Oncologic PET/CT: A primer for radiologists

By Stephen Humes, M.D.
General considerations

Introduction

PET/CT represents a major paradigm shift in radiology: it takes us from conventional technologies that evaluate structural anatomy to a molecular modality that images the metabolic activity of tissue.

This primer is written primarily for practicing radiologists with only residency training in nuclear medicine and who are now interpreting PET/CT studies. It is intended as a succinct guide to practicing radiologists for interpretation of the images, as well as a quick reference when consulting with referring physicians as to the appropriateness of performing PET/CT to address a specific clinical question.

The document begins with a general overview and the all-important areas of normal distribution commonly found on PET scans. It is then arranged according to the most commonly encountered oncology patients, including those with the following:

- Lung cancer
- Colon cancer
- Breast cancer
- Head and neck cancer
- Lymphoma
- Melanoma
- Esophageal cancer
- Cervical cancer

Each section includes the appropriate indications for performing PET/CT in these patients, as well as basic information concerning staging and management issues. Also included are the limitations of PET scans, including known false positives and false negatives.

Addended text includes samples of patient information sheets and protocols for PET/CT for specific clinical issues such as solitary pulmonary nodules, head and neck cancer, and melanoma. A section on interpreting and dictating PET/CT scans is also provided.

My special thanks are extended to Mary Stoner for writing the section on PET/CT protocols, and to Dr. Scott Williams of Advanced Radiology Consultants in Bridgeport, CT, for his review of the manuscript.
FDG

Malignant cells have increased glucose transporter proteins on their cell surface, as well as enhanced rates of glycolysis. It is this attribute that causes metabolically active tumors to appear "hot" on PET scans.

Currently, F-18 fluorodeoxyglucose (FDG) is the radiotracer most commonly used for PET imaging. The molecule is easiest to understand by taking it backward, starting with a molecule of glucose. The deoxy part implies cleavage of a hydroxyl group from the glucose. We then attach the F-18 tracer to the glucose to replace the hydroxyl group.

In this way, the molecule acts like glucose during initial enzymatic reactions within cells, but the altered structure prevents further metabolism, which essentially traps FDG within cells. FDG competes with glucose for transport into cells, where it is subsequently phosphorylated by hexokinase to become FDG-6-phosphate. Again, once phosphorylated, FDG does not undergo glycolysis but rather becomes trapped inside the cell.

PET measures FDG retention per volume of tissue. Some tumors are known to have high retention of FDG, such as lung cancer, breast cancer, and tumors of the head and neck. Others have variable retention of FDG, such as prostate cancer and hepatomas.

It is also important to realize that other tracers in addition to FDG are on the horizon for PET imaging:

- Amino acids and their analogs such as thymidine analogs (F-18-3'-fluoro-3'-deoxy-L-thymidine or FLT) to measure protein synthesis
- Choline to measure membrane synthesis
- Estrogens for breast cancer receptors
- Positron-labeled drugs to assess targets and response to therapy
- Also, F-18 as a bone imaging agent

SUV

The standardized uptake value (SUV) is a semiquantitative value that allows expression of FDG uptake in a lesion relative to the injected dose:

\[
SUV = \frac{(\mu Ci/gram \ in \ tissue)}{(total \ \mu Ci \ injected) \ body \ weight}
\]
An SUV of 1 means uniform distribution. An SUV greater than 2.5 has been associated with cancer, but many factors can affect the reliability of SUV, such as extravasation at the time of injection, the patient’s serum glucose levels, and the time interval between injection and image acquisition. Little is standardized regarding SUVs. It is best to use SUV as a guide to interpretation rather than an absolute value, and to rely more heavily on visual estimation of uptake to indicate whether a process is benign or malignant.
Important areas of normal uptake

Radiologists frequently refer to FDG as "smart contrast," but it's not perfect. A negative PET scan does not prove the patient is free of cancer, nor does a positive PET scan prove a lesion is cancer. FDG will localize to any part of the body where there is high physiologic activity. Basic to the proper interpretation of PET/CT scans is a clear understanding of the normal variants of uptake as well as benign processes that are FDG avid to avoid potential pitfalls in image interpretation.

Head and neck

Symmetry is helpful in evaluating FDG uptake in the head and neck, but it is important to realize that symmetry alone is not an absolute indicator of benign versus pathologic processes. Asymmetric activity may be the result of true pathology, or may be the result of surgical resection or radiation treatment. Clinical correlation is essential.

- Palatine and lingual tonsils (should be symmetric)
- Salivary glands (submandibular and sublingual)
- Parotid glands (common incidental finding on PET is Warthin's tumor)
- Vocal cords (if asymmetric, may be due to laryngeal nerve palsy)
- Cervical cord (on sagittal images)
- Base of tongue
- Ocular muscles
- Nose
- Muscles of the neck (trapezius, sternocleidomastoid, paraspinal muscles) -- This is frequently associated with anxiety and may also be found in young, thin females or cold patients.
- Genioglossus muscle
- Brown fat (base of neck, paraspinal) and mediastinal fat
- Thyroid gland (moderate to intense uptake) -- If there is focal asymmetric activity present, correlation with ultrasound should be performed to evaluate for thyroid nodule. Diffuse uptake can be seen in Graves' disease and thyroiditis.

Chest

- Esophagus and gastroesophageal junction (typically diffuse; if segmental, this activity can reflect carcinoma or esophagitis)
- Mediastinal contours
• Aorta and great vessels, especially if atherosclerotic disease is present
• Thoracic cord
• Left ventricle and papillary muscles
• Thymus activity (inverted "V" configuration on coronal images)
• Breast and nipples (lactating patients, patients on hormone therapy)
• Diaphragm

Abdomen and pelvis

• Stomach (round appearance on coronal images) -- If contracted, stomach may have focal uptake of activity. Water may be used to distend the stomach to minimize this artifact.
• Liver > spleen -- Uptake should be homogeneous. If spleen is greater than liver in lymphoma patients, think splenic involvement ("S" staging).
• Renal calyces
• Ureters
• Colon (cecum > small bowel > stomach) neuroblastoma -- Bowel uptake can be diffuse, but not focal. Use correlating CT and maximum intensity projection (MIP) images to increase specificity. If focal uptake is demonstrated, correlation with colonoscopy is recommended. Segmental uptake can be seen in inflammatory bowel disease and colitis.
• Uterus (increased uptake during ovulation and menstruation)
• Ovaries -- If patient is postmenopausal, malignancy must be excluded.
• Testicular uptake is normal (diffuse/homogeneous uptake, symmetric)

Extremities

• Skeletal muscle -- Uptake will occur if physical activity occurs after FDG administration
• Bone marrow (proximal humerus/femur)
• Muscular imbalance (postoperative)
• Healing fractures (less than three months)
• Decreased uptake can be seen in sites of previous radiation therapy
• Degenerative joint disease
• Joint protheses (not infection)
Miscellaneous

- Abscess
- Fistulas
- Ostomy sites
- Chest tubes
- Tracheostomies
- Active infection
- Healing incisions/biopsy sites
- Hematoma/thrombus
- Radiation necrosis/radiation pneumonitis
- Bursitis and joint capsules
- Active atherosclerotic disease ("hot" plaque + C-reactive protein)
Imaging checklist: 
PET/CT for lung cancer

Indications

- Characterizing indeterminate pulmonary nodules (nodules <3 cm)
- Staging and restaging of non-small cell lung cancers, including lymph node metastasis and distant metastasis to adrenal glands or bone
- Evaluating for recurrent disease
- Planning for radiation treatment in nonsurgical patients

Staging

- Important comments on tumor component of staging based on attenuation-corrected CT findings:
  - Lesion size and shape (e.g., spiculation, calcification)
  - Invasion of bronchus
  - Extension into chest wall/spine/heart/great vessels/bronchus
  - Presence/absence of a pleural effusion -- FDG retention corresponding with pleural effusion on CT images can distinguish benign from malignant effusions with an accuracy of 92%.
  - Presence/absence of distal atelectasis
  - Evaluation for intralobar satellite lesions (size, number, and corresponding metabolic activity on corresponding PET images)

- Stage I, II, and IIIa -- surgically resectable
- Stage IIIa (same side) versus Stage IIIb (different side) versus Stage IV (metastatic)
- Locally (T3-T4) or regionally advanced (N2-N3) -- radiation or radiation + chemotherapy
- Distant metastases (M1) -- radiation or chemotherapy

Considerations

- We use dual time-point imaging as outlined by Dr. Alexander Matthies (Journal of Nuclear Medicine, July 2002, Vol. 43:7, pp. 871-875) in the evaluation of patients with solitary pulmonary nodules to help distinguish inflammatory processes from metabolically active tumor. For further information, please see the PET/CT Protocols section below.
• In postoperative patients, a minimum six-to-eight-week wait is recommended before performing a PET scan to distinguish residual tumor from granulation tissue. This recommendation also applies to patients who have undergone biopsies and mediastinoscopy.

• In patients who have undergone radiation therapy, it is important to correlate the treatment port with the findings on PET scans. The uptake will usually be linear in the line of the port (best appreciated on sagittal images). Postradiotherapy (RT) changes also include esophagitis, which demonstrates increased uptake on PET scans.

• In patients who have not undergone chemotherapy, diffuse increased bone activity may be seen. This is thought to be due either to thrombocytopenia or secondary to cytokine secretion by tumor. It may also be due to an autoimmune reaction to the tumor.

• Wait approximately 12 weeks after chemotherapy or external beam radiotherapy (EBRT) of lung cancer to get accurate PET images, as this allows time for apoptosis and the inflammation to resolve.

**Limitations of PET/CT in evaluating lung cancer**

• PET may not resolve small lesions:
  o Less than 7 mm in lung, worse at bases due to respiratory motion
  o Less than 10 mm in liver

• Nonspecific supraclavicular activity is most often due to brown fat or uptake within the muscles of the neck. Correlation is made with CT images, or some authors advocate a follow-up study at one month with the patient wrapped in warm blankets prior to scanning. This occurs most frequently in thin female patients, or in highly anxious patients.

**Known false positives in PET**

• Acute infections
• Fungal infections including tuberculosis and histoplasmosis
• Sarcoïdosis ("grape-like" clusters of hypermetabolic activity)
• Bronchiectasis
• Pleurodesis (FDG retention may persist indefinitely)
• Radiation
• Abscess (typically positive at pleural surface)
Known false negatives in PET

- Carcinoid
- Bronchoalveolar cell carcinoma
- Mucinous carcinoma
- Lobular carcinoma
Imaging checklist:
PET/CT for colon cancer

Indications

- Early detection of recurrent disease for accurate staging, prior to the patient undergoing attempt at curative partial hepatic resection: Elevated carcinoembryonic antigen (CEA) levels correlate with tumor relapse, and PET can be used to detect extrahepatic disease or metastatic disease to the liver when conventional workup such as CT does not identify the site of recurrence. Extrahepatic abnormal uptake indicates unresectable disease, so it is critical to ensure that there is no abnormal retention of FDG outside the liver.

- Monitoring efficacy of treatment such as chemotherapy and radiation: In the future, PET may play an increasing role in evaluating response to treatment with newer techniques such as radiofrequency ablation, chemoembolization, and treatment with TheraSpheres (MDS Nordion, Kanata, Ontario). PET has already proved useful in distinguishing post-therapy changes from residual/recurrent tumor in these patients.

- FDG-PET is not indicated for screening or diagnosis, or in patients with known disseminated disease.

Staging

- Staging of colon cancer is performed surgically. The T stage is based on tumor depth, and the N stage is based on lymph node dissection. Although PET can assess regional lymph-node involvement, it has proved most effective for the M stage, especially for detecting metastatic disease to the liver.

- Up to 20% of patients present with liver metastases at time of initial surgery, and resection is their only option for cure. Surgery is attempted only if the patient has one to four metastases confined to one lobe of the liver, and no nodes or distant metastases are detected.

- PET has been reported to have an impact on patient staging in up to 65% of cases, usually by upstaging the patient's disease.
Considerations

- Following curative resection, there is a high recurrence rate in this patient population, ranging from 10% to 40%, usually within the first two years following surgery.
- Because of FDG's known avidity for granulation tissue, it is best to delay imaging until two to three months following radiation or surgery to assess treatment response.

Known false negatives in PET

- Small lesions (< 10 mm) in the liver or lesions near areas of normal increased activity (bowel)
- Micrometastases
- Mucinous carcinoma (lower sensitivity for metastatic disease)
- Hepatomas

Known false positives in PET

- Status postradiation with the presence of inflammatory tissue
- Artifact (metallic objects such as surgical clips)
- Flare phenomenon in lesions immediately following chemotherapy
- Pelvis: bladder diverticula
**Imaging checklist:**

**PET/CT for cervical cancer**

### Indications

- Detecting recurrence and differentiating between recurrence and post-treatment fibrosis and necrosis
- Retroperitoneal lymph node staging -- Authors have found a sensitivity of 81.6% and a specificity of 97% in detecting para-aortic lymph node metastases (*JNM*, November 2003, Vol. 44:11, pp. 1775-1783)
- Evaluating RT treatment response

### Staging

- Cervical cancer is based on a clinical staging system (Fédération Internationale de Gynécologie et d'Obstétrique, FIGO). Imaging procedures do not alter staging, but rather are used primarily for treatment planning.
- Cervical cancer grows in a predictable fashion, with initial dissemination to local structures and regional lymphatics and a later dissemination hematogenously.
- Growth typically arises from the cervix with local extension toward the vagina and paracervical spaces. Lymphatic drainage is to nodes in pelvis, para-aortic nodes, then to distant sites, which are rare at initial presentation.

### Known false positives in PET

- Uterine fibroids -- May demonstrate increased activity during menstruation.
- Ovulation -- Potential false positive during ovulation; one or both ovaries may demonstrate accumulation of FDG.
- GI activity within the pelvis
- Tubo-ovarian abscess

### Known false negatives in PET

- Supraclavicular lymph node metastases
**Imaging checklist:**

**PET/CT for breast cancer**

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**Indications**

- Identifying distant metastatic disease and locoregional recurrence -- PET serves as adjunct to conventional imaging modalities, including mammography, ultrasound, and MRI, in patients with high clinical suspicion of advanced disease.
- Monitoring patients with locally advanced breast cancer undergoing induction therapy for advanced disease
- Evaluating response to treatment -- Again, PET serves as adjunct to conventional imaging modalities.
- Evaluating internal mammary node involvement, and evaluating axillary nodes in women who will undergo neoadjuvant chemotherapy

**Staging**

- Tumor size can best be assessed with standard imaging techniques, but attenuation-corrected CT images can provide an estimate of size. Important additional information that can be gained from the CT includes extension of the tumor to the chest wall or skin.

**Considerations**

- A negative PET scan of the axilla is strong evidence against axially lymph node metastasis and may spare the patient from undergoing axillary lymph node dissection, yet PET is limited in detecting micrometastatic disease. For early staging, most patients undergo sentinel lymph node localization for surgical biopsy.
- PET does not replace sentinel node biopsy in early stage breast cancer patients.
- FDG-PET can more accurately detect metastatic internal mammary lymph node involvement than CT imaging.

**Limitations of PET/CT in evaluating breast cancer**

- PET/CT cannot determine the specific number of lymph nodes involved, which is an important prognostic indicator.
Known false positives in PET

- Status postbiopsy or postsurgery
- Fibroadenomas -- These may demonstrate low-grade uptake. Correlate with mammography.
- Tumors with low FDG accumulation -- Normal breast uptake can obscure these tumors.

Known false negatives in PET

- Lobular carcinoma
- Well-differentiated tumors (tubular carcinoma, carcinoma in situ)
- Lesions less than 1 cm in size
- Micrometastatic disease
Imaging checklist: 
**PET/CT for head and neck cancer**

### Indications

- Identifying unknown primary
- Initial staging of cervical and supraclavicular lymph node metastases
- Detecting residual or recurrent disease in postoperative/postradiation patients

### Considerations

- Symmetry is helpful at this level; however, there are limitations: asymmetric activity may be the result of true pathology, or the result of surgical resection or radiation treatment. Tumors may also be symmetric in their uptake.

- Poor prognostic indicators in patients with head and neck cancer include those with supraclavicular lymph node involvement, increased number of lymph nodes involved, and extracapsular spread of tumor to adjacent structures such as the carotid sheath.

- One-month postradiation scans have been shown to be inaccurate for predicting the presence of cancer. Four-month post-RT scans were a better predictor for the presence of residual/recurrent tumor (*Head and Neck*, November 2001, Vol. 23:11, pp. 942-946).

- We use "zoomed" images of the head and neck for evaluating patients with head and neck cancer. Please refer to the PET/CT Protocols section below.

### Limitations of PET/CT in evaluating head and neck cancers

- Sensitivity decreases with decreasing size of lesions, especially in small, flat mucosal lesions that may be better evaluated with direct visualization.
- Slow-growing neoplasms such as mucoepidermoid and adenoid cystic tumors may not avidly retain FDG.
Pitfalls

- Intense brain activity may obscure skull base lesions.

- The cervical spinal cord normally accumulates FDG and should not be confused with metabolically active tumor. Uptake is linear and confined to the cervical cord, and is best appreciated on sagittal images.

- Optic muscles, especially the inferior rectus muscle, can accumulate FDG and should not be confused with orbital lesions.

- The muscles of the neck may demonstrate increased FDG retention, especially if the patient is tense or cold. On coronal images, look for linear increased activity, which is usually symmetric. If the patient is postsurgical or postradiation treatment, there may be muscle imbalance resulting in asymmetric uptake of FDG. Correlation with the patient history is important in resolving these findings.

- Active inflammatory lesions of the sublingual glands such as sialoadenitis may result in increased FDG uptake and mimic neoplasm. Increased uptake can also be seen in certain benign processes such as Warthin's tumor and pleomorphic adenoma.

- Vocal cord uptake is frequently seen, usually due to patient talking after administration of FDG. This activity should be symmetric, but certain conditions such as radiation treatment may result in unilateral uptake. Unilateral uptake also may be seen in the normal cord contralateral to a paralyzed cord, which may be from benign or malignant causes. When unilateral cord uptake is noted, a diligent search for a tumor affecting the contralateral recurrent laryngeal nerve should be made (*Head and Neck*, June 2005, Vol. 27:6, pp.494-502).

- The most common incidental lesion discovered on PET is thyroid cancer, usually papillary. Diffuse symmetric uptake may be seen in the normal thyroid gland, but focal retention warrants further investigation. Differential considerations would include malignant nodules or radiation-induced thyroiditis.

- Dental artifacts from prostheses are frequently encountered and may cause overattenuation correction, resulting in apparent uptake. This uptake is not seen on nonattenuation-corrected images.

- Brown fat is a normal variant known to accumulate FDG. Uptake is usually seen at the base of the neck and paraspinal regions. Corresponding CT images demonstrate normal fat attenuation.
**Imaging checklist:**

**PET/CT for lymphoma**

**Indications**

- Initial staging in clinical correlation with imaging studies, includes CT combined with patient history, labs, bone marrow biopsy, and tissue biopsy
- Detecting recurrent disease following therapy
- Assessing residual disease following therapy
- Quickly assessing treatment efficacy (PET)

**Staging**

- Evaluate the spleen for uptake greater than the liver. A hot spleen with mottled uptake in an untreated patient is most consistent with splenic involvement with disease. This will result in an S designation in terms of the patient's staging.

- Evaluation for abnormal uptake within bone marrow is an important feature to evaluate in lymphoma patients. Physiologic uptake is known to occur. If there is diffuse, nonfocal increased uptake, correlate with patient's clinical history for a bone marrow transplant or treatment with granulocyte colony-stimulating factor. If the uptake is asymmetric and focal, the findings are more concerning for tumor involvement. If there is only small-volume involvement of bone marrow with tumor, this may result in a false negative on PET.

**PET and the different types of lymphomas**

- Not all lymphomas are equally avid for FDG. It is important to be aware of the cell type when interpreting the results of a PET scan:
  - Lymphomas with good FDG uptake:
    - Diffuse large-cell lymphoma
    - Mantle cell lymphoma
    - Follicular cell lymphoma
  - Lymphomas with poor FDG uptake:
    - Peripheral T-cell lymphoma
    - Marginal zone lymphoma
    - Mucosa-associated lymphoid tissue (MALT)
The degree of FDG uptake has been shown to correlate with the grade of tumor (Blood, November 1995, Vol. 86:9, pp. 3522-3527). High uptake of FDG is generally seen in high-grade tumors, and patients with a high glycolytic rate generally have a poorer prognosis.

Known false positives in PET

- TB
- Sarcoid
- Opportunistic infections
- Thymic rebound following chemotherapy
- Reactive lymph nodes

Known false negatives in PET

- Mucosa-associated lymphoid tissue (MALT)
- Low-grade lymphoma
- Lesions less than 1 cm

PET's impact on patient management

- Image-guided percutaneous biopsy: PET can provide key information to guide percutaneous biopsies.
- FDG-PET can be predictive of prognosis as early as after one cycle of chemotherapy in aggressive non-Hodgkin's lymphoma and Hodgkin's disease (JNM, August 2002, Vol. 43:8, pp. 1018-1027).
- Evaluation of the response to treatment is a key aspect in the management of lymphoma patients. In patients with curable subtypes of lymphoma, it is critical to assess the response to treatment and detect the presence of any viable residual tumor before completion of therapy (Radiologic Clinics of North America, November 2004, Vol. 42:6, pp. 1083-1100).
Imaging checklist:
PET/CT for melanoma

Indications

- PET is not used for staging of primary tumor, as this is accomplished via punch biopsy.
- Evaluation of local and regional lymph node metastases is performed via sentinel lymph node mapping and biopsy. PET's sensitivity for detecting regional lymph node involvement is lower than originally reported, in part due to micrometastatic disease, which is too small to detect.
- Preoperative staging for patients with clinically suspected lymph node involvement and to evaluate for distant metastases to skin or muscle.
- Postsurgical follow-up of patients at high risk of spread (usually at six months) for restaging. PET/CT is used for surveillance of high-risk patients, as most surgeons favor excision of metastases.

Staging

- The most common staging system for melanoma is the Breslow system, which measures the vertical height of the lesion. This is the most important prognostic factor in the initial evaluation of melanoma patients. The following measurements are used:
  - Less than 0.76 mm in height = favorable prognosis
  - Greater than 4 mm in height = poor prognosis (10-year survival < 40%).
  - Up to 70% of these patients will have distant metastasis at presentation
- Melanoma spreads hematogenously, resulting in unusual sites of involvement. Known sites of metastases include the skin, bone, muscles, orbits, and mesentery. This tendency requires scanning from the top of the head to the feet for accurate staging (see PET/CT Protocols section below).

Known false positives in PET

- Warthin's tumor of the parotid gland
- Granulation tissue (postoperative)
- Superficial phlebitis
- Skin nevus
Known false negatives in PET

- Micrometastatic disease
- Lesions less than 1 cm in size
- Brain metastases
Imaging checklist: PET/CT for esophageal cancer

Indications

- Detecting distant metastasis to abdominal lymph nodes, liver, lungs, bone, and adrenal glands
- Determining resectability of disease
- Distinguishing recurrent disease versus scar tissue status postsurgical resection
- Follow-up for patients undergoing chemotherapy and radiation treatment to evaluate response to therapy
- PET is not appropriate as an initial diagnostic procedure, and is limited in evaluating for local invasion by the primary tumor. Endoscopy with biopsy is usually indicated for initial evaluation. Endoscopic ultrasound is used to assess depth of tumor invasion.

Staging

- In the staging of esophageal carcinoma, regional lymph node metastases do not preclude curative surgery; however involvement of supraclavicular, cervical, and celiac nodes is considered distant metastasis (M1) rather than nodal metastasis (N1) and does preclude surgical resection.

- Location of distant metastases in esophageal carcinoma:
  - Abdominal lymph nodes (45% of cases)
  - Liver (35%)
  - Lung (20%)
  - Supraclavicular lymph nodes (18%)
  - Bone (9%)
  - Adrenal glands (5%)

Considerations

- With CT, understaging occurs more frequently than overstaging.
- Squamous cell carcinoma tends to occur more frequently in the upper esophagus, whereas adenocarcinoma generally occurs at the gastroesophageal junction secondary to Barrett's esophagus.
• Normal esophagus may take up FDG due to peristalsis and mucosal uptake, but the uptake is diffuse and relatively even throughout the esophagus. MIP images and sagittal projections are especially helpful in distinguishing this physiologic uptake from focal, abnormal uptake in metabolically active tumor.

• An inflamed esophagus due to esophagitis post-EBRT will demonstrate avid uptake of FDG. Correlation with the treatment portal is necessary for accurate interpretation.

• Postoperative changes must be correlated with PET/CT findings. Following esophagectomy, gastric pull-up is frequently performed, resulting in a photopenic defect in the right mediastinum.

**Known false positives in PET**

• Physiologic uptake in gastric mucosa, especially at the gastroesophageal junction
• Radiation-induced esophagitis (Wait eight to 12 weeks following treatment.)
• Postoperative granulation tissue

**Known false negatives in PET**

• Small lesions adjacent to areas of intense physiologic uptake (heart, bowel)
Sample of patient information sheet

What is a PET/CT scan and how does it work?

*PET* is an acronym for positron emission tomography, and *CT* is an acronym for computed tomography. PET scans work by using a special form of sugar called 18-FDG, or fluorodeoxyglucose. 18-FDG is a radioactive form of sugar that can be detected by a PET scanner. The administered levels of radioactivity are minimal and safe. The tracer stays in your body for only a short period of time and has no known side effects.

When cells are involved with tumor or other inflammatory processes, they tend to use more glucose than normal tissue. The PET scanner can detect where the 18-FDG localizes to tissue. When we combine a PET scan and a CT scan at the same time, we can be more precise in localizing exactly where the 18-FDG accumulates. We can also use the CT scan to determine if an abnormality tends to collect unusual amounts of FDG.

The purpose of the study is to determine whether abnormal tissue represents tumor or a benign, nonmalignant process. If you have already been diagnosed with cancer and have undergone therapy for the tumor, PET/CT can determine how the tumor is responding to the therapy, as well as whether the tumor has recurred.

Why am I getting a PET/CT scan?

PET scans have found many applications in the medical field, including use in patients with cancer, neurologic disorders, and cardiovascular disease. A PET scan has been shown to be particularly useful in oncology patients because of its capability to detect and stage primary cancers, as well as metastatic disease.

PET can help physicians differentiate between benign and malignant lesions, especially when patients have nodules in their lungs. In patients who have already undergone therapy such as surgery or radiation treatment, PET can help distinguish between changes from these therapies versus tumor recurrence.

PET is also being used to evaluate a patient's response to current treatment. Changes in the PET scan reflect changes on a molecular level, and can tell your doctor how effective your therapy is working -- even before changes would be seen on conventional imaging studies such as x-ray or CT scans.
What does PET/CT equipment look like?

If you've ever had a CT scan, you'll find that a PET/CT scanner looks very similar. Patients are placed on a flat table that moves through a doughnut-shaped machine, which acquires both sets of images. Note that the opening for a PET/CT scanner is not as long as those used for MRIs, and patients seldom have any troubles if they suffer from claustrophobia.

How can I prepare for the exam?

You need to inform us of several important issues prior to arriving for your PET scan, as these can affect your study. Please inform us if any of these conditions apply to you:

- You are diabetic. High serum blood-sugar levels (>200) will diminish the accuracy of your PET scan.
- You have had recent surgery.
- You may be pregnant or if you are currently nursing.
- You cannot lie still on a table for one to two hours.
- You cannot place your arms over your head for the exam.

Your diet is also important prior to the exam. We recommend that you follow a low-carbohydrate, high-protein, high-fat diet 12 hours before arriving for your PET scan.

You should fast at least six hours before the exam. This includes no hard candies, no coffee with cream and sugar, and no gum. We encourage you to drink as much water as you can before arriving for your scan. It is also important to drink a couple of glasses of water just prior to the exam.

You should also avoid any strenuous exercise, such as running, the day before the exam.

What can I expect the day of the exam?

You should allow about three hours total for your PET/CT scan to be performed. It is very important that you have fasted at least six hours before the exam. This includes any candies, gum, sugar or cream in coffee, as eating these may adversely affect your scan. You should take all your prescribed medications with water unless told otherwise.

Wear warm, comfortable clothing such as a sweatsuit on the day of the exam, and avoid any clothing that may contain metal, such as zippers or snaps. You will be able to wear your glasses or dentures.
When you come to the PET/CT suite for your exam, you will register and then be asked some important questions regarding your medical history prior to undergoing the scan. It is important that you provide accurate information on the following procedures:

- Have you had any biopsies recently? If so, what part of your body was biopsied?
- Have you undergone any recent surgeries? If so, what kind of surgery and when was it performed?
- Are you receiving chemotherapy? When was your last administration?
- Have you undergone radiation therapy? What part of your body was treated and when?
- Have you had any recent infections?
- Do you have any previous copies of CT, MRI, or PET scans? If so, it is important that you bring them with you so comparisons may be made.

You will then have an IV placed in your arm for the administration of the 18-FDG. Your blood glucose level will also be checked.

The 18-FDG is radioactive, and because of this, we want to minimize your exposure to others around you. Family members cannot be with you from the time the 18-FDG has been administered until after the exam.

After the 18-FDG has been injected, you will be placed in a quiet room until it is time for your exam. This is typically 45 minutes to 1½ hours. It is very important during this time that you rest quietly and do nothing strenuous, including no talking, gum chewing, or even reading.

Once you are ready for your PET/CT scan, you will lie on your back on a table with your arms above your head. The table will slowly move through the gantry while the data for the images are collected. You will be on the table for approximately 30 minutes for the standard exam. Additional views, if needed, take about 15 minutes.

After the exam, the data is processed and the images are interpreted by a radiologist. A report is dictated, which is then sent to your referring physician.

**What happens after the exam?**

After the exam is completed, you may resume your normal routine, including diet and medications. The dose of radiation you received for the exam requires no special precautions.
Interpreting and dictating PET/CT scans

Introduction

A PET/CT scan merges anatomic and molecular data with the goal of producing one integrated diagnosis. The attenuation-corrected CT scan is performed to aid in the anatomic localization of the PET scan findings, but it is important to recognize that it also provides important anatomic diagnostic information, as would any CT. From the CT, you can discern fat planes, effusions, osseous erosive changes, and other significant prognostic information that should be included as a part of your report.

Patient history

It is important to begin with an accurate patient history. The patient history in the report should read as a consult, including such information as recent biopsies or surgeries, date of last chemotherapy or radiation treatment (including the radiation port), and any recent infections, as these can all have a bearing on the findings and final interpretation.

Viewing and interpreting cases

When viewing the cases for interpretation, it is important to have the MIP image on display at all times. The MIP image should be linked to the attenuation-corrected CT and PET images, which will allow initial localization of lesions. The MIP image also provides additional information for identifying physiologic uptake such as ureteral activity on axial images.

For initial surveys and dictations, I find it helpful to break the scan down into the following regions: head and neck, chest, abdomen, and pelvis. The coronal PET images can be viewed as a "fly through" for the initial survey, which allows one to identify those areas requiring close attention on the corresponding axial images. I typically dictate from the axial images, based on convention and habit. The coronal and sagittal projections, however, are frequently helpful for more precise localization of a region of interest.

The PET images should be matched side by side with the corresponding CT images while interpreting the scan. The images should be large enough to be easily viewed. It is helpful also to have the CT windows for soft tissues and lung always displayed. The nonattenuation-corrected images should also be displayed to allow for the evaluation of potential artifacts on the attenuation-corrected images. Coordinated cursors between all of these image sets are especially helpful to localize specific regions of interest between
the sets of images. The so-called "fusion" images are of little value when interpreting the scans, as one dataset only obscures the findings on the other. Below is an example of a screen layout that we typically use for interpreting PET/CT scans.

<table>
<thead>
<tr>
<th>MIP</th>
<th>Attenuation-corrected PET</th>
<th>Nonattenuation-corrected PET</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**CT (soft-tissue window)**

**CT (lung/bone window)**

**Formats for dictation**

There are several formats that can be used when dictating the results of a PET/CT scan. Some prefer to follow conventional dictations along an organ-based approach. The CT and PET portions of the report may be dictated separately or as an integrated report. The key again is to provide an integrated diagnosis and conclusion.

For the impression portion of the report, I find it helpful to follow a "TNM" format: commenting on the primary tumor first, followed by any nodal involvement with disease, then the presence of any distant metastatic lesions. For follow-up scans, it is important to include in the impression the progression of disease or whether the scan shows interval stability. Incidental CT findings may also be included in the impression. A sample dictation format is provided below.

**A final word about oncology patients**

Patients with cancer are a unique population in terms of their care. Most are very proactive, seeking the latest alternatives in terms of therapy. They often have copies of all their films and reports. PET reports are often read by the patients themselves, and it is important to dictate the report with the patient in mind. You should assume the patient will read the report -- and be prepared to explain it.
**Sample dictation**

**History**

Fifty-two-year-old female with known history of left breast cancer is now status postchemotherapy (December 2004) and radiation therapy (March 2005 to left chest) presenting for whole-body PET/CT to evaluate response to therapy. She is status post left lumpectomy in January 2005.

**Dose**

14.9 mCi F-18 fluorodeoxyglucose

**Procedure**

Following the IV administration of F-18 FDG and a delay to allow for radiotracer uptake, a series of overlapping emission PET images were obtained from the skull base through the midthighs. The patient’s serum glucose level at the time of FDG administration was 115 mg/dL. The patient fasted more than eight hours prior to the exam. As a part of this exam, a nondiagnostic CT scan was obtained over the same region. The CT scan was used for anatomic correlation and attenuation correction. The entire study was reviewed in standard axial, sagittal, and coronal imaging planes on a computer workstation. A 3D MIP was reviewed as a cine sequence on the computer workstation. The resolving capacity of a dedicated PET scanner ranges from 4 mm to 7 mm.

**Findings**

Comparison is made with prior PET scan from 29 July 2004.

**Head and neck**

From the base of the skull to the thoracic inlet, there is symmetric, physiologic distribution of activity with no focal areas of abnormal retention demonstrated.

**Chest**

There is a large focus of abnormal retention seen within a soft-tissue mass adjacent to the left anterior chest wall. On CT images, the mass measures ~2 cm in diameter. Bone
windows demonstrate no evidence of osseous erosive changes at this level. This lesion would be amenable to percutaneous biopsy under ultrasound guidance.

Multiple discrete focal areas of abnormal retention are also seen within the left axilla, correlating with pathologically enlarged lymph nodes on attenuation-corrected CT.

Evaluation of the mediastinum demonstrates multiple focal areas of abnormal retention, including an enlarged left para-aortic lymph node, which measures 1.6 cm in greatest dimension.

Attenuation-corrected CT demonstrates findings consistent with mediastinal lymphadenopathy as above. There is no evidence of pericardial effusion, pulmonary nodules, or pleural effusion. Vascular calcifications are seen within the LAD coronary artery.

**Abdomen and Pelvis**

Beneath the diaphragm, there is a large focus of abnormal retention seen involving the posterior segment of the right lobe of the liver.

Corresponding CT images demonstrate a low attenuation lesion measuring approximately 4 cm in diameter. This lesion would be amenable to percutaneous biopsy under either CT or ultrasound guidance. Attenuation-corrected CT shows no evidence of intrahepatic biliary dilatation. The gallbladder, spleen, and pancreas are within normal limits. The bowel shows no evidence of obstruction.

**Impression**

1. Findings consistent with interval progression of disease with metabolically active tumor involving left chest wall mass as above.
2. Nodal metastatic disease involving left axillary and para-aortic lymph nodes.

3. Findings are consistent with distant metastatic disease involving the posterior segment of the right lobe of the liver. Biopsy recommended as above.
**PET/CT protocols**
*By Mary Stoner*

**Introduction**

The following acquisition protocols are performed on a Siemens Medical Solutions (Malvern, PA) Biograph six-slice PET/CT scanner (CTI Reveal Hi-REZ Pico six-slice PET/CT) running software version 4.0.1. Please note that when our system was upgraded to version 4.0.1 we noticed a dramatic change in the appearance of the processed data. The old protocols for filtering the data no longer gave us the expected visual result, so be aware that when new software is loaded, you may need to review data for unexpected changes.

In addition to our regular PET/CT protocol, we have specific protocols available to tailor the exam to a patient's clinical history. The protocols outlined in this section address the following clinical situations:

- Solitary pulmonary nodule
- Head and neck cancer
- Pelvic disease (cervical cancer, lymphoma)
- Melanoma
- Brain

**Patient preparation**

All patients are phoned the evening prior to their exam by a technologist. This call is to remind them of their appointment, and review instructions for prep. The technologist can answer any questions the patient may have about the PET/CT scan. Upon arrival, patients change into a hospital gown, unless they are wearing street clothing and undergarments that have no metal objects: zippers on trousers, or clasps or underwires on bras. Patients are offered a trip to the restroom before being escorted to the PET suite.

Once the patient is settled into the injection/holding room, time is taken to ensure the patient is comfortable. Wall oxygen is available, pillows and warm blankets are offered, and a glass of water is left with the patient. These comfort tools at the onset ensure the patient will be at ease and the technologist will not need to spend time in the holding room after the patient has been injected. We have found the use of a blanket warmer a
must: not only has it dramatically decreased the amount of patients we see with uptake
due to brown fat, but the comforting effect is remarkable -- patients immediately relax.

A history is taken from both the patient and the office notes provided by referring
physician. IV access is obtained using either a 25 ga butterfly or a 22 ga intercatheter if a
diagnostic CT with contrast has been ordered. Blood glucose level is checked from a
small sample drawn from the IV. If the patient has a glucose level greater than 200, the
reading radiologist is notified.

The FDG dose is assayed and injected, noting the time of injection and assayed dose on
the patient’s history sheet. The butterfly needle is pulled after being flushed with 10 cc of
normal saline. Patients are reminded to stay seated in the holding room. A call button is
available to contact the technologist if needed.

**Handling the claustrophobic patient**

Being in an outpatient setting, we do not sedate any PET/CT patients. We have found
very few patients who cannot tolerate the exam if we take the extra time to prepare them
for their appointment. We specifically ask on scheduling if the patient is claustrophobic,
and most will provide an example of what they are able to tolerate. We offer patients who
believe they cannot tolerate the exam the opportunity to come and see the equipment
prior to their appointment. Most patients respond very well to this approach.

We also instruct these patients to have their referring physician write them a prescription
for diazepam, or Valium, that they should bring for their appointment. We clearly instruct
these patients not to take the oral medications prior to their appointment, that we will
have them take the medications about 30 minutes before we scan them. We have a CD
player in the scanner room, dimmer switches for the lights, a small black silk beanbag to
cover the eyes, and warm blankets. All or some of these tools comfort even the most
claustrophobic patients.
Pulmonary nodule protocol

The patient is asked to empty their bladder 45 minutes postinjection. All patients are imaged with their arms up, if at all possible.

An early set of images of the chest are performed using the following acquisition parameters. A PET/CT whole-body protocol is performed with a shortened scan length. For most, a length of 768 mm includes the entire lung field.

### Pulmonary nodule acquisition parameters

**Topogram routine**
- mAs 50
- kVp 110
- 16.2-sec scan time
- 1-mm slice
- Tomogram length 768 mm
- AP tube position
- Craniocaudal direction of scan
- Kernel T80s sharp

**CT attenuation-correction routine**
- Effective mAs 70
- kVp 130
- Slice 5 mm, collimation 6 x 3 mm
- Kernel B30 medium smooth
- Window mediastinum

**PET whole-body routine**
- Injected dose -- from history sheet
- Time of injection -- from history sheet
- Scan duration per minute of bed position is calculated from patient weight as follows:
  - <120 lb = 3 minutes per bed position
  - 120-180 lb = 3.5 minutes per bed position
  - 181-200 lb = 4 minutes per bed position
  - 201-250 lb = 4.5 minutes per bed position
  - >250 lb = 5 minutes per bed position
PET whole-body reconstruction

Method iterative
Image size 168, Zoom 1
Filter full-width at half-maximum (FWHM) 5 mm
Iterations and subsets determined by patient weight:
<120 lb = 5 iterations, 8 subsets
150-220 lb = 4 iterations, 8 subsets
>220 lb = 2 iterations, 8 subsets

After the early chest images are acquired and reviewed, a whole-body eyes-to-thighs PET/CT acquisition is performed using the following parameters:

Topogram routine
mAs 50
kVp 110
16.2-sec scan time
1-mm slice
Topogram length 1,536 mm
AP tube position
Craniocaudal direction of scan
Kernel T80s sharp

CT attenuation-correction routine
Effective mAs 70
kVp 130
Slice 5 mm, collimation 6 x 3 mm
Kernel B30 medium smooth
Window mediastinum

PET whole-body routine
Injected dose -- from history sheet
Time of injection -- from history sheet
Scan duration per minute of bed position is calculated from patient weight as follows:
<120 lb = 3 minutes per bed position
120-180 lb = 3.5 minutes per bed position
181-200 lb = 4 minutes per bed position
201-250 lb = 4.5 minutes per bed position
>250 lb = 5 minutes per bed position
PET whole-body reconstruction

Method iterative
Image size 168, Zoom 1
Filter FWHM 5 mm
Iterations and subsets determined by patient weight:
<120 lb = 5 iterations, 8 subsets
150-220 lb = 4 iterations, 8 subsets
>220 lb = 2 iterations, 8 subsets

For more information on this protocol, please refer to JNM, July 2002, Vol. 43:7, pp. 871-875.
**Head and neck protocol**

The patient is instructed not to speak during or immediately following the FDG injection.

The patient is asked to empty their bladder 60 minutes postinjection.

All patients are imaged with their arms up, if at all possible. The first set of images acquired is a top of head to thighs whole-body PET/CT using the following parameters:

**Head and neck acquisition parameters**

**Topogram routine**  
mAs 50  
kVp 110  
16.2-sec scan time  
1-mm slice  
Topogram length 2,048 mm  
AP tube position  
Craniocaudal direction of scan  
Kernel T80s sharp

**CT attenuation-correction routine**  
Effective mAs 70  
kVp 130  
Slice 5 mm, collimation 6 x 3 mm  
Kernel B30 medium smooth  
Window mediastinum

**PET whole-body routine**  
Injected dose -- from history sheet  
Time of injection -- from history sheet  
Scan duration per minute of bed position is calculated from patient weight as follows:  
<120 lb = 3 minutes per bed position  
120-180 lb = 3.5 minutes per bed position  
181-200 lb = 4 minutes per bed position  
201-250 lb = 4.5 minutes per bed position  
>250 lb = 5 minutes per bed position
PET whole-body reconstruction

Method iterative
Image size 168, Zoom 1
Filter FWHM 5 mm
Iterations and subsets determined by patient weight:
<120 lb = 5 iterations, 8 subsets
150-220 lb = 4 iterations, 8 subsets
>220 lb = 2 iterations, 8 subsets

After the whole-body PET/CT has been completed and reviewed, the patient is instructed to bring their arms down to their sides or over their abdomen. A separate acquisition is set up to acquire images of the neck. A PET/CT brain protocol is edited for use to zoom the acquisition of the neck, which results in an acquisition zoom rather than a processing zoom. The following acquisition parameters are used:

**Zoom neck acquisition parameters**

**Topogram routine**
mAs 50
kVp 110
0.8-sec scan time
1-mm slice
Topogram length 256 mm
LAT tube position
Craniocaudal direction of scan
Kernel T20s standard

**CT attenuation-correction routine**
Effective mAs 240
kVp 130
Slice 3 mm, collimation 6 x 2 mm
Kernel B30 medium smooth
Window mediastinum

**PET brain routine**
Injected dose -- from history sheet
Time of injection -- from history sheet
Scan duration:
15 minutes if < 180 lb
20 minutes if > 180 lb
| **PET brain reconstruction** | Method iterative  
|                            | Image size 256, Zoom 2  
|                            | Filter FWHM 2 mm  
|                            | Output corrected and uncorrected  
|                            | 4 iterations, 8 subsets |
**Pelvis protocol**

The patient is asked to empty their bladder 60 minutes postinjection. All patients are imaged with arms up, if at all possible. The first set of images acquired is a standard eyes-to-thighs whole-body PET/CT using the following parameters:

### Pelvis acquisition parameters

**Topogram routine**
- mAs 50
- kVp 110
- 16.2-sec scan time
- 1-mm slice
- Topogram length 1,536 mm
- AP tube position
- Craniocaudal direction of scan
  - Kernel T80s sharp

**CT attenuation-correction routine**
- Effective mAs 70
- kVp 130
- Slice 5 mm, collimation 6 x 3 mm
- Kernel B30 medium smooth
- Window mediastinum

**PET whole-body routine**
- Injected dose -- from history sheet
- Time of injection -- from history sheet
- Scan duration per minute of bed position is calculated from patient weight as follows:
  - <120 lb = 3 minutes per bed position
  - 120-180 lb = 3.5 minutes per bed position
  - 181-200 lb = 4 minutes per bed position
  - 201-250 lb = 4.5 minutes per bed position
  - >250 lb = 5 minutes per bed position
PET whole-body reconstruction
Method iterative
Image size 168, Zoom 1
Filter FWHM 5 mm
Iterations and subsets determined by patient weight:
<120 lb = 5 iterations, 8 subsets
150-220 lb = 4 iterations, 8 subsets
>220 lb = 2 iterations, 8 subsets

After the whole-body PET/CT has been completed and reviewed, the patient is instructed to again empty their bladder. A separate set of images are acquired as a postvoid pelvis set. The postvoid acquisition is set to the same acquisition parameters as the standard whole-body PET/CT with the exception of the length of the topogram, which is set at 768 mm, providing two bed positions on the postvoid set.
Melanoma protocol

At the time of injection we always attempt to inject the patient on the opposite side of their original disease; for example, if the original site of disease was the right shoulder, we would choose to inject on their left shoulder. The patient is asked to empty their bladder 60 minutes postinjection.

All patients are imaged with their arms up, if at all possible. The first set of images acquired is a true whole-body set, bearing in mind that the entire skin surface must be scanned. If the arms are positioned above the head, they must still be included in the imaging data. The whole-body PET/CT is acquired using the following parameters:

**Melanoma acquisition parameters**

**Topogram routine**
- mAs 50
- kVp 110
- 16.2-sec scan time
- 1-mm slice
- Topogram length 2,048 mm
- AP tube position
- Craniocaudal direction of scan
- Kernel T80s sharp

**CT attenuation-correction routine**
- Effective mAs 70
- kVp 130
- Slice 5 mm, collimation 6 x 3 mm
- Kernel B30 medium smooth
- Window mediastinum

**PET whole-body routine**
- Injected dose -- from history sheet
- Time of injection -- from history sheet
- Scan duration per minute of bed position is calculated from patient weight as follows:
  - <120 lb = 3 minutes per bed position
  - 120-180 lb = 3.5 minutes per bed position
  - 181-200 lb = 4 minutes per bed position
  - 201-250 lb = 4.5 minutes per bed position
  - >250 lb = 5 minutes per bed position
PET whole-body reconstruction

Method iterative
Image size 168, Zoom 1
Filter FWHM 5 mm

Iterations and subsets determined by patient weight:
<120 lb = 5 iterations, 8 subsets
150-220 lb = 4 iterations, 8 subsets
>220 lb = 2 iterations, 8 subsets

Notice how far on a patient a 2,048 scan length covers -- for most patients this extended length will scan to below their knees. When the upper portion of the patient has been scanned, the patient must turn 180° to image the lower legs (the feet are placed in the head holding device). The patient must be positioned with their toes at the gantry. The lower legs are imaged using the following whole-body PET/CT parameters:

**Topogram routine**

- mAs 50
- kVp 110
- 16.2-sec scan time
- 1-mm slice
- Topogram length 512 mm or 768 mm, depending on the size of the patient
- AP tube position
- Caudocranial direction of scan
- Kernel T80s sharp

**CT attenuation-correction routine**

- Effective mAs 70
- kVp 130
- Slice 5 mm, collimation 6 x 3 mm
- Kernel B30 medium smooth
- Window mediastinum
PET whole-body routine

- Injected dose -- from history sheet
- Time of injection -- from history sheet
- Scan duration per minute of bed position is calculated from patient weight as follows:
  - <120 lb = 3 minutes per bed position
  - 120-180 lb = 3.5 minutes per bed position
  - 181-200 lb = 4 minutes per bed position
  - 201-250 lb = 4.5 minutes per bed position
  - >250 lb = 5 minutes per bed position

PET whole-body reconstruction

- Method iterative
- Image size 168, Zoom 1
- Filter FWHM 5 mm
- Iterations and subsets determined by patient weight:
  - <120 lb = 5 iterations, 8 subsets
  - 150-220 lb = 4 iterations, 8 subsets
  - >220 lb = 2 iterations, 8 subsets
Brain protocol

Patients scheduled for a PET/CT brain exam are handled differently from injection through imaging than the oncology patient. Clothing with metal is not an issue with the brain patient, removable dental appliances are; for this reason we ask brain patients to remove all dental appliances.

The patient is made comfortable in the holding room, a history is taken, and the IV is placed but the FDG is not yet injected. The lights in the holding room are turned off, and the patient is instructed to keep their eyes closed. This period of relaxation is given so that the patient can be relaxed mentally as well as physically prior to FDG administration.

The patient relaxes in the dark with their eyes closed for approximately five minutes, the FDG is then injected, and the IV is pulled. The patient is asked to empty their bladder 60 minutes postinjection. The brain PET/CT images are acquired using the following parameters:

**Brain acquisition parameters**

<table>
<thead>
<tr>
<th>Topogram routine</th>
<th>CT attenuation-correction routine</th>
</tr>
</thead>
<tbody>
<tr>
<td>mAs 50</td>
<td>Effective mAs 240</td>
</tr>
<tr>
<td>kVp 110</td>
<td>kVp 130</td>
</tr>
<tr>
<td>3.4-sec scan time</td>
<td>Slice 3 mm, collimation 6 x 2 mm</td>
</tr>
<tr>
<td>1-mm slice</td>
<td>Kernel B30 medium smooth</td>
</tr>
<tr>
<td>Topogram length 256 mm</td>
<td>Window mediastinum</td>
</tr>
<tr>
<td>LAT tube position</td>
<td>Field-of-view (FOV) 300 mm</td>
</tr>
<tr>
<td>Craniocaudal direction of scan</td>
<td></td>
</tr>
<tr>
<td>Kernel T20s standard</td>
<td></td>
</tr>
</tbody>
</table>

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PET brain routine

- Injected dose -- from history sheet
- Time of injection -- from history sheet
- Scan duration:
  - 15 minutes if <180 lbs
  - 20 minutes if >180 lb (if able)

PET brain reconstruction

- Method iterative
- Image size 256, Zoom 2
- Filter FWHM 2 mm
- Output corrected (first reconstruction)
- Output uncorrected (second reconstruction)
- 4 iterations, 8 subsets