

Procedure Guideline for Tumor Imaging with ^{18}F -FDG PET/CT 1.0*

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I. PURPOSE

The purpose of these guidelines is to assist physicians in recommending, performing, interpreting, and reporting the results of ^{18}F -FDG PET/CT for oncologic imaging of adult and pediatric patients.

II. BACKGROUND INFORMATION AND DEFINITIONS

PET is a tomographic scintigraphic technique in which a computer-generated image of local radioactive tracer distribution in tissues is produced through the detection of annihilation photons that are emitted when radionuclides introduced into the body decay and release positrons. ^{18}F -FDG PET is a tomographic imaging technique that uses a radiolabeled analog of glucose, ^{18}F -FDG, to image relative glucose use rates in various tissues. Because glucose use is increased in many malignancies, ^{18}F -FDG PET is a sensitive method for detecting, staging, and monitoring the effects of therapy of many malignancies. CT is a tomographic imaging technique that uses an x-ray beam to produce anatomic images. This anatomic information is used to detect and to help determine the location and extent of malignancies. Combined PET/CT devices provide both the metabolic information from ^{18}F -FDG PET and the anatomic information from CT in a single examination. As shown in some clinical scenarios, the information obtained by PET/CT appears to be more accurate in evaluating patients with known or suspected malignancies than does the information obtained from either PET or CT alone or the results obtained from PET and CT separately but interpreted side by side.

^{18}F -FDG PET and CT are proven diagnostic procedures. Although techniques for registration and fusion of images obtained from separate PET and CT scanners have been

available for several years, the readily apparent and documented advantages of having PET and CT in a single device have resulted in the rapid dissemination of this technology in the United States. This Procedure Guideline pertains only to combined PET/CT devices.

Definitions

- A. A PET/CT scanner is an integrated device containing both a CT scanner and a PET scanner with a single patient table and therefore capable of obtaining a CT scan, a PET scan, or both. If a patient does not move between the scans, the reconstructed PET and CT images will be spatially registered.
- B. PET/CT registration is the process of aligning PET and CT images for the purposes of combined image display (fusion) and image analysis.
- C. PET/CT fusion is the combined display of registered PET and CT image sets. Superimposed data typically are displayed with the PET data color coded to the CT data in gray scale.
- D. PET/CT acquisitions can include the whole body, an extended portion of the body, or a limited portion of the body. These acquisitions are defined in Current Procedural Terminology 2005 as follows:
 1. Whole-body tumor imaging: from the top of the head through the feet
 2. Skull base-to-midhigh tumor imaging
 3. Limited-area tumor imaging
- E. Methods of attenuation correction:
 1. CT transmission imaging with PET/CT scanners
 2. Transmission scanning with an isotopic source: not commonly used with PET/CT scanners

III. EXAMPLES OF CLINICAL OR RESEARCH APPLICATIONS

Indications for ^{18}F -FDG PET/CT include but are not limited to the following:

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

- A. Differentiating benign from malignant lesions
- B. Searching for an unknown primary tumor when metastatic disease is discovered as the first manifestation of cancer or when the patient presents with a paraneoplastic syndrome
- C. Staging known malignancies
- D. Monitoring the effect of therapy on known malignancies
- E. Determining whether residual abnormalities detected on physical examination or on other imaging studies after treatment represent tumor or posttreatment fibrosis or necrosis
- F. Detecting tumor recurrence, especially in the presence of elevated levels of tumor markers
- G. Selecting the region of a tumor most likely to yield diagnostic information for biopsy
- H. Guiding radiation therapy planning
- I. Nononcologic applications, such as evaluation of infection and atherosclerosis

¹⁸F-FDG PET/CT is not equally effective for all malignancies, but other tracers are available; however, many of these are not yet approved by the U.S. Food and Drug Administration or reimbursable by the Medicare program. The scientific literature concerning its utility continues to evolve rapidly.

IV. PROCEDURE

A. Patient Preparation

The optimum preparation for patients about to undergo PET/CT is evolving. The major goals of preparation are to minimize tracer uptake in normal tissues, such as the myocardium and skeletal muscle, while maintaining uptake in target tissues (neoplastic disease). The following is a commonly used protocol.

1. Pregnancy and breast-feeding: see the Society of Nuclear Medicine Procedure Guidelines for General Imaging
2. Before arrival

Patients should be instructed to fast and not consume beverages, except for water, for at least 4–6 h before the administration of ¹⁸F-FDG to decrease physiologic glucose levels and to reduce serum insulin levels to near basal levels. Oral hydration with water is encouraged. Intravenous fluids containing dextrose or parenteral feedings also should be withheld for 4–6 h.

When intravenous contrast material is to be used, patients should be screened for a history of iodinated contrast material allergy, use of metformin for the treatment of diabetes mellitus, and renal disease. Intravenous contrast material should not be administered when the serum creatinine level is above 2.0 mg/dL.

3. Before injection

- a. For brain imaging, the patient should be in a quiet and dimly lit room for ¹⁸F-FDG administration and the subsequent uptake phase.
- b. For body imaging, the patient should remain seated or recumbent for ¹⁸F-FDG administration and the subsequent uptake phase to avoid muscular uptake.
- c. The blood glucose level should be checked before ¹⁸F-FDG administration. Tumor uptake of ¹⁸F-FDG is reduced in hyperglycemic states. Most institutions reschedule the patient if the blood glucose level is greater than 150–200 mg/dL. Reducing the serum glucose level by administering insulin can be considered, but the administration of ¹⁸F-FDG should be delayed after insulin administration (with the duration of the delay being dependent on the type and route of administration of insulin).
- d. For either a CT scan done for attenuation correction/anatomic localization (AC/AL) or a 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 it is 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 Guidelines for General Imaging.

1. Focused history, including the type and site of malignancy, dates of diagnosis and treatment (biopsy results, surgery, radiation, chemotherapy, and administration of bone marrow stimulants and steroids), and current medications.
2. History of diabetes, fasting state, and recent infection
3. Patient's ability to lie still for the duration of the acquisition (15–45 min)
4. History of claustrophobia
5. Patient's ability to put his or her arms overhead

C. Precautions

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

D. Radiopharmaceutical

With PET/CT, the radiation dose to the patient (Table 1) is the combination of the radiation dose from the PET 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 PET/CT study. For example, a body scan may include various portions of the body and may use protocols aimed to reduce the

TABLE 1
¹⁸F-FDG Radiation Dosimetry for Adults and Children

| Patient | Intravenously administered activity | Organ receiving the largest radiation dose, mGy/MBq (rads/mCi) | Effective dose, mSv/MBq (rems/mCi) |
|-----------------|-------------------------------------|--|------------------------------------|
| Adult | 370–740 MBq (10–20 mCi) | Bladder, 0.16* (0.59) | 0.019 (0.070) |
| Child (5 y old) | 5.18–7.4 MBq/kg (0.14–0.20 mCi/kg) | Bladder, 0.32 [†] (1.2) | 0.050 (0.18) |

*Voiding interval, 3.5 h. Changes in bladder wall dose are approximately linear with changes in voiding interval; therefore, for a voiding interval of 2.0 h, dose to bladder wall would change by a factor of 2/3.5.

[†]Voiding interval, 2.0 h.

Data are from International Commission on Radiological Protection. *Radiation Dose to Patients from Radiopharmaceuticals*. St. Louis, MO: Elsevier; 2000:49. ICRP publication 80.

radiation dose to the patient or aimed to optimize the CT scan for diagnostic purposes. The effective dose could range from approximately 5 to 80 mSv (0.5–8.0 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.

E. Image Acquisition

See also the Society of Nuclear Medicine PET Tumor Imaging Guidelines and the “Specifications of the Examination” and “Documentation” 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.

1. Field of view, positioning, and preacquisition preparation
 - a. Skull base-to-proximal thigh imaging generally is recommended to survey the body in the search for areas of abnormal ¹⁸F-FDG accumulation for most tumor types. Such PET/CT scans typically are acquired from the external auditory meatus to the midthigh region. For tumors with a high likelihood of scalp, skull, or brain involvement or lower-extremity involvement, whole-body tumor imaging is performed.
 - b. Limited-area tumor imaging can be considered when critical abnormalities are likely to be localized in a known region of the body (e.g., solitary pulmonary nodule, probable lung cancer, evaluation of hilar lymph node involvement, diagnosis of head and neck cancer, and monitoring of therapy of locally advanced breast cancer). However,

performing whole-body tumor imaging offers the advantage of staging the entire body.

- c. For optimal imaging of the body, the arms should be elevated over the head if that position can be tolerated by the patient. Arms along the side may produce beam-hardening artifacts over the torso. However, for optimal imaging of the head and neck, the arms should be positioned along the side.
 - d. The patient should void the bladder before the acquisition of the images to limit the radiation dose to the renal collecting system and bladder.
 - e. Metallic objects should be removed from the patient whenever possible.
2. Protocol for CT imaging

The CT component of a PET/CT examination can be performed either for 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 a diagnostic CT scan, such optimization has been attempted. In some circumstances, both an initial CT acquisition for AC/AL (before the PET data acquisition) and diagnostic CT (after the PET data acquisition) are performed. Optimization of the CT technique used in PET/CT continues to evolve.

 - a. If the CT scan is obtained for AC/AL, 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 intravascular concentrations of intravenous

contrast material may cause an attenuation correction artifact on the PET image, but the impact usually is modest. This artifact is minimized on scanners by use of appropriate correction factors.

- c. For either a CT scan done for AC/AL or an optimized diagnostic CT scan of the abdomen or pelvis, an intraluminal gastrointestinal noncaloric contrast agent may be administered to provide adequate visualization of the gastrointestinal tract unless it is medically contraindicated or unnecessary for the clinical indication. This agent may be a positive contrast agent (such as dilute barium), an oral iodinated contrast agent, or a negative contrast agent (such as water). Collections of highly concentrated barium or iodinated contrast agents can result in an attenuation correction artifact that leads to a significant overestimation of the regional ^{18}F -FDG concentration; other, dilute positive and negative oral contrast agents cause less overestimation and do not affect PET image quality.
 - d. With regard to the breathing protocol for CT transmission scanning, in PET/CT, the position of the diaphragm on the PET emission images 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 PET/CT because it may result in substantial respiratory motion misregistration on PET 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. Respiratory motion results in inaccurate localization of lesions at the base and periphery of the lungs, in the dome of the liver, or near any lung–soft tissue interface and may result in spurious standardized uptake value (SUV) determinations. Motion correction or respiratory gating is recommended when available.
3. Protocol for PET emission imaging
- a. The radiopharmaceutical should be injected at a site contralateral to the site of concern. Emission images should be obtained at least 45 min after radiopharmaceutical injection. The optimal ^{18}F -FDG distribution phase is controversial. Many facilities start the acquisition of the images at 60 or 90 min after ^{18}F -FDG administration. Some facilities obtain a second set of images to assess the change in uptake over time. The ^{18}F -FDG uptake time should be constant whenever possible and certainly when 2 studies are being compared by use of semiquantitative parameters, especially the SUV.
 - b. The emission image acquisition time varies from 2 to 5 min or longer per bed position for body

imaging and is based on the administered activity, patient body weight, and sensitivity of the PET scanner (as determined largely by detector composition and acquisition method). Typically, for imaging skull to midthigh, the total acquisition time ranges from 15 to 45 min. The imaging time typically is prolonged for the acquisition of brain images or for images of a limited region of interest.

- c. Semiquantitative estimation of tumor glucose metabolism by use of the SUV is based on relative lesion radioactivity measured on images corrected for attenuation and normalized for the injected dose and body weight, lean body mass, or body surface area. This measurement is obtained on a static emission image typically acquired more than 45 min after injection. The accuracy of SUV measurements depends on the accuracy of the calibration of the PET scanner, among other factors. The reproducibility of SUV measurements depends on the reproducibility of clinical protocols, for example, dose infiltration, time of imaging after ^{18}F -FDG administration, type of reconstruction algorithms, type of attenuation maps, size of the region of interest, changes in uptake by organs other than the tumor, and methods of analysis (e.g., maximum and mean).
- d. Semiquantitative estimation of tumor metabolism can be based on the ratio of ^{18}F -FDG uptake in a lesion to ^{18}F -FDG uptake in internal reference regions, such as the blood pool, mediastinum, liver, and cerebellum.

F. Interventions

1. Intense urinary bladder tracer activity degrades image quality and can confound the interpretation of findings in the pelvis. Hydration and a loop diuretic, without or with bladder catheterization, may be used to reduce accumulated urinary tracer activity in the bladder. Bladder catheterization with a 3-way flushing catheter running a continuous bladder flush after injection until imaging has been used successfully to clear bladder activity.
2. Keeping the patient in a warm room for 30–60 min before the injection of ^{18}F -FDG, particularly in cold climates and air-conditioned environments, will help to minimize brown fat uptake. Lorazepam or diazepam given before the injection of ^{18}F -FDG may reduce uptake by brown adipose tissue or skeletal muscle. β -Blockers also may reduce uptake by brown fat.

G. Processing

1. PET reconstruction: PET emission data consist of the number of events along lines of response between detector pairs. The emission data must be corrected for detector efficiency (normalization), system dead time, random coincidences, scatter, attenuation, and

sampling nonuniformity. Some of these corrections (e.g., attenuation) can be incorporated directly into the reconstruction process. Scanners with retractable septa can acquire data in both 2-dimensional (2D) and 3-dimensional (3D) modes, whereas scanners without septa acquire data in the 3D mode only. Datasets acquired in the 3D mode either can be rebinned into 2D data and reconstructed with a 2D algorithm or can be reconstructed with a fully 3D algorithm. Iterative reconstruction approaches are now widely available for clinical applications in both 2D and 3D modes, largely replacing the direct, filtered backprojection methods used previously. For a given algorithm, the appropriate reconstruction parameters will depend on the acquisition mode, the type of scanner, and the imaging task. It is considered good practice to archive reconstructions both with and without attenuation correction to resolve issues arising from potential artifacts generated by the CT-based attenuation correction procedure. The reconstructed image volume can be displayed in transaxial, coronal, and sagittal planes and as a rotating maximum-intensity-projection image.

2. CT reconstruction: CT sinograms are reconstructed by filtered backprojection at full field of view for the data used for attenuation correction of the PET emission data and separately for CT interpretation with appropriate zoom, slice thickness and overlap, and reconstruction algorithms for the particular region of the body scanned. The filtered backprojection can be either 2D after appropriate portions of the spiral CT data are collected into axial or tilted planes or fully 3D. 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 for emphasizing certain image features, for example, bone, lung, or head algorithms. For attenuation correction, only the standard kernels are used. Because CT volumes today are nearly isotropic, reslicing in coronal, sagittal, or even curved displays often is 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, often are used. Organ- and task-specific automatic or semiautomatic segmentation algorithms and special evaluation algorithms also are in routine use.
3. Display: With an integrated PET/CT system, typically the software packages provide registered and aligned CT images, ^{18}F -FDG PET images, and fusion images in the axial, coronal, and sagittal planes as well as maximum-intensity-projection images for review in the 3D cine mode. ^{18}F -FDG PET images with and without attenuation correction should be available for review.

H. Interpretation Criteria

1. Normal physiologic uptake of ^{18}F -FDG can be seen to some extent in every viable tissue, including the brain, myocardium (where the uptake is significant in some patients despite prolonged fasting), breast, liver, spleen, stomach, intestines, kidneys and urine, muscle, lymphoid tissue (e.g., tonsils), bone marrow, salivary glands, thymus, uterus, ovaries, testes, and brown adipose tissue (see Section K).
2. For whole-body surveys, studies have shown that ^{18}F -FDG PET of the brain is relatively insensitive for the detection of cerebral metastases, because of high physiologic ^{18}F -FDG uptake in the gray matter.
3. Increased uptake of ^{18}F -FDG can be seen in neoplasms, granulation tissue (e.g., healing wounds), infections, and other inflammatory processes.
4. Although the pattern of ^{18}F -FDG uptake and specific CT findings as well as the correlation with history, physical examination, and other imaging modalities usually are the most helpful features in differentiating benign from malignant lesions, semiquantitative estimates (e.g., SUV) also may be of value, especially for evaluating changes over time or with therapy.

I. Reporting

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

1. Study identification
2. Clinical information
 - a. Indication for the study
 - b. Relevant history
 - c. Information needed for billing
3. Procedure description and imaging protocol
 - a. Radiopharmaceutical, including administered activity, route of administration, and ^{18}F -FDG uptake time
 - b. Other drugs administered and procedures performed, such as placement of intravenous line; hydration; insertion of Foley catheter (size of catheter); administration of furosemide (amount and time), muscular relaxants, or pain medications; and sedation procedures (briefly describe the procedure, state the type of medication and time of sedation in relation to the radiotracer injection, and state the patient condition at the conclusion of the PET study)
 - c. Field of view and patient positioning: whole body, skull base to mid thigh, or limited area and position of the arms
 - d. Baseline glucose level
 - e. CT transmission protocol (for AC/AL or diagnostic CT protocol with or without oral or intravenous contrast material and with the appropriate protocol for the clinical scenario and body region of interest)
 - f. PET emission protocol: see the Society of Nuclear Medicine Procedure Guidelines for General Imaging

4. Description of findings

- a. Quality of the study: for example, limited because of motion, muscular uptake, or hyperglycemia
- b. Describe the location, extent, and intensity of abnormal ^{18}F -FDG uptake in relation to uptake in normal comparable tissues and describe the relevant morphologic findings related to PET abnormalities on the CT images. An estimate of the intensity of ^{18}F -FDG uptake can be provided by the SUV; however, the intensity of uptake may be described as mild, moderate, or intense or in relation to the background uptake in normal hepatic parenchyma (average SUV: 2.0–3.0; maximum SUV: 3.0–4.0). The integrated PET/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 PET/CT report can refer to the diagnostic CT scan report for findings not related to the PET/CT examination.
- c. Limitations: when appropriate, identify factors that can limit the sensitivity and specificity of the examination (e.g., small lesions or an inflammatory process)
- 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. PET/CT studies are more valuable when correlated with previous diagnostic CT, previous PET, previous PET/CT, previous MRI, and all appropriate imaging studies and clinical data that are relevant.

When PET/CT is performed for monitoring therapy, a comparison of the extent and intensity of uptake may be summarized as metabolic progressive disease, metabolic stable disease, metabolic partial response, or metabolic complete response. The European Organization for Research and Treatment of Cancer has published criteria for these categories, although these criteria have not yet been validated in outcome studies. A change in the intensity of uptake with semiquantitative measurements, expressed in absolute values and percent change, may be appropriate in some clinical scenarios. However, the technical protocol and analysis of images need to be consistent in the 2 sets of images, as described in Section E.3.

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 Guidelines for Use of Radiopharmaceuticals.

2. Instrumentation specifications

See also the “Equipment Specifications” and “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.

a. Equipment performance guidelines

For patient imaging, state-of-the-art scanners meet or exceed the following specifications:

For the CT scanner: see the American College of Radiology guidelines mentioned above.

For the PET scanner: These specifications are based on manufacturers’ data obtained according to National Electrical Manufacturers Association (NEMA) 2001 protocols; the uniformity estimate is based on the NEMA 1994 protocol. For lutetium oxyorthosilicate–based scanners, a modified NEMA protocol is defined to account for the natural radioactive background from lutetium oxyorthosilicate.

- In-plane spatial resolution: <6.5 mm
- Axial resolution: <6.5 mm
- Sensitivity (3D): >4.0 cps/kBq
- Sensitivity (2D): >1.0 cps/kBq
- Uniformity: $<5\%$

For the PET/CT scanner:

- Maximum co-scan range (CT and PET): >160 cm
- Maximum patient weight: at least 157.50 kg (350 lb)
- Patient port diameter: at least 59 cm

All currently available commercial PET/CT scanners meet or exceed these specifications.

The CT field of view should be at least 50 cm in diameter to minimize artifacts from CT-based attenuation correction because of mismatch between the CT and the PET fields.

A workstation with the capability to display CT, PET, and fused images with different percentages of CT and PET blending also should be available. The workstation should allow multi-planar display with linked CT and PET cursors. Postcollection registration of the PET and CT datasets and registration with other imaging studies, including nonrigid registration, are desirable.

b. Equipment quality control

PET performance monitoring should be in accordance with the American College of Radiology Technical Standard for Medical Nuclear Physics Performance Monitoring of Nuclear Medicine Imaging Equipment.

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

The quality control procedures for PET/CT should incorporate both CT procedures and PET procedures according to the American College of Radiology technical standards mentioned above. 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 PET 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 also should be performed to identify detector failures and drifts.

In addition, for PET/CT, a check on the alignment between the CT and the PET scanners should be performed periodically. Such a gantry alignment check should determine any offset between the CT and the PET 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

Processes other than malignancies may cause false-positive and false-negative results. The following list, although not all-inclusive, includes the most commonly encountered causes:

1. False-positive findings

- a. Physiologic uptake that may lead to false-positive interpretations
 - Salivary glands and lymphoid tissues in the head and neck
 - Thyroid

- Brown adipose tissue
- Thymus, especially in children
- Lactating breast
- Areola
- Skeletal and smooth muscles (e.g., neck or paravertebral; hyperinsulinemia)
- Gastrointestinal (e.g., esophagus, stomach, or bowel)
- Urinary tract structures (containing excreted ^{18}F -FDG)
- Female genital tract (e.g., uterus during menses or corpus luteum cyst)

b. Inflammatory processes

- Postsurgical inflammation, infection, or hematoma; biopsy site; or amputation site
- Postradiation (e.g., radiation pneumonitis)
- Postchemotherapy
- Local inflammatory disease, especially granulomatous processes (e.g., sarcoidosis, fungal disease, or mycobacterial disease)
- Ostomy site (e.g., trachea or colon) and drainage tubes
- Injection site
- Thyroiditis
- Esophagitis, gastritis, or inflammatory bowel disease
- Acute and occasionally chronic pancreatitis
- Acute cholangitis and cholecystitis
- Osteomyelitis, recent fracture sites, or joint prostheses
- Lymphadenitis

c. Benign neoplasms

- Pituitary adenoma
- Adrenal adenoma
- Thyroid follicular adenoma
- Salivary gland tumors (e.g., Warthin's tumor or pleomorphic adenoma)
- Colonic adenomatous polyps and villous adenoma
- Ovarian thecoma and cystadenoma
- Giant cell tumor
- Aneurysmal bone cyst
- Leiomyoma

d. Hyperplasia or dysplasia

- Graves' disease
- Cushing's disease
- Bone marrow hyperplasia (e.g., anemia or cytokine therapy)
- Thymic rebound hyperplasia (postchemotherapy)
- Fibrous dysplasia
- Paget's disease

e. Ischemia

- Hibernating myocardium

f. Artifacts

- Misalignment between PET and CT data can cause attenuation correction artifacts. PET images

without attenuation correction and fusion images can be used to help identify these artifacts.

- Inaccuracies in converting from polychromatic CT energies to the 511-keV energy of annihilation radiation can cause artifacts around metal or dense barium, although these artifacts are less common with newer conversion algorithms.

2. False-negative findings

- Small size (<2 times the resolution of the system)
- Tumor necrosis
- Recent chemotherapy or radiotherapy
- Recent high-dose steroid therapy
- Hyperglycemia and hyperinsulinemia
- Some low-grade tumors (e.g., sarcoma, lymphoma, or brain tumor)
- Tumors with large mucinous components
- Some hepatocellular carcinomas, especially well-differentiated tumors
- Some genitourinary carcinomas, especially well-differentiated tumors
- Prostate carcinoma, especially well-differentiated tumors
- Some neuroendocrine tumors, especially well-differentiated tumors
- Some thyroid carcinomas, especially well-differentiated tumors
- Some bronchioloalveolar carcinomas
- Some lobular carcinomas of the breast
- Some skeletal metastases, especially osteoblastic or sclerotic tumors
- Some osteosarcomas

V. QUALIFICATION OF PERSONNEL

A. Physicians

The use of PET/CT technology is becoming common practice. Because it is inefficient to have PET/CT images interpreted by 2 different imaging experts and then to have

their observations subsequently integrated, there is a need to define the training for people who can interpret and integrate both components of PET/CT scans. Regardless of previous training, imaging experts interpreting PET/CT scans should have appropriate training in both PET and CT. Ideally, a diagnostic radiologist who has not received training and experience in PET should have training and experience in PET similar to that of a nuclear medicine physician, and a nuclear medicine physician should have training and experience in CT similar to that of a diagnostic radiologist, including treatment of contrast material reactions. In most instances, it is not feasible for a practicing diagnostic radiologist to duplicate exactly the PET training that a nuclear medicine physician receives during a nuclear medicine residency, nor is it possible for a practicing nuclear medicine physician to duplicate the CT training obtained in a diagnostic radiology residency.

An article summarizing discussions regarding issues relating to imaging with PET, CT, and PET/CT recently was published by a collaborative working group with representatives from the American College of Radiology, 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 training recommendations from the collaborative working group are summarized in Table 2. Alternative approaches, such as determining 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, may have equal or greater validity.

In the future, the requirements of radiology and nuclear medicine residency training programs will include training

TABLE 2
Summary of PET/CT On-The-Job Training Requirements

| Training | Board certification | No. of PET/CT interpretations (supervised)* | No. of CT interpretations (supervised)† | PET/CT CME credits | CT CME credits |
|-------------------------------------|---------------------|---|---|--------------------|----------------|
| Nuclear medicine | ABNM | 150 | 500 | 8 | 100 |
| Diagnostic radiology (recent CT)‡ | ABR | 150 | | 35 | |
| Nuclear radiology (recent CT)‡ | ABR | 150 | | 8 | |
| Radiology (recent CT)‡ | ABR and ABNM | 150 | | 8 | |
| Diagnostic radiology (no recent CT) | ABR | 150 | 500 | 35 | 100 |

*Supervision should be performed by qualified nuclear medicine physicians or diagnostic radiologists who have interpreted more than 500 PET/CT studies.

†Supervision should be performed by qualified diagnostic radiologists as defined in American College of Radiology Practice Guidelines for Performing and Interpreting Diagnostic Computed Tomography. CT cases should include reasonable distribution of head and neck, chest, abdomen, and pelvis.

‡Includes radiologists or nuclear radiologists with recent experience in body CT (100 body CT cases/y for preceding 5 y).
ABNM = American Board of Nuclear Medicine.

in the interpretation and supervision of integrated PET/CT studies. Certifying and recertifying examinations will include testing on CT, PET, and PET/CT. Eligibility for taking the recertification examinations will mandate participation in a maintenance of certification (MOC) program and will include training in the interpretation of PET, CT, and PET/CT images. Some components of the MOC 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 in the techniques and interpretation related to the procedures discussed in these guidelines. Where MOC programs exist, physicians should be able to show evidence of participation.

If no physicians with training in the interpretation of integrated PET/CT studies are available, PET scans should be interpreted by nuclear medicine physicians with expertise in PET, and CT scans should be interpreted by diagnostic radiologists with expertise in CT. Strong opinions have been expressed that a single report should be issued to avoid inconsistencies, confusion, and redundancy, although reimbursement issues still are being debated.

B. Technologists

PET/CT technology presents similar practice issues regarding the education, training, and certification of technologists to become appropriately qualified and competent to perform PET/CT. Additional issues arise with regard to ensuring competency, standardizing the educational experience of technologists, and barriers placed by licensure and regulation at the state level. The Society of Nuclear Medicine Technologist Section (SNMITS) and the American Society of Radiologic Technologists (ASRT) have jointly developed a master plan and set into motion mechanisms to sort out the practice issues regarding PET/CT. This master plan was crafted in July 2002 during a stakeholders' meeting known as the PET/CT Consensus Conference. 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 professional associations to establish standards, delineate mechanisms for obtaining the training necessary to promote a qualified and competent workforce to perform these procedures, and partner with organizations that can assist in sorting out practice issues. To address educational needs, the ASRT and the SNMITS spearheaded the development of a PET/CT curriculum, which was endorsed by numerous professional organizations and distributed to each state radiation control board and 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 Nuclear Medicine Technology Certification Board (NMTCB) has developed a PET specialty examination that is open to certified or registered nuclear medicine technologists, registered radiologic technologists, CT technologists, and registered radiation therapists, as long as they have fulfilled the required prerequisites, as defined on the NMTCB Web site (www.nmtcb.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.rrt.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 as well as the opportunities that radiologic technologists have for gaining the PET experience needed to take the NMTCB PET examination. The SNMITS is approaching these issues through both legislative and regulatory pathways. The SNMITS has been promoting the Consumer Assurance of Radiologic Excellence bills pending before the U.S. Congress. The Consumer Assurance of Radiologic Excellence 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:

- ABR: "Medical Nuclear Physics" with initially at least 15 h of continuing education credits in CT imaging physics, or
- "Diagnostic Radiological Physics" with initially at least 15 h of continuing education credit in PET imaging physics, or
- ABSNM: "Nuclear Medicine Physics and Instrumentation" with initially at least 15 h of continuing education credits in CT imaging physics.

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

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

A qualified medical physicist or other qualified scientist performing physics services in support of a PET/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

- A. Use of AC/AL CT, use of optimized diagnostic CT, or both may depend on the indication; the selection of the CT protocol to be used with PET/CT is under evolution
- B. Role of reregistration to correct for respiratory and other motion artifacts
- C. Role of axial collimation
- D. Role of respiratory gating for PET, CT, or both
- E. Optimal distribution time for ^{18}F -FDG, scan time per bed position, image regularization (smoothing), reconstruction algorithm, and best method for CT-based attenuation correction
- F. Optimal methods for semiquantitative measurements (e.g., SUV)

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VIII. DISCLAIMER

The Society of Nuclear Medicine has written and approved these guidelines 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. These guidelines should not be deemed inclusive of all proper procedures or exclusive of other procedures reasonably directed to obtaining the same results. They are neither inflexible rules nor requirements of practice and are not intended nor should they be used to establish a legal standard of care. For these reasons, the Society of Nuclear Medicine cautions against the use of these guidelines in litigation in which the clinical decisions of a practitioner are called into question.

The ultimate judgment about the propriety of any specific procedure or course of action must be made by the

physician when considering the circumstances presented. Therefore, an approach that differs from the guidelines is not necessarily below the standard of care. A conscientious practitioner may responsibly adopt a course of action different from that set forth in the guidelines when, in his or her reasonable judgment, 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 guidelines.

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

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

IX. APPROVAL

These guidelines were approved by the Board of Directors of the Society of Nuclear Medicine on February 11, 2006.