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EDITORIAL

Camera-Based PET: The Best Is Yet to Come

Radionuclide imaging provides a sensitive method to characterize in vivo chemistry. Imaging studies of bone mineral turnover using ^{99m}Tc-MDP, transferrin receptors using ^{67}Ga-citrate, somatostatin receptors using ^{111}In-pentetreotide, uptake and vesicular storage using ^{131}I-MIBG and radiolabeled monoclonal antibodies now are being used to diagnose diseases by a specific aspect of chemistry. Fluorine-18-2-fluoro-2-deoxyglucose (FDG) has been used for many years in PET facilities throughout the world, and its use in demonstrating glucose metabolism has been well documented. It is now becoming more widely available through multiple distribution sites located in several large metropolitan areas in the U.S.

Imaging from FDG-PET has been demonstrated to have clinical use in several neurologic, cardiac and oncologic diseases (*1–3*). Most recently, the oncologic applications have been validated and accepted (*3–5*). Brain tumor imaging was the first oncologic application of FDG-PET (*6*), and its use is in the characterization of the degree of malignancy of a tumor and in the differentiation of necrosis from tumor after either radiation therapy or chemotherapy (*7*). The use of FDG-PET in lung cancer has been demonstrated to provide unique (*8*) and cost-effective (*9*) information in patient management. It is very accurate in the differentiation of benign and malignant solitary pulmonary nodules that are indeterminate by chest radiograph and CT (*8*), in staging the extent of disease (*10*), and in the differentiation of fibrosis from residual tumor after therapy (*11*).

The use of FDG-PET in other malignancies has achieved very good results (*3*), but its role in these other malignancies is not as well developed as in lung cancer. The other malignancies in which FDG-PET is being used include melanoma, lymphoma, persistent or recurrent colorectal carcinoma, breast cancer, head and neck cancer, gynecologic malignancy and bone and soft tissue malignancies (*3*).

The data, in the literature, that support the clinical applications of FDG have been obtained with dedicated PET scanners. Because of the cost of these scanners and the limited number (approximately 60 in the U.S.), the data to support the clinical applications of FDG-PET have been slow to develop. Nevertheless, the data clearly demonstrate that FDG imaging is going to have an important role in the future of nuclear medicine.

The widespread availability of FDG-PET imaging has been limited because of the cost of the imaging equipment and the need to have a cyclotron and a radiochemistry laboratory to produce the FDG. Availability of FDG is being addressed through the development of multiple distribution sites. The availability of imaging devices is being addressed by several manufacturers of gamma cameras who are modifying their devices to image FDG.

PET scanners, as we know them today, were developed in the early 1970s by Phelps et al. (*12*) at the Mallinckrodt Institute of Radiology. Multiple improvements have been made in the technology since that time. The original scanner was a single slice device with a resolution of 17 mm, and today's scanners have a 15–30 cm axial field of view with a 4–5 mm intrinsic resolution (*13,14*).

In the mid-1970s, Muellehner et al. (*15*) at Searle Radiographics attempted to perform coincidence imaging using opposed gamma cameras. Investigators had proposed the use of coincidence imaging

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For correspondence or reprints contact: R. Edward Coleman, Box 3949, Duke University Medical Center, Durham, NC 27710.

with two gamma cameras as early as 1959 (*16*). The electronics of the gamma cameras and the available computers were too limited for the technology to be effective. With the recent data demonstrating the clinical applications of FDG, there has been a renewed interest in imaging FDG with gamma cameras. Studies have been performed that demonstrate the ability to image FDG in a singles mode using an ultra-high energy collimator and SPECT (*17*). An image resolution of 17 mm is obtainable with the collimated systems, and the count rates are quite low (*17*). These studies have typically been performed using gamma cameras that have crystals that are 3/8 in thick and have approximately 12% sensitivity for the 511 keV photons. Despite these limitations, several investigators have documented the utility of collimated gamma camera imaging of the heart. Simultaneous imaging of perfusion and metabolism can be performed using pulse-height discrimination of ^{99m}Tc-sestamibi and FDG (*18*). However, collimated imaging has not been adequate for oncologic imaging of FDG (*17*).

The electronics of gamma cameras have changed since the mid-1970s, and more sophisticated computers are available. These changes now make coincidence detection practical, and most manufacturers have developed coincidence detection systems. These systems used 3/8 in crystals initially, but more recently thicker crystals are being used to increase the coincidence counting rates. The systems have an excellent intrinsic resolution of 4 mm for ^{18}F; however, obtaining adequate counts to take advantage of the resolution is still a problem. With the camera-based systems, a few thousand counts per second are obtained compared to more than 10–100 times that count rate using dedicated PET systems. The preliminary studies of oncologic patients demonstrate that large FDG-avid lesions can be identified, but small lesions that are detected by dedicated PET scanners are obscured by image noise. Prolonged imaging times of one area of the body are needed to take advantage of the system resolution. Shorter imaging times can be used in the evaluation of lesions several centimeters in size.

Is camera-based PET ready for routine clinical use? Camera-based PET is in its infancy, and it will improve rapidly. Just as the dedicated PET scanners have improved dramatically since their development in the early 1970s, the camera-based systems will improve and will be ready for clinical use soon. While these developments occur, the present users of camera-based PET need to focus their efforts on imaging a limited area for a long acquisition time or on large lesions.

Several improvements in camera-based PET imaging need to occur prior to its routine clinical use. For example:

1. The detectors need to be more sensitive, with higher count rate capabilities, through the use of thicker sodium iodide crystals. This crystal thickness must have minimal effect on clinical images of ^{99m}Tc radiopharmaceuticals if these devices are to have a general use in nuclear medicine.
2. An accurate method of attenuation correction needs to be incorporated into the camera-based system. Although nonattenuation corrected imaging is used with dedicated PET scanners, small deep-seated lesions are missed on nonattenuation corrected images that are detected on attenuation corrected images.
3. Better reconstruction algorithms are being evaluated for a camera-based system.

After these improvements have been made, clinical trials are needed to demonstrate the specific applications of camera-based PET imaging. The use of camera-based systems may be different than the use of dedicated PET scanners.

CONCLUSION

Camera-based PET imaging is available and will have a major effect on the practice of nuclear medicine. These systems are new and are not optimized yet for clinical oncologic applications. However, the changes necessary to make these systems appropriate for routine usage in oncology are being made and will be available soon. At that time, clinical trials will demonstrate their use. If clinical use in oncology is assumed now, the technology will come under criticism because of the mistakes that will be made. If we are patient and work with development of this technology, it likely will be demonstrated to be useful in oncology. This technology will then permit the widespread use of metabolic imaging that is the strength of nuclear medicine. If we attempt to use these devices inappropriately or prematurely, the results will be less accurate and the technology will not be accepted. Camera-based PET systems are not equivalent to dedicated PET scanners. We should not assume that the results from studies obtained using dedicated PET scanners are applicable to camera-based systems.

R. Edward Coleman
Duke University Medical Center
Durham, North Carolina

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