor imaging: technical aspects and clinical applications. *Semin Nucl Med.* 2003;33:205–218.
- M. Kinahan PE, Hasegawa BH, Beyer T. X-ray based attenuation correction for PET/CT scanners. *Semin Nucl Med.* 2003;33:166–179.
- N. Krausz Y, Keidar Z, Kogan I, et al. SPECT/CT hybrid imaging with ¹¹¹In-pentetreotide in assessment of neuroendocrine tumours. *Clin Endocrinol (Oxf).* 2003;59:565–573.
- O. Nakamoto Y, Chin BB, Kraitchman DL, et al. Effects of nonionic intravenous contrast agents at PET/CT imaging: phantom and canine studies. *Radiology.* 2003;227:817–824.
- P. Osman MM, Cohade C, Nakamoto Y, Wahl RH. Clinically significant inaccurate localization of lesions with PET/CT: frequency in 300 patients. *J Nucl Med.* 2003;44:240–243.
- Q. Palumbo B, Sivoletta S, Palumbo I, Liberati AM, Palumbo R. ⁶⁷Ga-SPECT/CT with a hybrid system in the clinical management of lymphoma. *Eur J Nucl Med Mol Imaging.* 2005;32:1011–1017.
- R. Patton JA, Delbeke D, Sandler MP. Image fusion using an integrated, dual-head coincidence camera with x-ray tube-based attenuation maps. *J Nucl Med.* 2000;41:1364–1368.
- S. PET-CT Consensus Conference. Fusion imaging: a new type of technologist for a new time of technology. *J Nucl Med Technol.* 2002;30:201–204.
- T. Plotkin M, Wurm R, Eisenacher J, et al. Combined SPECT/CT imaging using ¹²³I-IMT in the detection of recurrent or persistent head and neck cancer. *Eur Radiol.* 2006;16:503–511.
- U. Schillaci O, Danieli R, Manni C, Capocchetti F, Simonetti G. Technetium-99m-labelled red blood cell imaging in the diagnosis of hepatic haemangiomas: the role of SPECT/CT with a hybrid camera. *Eur J Nucl Med Mol Imaging.* 2004;31:1011–1005.
- V. Ruf J, Lehmkuhl L, Bertram H, et al. Impact of SPECT and integrated low-dose CT after radioiodine therapy on the management of patients with thyroid carcinoma. *Nucl Med Commun.* 2004;25:1177–1182.
- W. Tharp K, Israel O, Hausmann J, et al. Impact of ¹³¹I-SPECT/CT images obtained with an integrated system in the follow-up of patients with thyroid carcinoma. *Eur J Nucl Med Mol Imaging.* 2004;31:1435–1442.
- X. Yau YY, Chan WS, Tam YM, et al. Application of intravenous contrast in PET/CT: does it really introduce significant attenuation correction error? *J Nucl Med.* 2005;46:283–291.
- Y. Wagner A, Schicho K, Glaser C, et al. SPECT-CT for topographic mapping of sentinel lymph nodes prior to gamma probe-guided biopsy in head and neck squamous cell carcinoma. *J Craniomaxillofac Surg.* 2004;32:343–349.

VIII. DISCLAIMER

The SNM has written and approved this Procedure Guideline as an educational tool designed to promote the cost-effective use of high-quality nuclear medicine procedures in medical practice or in the conduct of research and to assist practitioners in providing appropriate care for patients. The Procedure Guideline should not be deemed inclusive of all proper procedures or exclusive of other procedures reasonably directed to obtaining the same results. The guidelines 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, the SNM cautions against the use of this Procedure Guideline 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. Therefore, an approach that differs from the Procedure Guideline 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 Procedure Guideline when, in his or her reasonable judgment, that 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 Procedure Guideline.

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 this Procedure Guideline is to assist practitioners in achieving this objective.

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

IX. APPROVAL

This Procedure Guideline was approved by the Board of Directors of the SNM on April 30, 2006.