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

PREAMBLE

This document is an educational tool designed to assist practitioners in providing appropriate radiologic care for patients. Practice Parameters and Technical Standards are not inflexible rules or requirements of practice and are not intended, nor should they be used, to establish a legal standard of care¹. For these reasons and those set forth below, the American College of Radiology and our collaborating medical specialty societies caution against the use of these documents 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 practitioner in light of all the circumstances presented. Thus, an approach that differs from the guidance in this document, 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 this document 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 this document. However, a practitioner who employs an approach substantially different from the guidance in this document 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 the guidance in this document 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 this document is to assist practitioners in achieving this objective.

¹ *Iowa Medical Society and Iowa Society of Anesthesiologists v. Iowa Board of Nursing*, _ N.W.2d _ (Iowa 2013) Iowa Supreme Court refuses to find that the *ACR Technical Standard for Management of the Use of Radiation in Fluoroscopic Procedures* (Revised 2008) sets a national standard for who may perform fluoroscopic procedures in light of the standard's stated purpose that ACR standards are educational tools and not intended to establish a legal standard of care. See also, *Stanley v. McCarver*, 63 P.3d 1076 (Ariz. App. 2003) where in a concurring opinion the Court stated that "published standards or guidelines of specialty medical organizations are useful in determining the duty owed or the standard of care applicable in a given situation" even though ACR standards themselves do not establish the standard of care.

I. INTRODUCTION

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

FDG-PET is a scintigraphic technique that provides information about glucose metabolism in the body and is a sensitive method for detecting, staging, and monitoring the effects of therapy for many malignancies. Computed tomography (CT) uses an external source of radiation to produce 3-D images that demonstrate the size, shape, and composition 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 [2-17]. 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 parameter pertains only to hybrid PET/CT devices.

Issues related to PET/CT practice include equipment specifications, image acquisition protocols, supervision, interpretation, professional qualifications, and safety. A discussion of these issues by representatives of the ACR, the Society of Nuclear Medicine and Molecular Imaging (SNMMI), and the Society of Computed Body Tomography and Magnetic Resonance (SCBT-MR) is available [18,19].

II. DEFINITIONS

For the purposes of this practice parameter, the following definitions apply:

PET/CT scanner: A hybrid device that includes a single patient table for acquiring a PET scan and CT scan in sequential fashion. 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 tumor imaging can be tailored to suit the specific indications, such as skull vertex to midhighs, with the following fields of view considered standard [20]:

1. Whole body from skull vertex through feet
2. Skull base to midhighs
3. Limited region (eg, brain only, chest only)

PET/CT registration: The process of aligning PET and CT image sets that represent the same body volume such that there is a voxel-by-voxel match for the purpose of attenuation correction as well as combined image display (fusion)

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. Staging on presentation for guiding initial treatment strategy in patients with a known malignancy

2. Monitoring response to therapy to include determining whether residual abnormalities identified with another imaging modality represent persistent viable tumor or post-treatment changes (inflammation, fibrosis, or necrosis)
3. Restaging in the setting of relapse
4. Attempting to localize the site of primary tumor when metastatic disease is the initial manifestation of malignancy
5. Verifying and localizing “occult” disease, especially in the presence of clinical indicators such as elevated tumor markers
6. Evaluating an abnormality considered “indeterminate” by another imaging modality to determine whether glucose metabolism in that abnormality favors a benign or malignant process
7. Guiding specific clinical strategies, such as radiation therapy planning or directed biopsy

FDG uptake is variable for different tumor types and can range from high to low uptake. A continuing review of the literature is recommended to determine the most effective applications.

For information on radiation risks to the fetus, see the [ACR–SPR Practice Parameter for Imaging Pregnant or Potentially Pregnant Adolescents and Women with Ionizing Radiation](#) [21].

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, or Interventional Radiology/Diagnostic Radiology (IR/DR) by the American Board of Radiology (ABR), the American Osteopathic Board of 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 for 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 and 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. At least 150 oncologic PET/CT examinations must be interpreted or multi-read during the previous 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

Interpret a minimum of 150 PET/CT examinations in 3 years (multi-reading is acceptable).

Continuing Education

Complete 150 hours (that include 75 hours of Category 1 CME) during the preceding 3 years pertinent to the physician’s practice patterns, including PET imaging.

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 of imaging procedures and the safe handling of radioactive materials.

B. Qualified Medical Physicist

For Qualified Medical Physicist qualifications, see the [ACR–AAPM Technical Standard for Medical Physics Performance Monitoring of PET/CT Imaging Equipment](#) [22].

C. Radiologic and Nuclear Medicine Technologist

Representatives of the SNMMI and the American Society of Radiologic Technologists (ASRT) met in 2002 to discuss the training and certification of technologists for PET/CT. The recommendations from that conference are outlined in the published consensus statement [23]. A key point is that technologists operating hybrid PET/CT units would ideally be a credentialed in both CT and nuclear medicine. However, that is a goal and not a requirement and any registered radiographer with the credential R.T.(R), registered radiation therapist with the credential R.T.(T), registered nuclear medicine technologist with the credentials R.T.(N) or a certified nuclear medicine technologist C.N.M.T. may operate PET/CT equipment after obtaining appropriate additional education or training and demonstrating competency.

As a result of the consensus conference, a PET/CT Project Group meeting was convened by the ASRT and the Society of Nuclear Medicine Technologist Section to identify the skills and knowledge required for technologists performing PET/CT examinations and to recommend educational pathways for technologists to transition to PET/CT. The PET/CT curriculum was a product of this meeting (<http://www.asrt.org/educators/asrt-curricula/pet-ct>).

The Nuclear Medicine Technology Certification Board (NMTCB) has developed PET and CT specialty examinations (www.nmtcb.org) and the American Registry of Radiologic Technologists (ARRT) offers a CT certification examination (www.arrt.org).

For more information regarding training and certification, see the [ACR Practice Parameter for Performing and Interpreting Diagnostic Computed Tomography \(CT\)](#) and the [ACR–SPR Technical Standard for Diagnostic Procedures Using Radiopharmaceuticals](#) [24,25].

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 [26].

V. FDG PET/CT EXAMINATION SPECIFICATIONS

See the [ACR–ASNR–SPR Practice Parameter for the Performance of Computed Tomography \(CT\) of the Extracranial Head and Neck](#), the [ACR–SCBT-MR–SPR Practice Parameter for the Performance of Thoracic Computed Tomography \(CT\)](#), and the [ACR–SPR Practice Parameter for the Performance of Computed Tomography \(CT\) of the Abdomen and Computed Tomography \(CT\) of the Pelvis](#) [27-29].

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)

B. Patient Preparation [30]

The major goals of preparation are to minimize radiopharmaceutical uptake in normal tissues, such as the myocardium, skeletal muscle, and brown fat, while maintaining uptake in target tissues (neoplastic disease). The preparation should include, but not be limited to, the following:

1. Prior to appointment:
 - a. Instruct patients to avoid strenuous activity 24 hours prior to FDG injection.
 - b. Recommend low-carbohydrate meals for 24 hours prior to FDG injection and no alcohol the evening prior to examination.
 - c. Provide fasting instructions (a minimum of 4 hours) with no parenteral nutrition or oral/intravenous fluids containing sugar or dextrose for the same period.
 - d. Encourage oral hydration with a goal of 1 L (34 oz) in 2 hours prior to appointment [30-32].
2. Prior to FDG injection:
 - a. Perform pregnancy testing when appropriate (see the [ACR-SPR Practice Parameter for Imaging Pregnant or Potentially Pregnant Adolescents and Women with Ionizing Radiation](#)) [21].
 - b. Obtain a focused history that includes:
 - i. Reason for examination (symptoms, diagnoses, and recent imaging examinations)
 - ii. Treatment (surgical, radiation, and/or chemotherapy)
 - iii. Medications
 - iv. Recent trauma/exercise
 - v. Presence of concurrent infection
 - vi. Presence of diabetes
 - vii. Specific details and dates should be obtained whenever possible.
 - c. Consider premedications:
 - i. Anxiolytics can be administered in patients with claustrophobia or anxiety. Oral alprazolam (0.5 mg given 10 to 60 minutes prior to FDG injection) is an option, though patients must be counseled against driving given the medication's sedative and motor-impairing effects.
 - ii. Oral beta-blockers, such as propranolol 20 mg, can be administered 60 minutes prior to injection to patients with a history of prominent brown fat uptake, but the utility of this intervention is unclear.
 - iii. Intravenous narcotic pain medications, such as fentanyl, can be administered shortly before FDG injection as an alternative means of limiting brown fat uptake of FDG [33].
 - d. Serum glucose analysis performed immediately prior to FDG administration (<200 mg/dL acceptable)
 - i. If the serum glucose is >200 mg/dL, then the patient should usually be rescheduled. Prior to rescheduling, a repeat measurement can be performed in about 20 to 30 minutes. If the serum glucose level decreases to 200 mg/dL, then FDG can be administered. If the serum glucose level is decreasing but still >200 mg/dL, then another repeat measurement can be performed in about 20 to 30 minutes or FDG can be administered at the discretion of the interpreting physician.
 - ii. If the serum glucose is >300 mg/dL, then the patient should be rescheduled.
 - e. Diabetic patient guidelines:
 - i. PET scan should be scheduled early in the morning (if possible) as this is the time that most diabetic patients have the lowest glucose level. However, some diabetic patients may have lower glucose levels in the afternoon, and for these patients an afternoon appointment is preferable.
 - ii. Diabetic patients should take their usual insulin or oral medications the day before; after midnight patients should fast (except for water) and take nondiabetic medications.

- iii. On the morning of the PET scan, hold all insulin and oral medications if FDG injection is scheduled in the early morning.
 - iv. If PET scan is scheduled after 10 AM, patient should eat a low-carbohydrate breakfast at least 4 hours before the injection of 1/2 of usual regular (short-acting) insulin or regular dosage of oral medications at least 4 hours before the appointment. Do not use long-acting or mixed (70/30) insulin after midnight.
 - v. If the patient is on an insulin pump alone, the setting should be maintained until the start of the PET scan. After the PET scan, settings can be adjusted as prescribed.
 - vi. After completion of the PET scan, patients should be encouraged to eat a meal immediately. It may be advisable for patients to take 1/2 of the usual morning dosage of insulin or regular dosage of oral medications with the post-PET meal to avoid the risk of hypoglycemia.
 - vii. Technologist should inform the interpreting physician if the patient has hyperglycemia >200 mg/dL or hypoglycemia <70 mg/dL. In these situations waiting approximately 20 to 30 minutes and repeating a finger-stick glucose measurement should be considered prior to rescheduling the patient. When there is hypoglycemia, the patient should be treated and rescheduled.
3. Following injection (uptake period):
- a. Have patient remain seated or recumbent in a quiet room during uptake period (decreases muscle uptake). Additionally, in adult patients with head and neck cancer, oral alprazolam 0.5 mg given immediately after FDG injection reportedly can reduce skeletal muscle uptake that can impede lesion detection and confound scan interpretation [34].
 - b. Consider use of heated blankets and a warm waiting room during uptake period (decreases brown fat activity).
 - c. Patients should void immediately prior to being positioned on the PET/CT table for imaging. In special circumstances, intravenous hydration, diuretic administration, and/or bladder catheterization can be used to reduce radiation burden and artifacts related to accumulated physiologic radiopharmaceutical activity in the ureters and urinary bladder.
 - d. Consider use of sedation as necessary in younger children or developmentally delayed patients. (See the [ACR–SIR Practice Parameter for Sedation/Analgesia](#) [35].)

C. Radiopharmaceutical

For adults, the administered activity of FDG should be 185 to 740 MBq (5 to 20 mCi).

For children, the administered activity of FDG should be determined based on body weight and should be as low as reasonably achievable (ALARA) for diagnostic image quality.² Typically, the dosage range for children is 3.7 to 5.2 MBq/kg (0.10 to 0.14 mCi/kg).

The specific administered activity typically depends upon the local imaging protocol. The local protocol may require a standard activity or the activity may vary as a function of various parameters such as patient size, scanning mode (2-D versus 3-D), percentage of scan bed (slice) overlap, or clinical indication. For variable dosages, other means of determining the administered activity can be based upon a combination of factors, for example, as outlined in European Association of Nuclear Medicine guidelines [36], which use the patient's weight, duration of bed positions in minutes, and percent bed position overlap in certain PET/CT systems (some systems do not use bed positions). The variable dose calculation's goal is to optimize a personalized dosage with the ALARA principle. Without a dedicated dosage injector with the ability to precisely elute a calculated dosage, a fixed dose with a range may be more practical for adults. To date there are no clear data providing evidence of superiority of parameter-dependent administered activity protocols [37].

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 examination. Lower administered activities or changes in CT parameters resulting in decreased radiation dose may be appropriate with advances in PET/CT technology.

²For more specific guidance on pediatric dosing, please refer to the *Pediatric Radiopharmaceutical Administered Doses: 2010 North American Consensus Guidelines*.

When feasible, the radiopharmaceutical should be injected intravenously at a site away from sites of known or suspected disease.

D. Protocol for CT Imaging

The CT performed as part of a PET/CT examination provides attenuation-correction information and 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 with intravenous and/or oral contrast media and optimized CT parameters designed to lower image noise. 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.

For a diagnostic CT scan of the abdomen and/or pelvis, intraluminal gastrointestinal contrast media may be administered to improve visualization of the gastrointestinal tract unless medically contraindicated or unnecessary for the clinical indication. This may be positive-contrast media such as diluted barium sulfate or diatrizoic acid or negative-contrast media 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 [38]; dilute barium sulfate and oral iodinated contrast media cause less overestimation and are less likely to have an adverse impact on PET image quality [38-41].

When indicated, the CT scan can be performed with intravenous contrast media using appropriate injection techniques. High intravascular concentrations of intravenous contrast media may cause a localized attenuation-correction artifact on the PET image [39,42], but the impact is usually limited [39,43].

Breathing patterns during CT acquisition should be optimized so that the positions of the diaphragm 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. If respiration is not suspended during CT imaging, the patient should be coached on shallow/quiet breathing. To optimize breathing pattern, gating of the PET and/or CT can be performed in more modern PET/CT scanners.

E. Protocol for PET Emission Imaging

Emission images are generally obtained 60 minutes following radiopharmaceutical administration. However, this time period may be shorter (no less than 45 minutes) or longer for certain trials or unique clinical situations. Note that consistency of standardized uptake value (SUV) measurements depends on strict observance of the uptake time; therefore, when using a 60-minute interval, an acceptable range of injection to scan time is 55 to 75 minutes [44].

Emission image acquisition time typically varies from 1 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 (as determined largely by the detector composition and acquisition method). Acquisition time can be adjusted in certain clinical situations to provide higher count images in a given anatomic area.

Semiquantitative estimation of FDG accumulation using the SUV is based on local radioactivity concentration measured on images corrected for attenuation and normalized for the injected 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 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 that may affect it. These include using the same scanner

configuration on subsequent examinations (including reconstruction algorithms, attenuation maps, etc), maintaining the same interval between injection and scanning, avoiding infiltration of injected activity, and using the same measurement techniques, (VOI volumes, max/peak/mean measurements). Some factors that affect SUV currently remain beyond control, such as variations in serum glucose and patient motion/breathing-related attenuation-correction artifacts [45].

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 consistent in the 2 data sets.

F. Interpretation

With integrated PET/CT systems, the software packages typically provide a comprehensive platform for image review, including registered and aligned CT images, FDG-PET images with and without attenuation correction, 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 generated for review. FDG-PET images with and without attenuation correction should be available for review.

On whole-body scans, studies have shown that FDG-PET imaging of the brain is relatively insensitive for detecting cerebral and cerebellar metastases. This is due in part to the high physiologic FDG uptake in the normal gray matter, and thus images of the brain should be reviewed with attention to both FDG-avid and photopenia (non-FDG-avid) areas.

Although the pattern of FDG uptake and 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 (eg, SUV) may also be of value, especially for evaluating changes with time or therapy.

Tissues other than neoplastic disease may show substantial FDG uptake. Other conditions may lead to poor FDG uptake in neoplastic tissue. 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 that can lead to false-positive FDG-PET/CT interpretation:
 - a. Physiologic uptake
 - Salivary glands and lymphoid tissue in the head and neck
 - Thyroid
 - Orbital, speech, and tongue muscle (especially in children)
 - Brown adipose tissue
 - Thymus, especially in children and young adults
 - Lactating breast
 - Areola
 - Skeletal and smooth muscle (more marked with hyperinsulinemia)
 - Gastrointestinal tract (eg, esophagus, stomach, bowel, and anal sphincter, with large-bowel uptake often very intense in patients using metformin)
 - Urinary tract structures (containing excreted FDG)
 - Female genital tract (eg, uterus during menses, corpus luteum cyst)
 - Skeletal physes (in children)
 - Ischiopubic synchondrosis
 - b. Inflammatory processes
 - Postsurgical inflammation/infection/hematoma, biopsy site, amputation site
 - Postradiation inflammation (eg, radiation pneumonitis)
 - Postchemotherapy changes, including inflammation and necrosis

- Local inflammatory disease, especially granulomatous processes (eg, sarcoidosis, fungal and mycobacterial disease)
 - Ostomy site (eg, trachea, colon) feeding and drainage tubes
 - Injection site
 - Thyroiditis
 - Esophagitis, gastritis, inflammatory bowel disease, appendicitis
 - Acute and occasionally chronic pancreatitis
 - Acute cholangitis and cholecystitis
 - Osteomyelitis, recent fractures, joint prostheses
 - Lymphadenitis and reactive lymph nodes (especially in children)
 - Vascular inflammation, including vasculitis and atherosclerotic disease
- c. Benign tumor or tumor-like conditions
- Pituitary adenoma
 - Adrenal adenoma
 - Thyroid gland follicular adenoma
 - Salivary gland tumors (eg, Warthin, pleomorphic adenoma)
 - Colonic adenomatous polyps
 - Ovarian thecoma and cystadenoma
 - Giant cell tumor
 - Aneurysmal bone cyst
 - Benign fibro-osseous lesions (in pediatric patients)
 - Leiomyoma
- d. Hyperplastic and dysplastic conditions
- Graves disease
 - Cushing disease
 - Bone marrow hyperplasia (eg, anemia, colony-stimulating factor)
 - Thymic rebound hyperplasia (after chemotherapy)
 - Fibrous dysplasia
 - Paget disease
- e. Artifacts
- Misalignment between PET and CT data can cause attenuation correction artifacts. Fusion images and PET images without attenuation correction 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 implanted devices, metal, highly concentrated iodinated contrast, 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 ($<2 \times$ resolution of the system)
 - Hyperglycemia and hyperinsulinemia
 - Recent therapy
 - > Chemotherapy
 - > Radiotherapy
 - > Steroid therapy
 - Tumors with low metabolic activity
 - > Certain low-grade or well-differentiated tumors, such as mucinous neoplasms including lung adenocarcinoma in situ
 - > 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 cell lymphocytic lymphoma

VI. EQUIPMENT SPECIFICATIONS

See the [ACR–AAPM Technical Standard for Medical Physics Performance Monitoring of PET/CT Imaging Equipment](#), the [ACR–ASNR–SPR Practice Parameter for the Performance of Computed Tomography \(CT\) of the Extracranial Head and Neck](#), the [ACR–SCBT–MR–SPR Practice Parameter for the Performance of Thoracic Computed Tomography \(CT\)](#), and the [ACR–SPR Practice Parameter for the Performance of Computed Tomography \(CT\) of the Abdomen and Computed Tomography \(CT\) of the Pelvis](#) [22,27-29].

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 (3-D): >4.0 cps/kBq
 - d. Sensitivity (2-D): >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
 - b. Maximum patient weight: >350 lb
 - c. Patient port diameter: >59 cm

B. Appropriate emergency equipment and medications must be immediately available to treat adverse reactions associated with administered medications, to include iodinated contrast media. 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 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 in order to best match patient positioning during radiation therapy.

VII. DOCUMENTATION

A. Reporting should be in accordance with the [ACR Practice Parameter for Communication of Diagnostic Imaging Findings](#) [46].

The technique section of the report should include the radiopharmaceutical (eg, 18F-FDG), the administered activity, route and site of administration, as well as any pharmaceuticals administered (eg, diuretics, benzodiazepines). The serum glucose level at the time of radiopharmaceutical administration should be reported

as well as patient weight, time from injection to scanning, and technique for calculating SUVs (ie, body weight, lean body weight, or body surface area) [47].

Details of oral or intravenous contrast agents, if used for the CT attenuation-correction portion of the examination, should also be reported, to include the volume 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 examination.

The findings section should include description of the location, extent, and intensity of abnormal FDG uptake in relation to normal comparable tissues and should describe the relevant morphologic findings on the CT images. Ideally, image and series numbers should also be included. Additionally, background activity (eg, mediastinal blood pool and/or volumetric normal liver) should be measured to help ensure comparable SUV values [48]. Often injection-site infiltrates, such as in arms, or attenuation-correction errors can significantly alter SUV values in lesions, leading to false conclusions. 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 or the mediastinal blood pool.

If the CT scan was requested and performed as a diagnostic examination, the CT component of the examination should be reported separately to satisfy regulatory, administrative, or reimbursement requirements. In that case, the PET/CT report should refer to the diagnostic CT scan report for findings not related to the PET/CT combined findings [49-51]. Even if the CT scan was not requested as a diagnostic examination, clinically important non-oncologic findings (eg, pneumothorax, aortic aneurysm, bowel obstruction, pneumoperitoneum, fracture) on the CT scan should be reported.

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 [52,53].

VIII. EQUIPMENT QUALITY CONTROL

PET performance monitoring should be in accordance with the [ACR–AAPM Technical Standard for Medical Nuclear Physics Performance Monitoring of Gamma Cameras](#) and the [ACR–AAPM Technical Standard for Medical Physics Performance Monitoring of PET/CT Imaging Equipment](#) [22,54].

CT monitoring should be in accordance with the [ACR–AAPM Technical Standard for Diagnostic Medical Physics Performance Monitoring of Computed Tomography \(CT\) Equipment](#) [55].

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 radiopharmaceutical 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, registered radiologist assistants, radiologic technologists, and all supervising physicians have a responsibility for safety in the workplace by keeping radiation exposure to staff, and to society

as a whole, “as low as reasonably achievable” (ALARA) and to assure that radiation doses to individual patients are appropriate, taking into account the possible risk from radiation exposure and the diagnostic image quality necessary to achieve the clinical objective. All personnel that work with ionizing radiation must understand the key principles of occupational and public radiation protection (justification, optimization of protection and application of dose limits) and the principles of proper management of radiation dose to patients (justification, optimization and the use of dose reference levels)

http://www-pub.iaea.org/MTCD/Publications/PDF/Pub1578_web-57265295.pdf.

Nationally developed guidelines, such as the ACR [Appropriateness Criteria](#)[®], should be used to help choose the most appropriate imaging procedures to prevent unwarranted radiation exposure.

Facilities should have and adhere to policies and procedures that require varying ionizing radiation examination protocols (plain radiography, fluoroscopy, interventional radiology, CT) to take into account patient body habitus (such as patient dimensions, weight, or body mass index) to optimize the relationship between minimal radiation dose and adequate image quality. Automated dose reduction technologies available on imaging equipment should be used whenever appropriate. If such technology is not available, appropriate manual techniques should be used.

Additional information regarding patient radiation safety in imaging is available at the Image Gently[®] for children (www.imagegently.org) and Image Wisely[®] for adults (www.imagewisely.org) websites. These advocacy and awareness campaigns provide free educational materials for all stakeholders involved in imaging (patients, technologists, referring providers, medical physicists, and radiologists).

Radiation exposures or other dose indices should be measured and patient radiation dose estimated for representative examinations and types of patients by a Qualified Medical Physicist in accordance with the applicable ACR technical standards. Regular auditing of patient dose indices should be performed by comparing the facility’s dose information with national benchmarks, such as the ACR Dose Index Registry, the NCRP Report No. 172, Reference Levels and Achievable Doses in Medical and Dental Imaging: Recommendations for the United States or the Conference of Radiation Control Program Director’s National Evaluation of X-ray Trends. (ACR Resolution 17 adopted in 2006 – revised in 2009, 2013, Resolution 52).

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 website (<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 Parameter for Performing and Interpreting Diagnostic Computed Tomography \(CT\)](#) [24].

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

Equipment performance monitoring should be in accordance with the [ACR–AAPM Technical Standard for Diagnostic Medical Physics Performance Monitoring of Computed Tomography \(CT\) Equipment](#) [55].

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