

the total scan time for attenuation. We should not make the same mistake as with SPECT imaging of the heart, where the lack of attenuation correction has resulted in thousands of misdiagnosed and equivocal results.

An unwritten law in physics states that you don't get something for nothing. The current GCC systems with thin sodium iodide crystals are not as good from the physics of detection as are the dedicated PET systems. Therefore, they will not be able to detect small lesions as accurately as PET. Coleman et al. and Weber et al. showed with phantom and clinical studies that small nodules are missed by the current GCC systems but not by PET. Lymph nodes, which are small and are involved with lung metastasis in the mediastinum and the hilar regions, are as important as detecting solitary nodules in the lung. Detection of small lesions with high accuracy will require detection systems that are properly designed to do so. Comparing the diagnostic accuracy of GCC and PET for detecting lesions has to be done with a full understanding of the impact of resolution, lesion size, system resolution, and statistical noise in the images. Selection of these parameters in a clinical protocol can influence the outcome of the results, and this is why standard phantoms such as the Coleman lung phantom should be used to characterize the detection of lesions with different detection systems.

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## Does Attenuation Correction Work?

**TO THE EDITOR:** The editorial by Dr. Wackers (1) and the article by Vidal et al. (2) in the August issue are timely. Having been involved for some time in developing methods for acquiring transmission data for subsequent use in attenuation correction (3,4), it has been both encouraging to see the widespread interest in producing correct reconstructions of the distribution of radiopharmaceutical and disappointing to see that the adoption of the methods has become so contentious. In early studies by our group in Sydney we discovered that correcting properly for attenuation was only part of the total solution to the problem of producing artifact-free reconstructions. In our first clinical report on the outcome of attenuation correction in <sup>201</sup>Tl myocardial perfusion scanning in 11 patients, with angiographic correlation in 7, we reported (5) the following:

"In 2 patients with normal right coronary arteries and no past

history of inferior infarction, inferior wall defects erroneously identified using NC (no correction) were correctly reported as normal using AC (attenuation correction). In addition, one patient with a 90% LAD lesion showed an anterior wall defect only with AC. Thus, the use of AC led to 3 additional cases being correctly reported. Conversely, in one patient with a low likelihood of CAD but no coronary angiography, AC demonstrated an anterior defect whereas NC was normal. In the remaining 7 cases, there was no difference in final diagnosis between AC and NC."

As Dr. Wackers correctly points out, many other factors may influence the reconstruction of myocardial perfusion data. These include variable resolution with depth, choice of reconstruction algorithm, partial volume effects, patient movement, cardiac motion, respiratory motion, and scattered photons. There are several other possible sources of error in addition to these in the study of Vidal et al. They include the following: truncation of the emission and transmission data caused by the use of fanbeam collimators, leading to incomplete projection data and possible artifacts in the reconstructed data; lack of a downscatter correction from <sup>201</sup>Tl (167 keV) into the <sup>99m</sup>Tc window (140 keV), especially in the region of the heart where transmission is low and the emission counting rate is reasonably high; and lack of photopeak scatter correction in the <sup>201</sup>Tl (72 keV) window.

We have spent some time in our group in London examining one commercial version of the <sup>153</sup>Gd scanning line-source approach for simultaneous emission/transmission scanning (Vantage; ADAC Laboratories, Milpitas, CA). We found that downscatter from the 100-keV <sup>153</sup>Gd photons to the lower 72-keV <sup>201</sup>Tl window, one of our main concerns, was sufficiently low that it could be ignored. In spite of this, though, we found initially that image quality had been compromised because of a different factor, the slight decrease in counting rate caused by the electronic transmission window, and corrective action was required. This is exacerbated by the relatively low <sup>201</sup>Tl doses (74 MBq) permitted for myocardial perfusion scanning in the United Kingdom.

We propose that, on the basis of exhaustive testing that has been reported in the scientific literature, we accept that attenuation correction in heterogeneous data works (1,2). However, testing in the laboratory is often different from commercial realizations of a method. Therefore, we agree with Dr. Wackers that new, novel acquisition schemes should be proven to work, and we should not simply accept the manufacturer's word that their implementation of the system described by another group produces identical results. In this area, the proposal to have more standardized phantom testing should be endorsed. However, we do not believe that this is going to solve the problems that have been highlighted in the article by Vidal et al. and the editorial by Dr. Wackers.

If we accept the proposal that attenuation correction does work, we are then left with the question as to what is causing the confusing results in the articles cited, especially in the anterior wall and apex of the heart. It is certainly possible that correcting properly for attenuation will enhance some physical errors—for example, scatter will be worse toward the center of the body and will be increased preferentially relative to the edge of the body. Also, lack of scatter correction will artifactually redistribute reconstructed counts into areas of lower attenuation such as the lungs. Motion may play a role in the change in the reconstructed activity toward the apex of the heart between corrected and noncorrected data.

It seems to us that 1 way forward is to try to separate these effects and study them in isolation, if possible. Phantom testing has

already been used extensively to study attenuation correction. Likewise, this would be appropriate for scatter correction in loosely realistic situations. Where we differ with Dr. Wackers, though, is that once a method is shown to be working effectively, we should accept that and move on to the next possible source of error. Constantly focusing on attenuation correction alone may be missing the point. For example, in London we are currently examining the impact of adjacent sources of radioactivity (roughly simulating a hot liver) on cardiac phantoms to gain some insight as to the regional artifacts that this causes. The motion issue may be answered by gating the data.

There has been so much novelty in the design and implementation of transmission scanning devices and the algorithms for the correction and reconstruction of the data that Dr. Wackers' plea for rigorous testing should be endorsed. The journal and its reviewers have a role to play in this, as do the manufacturers and the users. We may be in danger of throwing the baby out with the bath water, though, by constantly questioning whether attenuation correction is working properly.

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**REPLY:** We appreciate the comments of Drs. Bailey and Meikle regarding Dr. Wackers' editorial (1) and our article (2). We agree completely that our results should not cast doubt on the relevance of attenuation correction itself. Rather, we think that the results show that attenuation correction alone, as currently included in some commercially available  $\gamma$  camera software, should be used with caution because, under some conditions (e.g., transmission with  $^{99\text{m}}\text{Tc}$  and for the patient population we considered), it can produce deleterious effects in the territory of the left anterior descending artery. Such results do not mean that the attenuation correction method does not work (several reports have shown that it actually does). The results mean that other issues that can interfere with attenuation correction should be considered before attenuation correction can be confidently included in routine practice. Two points should be considered:

First, an attenuation correction algorithm has been shown to work, assuming the attenuation map has been estimated properly (is not truncated, is registered properly with the emission data when using sequential transmission/emission imaging, and contains appropriate  $\mu$  values). How truncation of fanbeam-acquired attenuation maps affects the result is controversial (3). It has been shown

that misregistration can yield severe artifacts (4), whereas the effect of inaccurate  $\mu$  values still needs to be clarified.

Second, other phenomena, such as scatter, motion, or depth-dependent collimator response, can be neglected when attenuation is not compensated because attenuation is the major degrading factor in cardiac imaging. However, when correction is made for attenuation, the artifacts created by these phenomena can be magnified and become a significant source of errors.

Our results, therefore, should not prompt the nuclear medicine community to reject attenuation correction but, rather, should stimulate further research about other effects that interfere with attenuation correction. Attenuation correction is definitely a huge step toward accurate quantitation in SPECT and is not a farce like the emperor's new clothes (1). However, we should all be aware that some other issues must be resolved to achieve reliable quantitative SPECT imaging.

Concerning the crucial point raised by Dr. Wackers of how to validate the development of artifact-free imaging methods, we suggest adherence to the recently published guidelines for evaluation of image processing procedures (5). By following these recommendations, clinical trials will become necessary after experimental validations have been made. More complete correction packages for SPECT myocardial perfusion imaging should undergo this type of evaluation process to guarantee that the emperor will be dressed appropriately and that his new clothes will be seen and appreciated by most nuclear physicians.

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## Hybrid PET/CT Machines: Optimized PET Machines for the New Millennium?

**TO THE EDITOR:** We are moved to write to the journal by the recent Newsline article (1) concerning the development of single-gantry hybrid PET/CT machines. We wish to express our opinion regarding 1 particular issue: Should the quality of the CT images be maximized to equal the best stand-alone CT images?

The switch from high-energy-photon transmission data obtained from a current germanium- or cesium-source PET scanner to hybrid machines using low-energy, x-ray photon sources has 3 potential advantages for a patient. The first is generation of images that provide anatomic detail, which is related to the machine's