Usefulness of positron emission tomography in clinical oncology

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Although positron emission tomography (PET) is expensive in terms of absolute dollars per exam ($2000 reimbursement by Medicare), its superior accuracy for multiple oncologic indications makes it a promising tool. Oncologists can improve treatment selection when they have access to the most accurate staging data. In addition, the more accurate noninvasive data obtained with PET may provide considerable cost savings for the health care system through prevention of unnecessary invasive diagnostic and therapeutic procedures. Consequently, unnecessary morbidity may be avoided. For these reasons, clinical PET is poised to enter the mainstream of clinical medicine and shows potential for substantial contributions to the field of oncology.

PET is, after >25 years in existence, finally poised to enter the mainstream of clinical medicine in the oncology arena. Its evolution into a clinical tool has been delayed, at least partially, by the intense scrutiny of third-party payers, unlike that brought to bear on any other imaging modality before or since. In this era of managed care and capitated health care contracts, a costly “new” imaging modality must prove its value, not only by having superior clinical accuracy, but also by being cost neutral or, preferably, cost beneficial. The Health Care Financing Administration (HCFA) approved PET for Medicare reimbursement in January 1998, but reimbursement was restricted to staging non–small cell lung cancer and characterizing the indeterminate solitary pulmonary nodules. Effective July 1, 1999, additional Medicare-covered indications include 1) detection of recurrent colorectal carcinoma with an unexplained rising carcinoembryonic antigen; 2) staging of primary and recurrent Hodgkin's disease or non-Hodgkin's lymphoma in place of gallium imaging; and 3) identification of metastases in suspected melanoma recurrence. Private third-party payers also are recognizing PET's clinical value, and many are providing reimbursement for PET charges for a variety of oncologic indications. Expanding reimbursement policies and consistently excellent clinical results have stimulated widespread interest in clinical PET.

HISTORY AND BASIC PRINCIPLES OF PET

The first PET scanner was built at Washington University, St. Louis, in the early 1970s when early computed tomography (CT) also was being developed. Like CT, PET has seen many technical improvements over the years and now has become a mature technology.
While CT entered the clinical arena almost immediately, PET remained in the research domain until more recently. In its early years, PET was heralded for its ability to visually depict many biochemical and physiologic processes in the brain and heart. Indeed, much of our knowledge of brain-function mapping was obtained with this technology. PET evaluation of myocardial viability is still considered the noninvasive gold standard.

In the early 1980s, the first oncologic applications were reported in the evaluation of brain tumors and colon cancer. Throughout the remainder of the decade, sporadic reports of additional oncologic applications appeared in medical literature. The early growth potential of oncologic PET was hampered by the small viewing field of early generation PET cameras, as well as other hardware and software limitations, that precluded the type of large-area imaging necessary for optimal staging of malignant neoplasms. By 1992, evolution of newer PET cameras with larger axial viewing fields and improved image reconstruction methods allowed whole-body PET imaging, similar to traditional nuclear medicine exams (e.g., bone scintigraphy). These and other continuing developments have allowed PET to provide accurate whole-body tumor staging in one brief imaging session and have helped stimulate the growth of oncologic PET imaging.

The basis of PET imaging is the labeling of small, biologically important molecules, such as sugars, amino acids, and water, with positron-emitting radionuclides that can map physiologic functions in vivo. A positron is a positively charged electron that originates in the nucleus of specific types of radioactive atoms. When emitted in the process of radioactive decay, the positron typically travels only a few millimeters in tissue before colliding with a free electron. The positron-electron (antimatter-matter) interaction results in the total annihilation of both particles and the conversion of their masses into two 511-keV photons of pure energy that are emitted in opposite directions (at almost 180 degrees). These “coincident” photons can be identified on opposite sides of the body by opposing detectors. In a modern, high-resolution PET scanner, thousands of small detectors are oriented in a configuration of multiple rings that surround the patient's body.

The size and external appearance of a PET camera are similar to those of a CT scanner: a shallow orifice centrally located within a larger, solid gantry through which a patient's body passes during data acquisition (Figure 1). Opposing detectors are coupled to each other through advanced electronic circuitry that allows identification and localization of hundreds of thousands of these “coincident” photon pairs per second. Computer reconstruction, similar to that of standard CT, then creates a tomographic depiction of the in vivo distribution of the positron-emitting radiopharmaceutical. Depending on the radiopharmaceutical used, various metabolic functions can be tracked with PET. Improvements in image quality also can be made by mapping the soft-tissue attenuation properties of each patient and applying these mathematical corrections to the “emission” data.

Most clinically useful positron-emitting radionuclides must be produced in a medical cyclotron. These include O-15, N-13, C-11, and F-18, with short radioactive half-lives of 2, 10, 20, and 110 minutes, respectively. After production, these radionuclides are converted to radiopharmaceuticals by chemical linkage to biologically relevant compounds that dictate
their physiological behavior when injected into a patient. F-18 is an especially important positron-emitting radionuclide because, when linked to glucose, it forms [F-18]-2-fluorodeoxyglucose (FDG), the most common radiopharmaceutical used in PET scanning today. An advantage of the F-18 label is its 2-hour half-life, which allows production in a regional commercial cyclotron that can supply the needs of multiple clinical PET facilities. This arrangement eliminates the need for a dedicated cyclotron at each PET center, dramatically reducing the complexity, as well as the start-up and operating costs, of a new PET center.

**RATIONALE AND INDICATIONS FOR ONCOLOGY IMAGING**

Compared with normal tissues, tumors generally exhibit accelerated metabolism, including increased glucose metabolism. Glucose is the preferred energy substrate for most cancers. Metabolism can be effectively visualized with FDG, a glucose analogue. Malignant tumors typically are depicted as areas of increased FDG activity (“hot spots”) compared with normal tissues and benign lesions.

Many people erroneously believe that other advanced imaging tools, such as CT, magnetic resonance imaging (MRI), and ultrasonography, permit little room for improvement in cancer evaluation. Although they are and will remain instrumental for a variety of oncologic applications, CT and MRI share multiple shortcomings, including their inability in many instances to

1. differentiate scar or radiation necrosis from active tumor;
2. determine if a mass lesion is malignant;
3. characterize enlarged lymph nodes as benign or malignant;
4. detect malignancy in normal-sized lymph nodes or normal-appearing tissue; and
5. evaluate early tumor treatment response.

Herein lies the key difference between PET and other imaging modalities: PET tracks the metabolic and physiologic properties of tumors, whereas CT and MRI depend primarily upon morphologic alterations for diagnoses. Because tissue metabolic abnormalities typically precede anatomic changes, PET has proven superior in solving many difficult clinical dilemmas for a variety of cancer types.

**DISEASE-SPECIFIC ONCOLOGIC APPLICATIONS**

**Solitary pulmonary nodule**

Approximately 130,000 new solitary pulmonary nodules are discovered each year. Nationwide, 40% of these nodules are malignant and 60% are benign. The goal of noninvasive imaging is to differentiate those lesions with a high likelihood of malignancy, which require invasive testing for diagnosis or thoracotomy for curative resection, from those with a high likelihood of benign disease, which can be followed noninvasively. If the nodule's appearance is stable radiographically over 2 years or if the nodule has a typical pattern of stippled internal calcification, the nodule is probably benign and can be followed
radiographically. Often, however, the nodule is “indeterminate” after chest radiography and CT (or MRI), and further evaluation is required. Transthoracic needle aspiration biopsy is often applied in this situation. A negative transthoracic needle aspiration biopsy result, however, is unreliable because of sampling error in choosing the site(s) to biopsy. In addition, transthoracic needle aspiration biopsy is invasive and has associated morbidity. Fiber-optic bronchoscopic biopsy is commonly attempted but frequently is unable to access a peripheral nodule. Video-assisted thoracoscopy is a newer option for diagnosis that, by early reports, has high diagnostic accuracy. It is, however, relatively expensive and invasive, and it requires general anesthesia.

Recent data have shown that FDG-PET is a good discriminator for differentiating high-risk from low-risk solitary pulmonary nodules. In general, malignant solitary pulmonary nodules hypermetabolize glucose, resulting in focally intense FDG uptake into the nodule. Conversely, most benign nodules (e.g., inflammation or scar) are not highly FDG avid (Figure 2 and 3). Lowe recently reviewed 555 patients whose solitary lung nodules were indeterminate after CT scans. These patients then had FDG-PET scans and adequate follow-up for a diagnosis (1). The sensitivity and specificity of the PET study were 95% and 81%, respectively, for detecting malignancy. The 5% false-negative rate is superior to transthoracic needle aspiration biopsy and fiber-optic bronchoscopic biopsy, and it is sufficiently low that patients with negative PET scans are generally placed into a low-risk group that can be followed radiographically. Many invasive procedures are thus avoided when the FDG-PET scan is negative.

The specificity of FDG-PET, although still relatively high, usually is reported to be lower than the sensitivity. This is because some inflammatory lesions, especially granulomatous lesions, also occasionally demonstrate high FDG avidity. False-positive results may be seen in tuberculous or fungal lesions and in sarcoidosis. Therefore, the detection of a hypermetabolic (“hot”) solitary pulmonary nodule through FDG-PET should be followed by a tissue biopsy to confirm the diagnosis. Since the likelihood of malignancy rises to 80% when high levels of FDG accumulate within the lesion, some investigators recommend proceeding directly to thoracotomy or thoracoscopy after a positive PET. Obviously, patient management also will be influenced by assessment of pretest risk, based on clinical or radiographic factors.

A new imaging modality must prove not only clinically effective but also cost effective to be accepted in today's medico-economic environment. At the current Medicare reimbursement level of $2000 per scan (which includes the substantial cost of FDG, as well as physician supervision and interpretation), PET can save health care dollars. Several studies have shown a cost savings of $1200 to $2200 per patient for each PET scan performed (2, 3). The savings come almost exclusively from preventing unnecessary invasive tests and surgeries for patients with negative PET scans. Furthermore, there is an equally important avoidance of morbidity from unnecessary invasive and surgical procedures. These data have been confirmed repeatedly, and they eventually prompted HCFA to approve PET reimbursement for PET characterization of solitary pulmonary nodules.
**Staging non–small cell lung cancer**

Staging non–small cell lung cancer after its histologic diagnosis was the second oncologic PET scan indication initially designated for Medicare reimbursement. Surgical treatment with intent to cure non–small cell lung cancer depends upon proof that the cancer is limited in extent prior to surgery. Surprisingly, the Radiological Diagnostic Oncology Group found the sensitivity and specificity for preoperative staging of the mediastinum to be only about 50% for CT and 65% for MRI (4). The limited accuracy of CT and MRI is due to their reliance on size criteria for disease detection, although metastases may be present in normal-sized nodes, and enlarged lymph nodes may be benign (e.g., reactive hyperplasia). Mediastinoscopy has a higher sensitivity (85% to 90%) for detecting localized metastatic disease, but not all nodes are accessible to the mediastinoscope (5). Additionally, as with CT and MRI, the key parameter for the sampling of lymph nodes during this procedure is based on enlarged size of the nodes. Finally, mediastinoscopy is invasive and more expensive, and it requires general anesthesia.

FDG-PET has shown clinical effectiveness in staging the mediastinum, as well as the remainder of the body, because it is not constrained by anatomic criteria. Its performance is linked to the metabolic behavior of metastatic foci which, like the primary tumor, are routinely hypermetabolic. In a recent compilation of 8 clinical series that included 339 patients (1), the average sensitivity and specificity for PET detection of metastatic disease were 88% and 93%, respectively. These values were comparable to those of mediastinoscopy, but at a lower cost and morbidity. As with the solitary pulmonary nodule, substantial cost savings of $1000 to $2000 per patient were realized for each PET scan performed, because unnecessary surgeries were prevented when inoperable metastatic disease was discovered (6). Clinical risk factors still will play a role in determining whether specific patients should undergo histologic confirmation of PET results. Even in these cases, PET is likely to facilitate patient evaluation by localizing hypermetabolic lesions.

**Recurrent colorectal carcinoma**

The recurrence rate of colorectal carcinoma after initial treatment is 30% to 40%, most of which is detected within 2 years of primary surgery (7). Early detection and treatment of recurrence when it is still localized lead to an improved survival rate. Still, only about 25% of patients with apparently limited disease achieve a cure after surgical re-resection (8). Presumably, the high failure rate reflects unrecognized disease prior to surgery.

FDG-PET has shown more efficacy in detecting recurrent colorectal carcinoma than any other imaging modality in these clinical settings: 1) determining the source of an unexplained carcinoembryonic antigen elevation, 2) differentiating posttreatment scar from recurrent disease in the operative bed, and 3) staging the whole body accurately prior to resection of a suspected isolated metastasis.

Serum carcinoembryonic antigen level is a tumor marker commonly used for colorectal cancer recurrence. Unfortunately, carcinoembryonic antigen elevation does not help localize the site of recurrence. Occasionally, an elevated carcinoembryonic antigen may not even be
associated with recurrent disease. FDG-PET has been especially useful in localizing the site of recurrence, detecting disease in as many as one half to two thirds of the patients who have rising carcinoembryonic antigen levels but otherwise negative workups (9).

Local recurrence of colorectal carcinoma at the surgical site is seen in 25% to 30% of patients within 2 years of surgery (10). CT, MRI, and ultrasonography cannot differentiate posttreatment scar from recurrent tumor because there are no distinguishing anatomic characteristics that reliably separate one process from the other using these imaging modalities. Thus, serial anatomic imaging studies often are required to document the growth that heralds tumor recurrence. PET can distinguish posttreatment scar from recurrent tumor, however, because of their dissimilar metabolic properties (11). Malignant tumor is hypermetabolic and FDG-avid on PET, whereas scar tissue is not. PET's greater accuracy is crucial for confident detection of tumor recurrence at an earlier stage, when surgical cure may be possible.

When a suspected solitary tumor recurrence, often in the liver, is detected by standard anatomic imaging modalities, the likelihood of surgical cure is dramatically reduced if there is additional, unsuspected metastatic disease in other sites. Accurate staging of metastatic disease outside the liver is particularly troublesome for CT and MRI, with sensitivities in the 60% to 70% range. FDG-PET has demonstrated at least 90% sensitivity in detecting extrahepatic metastatic colorectal carcinoma (3, 11). It also has shown slightly higher accuracy in detecting liver metastases (92% to 98%) than CT (80% to 93%) (11, 12). Consequently, PET has detected unsuspected metastases not seen by CT, MRI, and ultrasonography in 15% to 30% of patients, altering surgical management in many cases. As a result, cost savings in excess of $2000 per patient were realized when PET was added to the workup for selecting appropriate candidates for surgical resection of recurrent disease (3).

Several series have reported good results with FDG-PET in staging primary colon cancer preoperatively (13–15). At this time, however, the data are insufficient and the impact on patient management is too uncertain to recommend the routine use of FDG-PET for this application.

**Lymphoma**

As with colorectal carcinoma, there are problems differentiating posttreatment scar tissue from residual malignant disease after treatment of non-Hodgkin's and Hodgkin's lymphoma. Current anatomic tests require growth on serial studies to confirm malignant disease, delaying the reinitiation of potentially curative therapy and increasing costs due to repetitive imaging studies. Metabolic imaging with PET is especially well suited for this enigma, since hypermetabolic foci indicate active disease in a treatment site, while the absence of excessive FDG uptake is characteristic of fibrosis (16). This is usually a simple distinction.

Another recent application for FDG-PET is in differentiating AIDS-related central nervous system lymphoma from acquired opportunistic infections, especially toxoplasmosis. Although they are usually indistinguishable on CT and MRI, lymphoma is FDG-
hypermetabolic, while toxoplasmosis is hypometabolic (17).

In some centers, gallium-67 scintigraphy has been the standard for evaluating lymphoma activity. Although few studies have compared FDG-PET with gallium-67 scintigraphy in detecting lymphoma, most centers that have both modalities available have observed FDG-PET superiority over gallium-67 scintigraphy, especially in lower-grade neoplasms. Indeed, animal research has shown lymphoma to be one of the most FDG-avid malignancies (18). Therefore, in these centers, FDG-PET has successfully replaced gallium-67 scintigraphy for the evaluation of residual and recurrent lymphoma.

Ultimately, FDG-PET may prove to be useful in the initial evaluation of lymphoma patients to stage the extent of disease accurately and to direct therapy accordingly (19). Presently, as with primary colon cancer staging, there is insufficient experience with this indication for PET to be strongly recommended.

**Melanoma**

The incidence of melanoma is increasing at a faster rate than any other malignancy. In the experimental animal model, this tumor, like lymphoma, has an unusually high avidity for FDG, making it particularly well suited for FDG-PET imaging. Ultimately, PET may be recommended for preoperative staging of the primary tumor. However, data on its efficacy for this purpose remain limited. There are good data for 2 different indications: characterizing abnormal radiographic findings in primary or recurrent disease and more accurate whole-body staging prior to attempted curative resection of a suspected solitary recurrence.

As with virtually all neoplasms, metabolic derangements will precede anatomic changes in metastatic melanoma. Therefore, at least theoretically, metabolic PET imaging should be superior to CT, MRI, and ultrasonography in the early detection of disease. This has been confirmed, as several studies have demonstrated an accuracy of 90% to 95% for FDG-PET compared with 40% to 80% for the standard diagnostic workup (20). In the largest study, only the lungs were better staged with the standard workup, because PET may miss very small (subcentimeter) metastases (21).

In a cost-effectiveness analysis of 45 patients evaluated for possible curative resection of suspected solitary metastases, surgical management was changed for 36% of patients based on the PET findings. As a result of avoiding surgery, based on discovery by PET of unresectable disease, the cost savings was $2200 per patient and considerable morbidity was spared (3). A corollary result, of course, should be improved overall surgical outcomes in those patients who do have surgery, due to the surgeons' use of PET to aid them in selecting optimal candidates for re-resection.

**Brain tumors**

The first described oncologic application of FDG-PET was for brain tumor evaluation in the early 1980s. A potential problem with brain imaging is the intense baseline FDG uptake in
gray matter, which could obscure visualization of FDG uptake in tumors of intermediate and low metabolic activity. However, this characteristic has been used to advantage. Typically, high-grade tumors show intense FDG uptake, greater than that in the surrounding gray matter, while lower-grade gliomas have less intense uptake, comparable to normal white matter (although there is some overlap among the groups). Studies have shown that the intensity of uptake correlates with prognosis. Patients with hypermetabolic lesions have a significantly shorter survival rate than those with hypometabolic lesions (22). PET also has been used to follow patients with low-grade tumors who were not good surgical candidates. It can recognize the transformation of low-grade gliomas into higher-grade gliomas, a signal of the need for more aggressive therapy.

When CT or MRI uncovers a new contrast-enhancing lesion in the treatment field of a brain tumor, radiation necrosis cannot be distinguished from recurrent tumor. Because FDG-PET tracks tissue metabolism, it is well suited for this application (23). FDG uptake greater than white matter (and frequently greater than gray matter) indicates residual or recurrent tumor, whereas radiation necrosis appears as a focal FDG void. This finding assumes that the tumor was FDG-avid before treatment, which stresses the importance of baseline scans for brain tumors, especially in lower-grade gliomas.

Conversely, FDG-PET has not been as reliable as other imaging methods in detecting metastases to the brain arising from a variety of primary neoplasms. This outcome has been attributed to the inability of FDG-PET to distinguish often small, variable-intensity metastatic lesions from the highly active normal gray matter (24). PET should not substitute for MRI or CT imaging of the brain for cancer staging, but if hypermetabolic brain lesions are discovered on a whole-body scan for cancer staging, they usually indicate central nervous system metastases.

**Head and neck carcinoma**

Although somewhat controversial, several studies have shown similar efficacy of FDG-PET and MRI in the preoperative staging of primary squamous cell carcinoma of the head and neck, with sensitivities for detecting primary and metastatic lesions in the 80% to 90% range (25, 26). However, MRI provides exquisite anatomic detail, a preoperative requirement, making it the study of choice for surgical or radiotherapy planning of primary head and neck carcinoma.

A more difficult challenge is evaluating patients with suspected recurrent disease who were previously treated with surgery and radiotherapy. Altered tissue planes and heterogeneous fibrosis make correct interpretation of CT and MRI challenging in these patients, whereas interpretation of the metabolic FDG-PET study usually is much more straightforward. Additionally, the whole-body feature of PET allows for the detection of unsuspected distant metastases, thus improving patient management. Finally, early data also suggest significant advantages of PET over other imaging modalities in the detection of unknown primary tumor sites in patients with metastatic head and neck cancer of uncertain origin (27).
Breast cancer

As with primary colon cancer and lymphoma, data are insufficient on the use of PET in staging primary breast carcinoma. Several investigators suggest staging the axilla with FDG-PET studies because of reported sensitivity as high as 95% (28, 29). However, conflicting data report a lower sensitivity. A large, multi-institutional trial using FDG-PET for preoperative assessment of the axilla in primary breast carcinoma is now in progress. Even if the 95% sensitivity level is confirmed, a false-negative rate of 5% may not be low enough to eliminate the axillary dissection staging for risk stratification, due to current societal expectations. Perhaps, however, the combination of PET and limited axillary sentinel node resection, using lymphoscintigraphy, will be an acceptable strategy in the future.

Currently, PET is used for problem solving in suspected recurrent breast cancer (30). For example, FDG-PET can be used to characterize an indeterminate lesion on CT as malignant or benign, and it may assist in whole-body restaging prior to surgical resection of a suspected solitary metastatic lesion. Similarly, PET may play a role in more accurately staging patients with high-risk metastatic breast cancer prior to stem cell transplantation, where current high failure rates probably reflect inadequate staging by presently used methods.

Other cancers

FDG-PET has been successfully used as an assessment tool in a variety of other cancer types, including esophageal, pancreatic, ovarian, renal cell, testicular, hepatocellular, and bladder. Overall experience with these cancers, however, is too limited to recommend its routine use. Future studies may confirm a routine role for PET in some of these neoplasms. Its application in detecting prostate cancer has been particularly disappointing for both primary lesions and osseous metastases (31). Several series have reported a sensitivity of only 20% to 50% for detecting metastatic skeletal lesions from prostate cancer. The accuracy of FDG-PET for osseous metastases from other primary malignancies is still uncertain, due to insufficient data. In one small series of breast cancer patients with confirmed osseous metastatic lesions, FDG-PET was found to be superior to standard bone scintigraphy for detection of osteolytic bone lesions but inferior for detection of osteoblastic lesions (32). Presumably, the latter lesions do not have sufficient metabolic activity or cellular mass to be detected by PET. Until more data are available, PET should not be substituted for bone scintigraphy in staging primary malignancies.

FUTURE DIRECTIONS OF PET

Immense untapped potential still exists for oncologic clinical PET. As more experience is obtained, additional indications will surely emerge. One possible role for PET is in monitoring cancer treatment. This may eventually result in its greatest impact on disease management. CT and MRI rely on anatomic changes to predict tumor therapeutic response, but these changes typically lag several months behind metabolic changes in a treated tumor. PET effectively depicts key metabolic changes, such as glucose metabolism, allowing
earlier assessment of therapeutic response. FDG accumulation into a tumor is proportional to the number of viable neoplastic cells (33). Hence, by using semiquantitative methods, PET has the potential to quantify tumor burden before and after treatment, thereby predicting treatment response sooner than is possible with existing methods. The ideal timing of the PET study after initiating therapy is uncertain and may even differ for each cancer type. Additional studies in this important area are likely to help refine the recommendations for use of PET in monitoring cancer therapy.

In the future, we may see pretreatment PET scans with positron-emitting labeled chemotherapeutic drugs that predict the extent of drug localization into the neoplasm prior to initiating chemotherapy. For example, 5-fluorouracil has been labeled with F-18 and injected into patients with liver metastases from colon cancer. In general, those patients with high tumor uptake of the labeled analog respond better to 5-fluorouracil therapy than those with low tumor uptake of the tracer (34). As with other interesting PET applications, more studies with additional agents are indicated prior to recommending its routine use.

FDG has generic avidity for many tumors; however, inflammatory lesions occasionally produce false-positive FDG-PET scans. New positron-emitter labeled radiopharmaceuticals are being sought that offer greater specificity for tumor detection without sacrificing high sensitivity. What form these may take is uncertain, but positron-emitter labeled monoclonal antibodies or small molecules directed against tumor-specific receptors are being studied, as are labeled amino acids that track protein synthesis. The very nature of positron-emitting elements offers nearly unlimited potential for synthesis of novel molecules.

Technical advances in PET scanners will continue, as with other imaging modalities. Gamma camera manufacturers are now marketing a less expensive, hybrid, dual-head gamma camera with standard nuclear medicine detectors, modified electronically to also accept coincidence events from positron emitters. Initial studies report a lower sensitivity for detecting cancer with these “SPECT-PET” cameras than with dedicated PET systems, especially for smaller lesions, but the imaging characteristics of these hybrid systems are expected to improve. For the smaller nuclear medicine department that cannot support a full-time PET camera, the flexibility of the hybrid gamma camera, which can also perform all standard nuclear procedures, provides a less expensive alternative for entering the FDG arena.

Dedicated PET cameras also are seeing technological improvements. New detectors, which will provide improved scan speed and resolution, are currently being perfected and will probably be available on PET cameras within several years. Theoretically, these detectors should improve the ability to detect smaller lesions. Perhaps most exciting is the development of a single-unit CT and PET camera. A prototype of this product is currently being tested. These systems provide a perfectly registered superimposition of the metabolic PET data with the anatomic CT data. This system could assist greatly in surgical and radiotherapeutic planning.
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