Radiology Rounds

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When to Select PET/CT versus Stand-Alone PET

- **PET/CT scans result in more accurate interpretations of pathology, especially in the head and neck, the abdomen, and the extremities**
- **PET alone is recommended for brain studies because CT has less clinical utility than MRI for brain evaluation**
- **PET alone is appropriate for solitary pulmonary nodule evaluation if there is a recent (within 1 month) CT scan**
- **PET alone may be considered for follow-up of treated, asymptomatic cancer patients when there is a low suspicion for recurrence**

PET and CT are complementary imaging techniques that, when used in conjunction with one another, have better diagnostic accuracy than either technique alone. PET imaging, using the glucose analog 18F-FDG as a tracer, is functional imaging which detects sites at which metabolic activity is significantly higher than the surrounding region but contains little information on the anatomic location of that activity. CT, on the other hand, provides little functional information but combines high spatial resolution with good anatomical contrast. When the images are co-registered, it is possible to identify the anatomy of a "hot spot" and to distinguish between tumors and other sites that may have high metabolic rate, such as muscle, brown fat, or glands.

PET/CT

PET/CT scanners incorporate both CT and PET detectors in a single gantry and exam table. Because the patient remains in the same position throughout both the CT and PET exams, automated software can accurately co-register the PET and CT images to create fused PET/CT images (Figure 1). Although software co-registration of data from temporally separate PET and CT examinations may be possible, this option is less accurate because the patient is not likely to assume exactly the same position and because internal organs shift around. Therefore, it easier to determine the anatomic structures associated with high tracer activity in combined PET/CT images, which results in fewer equivocal interpretations and reduced need for further testing. This is especially significant in regions of complex anatomy, such as in the abdomen and in the head and neck. In addition, PET/CT is more convenient to the patient because the combined scans require only one visit to the hospital and the imaging time is shorter than a PET scan alone.

There is considerable evidence the combination of PET and CT examinations is significantly more sensitive and specific than either method alone. Furthermore, there is growing evidence that a PET/CT examination demonstrates superior diagnostic performance than separate PET and CT exams that are interpreted side-by-side. For example, PET/CT is more accurate for tumor localization and assessing tumor extent for staging non-small cell lung cancer and other solid tumors, especially in the abdomen and pelvis, as well as for assessing response to short-term therapy in gastrointestinal tumors. In the head and neck, PET/CT images can easily distinguish between abnormalities and physiological structures such as muscle and brown fat and hybrid imaging has been shown to have superior sensitivity and specificity compared to viewing side-by-side PET and CT images for the diagnosis and staging of squamous cell carcinoma.

A PET/CT scan can include a full diagnostic CT scan or an abbreviated scan of the region of interest for localization purposes. If a patient has had full diagnostic CT scan within the last month, a localization scan is sufficient. In almost all other cases, a PET/CT examination should include a full diagnostic CT examination. Table 1 shows the recommended anatomy for the diagnostic CT examination for the most common conditions.

In some instances, PET alone may be sufficient. If PET imaging is required for the evaluation of a solitary lung nodule >8 mm in diameter, the accuracy of software co-registration of PET and CT images obtained temporally separately is comparable to that obtained from PET/CT provided that a recent CT (within the last 30 days) is available. However, software co-registration poses logistic challenges in clinical practice and certainly a combined PET/CT scan is recommended if there are no recent tomographic images.

A stand-alone PET scan is also recommended for brain studies because CT has less clinical utility than MRI for brain disease. In addition, for patients who weigh >250-300 lbs, separate stand-alone PET and CT scans are preferable because they result in better PET image quality than a PET/CT scanner.

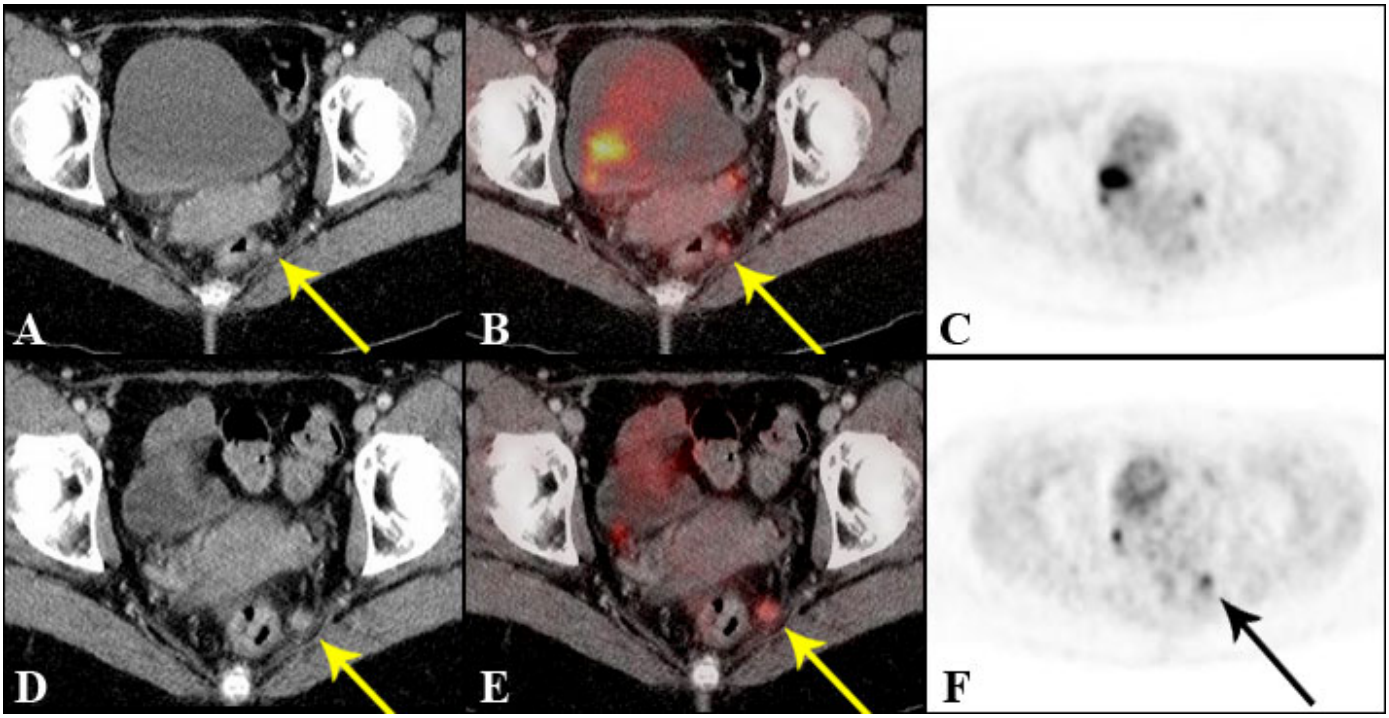

Figure 1. 44 year old woman with squamous cell cancer of the anus presented for routine follow-up examination after chemoradiation therapy. CT image from PET/CT showed a small perirectal node (A, arrow). Fusion images (B, arrow) showed mild uptake within the node. PET images (C) alone did not show worrisome areas of uptake.

Follow-up of the same patient 2 months later (D, E, F, arrows) confirmed growth and further uptake in the node. This case demonstrates how small size is a limitation of PET and how the high structural resolution and anatomical localization of CT can help PET.

Other circumstances in which PET alone may be considered include the assessment of tumor response to therapy and for assessing certain oncologic patients when there is a low suspicion for recurrence.

Limitations

Although most tumors have a high metabolic rate and take up FDG avidly, there are exceptions such as carcinoid tumors, well-differentiated low grade tumors such as bronchioalveolar cell carcinoma in the lung, and most mucinous cancers. Therefore, a negative FDG-PET scan is not an absolute indication of a benign lesion. In addition, the spatial resolution of PET is about 4-6 mm, inferior to that of other imaging methods, such as CT, which means that tumors must be at least 7 mm before they can be detected. A list of conditions that are recognized as suitable for evaluation with PET is shown in Table 2.

False positive diagnoses can arise from high FDG uptake into tissues that have unusually high metabolic rates, such as inflammatory lesions. Therefore, PET should generally not be performed until 2-3 months after radiation therapy and the interpreting physician needs to have all pertinent clinical information concerning recent surgery, chemotherapy, bone fractures or other trauma, as well as the date of the last menstrual period in pre-menopausal women.

Patient Preparation

In general, patients are required to fast for 6 hours prior to a FDG-PET or FDG- PET/CT scan but may continue to take regular medication. Diabetic patients should fast for 4 hours before the study, and should eat just prior to fasting. While fasting, water is permitted but no sweetened beverages. If the patient is on an IV, there should be no glucose in the IV solution in the hours preceding the scan. This is necessary to minimize the amount of insulin circulating in the blood and, therefore, maximize FDG uptake into the metabolically active cells. All patients will have a blood glucose level measured before the scan. In a diabetic patient, a blood glucose level below 200 mg/100ml is acceptable. Above that level, the scan will be performed only if the referring physician does not believe that is possible for the patient to safely lower his or her glucose level.

PET/CT Procedure

Patients receive an injection of 18F-FDG-PET about an hour before the start of imaging to allow time for metabolic uptake of the tracer. Both before injection and between injection and imaging, physical activity or repetitive movement should be avoided to avoid unnecessary uptake into the muscles. At the start of the examination, the patient is positioned comfortably on the imaging table and is asked to stay motionless for the duration of the imaging procedure. A low radiation dose non-contrast transmission CT scan is performed first, which provides data to correct for attenuation for the PET scan. The FDG-PET scan is performed next that, depending on the size of the patient, takes about 25-35 minutes for a routine whole-body scan, which entails imaging of the neck, chest, abdomen, and pelvis. After the PET scan is complete, intravenous contrast is administered to the patient for a standard radiation dose diagnostic CT scan if it has been requested.

The radiation exposure for a PET/CT scan is about 110 mrem for a whole body low-dose attenuation correction scan, 2,600 mrem for a whole body (neck/chest/abdomen/pelvis) diagnostic CT scan, and about 1,600 mrem for the PET portion which is from injection of 18F (15 mCi) in an average sized patient. 18F has a half-life of 109 minutes and is effectively fully decayed within a few hours of administration. If radiation exposure is a concern, it is possible perform essentially a PET only scan by using the PET/CT scanner with a non-diagnostic, low quality CT not reliable for making CT diagnoses but sufficient for PET attenuation purposes.

A radiologist specializing in the relevant anatomy as well as a nuclear medicine specialist, routinely read PET/CT images in a joint interpretation format, and issue separate, but concordant, reports for the PET/CT scans.

Table 1. Guidelines for the Selection of PET/CT and PET Examinations:

Patient Condition	Recommended Approach*
Thymoma staging	PET/CT including diagnostic CT of the chest PLUS other affected body part, if any
Solitary pulmonary nodule evaluation**	PET/CT including diagnostic CT of the chest
Head & neck cancers (Tongue, larynx, thyroid, parotid, etc)	PET/CT including diagnostic CT of neck and chest
Abdominal cancers (most) Esophageal cancer Lung cancer staging Mesothelioma staging Sarcoma	PET/CT including diagnostic CT of chest, abdomen, and pelvis
Breast cancer Lymphoma Melanoma	PET/CT including diagnostic CT of neck, chest, abdomen, and pelvis
Brain disease	PET only

**If the patient has received a diagnostic CT examination within the past 30 days, the PET/CT examination need only include a CT scan of the anatomical region of the abnormality for localization purposes.*
***PET alone is sufficient if patient has had diagnostic chest CT within past 30 days.*

Table 2. Applications of FDG PET Covered by Medicare

Cancer	Diagnosis	Staging	Restaging	Monitoring Tumor Response
Non-Small Cell Lung Cancer	Yes	Yes	Yes	No
Esophageal Cancer	Yes	Yes	Yes	No
Colorectal Cancer	Yes	Yes	Yes	No
Lymphoma	Yes	Yes	Yes	No
Melanoma	Yes	Yes	Yes[1]	No
Breast Cancer	No	Yes[2]	Yes[3]	Yes[4]
Head and Neck Cancers[5]	Yes	Yes	Yes	No
Thyroid Cancers	No	Yes[6]	No	No
Cervical Cancer	No	Yes[7]	No	No
Other				
Fronto-temporal dementia	Yes			
Alzheimer's disease	Yes			
Myocardial viability	Yes[8]			
Myocardial perfusion	Yes			

[1]Evaluation of regional nodes not covered.
[2]Staging breast cancer patients for distant metastasis; initial diagnosis and staging of axillary nodes are not covered.
[3]Restaging breast cancer patients with loco-regional recurrence or metastasis.
[4]Monitoring tumor response to treatment for locally advanced and metastatic breast cancer when a change in therapy is anticipated.
[5]Not central nervous system.
[6]Restaging of recurrent or residual thyroid cancers of follicular cell origin previously treated by thyroidectomy and radioiodine ablation, have a serum thyroglobulin >10ng/ml and negative I-131 whole body scan.
[7]Staging in patients with newly diagnosed and locally advanced cervical cancer with no extra-pelvic metastasis on conventional imaging tests.
[8]Only following negative inconclusive SPECT

Scheduling

PET and PET/CT is currently available on the main campus only. An additional PET/CT scanner is scheduled to be installed in the Chelsea Imaging Center in the fall of 2007. PET/CT examinations may be scheduled online through Radiology Order Entry system, (http://mghroe) or by calling 617-724-9729 (4-XRAY).

Further Information

For further questions on PET/CT, please contact Alan Fischman, M.D., Director of Nuclear Medicine (617-726-8294) or Michael Blake, M.D., (617-726-8743), Staff Radiologist in the Division of Abdominal Imaging and Intervention, MGH Department of Radiology.

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