

ability to differentiate between soft tissues of similar attenuation coefficients; this is currently not possible with high-energy transmission sources. The second potential advantage is to reduce the noise in transmission datasets to allow images to more accurately represent the true tracer distribution in the body, enabling more accurate quantification. The third potential advantage is to allow precise fusion of the anatomic information with the functional information. We believe that the new hybrid machines should be developed and marketed as a specialized PET machine with an upgraded attenuation measurement and anatomic localization system rather than as a combined CT and PET device.

To obtain state-of-the-art CT images of the abdomen and pelvis, adequate quantities of enteric and intravenous contrast agents need to be given. One of the major advantages of the newest generation of helical CT machines is the ability to very rapidly acquire studies, enabling acquisition of both arterial and venous phases after intravenous contrast injection, often using a power injector. The rapid acquisition sequence allows data to be collected with a single breath-hold, virtually eliminating motion artifacts related to respiration. In addition, the design of the detectors permits the display of images with very narrow slice thickness.

For a hybrid system to compete directly in terms of image quality with a state-of-the-art helical machine, the imaging suite would need to be equipped with a power injector and a helical attenuation device attached to the dedicated PET machine. In terms of staffing, the technologist would most likely need to be cross-trained to the same level as a qualified CT technologist. Therefore, to compete directly with CT in terms of image quality, a major investment in equipment and staffing costs is necessary. The alternative is to accept a nonhelical image, acquired without contrast, which still provides high-quality anatomic detail.

The second and third potential advantages for the patient are closely related mechanistically. To satisfy both requirements, it is vital to ensure that the transmission dataset can be mapped accurately to the position of the patient during the acquisition of the emission data. Herein is the crux of the problem: As coregistration improves, the referring clinicians will be asking us these types of questions: "Is the activity we see involving the wall of the aorta? Is it in the caudate lobe of the liver or in the portal nodes?" The registration has to be in the range of subcentimeter accuracy to answer questions of resectability. A typical PET emission scan is acquired over a given segment of the body for several minutes per bed position. During this time there is considerable motion of internal structures associated with both respiration and the cardiac cycle. A typical CT scan is acquired over a few seconds, during which time almost no diaphragmatic motion occurs. The use of single-run helically acquired data is potentially problematic because the attenuation coefficient thus generated will then represent a single portion of the cardiorespiratory cycle rather than a mean average of the cardiorespiratory cycle, which is what the PET emission data represent. Therefore, it is likely that there will be significant artifacts in the attenuation-corrected scans associated with misregistration of the emission and CT data related to the cardiorespiratory cycle. This will result in incorrect quantification and image fusion.

Thus, there are several reasons why the design of the machine should not aim primarily at producing a dedicated helical CT scan. In addition, this approach will obviate the need to justify to the referring clinician, patient, and his or her insurance company the introduction of a new CT device that is not capable of producing a state-of-the-art set of diagnostic CT images. The nuclear medicine

community should develop these systems as an advanced attenuation device that provides high-quality anatomic data.

In terms of implementation of the technology, there are several challenges that we, as nuclear physicians, must address. The first challenge for nuclear physicians is to ensure they are adequately trained to recognize and name anatomic structures revealed by this technique. The next challenge concerns reimbursement. Given the limitations of the diagnostic quality of the CT images produced by such a system compared with dedicated CT images, we should not be asking for reimbursement at the same level as that for a dedicated CT scan. Rather, we should seek a supplement to the standard reimbursement for a PET scan payable to centers that can perform this procedure in recognition of the extra effort required to provide the coregistered anatomic information.

REFERENCE

1. Wagner HN Jr. Fused image tomography: where do we go from here? *J Nucl Med.* 1999;40(10):30N-33N.

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REPLY: I am pleased that Drs. Akhurst and Chisin have responded to discuss a question presented in my questionnaire in *The Journal of Nuclear Medicine (J)*. I hope others will also do so. Today we can talk to each other as never before.

The question they address is the degree of anatomic detail that should be incorporated in the CT component of an integrated, fused PET/CT system. Clearly, lower energy, x-ray photons can provide more anatomic detail than can the higher energy photons of germanium or cesium sources now used in stand-alone PET or SPECT systems. Thus, PET/CT is here to stay. But important questions remain.

Can a CT scan obtained without contrast material provide clinically useful anatomic detail, even if the system is not fast enough to be operated with the use of contrast material? In other words, should the manufacturers sacrifice only the ability to use contrast material and then optimize every other CT capability?

How difficult is it to train a PET technologist to be able to operate a CT instrument? Intuitively, I believe this would not be a problem.

Akhurst and Chisin also raise the important question of image acquisition time and the simultaneity of the CT and PET data acquisition. I agree with them that the primary design should maximize the PET data. The attenuation corrections should be made over a period of time that is appropriate for the PET data processing. Do we know how good the attenuation corrections need to be? Perhaps the corrections do not have to be as rigorous as we might assume. Attenuation differences occurring over time might be an important problem but might not be for most clinical problems.

What will probably happen in the on-going design of the integrated instruments is 2-fold. First, manufacturers will probably optimize the PET data acquisition in the system design. Second, manufacturers will probably maximize the quality of the CT anatomic detail without causing problems in attenuation correction in PET data analysis of the CT x-ray photons rather than the higher energy photons of the germanium or cesium sources.

In practice, one would not need to obtain an optimized helical CT examination with a dedicated CT instrument until one sees whether the anatomic or biochemical information provided by the PET/CT system solves the clinical problem. If it does, performance of subsequent dedicated helical CT will not be needed. If it does not, the dedicated CT study should be done.

I agree that we would not do a CT study with only the fused PET/CT system if we do not do the PET study.

Again, many thanks to Drs. Akhurst and Chisin.

REFERENCE

1. Wagner HN Jr. Fused image tomography: where do we go from here? *J Nucl Med.* 1999;40(10):30N-33N.

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Indeterminate Adrenal Masses

TO THE EDITOR: I read with interest the paper by Delbeke (1) discussing the oncologic applications of FDG PET. I must disagree with the statement "CT cannot differentiate adrenal metastasis from benign nonhyperfunctioning adenomas, but MRI with T2-weighted imaging is promising." The year of the cited reference (2) is 1986. Indeed, since that time, a body of literature has been developed (3-5) documenting how to accurately identify adrenal adenomas with CT (using Hounsfield unit measurements) and MRI (with chemical shift imaging). This distinction is made in everyday clinical practice. FDG PET is useful when an adenoma cannot be proven with CT or MRI, especially when an adrenal biopsy may not be desirable.

I thank Dr. Delbeke for her timely and useful review of an emerging and important topic.

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1. Delbeke D. Oncological applications of FDG PET imaging. *J Nucl Med.* 1999;40:1706-1715.

2. Reinig JW, Doppman JL, Dwyer AJ, Johnson AP, Knop RH. Adrenal masses differentiated with MR imaging. *Radiology.* 1986;158:81-84.
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4. McNicholas MJ, Lee MJ, Mayo-Smith WW, Hahn PF, Boland GW, Mueller PR. An imaging algorithm for the differential diagnosis of adrenal adenomas and metastases. *AJR.* 1995;165:1453-1459.
5. Cirillo RL, Bennett WF, Vitellas KM, Poulos AG, Bova JG. Pathology of the adrenal gland: imaging features. *AJR.* 1998;170:429-435.

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REPLY: I want to thank Dr. Schuster for his interest in my article (1) and his constructive remarks. Problems in diagnosing adrenal lesions have been discussed in more detail in the references provided in my continuing education article, particularly references 76 and 77, published in 1995 and 1997, respectively (2,3). These 2 articles refer to a good portion of the body of literature published on CT and MRI criteria since 1986. Although CT and MRI have been used to differentiate benign from malignant adrenal masses, many masses remain indeterminate by current criteria. FDG PET is, of course, particularly helpful in these cases. However, FDG PET is often performed for staging purposes (especially in patients with non-small cell lung carcinoma, colorectal carcinoma, lymphoma, and melanoma) and offers the advantage of screening the entire body for metastases.

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1. Delbeke D. Oncological applications of FDG PET imaging. *J Nucl Med.* 1999;40:1706-1715.
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3. Erasmus JJ, Patz EF Jr, McAdams HP, et al. Evaluation of adrenal masses in patients with bronchogenic carcinoma using ¹⁸F-fluorodeoxyglucose positron emission tomography. *AJR.* 1997;168:1357-1360.

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Erratum

The two right columns of Table 2, under the column heading "Energy: 0.02 MeV," were printed incorrectly in the article, "Re-Evaluation of Absorbed Fractions for Photons and Electrons in Spheres of Various Sizes," by Stabin and Konijnenberg (*JNM* 2000;41:149-160). Data from "MIRD8" and "EGS4/MIRD8" columns should be aligned under the "EGS4/MCNP" and "Recommended value" columns, respectively. The corrected portion of the table is printed below.

Sphere mass (g)	Sphere radius (cm)	EGS4 ϕ	MCNP ϕ	MIRD8 ϕ	EGS4/MIRD8	MCNP/MIRD8	EGS4/MCNP	Recommended value
Energy: 0.02 MeV								
1	0.620	0.205	0.191				1.07	0.198
2	0.782	0.251	0.236				1.06	0.244
4	0.985	0.304	0.287				1.06	0.295
6	1.127	0.338	0.319				1.06	0.328
8	1.241	0.363	0.343				1.06	0.353
10	1.337	0.383	0.364				1.05	0.374
20	1.684	0.450	0.426				1.06	0.438
40	2.122	0.519	0.494				1.05	0.507
60	2.429	0.560	0.536				1.04	0.548
80	2.673	0.589	0.563				1.05	0.576
100	2.879	0.610	0.586				1.04	0.598