



PET/CT for Tumor Imaging

PET imaging using the glucose analog ^{18}F -FDG as a tracer is an excellent method to detect small focal sites of high metabolic activity, which are frequently indicative of tumors. However, it is very difficult to identify the anatomic location of these focal sites precisely with PET alone. The only anatomic markers in FDG-PET are organs, such as the heart, that are known to have high metabolic rate, and the excretory system. In addition, the spatial resolution of PET is about 5-6 mm, much lower than that of other imaging methods, such as CT. These limitations make it difficult to make an accurate interpretation of the anatomic location of the focal site of tracer uptake, especially in regions of the body where anatomy is complex, such as the neck and the abdomen. Therefore, patients often receive both PET and CT scans. Computer programs are used to co-register the scans and thus the anatomic information from CT is combined with the physiologic information from PET.

Combined PET/CT scanning is now available at MGH. This has several advantages if both PET and CT scans are needed. It 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. In addition, the co-registration of the images is much superior to that achieved for separate PET and CT scans because the patient remains in the same position throughout the imaging procedure. The improved co-registration makes it easier to determine the anatomic structures associated with high tracer activity, resulting in fewer equivocal interpretations and reduced need for further testing. Better co-registration is especially significant in regions of complex anatomy, such as in the abdomen, and in the head and neck.

When is PET/CT better than PET or CT alone?

PET alone has been proven to be more accurate than CT in a number of clinical situations, including staging of lung, colorectal, and head and neck cancers, and for lymphoma. PET and CT together are better than PET alone for imaging the neck, chest, abdomen, and pelvis. However, if a patient has had a CT already that has shown a solitary lung nodule that is greater than 7 mm in diameter, it is large enough to be detected by a

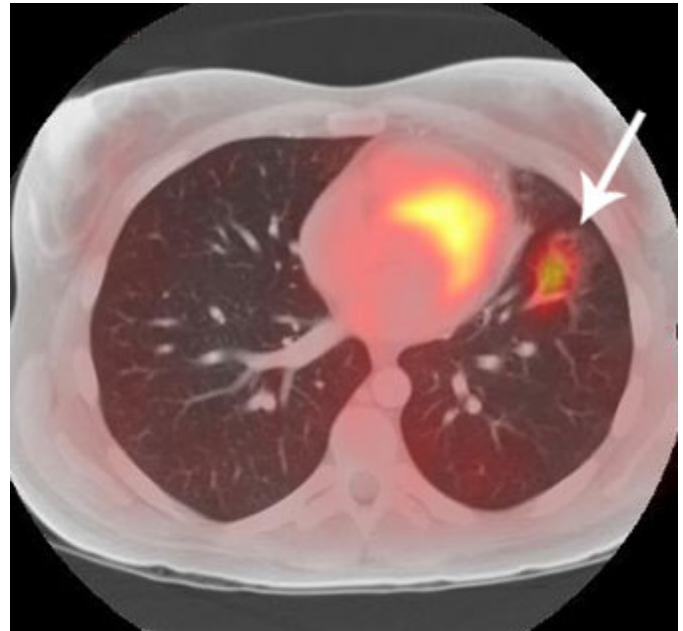


Figure 1. Fused PET/CT image clearly showing anatomic distribution of increased ^{18}F -FDG uptake corresponding with "ground glass" nodule on CT. Separate CT and PET images from the scan are shown in Figure 2 and 3.

PET scan alone and a combined PET/CT is not necessary.

In other cases, where the lesion is surrounded by complex anatomy or when some time has elapsed since the CT scan, a combined PET/CT scan is preferable but may not be necessary. Although some

preliminary studies indicate that diagnosis and staging is superior with a combined PET/CT scan, there are no good prospective studies at present that demonstrate the advantages of combined PET/CT versus PET and CT scanning.

On the other hand, if there are no prior tomographic images, it is clear that in most cases there are significant advantages in having a combined PET/CT scan. Exceptions to this rule are for brain scanning and for patients who weigh 250-300 lbs or more, since in these cases separate PET scans are less noisy than those obtained with the PET/CT scanner.

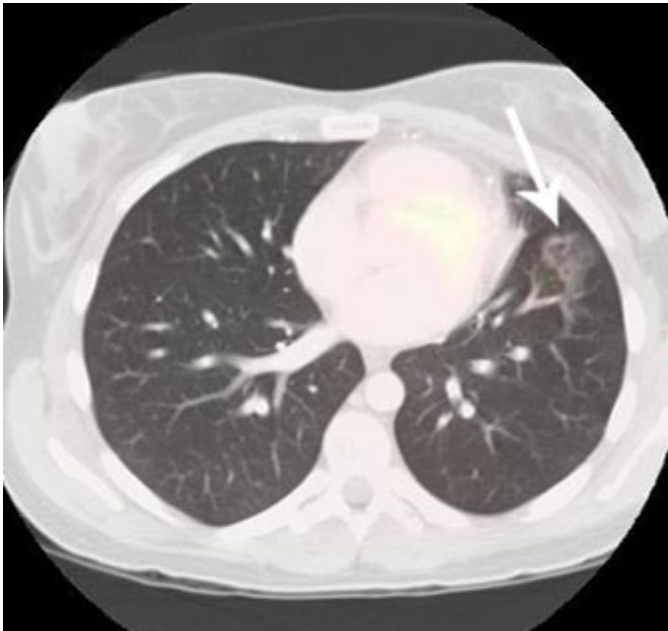


Figure 2. Axial CT image showing "ground glass" nodule in lingula, from same scan as [Figure 1](#).

Limitations

Although most tumors have a high metabolic rate and take up FDG rapidly, there are exceptions such as carcinoid tumors, well-differentiated low grade tumors such as bronchioalveolar cell carcinoma in the lung, and certain mucinous cancers such as ovarian. Therefore, a negative FDG-PET scan is not an absolute indication of a benign lesion. In addition, false positive diagnoses can arise from high FDG uptake into tissues that have unusually high metabolic rates, such as inflammatory lesions. Other limitations include the low spatial resolution of PET, which limits the size of tumors that can be detected to about 7 mm.

Because the indications for PET/CT are so specific, the study is normally ordered by physicians who are familiar with the clinical utility of the study.

PET/CT Procedure

In PET/CT, both the multidetector CT instrumentation and the PET detectors are mounted in the same gantry, one immediately behind the other. Both PET and CT are performed while the patient lies in the same position on the imaging table.

Patients receive an injection of ^{18}F -FDG-PET about an hour before the start of imaging to allow time for metabolic uptake of the tracer. 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 dose non-contrast transmission CT scan is performed first, which provides data to correct for attenuation for the



Figure 3. Coronal PET image showing increased ^{18}F -FDG uptake in the lingular nodule, from same scan as [Figure 1](#). Note normal metabolic uptake of ^{18}F into left ventricle and excretion into bladder.

PET scan. The FDG-PET scan is performed next, which takes about 25-35 minutes, depending on the size of the patient, for a routine whole-body scan, which entails neck, chest, abdomen, and pelvis. After the PET scan is complete, intravenous contrast is administered to the patient before a second rapid CT scan, which is used for clinical interpretation.

The radiation exposure for a PET/CT scan is about 800-1,000 mrem for each CT scan and about 1,600 mrem for ^{18}F (15 mCi). ^{18}F has a half-life of 109 minutes and is effectively fully decayed within a few hours of administration.

What is PET?

Positron emission tomography (PET) images the regional distribution of metabolically important tracer molecules that contain a positron-emitting isotope (e.g. ^{11}C , ^{13}N , ^{15}O , ^{18}F , or ^{124}I). When a radioactive nuclei emits a positron, it travels less than 1 mm before it collides with an electron, resulting in annihilation of both particles and the release of two high energy photons (511 keV) that travel in diametrically opposite directions. PET detectors record the simultaneous arrival of photons and tomographic reconstruction procedures are used to create the images.

The isotopes used in PET all have half-lives measured in minutes and must be created with a cyclotron shortly before their use. Then the isotope-containing tracer molecule must be chemically synthesized and rapidly transported to the imaging facility. This process limits the availability of PET. However, no other imaging method is able to provide the metabolic and physiological information that can be seen in PET.

Medicare Reimbursable Applications of PET

Characterization of solitary pulmonary nodule
Non-small cell lung cancer
Lymphoma
Head and neck cancer
Colorectal cancer
Breast cancer
Esophageal cancer
Melanoma

Note: PET/CT is billed as a PET and a CT scan.

Scheduling

PET/CT is available at the main campus only, in a trailer linked to the Founder's Building. It is accessible only to ambulatory patients weighing less than 250 lbs. PET/CT examinations may be scheduled online through [Radiology Order Entry \(ROE\)](#) (or by calling 617-724-9729). Single plane fusion images will be created, in addition to 3-D multiplanar fusion images for clinical viewing (unless otherwise requested). Separate reports for the PET and CT scans will be provided by the relevant subspecialty radiologists.

Patient Preparation

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. Water is permitted but no

References

Townsend, D, Carney, J, Yap, J and Hall, N. (2004) *PET/CT today and tomorrow*. J Nucl Med **45**, 4-14S.
Czernin, J and Schelbert, H. (2004) *PET/CT imaging: facts, opinions, hopes, and questions*. J Nucl Med **45**, 1-3S.

sweetened beverages. Diabetic patients should fast for 4 hours before the study, and should eat and take their insulin just prior to fasting. 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 it is possible for the patient to lower his or her glucose level.

Any physical activity or repetitive movement should be avoided before the scan to avoid unnecessary uptake into the muscles.

Further Information

For further questions on PET/CT, please contact [Alan Fischman, MD](#), Director of Nuclear Medicine (617-726-8294) or [Suzanne Aquino, MD](#), (617-724-4254) Thoracic Imaging, MGH Department of Radiology. Further information can also be found at [MGH Radiology PET/CT](#) website.

Kapoor, V, McCook, BM and Torok, FS. (2004) *An introduction to PET-CT imaging*. Radiographics **24**, 523-43.
Schoder, H, Erdi, YE, Larson, SM and Yeung, HW. (2003) *PET/CT: a new imaging technology in nuclear medicine*. Eur J Nucl Med Mol Imaging **30**, 1419-37.

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