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Procedure Guideline for Tumor Imaging Using Fluorine-18-FDG

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PART I: PURPOSE

The purpose of this guideline is to assist nuclear medicine practitioners in recommending, performing, interpreting and reporting the results of 18-fluoro-2-deoxyglucose (FDG) imaging in the evaluation of patients with suspected malignant disease, for staging malignant disease or for monitoring therapy.

PART II: BACKGROUND INFORMATION AND DEFINITIONS

There is a growing body of evidence for the use of FDG in differentiating malignant from benign disease, staging and grading malignant disease, differentiating recurrent disease from therapy-induced changes and monitoring response to therapy.

Depending on the clinical question and type of equipment available, the FDG imaging procedure may include the following:

Limited-Field Tomographic Images: Usually performed when critical abnormalities are likely to be localized in a known region of the body (e.g., probable lung carcinoma, evaluation of hilar lymph node involvement).

Dynamic Tomographic Images: Consist of multiple sequential three-dimensional images in a limited field. This type of acquisition often is used when quantitation of regional metabolic rates is needed.

Whole-Body Tomographic Images: Usually performed to survey the entire body to search for areas of abnormal FDG accumulation.

Attenuation Correction: The method for correcting emission photon attenuation by either:

Transmission Imaging: A set of corresponding images are acquired with an external source of radiation. Typically, these images are acquired with PET.

Mathematical Attenuation Correction: Typically used in brain imaging, where an estimated attenuation correction based on the emission data may be used instead of actually acquiring transmission data.

PART III: COMMON INDICATIONS

A. Differentiation of benign from malignant lesions (*2,3,6,7*).
B. Staging of malignant disease (*7,10,11*).
C. Grading of malignant brain lesions (*2,3*).
D. Differentiation of recurrent malignant disease from therapy-induced changes (*4,9,12*).
E. Monitoring response to therapy for breast cancer (*13*).

PART IV: PROCEDURE

A. Patient Preparation
   1. Prearrival
      Patients fast for at least 4 hr to diminish physiologic

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Note: All 26 SNM-approved procedure guidelines are available on the Society's home page. We encourage you to download these documents via the Internet at www.snm.org. If you would like information on the development of this guideline or to order a compendium of all 26 procedure guidelines for $20.00, contact Marie Davis, Society of Nuclear Medicine, at (703) 708-9000, ext. 250, or by e-mail at mdavis@snm.org.

TABLE 1
Radiation Dosimetry for Adults

Radio-pharmaceutical	Administered activity MBq (mCi)	Organ receiving the largest radiation dose* mGy (rad)	Effective dose* mSv (rem)
FDG†	350–750 i.v.	0.17 Bladder	0.027
	(10–20)	(0.63)	(0.10)

*Per MBq (per mCi).
†ICRP 53, page 76.

glucose utilization and thus FDG uptake by organs such as the heart (*1*).

2. Preinjection
   a. For brain imaging, after FDG administration and during the uptake phase of FDG, the patient should be in a quiet and darkened room.
   b. The patient's blood glucose level may be checked before FDG administration. Tumor uptake of FDG is reduced in hyperglycemic states (*8*).

B. Information Pertinent to Performing the Procedure
   1. Recent surgery (up to 6 mo), recent chemotherapy, radiation therapy or diagnostic procedures.
   2. History of diabetes or fasting state.
   3. Can patient lie still for 1–2 hr, or does patient require sedation?
   4. Can patient put arms over head?

C. Precautions
   None

D. Radiopharmaceutical (See Tables 1 and 2.)

E. Image Acquisition
   1. Acquisition parameters for FDG imaging with dedicated PET scanners.
      a. *Limited-Field Tomographic Images*: Used to most clearly delineate metabolic activity in lesions detected on physical examination and/or with other imaging modalities such as radiographs, CT or MRI. The addition of dynamic acquisition may allow quantification of metabolic rates of tumors. Since the field of view is limited, accurate and careful patient positioning is critical for adequately including suspected lesions in the tomograph's field of view.

         Transmission images are acquired. Acquisition times and total counts collected may vary between PET systems. Some institutions acquire transmission images of about 125 million counts over 15–20 min. Additionally, some imaging systems permit acquisition of the transmission images after collection of the emission images.

TABLE 2
Radiation Dosimetry for Children (5-yr-old)

Radio-pharmaceutical	Administered activity MBq/kg (mCi/kg)	Organ receiving the largest radiation dose* mGy (rad)	Effective dose* mSv (rem)
FDG†	5–10 i.v.	0.48 Bladder	0.073
	(0.15–0.30)	(1.8)	(0.27)

*Per MBq (per mCi).
†ICRP 53, page 76.

Intravenous injection of the radiopharmaceutical at a site contralateral to the site of concern is followed by the acquisition of the emission images beginning about 30–40 min later. For dynamic imaging, a sequence of serial images is initiated at the exact time of radiopharmaceutical injection (see *Dynamic image acquisition*, below).

Emission image acquisition typically ranges from 6 to 15 min and aims to collect 5 million–15 million total counts, depending on the body site.

Alternatively, the patient can be removed from the PET scanner after acquisition of the transmission images. Before leaving the scanner, careful identification of the patient's position in the scanner is essential to exactly reposition the patient in the scanner for emission imaging. Thirty minutes after FDG injection are allowed for metabolic trapping of the tracer. The patient is asked to void before being repositioned in the scanner for acquisition of the emission images. As mentioned above, some PET systems afford acquisition of the transmission images after the emission images.

Semiquantitative estimate of tumor metabolism (standardized uptake value) is based on relative lesion radioactivity normalized to injected dose and body weight. This requires a static emission image acquired typically at 30 min (images obtained after FDG reaches plateau concentration). In addition, it requires the total dose of FDG administered, the patient's weight or the patient's height for measurement of lean body mass or both for measurement of body surface area. A calibration factor is needed (see below). This measurement can be corrected for blood glucose concentration.

Dynamic image acquisition is required for the determination of metabolic rates of tumors. After the transmission image is acquired (as described above), a sequence of serial images is initiated precisely at the time of FDG administration and continues for 60–90 min.

Quantitative or semiquantitative estimates of tumor metabolism may require measurements of the arterial input function, determinations of the plasma FDG and glucose concentrations, the total dose of the administered FDG and the patient's height and body weight so that the body surface area can be estimated. In addition, a calibration factor is needed between scanner events in terms of counts/pixel/second and in vitro measured activity concentrations in counts/ml/second. This can be accomplished by imaging a cylindrical phantom with a known concentration of a positron emitter and by measuring the activity of an aliquot of the cylinder solution in a well counter. Whole-body imaging may be performed without attenuation correction.

   b. *Whole-body imaging* can be obtained with correction for photon attenuation, which requires acquisition of transmission images. Elimination of image artifacts requires the exact repositioning of the patient during the acquisition of both the transmission and emission whole-body images.

2. Acquisition parameters for FDG imaging with specially designed Anger-type gamma cameras.
   a. *Limited-Field Tomographic Images*: As with conventional PET tomographs, patients follow the

same preparation guidelines. FDG images are acquired over a 30-min period with 3° sampling acquired into a 64 × 64 matrix. The energy window used is 511 keV ± 10%.

b. *Whole-Body Planar Imaging*: Anterior and posterior views are generated. A scanning speed to achieve 450,000–1,000,000 counts for each view is recommended.

F. Interventions

A urinary catheter, hydration and a diuretic may be helpful to eliminate confusing urinary tract activity, which may confound the interpretation of local FDG accumulation in the pelvis or abdomen.

G. Processing

1. Processing images acquired with dedicated PET scanners.

a. *Standard Transaxial Images*: The data are reconstructed in the form of transaxial 128 × 128 pixel images or a pixel size of 4–5 mm. A final image resolution of 9–11 mm FWHM typically yields images of adequate resolution and noise. (Some laboratories employ a Shepp-Logan filter with a cutoff frequency of 0.1 cycles per pixel.) The image sets can be reoriented into coronal and/or sagittal slices. The contiguous transaxial and/or coronal or sagittal slices are then examined by visual inspection.

Estimates of metabolic rates of tumors, either quantitative or semiquantitative, are obtained by assigning regions of interest to the tumor and the blood pool on the dynamically acquired images. The resulting time-activity curves are then fitted with a tracer compartment model or submitted to graphical analysis to derive the rate of phosphorylation of FDG.

For semiquantitative or quantitative studies, accurate calibration of scanner counts to well-counter counts is needed; therefore, a cylindrical-type calibration should be performed on that day or at regular intervals, typically once or twice a week. The dose injected into the patient also should be recorded as accurately as possible.

b. *Whole-Body Images, Attenuation Corrected and Non-Attenuation Corrected (Including Both Upper and/or Lower Parts of the Body)*: The sequentially recorded sets of images for each bed position are corrected for radionuclide decay, rearranged into various projection images, reconstructed into a stack of transaxial images and resliced into a set of coronal whole-body images. The number of contiguous whole-body coronal slices may range from 15 to 45. Simultaneous computer displays of coronal, sagittal and transaxial cuts as well as rotating projection images aid in more precisely localizing the foci of abnormal tracer accumulations as well as in separating normal physiologic from abnormal pathologic radiopharmaceutical accumulations.

2. Processing of the SPECT images is performed after frame-by-frame decay correction. One method for processing images includes reconstruction with spatial smoothing and a Butterworth filter with a cutoff frequency of 0.35–0.45 cycles per pixel; order of 4.

H. Interpretation/Reporting

1. When other imaging data are available, correlation with relevant correlative images may be helpful.
2. Normal physiologic uptake of FDG can be seen in the brain, myocardium (where the uptake appears in some patients despite prolonged fasting), liver, spleen, stomach, intestines, kidneys and urine.
3. Increased uptake of FDG can be seen in tumorous sites, healing surgical wounds, granulomatous tissue, infections and other inflammatory-type tissue.
4. Quantitative and semiquantitative estimates may be helpful in identifying malignant lesions.

I. Quality Control

1. Radiopharmaceuticals
   See the *Society of Nuclear Medicine Procedure Guideline for Imaging with Radiopharmaceuticals.*
2. Instrumentation
   See the *Society of Nuclear Medicine Procedure Guideline for PET Imaging* (to be developed).

J. Sources of Error (*5*)

1. Residual bowel and/or urinary tract activity may cause both false-positive and false-negative abdominal examinations.
2. Local inflammatory disease may cause increased FDG uptake, especially granulomatous processes.
3. Chemotherapy and radiation therapy may decrease tumor uptake of FDG.
4. Physiologic uptake of FDG may be seen in the thymus, especially in younger patients.
5. Increased FDG uptake in the pulmonary parenchyma can be seen in radiation pneumonitis and in the pleura after radiation therapy.
6. Physiologic uptake of FDG may occur in the paraspinal muscles and in other skeletal muscles.
7. Images reconstructed without attenuation correction have the appearance of prominent peripheral body or skin activity.
8. Healing surgical wounds may have increased FDG activity up to 6 mo after surgery.

PART V: DISCLAIMER

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

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

PART VI: ISSUES REQUIRING FURTHER CLARIFICATION

Typical instrumentation for this procedure is the PET scanner, a tomographic imaging device that simultaneously detects a pair of annihilation photons after positron decay for creation of the emission image. The use of gamma cameras with high-energy collimation has shown promise, but additional work needs to be completed to establish the value and role of these instruments for this procedure. These Anger-type cameras

detect the annihilation photons by using either high-energy 511-keV collimation, or by coincidence detection through specifically modified 511-keV Anger-type cameras with electronic collimation. For tomographic image acquisition, gamma cameras can be fitted with specifically designed 511-keV collimators that may require hardware modifications to rotate the additional weight. Alternatively, the electronics of dual-headed Anger cameras can be modified to allow a high-energy model, up to 560 keV, with an extension of the medium-energy linearity maps into the high-energy range.

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