RESOLUTION NO. 24

BE IT RESOLVED,

that the American College of Radiology adopt the ACR–SPR Practice Guideline for Performing FDG-PET/CT in Oncology

Sponsored By: ACR Council Steering Committee

ACR–SPR PRACTICE GUIDELINE FOR PERFORMING FDG-PET/CT IN ONCOLOGY

PREAMBLE

These guidelines are an educational tool designed to assist practitioners in providing appropriate radiologic care for patients. They are not inflexible rules or requirements of practice and are not intended, nor should they be used, to establish a legal standard of care. For these reasons and those set forth below, the American College of Radiology cautions against the use of these guidelines in litigation in which the clinical decisions of a practitioner are called into question.

The ultimate judgment regarding the propriety of any specific procedure or course of action must be made by the physician or medical physicist in light of all the circumstances presented. Thus, an approach that differs from the guidelines, standing alone, does not necessarily imply that the approach was below the standard of care. To the contrary, a conscientious practitioner may responsibly adopt a course of action different from that set forth in the guidelines when, in the reasonable judgment of the practitioner, such course of action is indicated by the condition of the patient, limitations of available resources, or advances in knowledge or technology subsequent to publication of the guidelines. However, a practitioner who employs an approach substantially different from these guidelines is advised to document in the patient record information sufficient to explain the approach taken.
The practice of medicine involves not only the science, but also the art of dealing with the prevention, diagnosis, alleviation, and treatment of disease. The variety and complexity of human conditions make it impossible to always reach the most appropriate diagnosis or to predict with certainty a particular response to treatment. Therefore, it should be recognized that adherence to these guidelines will not assure an accurate diagnosis or a successful outcome. All that should be expected is that the practitioner will follow a reasonable course of action based on current knowledge, available resources, and the needs of the patient to deliver effective and safe medical care. The sole purpose of these guidelines is to assist practitioners in achieving this objective.

I. INTRODUCTION

This guideline has been developed revised collaboratively by the American College of Radiology (ACR) and the Society for Pediatric Radiology (SPR) to guide interpreting physicians performing positron emission tomography/computed tomography (PET/CT) with fluorodeoxyglucose (fluorine-18-2-fluoro-2-deoxy-D-glucose [FDG]) for oncologic imaging in adult and pediatric patients.

FDG-PET is a scintigraphic technique that provides three-dimensional information about the rate of glucose metabolism in the body and is a sensitive method for detecting, staging, and monitoring the effects of therapy for many malignancies. CT uses an external source of radiation to provide three-dimensional images of the density of the tissues in the body. CT images provide information about the size and shape of organs and abnormalities within the body. FDG-PET and CT are proven diagnostic procedures.

Techniques for registration and fusion of images obtained from separate PET and CT scanners have been available for years. Combined PET/CT devices [1,2] provide both the metabolic information from FDG-PET and the anatomic information from CT in a single examination. The information obtained by PET/CT has been shown to be more accurate in evaluating patients with known or suspected malignancy than either PET or CT alone or PET and CT obtained separately but interpreted together [3-18]. The advantages of having both PET and CT in a single device have resulted in rapid dissemination of this technology in the United States. This practice guideline pertains only to combined PET/CT devices.

FDG-PET and CT are proven diagnostic procedures. The advantages of having both PET and CT in a single device have resulted in rapid dissemination of this technology in the United States. Techniques for registration and fusion of images obtained from separate PET and CT scanners have been available for several years and have been shown to improve diagnostic accuracy [11-18]. This practice guideline, however, pertains only to combined PET/CT devices.

Several Issues related to PET/CT have arisen and include equipment specifications, image acquisition protocols, supervision, interpretation, professional qualifications, and
safety. A discussion of these issues by representatives of the ACR, the SNM, and the Society of Computed Body Tomography and Magnetic Resonance is available [19,20].

The goal of FDG-PET/CT imaging in oncology is to enable the interpreting physician to 1) distinguish benign from malignant disease, 2) determine the extent of disease, 3) detect residual and recurrent tumors, 4) monitor the effect of therapy, and 5) guide therapeutic decisions. therapy

II.  DEFINITIONS

For the purposes of this guideline, the following definitions apply:

PET/CT scanner: A device that includes a single patient table for obtaining a PET scan or CT scan, or both. If the patient stays reasonably immobile between the scans, the PET and CT data are aligned and can be accurately fused.

PET/CT acquisitions: The extent of scanning, which can be tailored to suit the specific indications.

1. Whole-body tumor imaging from the vertex of the skull through the feet.
2. Skull base to mid-thigh tumor imaging.
3. Limited area (e.g., brain-only, chest-only) tumor imaging.

PET/CT registration: The process of taking PET and CT image sets that represent the same body volume and aligning them such that there is a voxel-by-voxel match for the purpose of combined image display (fusion) or image analysis.

PET/CT fusion: The simultaneous display (superimposed or not) of registered PET and CT image sets. When superimposed, the image sets are typically displayed with the PET data color-coded onto the grayscale CT data.

III.  INDICATIONS

FDG-PET/CT imaging in oncology patients may provide guidance for choosing an appropriate course of action. Examinations should only be performed when there is reasonable expectation that the results will have an impact on patient care. Examples of indications for FDG-PET/CT include, but are not limited to, the following:

1. Evaluating an abnormality detected considered “indeterminate” by another imaging method in order to determine whether glucose the level of metabolism in that abnormality favors a benign or malignant process. and the likelihood of malignancy.
2. Guiding initial or subsequent treatment strategy in patients with known malignancy.
3. Monitoring therapeutic efficacy.
4. Determining whether residual abnormalities in another imaging method represent persistent viable tumor or post-treatment changes (inflammation, fibrosis, or necrosis) after completion of therapy.

5. Searching for an unknown Attempting to localize the site of primary tumor when metastatic disease is discovered as the first manifestation of malignancy. cancer

6. Detecting recurrence Localizing “occult” disease especially in the presence of clinical indicators such as elevated tumor markers.

7. Guiding specific clinical strategies, such as radiation therapy planning or directed biopsy.

8. Staging patients with known malignancy

9. Monitoring the effect of therapy on known malignancies

10. Determining if residual abnormalities on imaging studies following treatment represent tumor or post-treatment inflammation, fibrosis, or necrosis.

11. Assisting in treatment planning

FDG uptake varies in different tumor types. PET/CT does not work equally well for all tumors. A continuing review of the literature is recommended to determine the most effective applications.

For the pregnant or potentially pregnant patient, see the ACR Practice Guideline for Imaging Pregnant or Potentially Pregnant Adolescents and Women with Ionizing Radiation.

IV. QUALIFICATIONS AND RESPONSIBILITIES OF PERSONNEL

A. Physician

All PET/CT examinations must be performed under the supervision of and interpreted by a physician who has the following qualifications:

Certification in Radiology or Diagnostic Radiology Nuclear Radiology, or Nuclear Medicine by the American Board of Radiology, American Board of Nuclear Medicine, American Osteopathic Board of Radiology, American Osteopathic Board of Nuclear Medicine, the Royal College of Physicians and Surgeons of Canada, or the Collège des Médecins du Québec.

OR

At a minimum, completion of a formal Accreditation Council of Graduate Medical Education (ACGME) approved general nuclear medicine program which must include 200 hours in radiation physics and 500 hours of preparation in instrumentation, radiochemistry, radiopharmacology, radiation dosimetry, radiation biology, radiation safety and protection, and quality control. In addition, 1,000 hours of clinical training in general nuclear medicine is required which must cover technical performance, calculation of dosages, evaluation of images, correlation with other diagnostic modalities, and interpretation.

AND
1. Twenty hours of CME in PET
2. For oncologic PET examinations, at least 80 studies must be interpreted or multi-read in the past 3 years.

If interpreting oncologic PET examinations, interpretation must include direct image correlation with CT or MRI. Teaching cases are acceptable with documented interpretation.

Continuing Experience

Read a minimum of 200 studies in 3 years in PET (double reading is acceptable).

Continuing Education

Complete 150 hours (that includes 75 hours of Category 1 CME) in the prior 36 months pertinent to the physician’s practice patterns.

OR

Complete 15 hours CME in the prior 36 months specific to the imaging modality or organ system (half of which must be category 1).

In addition, all physicians supervising and/or interpreting nuclear medicine examinations must satisfy all applicable state and federal regulations, as well as any institutional policies that pertain to the in vivo use of radiopharmaceuticals, performance if imaging procedures and the safe handling of radioactive materials.

A. Physician

1. All PET/CT examinations must be performed under the supervision of and interpreted by a physician who has the following qualifications
   a. Certification in Radiology or Diagnostic Radiology by the American Board of Radiology, American Osteopathic Board of Radiology, the Royal College of Physicians and Surgeons of Canada, or the Collège des Médecins du Québec; and involvement with the interpretation, reporting, and/or supervised review of 300 PET and/or PET/CT examinations in the past 36 months; 15 hours of PET and PET/CT CME (AMA category 1), at least 8 of which are PET/CT; and meets the physician training and experience requirements of the ACR Practice Guideline for Performing and Interpreting Diagnostic Computed Tomography (CT)^1, and the physician qualifications in the ACR–SNM Technical Standard for Diagnostic Procedures Using Radiopharmaceuticals of

---

^1Should include cases that are representative of the following areas: abdomen, chest, neck, and pelvis. In meeting the requirements of the ACR Practice Guideline for Performing and Interpreting Diagnostic Computed Tomography, physicians who are certified by the ABNM and have completed the ACGME approved nuclear medicine residency program, can count up to 100 hours of didactic training in CT toward satisfying the 200 hours requirement in the guideline, and 500 CT cases interpreted under the supervision of a physician qualified under the ACR Practice Guideline for Performing and Interpreting Diagnostic Computed Tomography.
b. Completion of a diagnostic radiology residency program approved by the Accreditation Council for Graduate Medical Education (ACGME), the Royal College of Physicians and Surgeons of Canada (RCPSC), the Collège des Médecins du Québec, or the American Osteopathic Association (AOA) to include involvement with the interpretation, reporting, and supervised review of 500 or more PET and/or PET/CT examinations in the past 36 months; 15 hours of PET and PET/CT CME (AMA category 1), at least 8 of which are PET/CT; and meets the physician training and experience requirements of the ACR Practice Guideline for Performing and Interpreting Diagnostic Computed Tomography (CT)\textsuperscript{1}, and the physician qualifications in the ACR–SNM Technical Standard for Diagnostic Procedures Using Radiopharmaceuticals.

c. Certification in Nuclear Medicine by the ABNM or in special competence in nuclear medicine by the ABR; and involvement with the interpretation, reporting, and/or supervised review 300 PET and/or PET/CT examinations in the past 36 months; 15 hours of PET and PET/CT CME (AMA category 1), at least 8 of which are PET/CT; and meets the physician training and experience requirements of the ACR Practice Guideline for Performing and Interpreting Diagnostic Computed Tomography (CT)\textsuperscript{1}, and the physician qualifications in the ACR–SNM Technical Standard for Diagnostic Procedures Using Radiopharmaceuticals.

Physicians in the certification/training categories in a, b, and c above, but without the recent PET or PET/CT involvement specified may achieve the required PET/CT training experience equivalent by completing and documenting the following:

i. Physician category a: 150 PET and/or PET/CT interpretations in a supervised situation,\textsuperscript{2} at least 100 of which are PET/CT, and 15 hours of PET and/or PET/CT CME, at least 8 of which are PET/CT. The physician training requirements of the ACR Practice Guideline for Performing and Interpreting Diagnostic Computed Tomography (CT) and the physician qualifications in the ACR–SNM Technical Standard for Diagnostic Procedures Using Radiopharmaceuticals must be met.

ii. Physician category b: 200 PET and/or PET/CT interpretations in a supervised situation,\textsuperscript{2} at least 150 of which are PET/CT, and 25 hours of PET and/or PET/CT CME, at least 8 of which are PET/CT. The physician training requirements of the ACR Practice Guideline for Performing and Interpreting Diagnostic Computed Tomography (CT) and the physician qualifications in the ACR–SNM Technical Standard for Diagnostic Procedures Using Radiopharmaceuticals must be met.

\textsuperscript{2}Acceptable ways to have PET/CT and CT case interpretations in a supervised situation include practice-based learning locally or in a visiting fellowship, learning in an interactive live case based on conference where an interpretation is rendered and then scored or critiqued, or distance learning such as over the Internet, in an interactive case-based format where an interpretation is rendered and then scored or critiqued, under the supervision or review of physicians expert in the field.
iii. Physician category c: 150 PET and/or PET/CT interpretations in a supervised situation, at least 100 of which are PET/CT, and 15 hours of PET and/or PET/CT CME, at least 8 of which are PET/CT. The physician training requirements of the ACR Practice Guideline for Performing and Interpreting Diagnostic Computed Tomography (CT) and the physician qualifications in the ACR–SNM Technical Standard for Diagnostic Procedures Using Radiopharmaceuticals must be met.

d. Physicians not board certified in radiology or nuclear medicine, or not trained in a diagnostic radiology residency or nuclear medicine program who assume the responsibilities of supervising, interpreting, and reporting PET/CT examinations, should meet the following criteria: completion of an ACGME approved residency program plus 80 hours of PET and PET/CT CME, at least 40 of which are PET/CT, and supervision, interpretation, and reporting of 500 PET/CT cases in a supervised situation. In addition, these physicians must meet the training requirements in the ACR Practice Guideline for Performing and Interpreting Diagnostic Computed Tomography (CT) and the qualifications in the ACR–SNM Technical Standard for Diagnostic Procedures Using Radiopharmaceuticals.

2. The physician shall have documented training in the physics of nuclear medicine and diagnostic radiology. Additionally, the physician must demonstrate training in the principles of radiation protection; the hazards of radiation exposure to patients, radiological personnel and the public; handling radiopharmaceuticals; and the appropriate regulatory and monitoring requirement.

and

3. The physician should be thoroughly acquainted with the many morphologic, pathologic, and physiologic radiopharmaceutical distributions with artifacts demonstrated on PET/CT. Additionally, the supervising physician should have appropriate knowledge of alternative imaging methods, including the use and indications for general radiography and specialized studies such as angiography, ultrasonography, magnetic resonance imaging (MRI), and alternative nuclear medicine studies.

and

4. The physician should be familiar with patient preparation for the examination. The physician must have training in and knowledge of the properties of radiopharmaceuticals used as well as in the recognition and treatment of adverse effects of contrast materials that may be employed.

and

5. The physician shall have the responsibility for reviewing all indications for the examination; specifying the radiopharmaceutical dose and the type, dose, and administration rate of any contrast materials employed; specifying imaging technique and protocol; treating and documenting any adverse reactions and relevant patient counseling; interpreting images; generating official interpretations (final reports); and maintaining the quality of the images and the interpretations.
The required qualifications set forth in section V.A above will become applicable by July 1, 2009. Until then the physician should work toward achieving these requirements in a supervised situation or where expert consultation is readily available.

Maintenance of Competence

All physicians performing PET/CT examinations should demonstrate evidence of continuing competence in the interpretation and reporting of those examinations. If competence is assured primarily based on continuing experience, a minimum of 75 examinations per year is recommended in order to maintain the physician’s skills. Because a physician’s practice or location may preclude this method, continued competency can also be assured through monitoring and evaluation that indicates acceptable technical success, accuracy of interpretation, and appropriateness of evaluation.

B. Qualified Medical Physicist

A Qualified Medical Physicist is an individual who is competent to practice independently one or more of the subfields in medical physics. The ACR considers certification and continuing education and experience in the appropriate subfield(s) to demonstrate that an individual is competent to practice one or more of the subfields in medical physics and is a Qualified Medical Physicist. The ACR recommends that the individual be certified in the appropriate subfield(s) by the American Board of Radiology (ABR), the Canadian College of Physics in Medicine, or for MRI, by the American Board of Medical Physics (ABMP) in magnetic resonance imaging physics.

The appropriate subfields of medical physics for this standard are Diagnostic Radiological Physics and Radiological Physics.


Certification in Nuclear Medicine Physics and Instrumentation by the American Board of Science in Nuclear Medicine (ABSNM) is also acceptable.

The A Qualified Medical Physicist or other qualified scientist performing services in support of nuclear medicine facilities should meet all of the following criteria:

1. Advanced training directed at the specific area of responsibility (e.g., radiopharmacy, 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.
C. Radiologic and Nuclear Medicine Technologist

See the ACR Practice Guideline for Performing and Interpreting Diagnostic Computed Tomography (CT) and the ACR–SNM Technical Standard for Diagnostic Procedures Using Radiopharmaceuticals.

Representatives of the SNM and the American Society of Radiologic Technologists (ASRT) met in 2002 to discuss the training of technologists for PET/CT. The recommendations from that consensus conference and the plans for training technologists for PET/CT are given in [21]. As a consequence of this conference and ensuing educational recommendations, cross-training and continuing educational programs have been developed to educate radiologic, radiation therapy, and nuclear medicine technologists in PET/CT fusion imaging.

The Nuclear Medicine Technology Certification Board (NMTCB) has developed a PET specialty examination that is open to appropriately educated and trained, certified, or registered nuclear medicine technologists, registered radiologic technologists, CT technologists, and registered radiation therapists, as defined on the NMTCB Web site (www.nmtcb.org). The American Registry of Radiologic Technologists (ARRT) offers a CT certification examination for qualified radiologic technologists and allows certified or registered nuclear medicine technologists who have met the educational and training requirements to take this examination. Eligibility criteria are located on the ARRT Web site (www.arrt.org).

D. Radiation Safety Officer

The Radiation Safety Officer (RSO) must meet applicable requirements of the Nuclear Regulatory Commission (NRC) for training as specified in 10 CFR 35.50, or equivalent state regulations [22].

V. FDG PET/CT EXAMINATION SPECIFICATIONS

A. The written or electronic request for an FDG-PET/CT examination should provide sufficient information to demonstrate the medical necessity of the examination and allow for its proper performance and interpretation. Documentation that satisfies medical necessity includes 1) signs and symptoms and/or 2) relevant history (including known diagnoses).
Additional information regarding the specific reason for the examination or a provisional diagnosis would be helpful and may at times be needed to allow for the proper performance and interpretation of the examination.

The request for the examination must be originated by a physician or other appropriately licensed health care provider. The accompanying clinical information should be provided by a physician or other appropriately licensed health care provider familiar with the patient’s clinical problem or question and consistent with the state scope of practice requirements. (ACR Resolution 35, adopted in 2006)

Section VI. B, C, E, F, have been adapted from reference 23. [23]

Sections VI. B, C, E, F below have been copied adapted from the Journal of Nuclear Medicine, Technology “Procedure Guideline for Tumor Imaging with 18F-FDG PET/CT 1.0,” with permission from the Society of Nuclear Medicine

B. Patient Preparation

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 preparation should include, but not be limited to, the following:

1. Pregnancy testing when appropriate.
2. Fasting instruction (a minimum of 4 hours) and no oral or intravenous fluids containing sugar or dextrose. (4 to 6 hours)
3. Serum glucose analysis should be performed immediately prior to FDG administration.
4. Hydration, typically oral. In special circumstances, intravenous hydration, diuretic administration, or bladder catheterization can be used (a loop diuretic, without or with bladder) catheterization may be used to reduce accumulated tracer activity in the urinary bladder.
5. Keeping the patient in a warm room 30 to 60 minutes prior to injection and until the time of FDG injection to help minimize brown fat uptake. Lorazepam or diazepam given prior to injection of FDG may reduce uptake by brown adipose tissue or skeletal muscle. Beta-blockers may also reduce uptake by brown fat
6. Focused history regarding the reason for examination (symptoms, diagnoses, and recent imaging examinations), treatments and medications, recent trauma or infection, diabetes, and recent exercise. Specific details and dates should be obtained when possible. diabetes, recent exercise, dates of diagnosis and treatments, medications, and recent trauma or infections
7. Strategies to reduce unwanted FDG accumulation, particularly as applicable to children and adolescents.
   a. Warm blankets and warm uptake room during localization can decrease brown fat activity.
b. Pre-medication for anxiety if indicated.

c. Quiet uptake room (decrease anxiety).

d. No strenuous activity 24 hours prior to injection (to decrease muscle uptake).

e. Sedation in children younger than 5 years of age. (See the ACR–SIR Practice Guideline for Sedation/Analgesia.)

7. Patients should void prior to being positioned on the PET/CT table.

C. Radiopharmaceutical

For adults, the amount of radiopharmaceutical \( ^{18} \text{FDG} \) administered activity should be 370 to 740 MBq (10 to 20 mCi), and for children 5.18 to 7.4 MBq/kg (0.14 to 0.20 mCi/kg). Administered activity for children should be determined based on body weight and should be as low as reasonably achievable for diagnostic image quality. When feasible, the radiopharmaceutical should be injected intravenously at a site contralateral to sites of known or suspected disease, the site of concern. With PET/CT, the radiation dose to the patient is the combination of the dose from the PET radiopharmaceutical and the dose from the CT portion of the study. Lower administered activities may be appropriate with advances in PET/CT technology.

D. Protocol for CT Imaging

The CT performed as part of a PET/CT examination provides diagnostic information that may be relevant to both PET interpretation and overall patient care. A variety of protocols exist for performing the CT scan in the context of PET/CT scanning. In some cases, low dose CT scans are designed primarily to provide attenuation correction and anatomic localization. In other cases, the CT portion of the examination is performed as an optimized CT with parameters designed to lower image noise and the addition of intravenous and/or oral contrast material. can be performed either as a diagnostic PET/CT scan with the CT scan obtained for attenuation correction and anatomic correlation or as a diagnostic PET scan and an optimized CT scan, with or without contrast. If a diagnostic CT scan is requested as part of PET/CT, the CT protocol appropriate for the body region(s) requested should be used. Regardless of the CT technique used, a careful review of CT images is necessary for comprehensive interpretation of the PET/CT examination. If the CT scan is obtained for attenuation correction and anatomic correlation, the CT parameters should be set to minimize patient radiation dose, while still ensuring that the CT images are of sufficient quality to allow for accurate anatomic correlation of PET findings.

For a diagnostic CT scan of the abdomen and/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 may be a positive contrast agent such as diluted barium sulfate or

\[ \text{For more specific guidance on pediatric dosing, please refer to the } \textit{Pediatric Radiopharmaceutical Administered Doses: 2010 North American Consensus Guidelines.} \]
diatrizoic acid (e.g., Gastrografin®) or a negative contrast agent such as water. Highly concentrated barium collections may result in an attenuation-correction artifact that leads to a significant overestimation of the regional FDG concentration and should be avoided [24]; diluted barium sulfate and oral iodinated agents cause less overestimation and do not are less likely to have an adverse impact on PET image quality [24-27].

When indicated, the CT scan can be performed with intravenous contrast material using appropriate injection techniques. High intravascular concentrations of intravenous contrast agents may cause an attenuation-correction artifact on the PET image [28,29], but the impact is usually limited [25,30].

PET and CT findings should be correlated with each other. Clinically important findings on the CT scan should be reported.

Breathing patterns during CT acquisition for PET/CT should be optimized so that the positions of the diaphragm that appear on the PET emission and the CT transmission images match as closely as possible.

If a single breath-hold technique is used for CT imaging, optimal alignment of the PET and CT images is obtained with respiration suspended in the quiet end-expiratory (end tidal volume) phase.

E. Protocol for PET Emission Imaging

Emission images are obtained at least 45 minutes following radiopharmaceutical injection. Emission image acquisition time typically varies from 2 to 5 minutes or longer per bed position for body imaging and is based on the administered activity, patient body weight, and the sensitivity of the PET device tomograph (as determined largely by the detector composition and acquisition method).

Semiquantitative estimation of FDG accumulation tumor glucose metabolism using the standardized uptake value (SUV) is based on relative lesion radioactivity local radioactivity concentration measured on images corrected for attenuation and normalized for the injected dose activity and body weight, lean body mass, or body surface area. The accuracy of SUV measurements depends on the accuracy of the calibration of the PET tomograph device, among other factors. As the SUV is becoming a standard for determining tumor response over time, measures should be taken to minimize the factors which may affect it. These include using the same scanner configuration on subsequent examinations (including reconstruction algorithms, attenuation maps, etc.), maintaining the same time between injection and scanning, avoiding infiltration of injected activity, and using the same measurement techniques, (VOI volumes, max/peak/mean measurements). Some factors which affect SUV may be beyond control, such as serum glucose and fasting state. The reproducibility of SUV measurements depends on the reproducibility of clinical protocols, and is affected by dose infiltration, time of imaging after 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, methods of analysis (e.g., max, mean), etc. This measurement is performed on a static emission image typically acquired more than 45 minutes postinjection.

A change of **Recording changes in the** intensity of FDG uptake with semiquantitative measurements, expressed in absolute values and percent changes, may be appropriate in some clinical scenarios. However, the technical protocol and analysis of images need to be more consistent in the two **data sets** of images.

F. Interpretation

With an integrated PET/CT system, the software packages typically provide a **comprehensive platform for image review**, including registered and aligned CT images, FDG-PET images, and PET/CT fusion images in the axial, coronal, and sagittal planes. **In addition**, maximum-intensity-projection (MIP) images of the PET examination should be reviewed in for review in the 3D cine mode. FDG-PET images with and without attenuation correction should be available for review.

Normal and variable physiologic uptake of FDG can be seen to some extent in every viable tissue, including the brain, myocardium (where the **high** uptake is significant **can be seen** 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.

On whole-body scans, studies have shown that FDG-PET imaging of the brain is relatively insensitive for detecting cerebral and cerebellar metastases, partially related to the high physiologic FDG uptake in the normal gray matter.

Although the pattern of FDG uptake and specific **associated** CT findings as well as correlation with history, physical examination and other imaging modalities are usually the most helpful in differentiating benign from malignant lesions, semiquantitative estimates (e.g., SUV) may also be of value, especially for evaluating changes with time or therapy.

**Processes** Tissues other than neoplastic disease malignancies may **show substantial** FDG uptake. Other conditions may lead to poor FDG uptake in neoplastic tissue, cause false-positive and false-negative results. The following list, although not all-inclusive, includes the most commonly encountered situations in which **FDG uptake is caused by processes other than malignant disease, and in which FDG uptake does not occur despite the presence of malignant disease**:

1. **Situations which can lead to false-positive FDG-PET/CT interpretation:**
   a. Physiologic uptake that may lead to false-positive interpretations
      - Salivary glands and lymphoid tissue in the head and neck.
      - Thyroid.
Brown adipose tissue.
Thymus, especially in children.
Lactating breast.
Areola.
Skeletal and smooth muscle (more marked with hyperinsulinemia).
Gastrointestinal (e.g., esophagus, stomach, bowel).
Urinary tract structures (containing excreted FDG).
Female genital tract (e.g., uterus during menses, corpus luteum cyst).

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

c. Benign neoplasms tumor or tumor like conditions
- Pituitary adenoma.
- Adrenal adenoma.
- Thyroid gland follicular adenoma.
- Salivary gland tumors (e.g., Warthin’s, pleomorphic adenoma).
- Colonic adenomatous polyps. and villous adenoma.
- Ovarian thecoma and cystadenoma.
- Giant cell tumor.
- Aneurysmal bone cyst.
- Fibrous cortical defects (in pediatric patients).
- Leiomyoma.

d. Hyperplasia and dysplasia conditions
- Graves’ disease.
- Cushing’s disease.
- Bone marrow hyperplasia (e.g., anemia, colony stimulating factor). cytokine therapy).
- Thymic rebound hyperplasia (after chemotherapy).
- Fibrous dysplasia.
- Paget’s disease.
NOT FOR PUBLICATION, QUOTATION, OR CITATION

e. Ischemia
   - Hibernating myocardium

e. 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. Situations that can lead to false-negative FDG-PET/CT interpretation:

   - Small lesion size (< 2 x resolution of the system).
   - Tumor necrosis
   - Recent chemotherapy or radiotherapy
   - Recent high-dose steroid therapy
   - Hyperglycemia and hyperinsulinemia.
   - Recent therapy
     - Chemotherapy.
     - Radiotherapy.
     - Steroid therapy.
     - Certain low-grade or well-differentiated tumors, such as mucinous neoplasms including bronchoalveolar-subtype lung adenocarcinomas.
     - Prostate carcinoma.
     - Carcinoid tumor and islet cell tumors.
     - Medullary thyroid cancer.
     - Lobular carcinoma of the breast.
     - Hepatocellular tumors, including well-differentiated hepatocellular carcinoma.
     - Indolent lymphoma, including marginal zone lymphoma and small lymphocytic lymphoma.

   - Some low-grade tumors (e.g., sarcoma, lymphoma, 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 bronchialalveolar carcinomas
   - Some lobular carcinomas of the breast
   - Some skeletal metastases, especially osteoblastic or sclerotic tumors
   - Some osteosarcomas
VI. EQUIPMENT SPECIFICATIONS

See the ACR Technical Standard for Medical Nuclear Physics Performance Monitoring of PET/CT Imaging Equipment, the ACR–ASNR–SPR Practice Guideline for the Performance of Computed Tomography (CT) 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–SPR Practice Guideline for the Performance of Computed Tomography (CT) of the Abdomen and Computed Tomography (CT) of the Pelvis.

A. Performance Guidelines

For patient imaging, the PET/CT scanner should meet or exceed the following specifications:

1. For the PET scanner
   a. In-plane spatial resolution: <6.5 mm.
   b. Axial resolution: <6.5 mm.
   c. Sensitivity (3D): >4.0 cps/kBq.
   d. Sensitivity (2D): >1.0 cps/kBq.
   e. Uniformity: <5%.

2. For the CT scanner
   a. Spiral scan time: <5 seconds (<2 seconds is preferable).
   b. Slice thickness and collimation: <5 mm (<2 mm is preferable).
   c. Limiting spatial resolution: >8 lp/cm for >32 cm display field of view (DFOV) and >10 lp/cm for <24 cm DFOV.

3. For the combined PET/CT scanner
   a. Maximum co-scan range (CT and PET): >160 cm.
   c. Patient port diameter: >59 cm.

B. Appropriate emergency equipment and medications must be immediately available to treat adverse reactions associated with administered medications. The equipment and medications should be monitored for inventory and drug expiration dates on a regular basis. The equipment, medications, and other emergency support must also be appropriate for the range of ages and sizes in the patient population.

C. A fusion workstation with the capability to display PET, CT, and fused images with different percentages of PET and CT blending should also be available. The workstation should also have the capability to measure SUV, preferably with volumetric ROI.

D. PET/CT scanning done specifically for radiation therapy planning should be performed with a flat table top, immobilization devices as needed, and the use of appropriate positioning systems.
VII. DOCUMENTATION

A. Reporting should be in accordance with the ACR Practice Guideline for Communication of Diagnostic Imaging Findings.

In addition, the procedure section should include the dose of radiopharmaceutical, route of administration, uptake time, field of view, patient positioning, and baseline glucose level.

The report should include the radiopharmaceutical used, the dose, and the dose and route of administration, as well as any other pharmaceuticals administered. The serum glucose level at the time of radiotracer administration should be reported. Details of oral or intravenous contrast agents, if used for the CTAC portion of the examination should also be reported, to include the volume, rate, and route of administration. Other information relevant to contrast administration, such as steroid preparation, prehydration, or dialysis history, should be included. The report should also include documentation of contrast reactions and subsequent treatment, if observed during the study.

The findings section should include description of the location, extent, and intensity of abnormal FDG uptake in relation to normal comparable tissues and describe the relevant morphologic findings related to PET abnormalities on the CT images. An estimate of the intensity of FDG uptake can be provided with the SUV; however, the intensity of uptake may be described as mild, moderate, or intense in relation to the background uptake in normal hepatic parenchyma. (average SUV weight: 2.0 to 3.0, maximum SUV: 3.0 to 4.0)

If the CT scan was requested and performed as a diagnostic examination, the CT component of the study may should be reported separately if necessary to satisfy regulatory, administrative, or reimbursement requirements. In that case, the PET/CT report can should refer to the diagnostic CT scan report for findings not related to the PET/CT combined findings [31-33].

When PET/CT is performed for monitoring therapy, a comparison of extent and intensity of uptake may be summarized as metabolic progressive disease, metabolic stable disease, metabolic partial response, or metabolic complete response using published criteria for these categories [34,35].

VIII. EQUIPMENT QUALITY CONTROL

PET performance monitoring should be in accordance with the ACR Technical Standard for Medical Nuclear Physics Performance Monitoring of Gamma Cameras and the ACR Technical Standard for Medical Nuclear Physics Performance Monitoring of PET/CT Imaging Equipment.
CT monitoring should be in accordance with the ACR Technical Standard for Diagnostic Medical Physics Performance Monitoring of Computed Tomography (CT) Equipment.

The quality control (QC) procedures for PET/CT should include both the PET procedures and the CT procedures according to the ACR Technical Standards. The QC procedures for PET should include a calibration measurement of activity in a phantom containing a known radionuclide concentration, generally as a function of axial position within the scanner field of view. The QC procedures for the CT should include air and water calibrations in Hounsfield units for a range of kV. A daily check on the stability of the individual detectors should also be performed to identify detector failures and drifts.

In addition, for PET/CT, the alignment between the PET and CT scanners should be checked periodically. Such a check should determine an offset between the PET and CT scanners that is incorporated into the fused image display to ensure accurate image alignment.

IX. RADIATION SAFETY IN IMAGING

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

Facilities, in consultation with the medical physicist should have in place and should adhere to policies and procedures, in accordance with ALARA, to vary examination protocols to take into account patient body habitus, such as height and/or weight, body mass index or lateral width. The dose reduction devices that are available on imaging equipment should be active; if not; manual techniques should be used to moderate the exposure while maintaining the necessary diagnostic image quality. Periodically, radiation exposures should be measured and patient radiation doses estimated by a medical physicist in accordance with the appropriate ACR Technical Standard. (ACR Resolution 17, adopted in 2006 – revised in 2009, Resolution 11)

X. QUALITY CONTROL AND IMPROVEMENT, SAFETY, INFECTION CONTROL, AND PATIENT EDUCATION

Policies and procedures related to quality, patient education, infection control, and safety should be developed and implemented in accordance with the ACR Policy on Quality Control and Improvement, Safety, Infection Control, and Patient Education appearing under the heading Position Statement on QC & Improvement, Safety, Infection Control, and Patient Education on the ACR web site (http://www.acr.org/guidelines).
In all pediatric patients, the lowest exposure factors should be chosen that would produce images of diagnostic quality.

For specific issues regarding CT quality control, see the ACR Practice Guideline for Performing and Interpreting Diagnostic Computed Tomography (CT).

For specific issues regarding PET and PET/CT quality control, see section IX on Equipment Quality Control.

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

ACKNOWLEDGEMENTS

This guideline was revised according to the process described under the heading The Process for Developing ACR Practice Guidelines and Technical Standards on the ACR web site (http://www.acr.org/guidelines) by the Guidelines and Standards Committees of the Commissions on Nuclear Medicine and Pediatric Radiology in collaboration with the SPR.

Collaborative Committee – members represent their societies in the initial and final revision of this guideline

ACR

Eric M. Rohren, MD, PhD, Chair
Marguerite T. Parisi, MD, MS
Rathan Subramaniam, MD, PhD
Terence Z. Wong, MD, PhD

SPR

Helen R. Nadel, MD
Susan E. Sharp, MD
Lisa J. States, MD

ACR Guidelines and Standards Committee – Nuclear Medicine – ACR Committee

Darlene F. Metter, MD, FACR, Co-Chair
Jay A. Harolds, MD, FACR, Co-Chair
Thomas W. Allen, MD
Richard K.J. Brown, MD
Robert F. Carretta, MD
Gary L. Dillehay, MD, FACR
Lorraine M. Fig, MD, MB, ChB, MPH
Leonie L. Gordon, MD
REFERENCES


*Guidelines and standards are published annually with an effective date of October 1 in the year in which amended, revised or approved by the ACR Council. For guidelines and standards published before 1999, the effective date was January 1 following the year in which the guideline or standard was amended, revised, or approved by the ACR Council.

**Development Chronology for this Guideline**

2007 (Resolution 19)

Amended 2009 (Resolution 11)