EDITORIAL

Symbiotic Developments in PET and SPECT to Quantify and Display Myocardial Tomography

Positron emission tomography (PET) and single-photon emission computed tomography (SPECT) are often regarded as competing imaging modalities with very different technical difficulties to overcome. Yet, there are many common problems in which developments by researchers in each of these modalities have directly benefited the other. The article by Xu et al. (*1*) in this issue addresses one such problem related to the need for expediting the acquisition and objectifying the processing associated with attenuation correction in performing myocardial tomography. The main difficulty, which both PET and SPECT have to overcome in correcting for attenuation in the thorax, is the need to account for the variable attenuation across regions of different density such as soft tissue, lungs, and bone.

A naive analysis might lead a novice to conclude that there is no need to bother with attenuation correction in PET anyway, in order to obtain accurate quantification. This conclusion would result from a rationalization that the 511-keV photons used in PET imaging are associated with significantly less attenuation than, for example, the 80-keV photons used in thallium-201 (^{201}Tl) tomography. A more detailed analysis (*2*) shows that the two 511-keV photons emitted as a result of positron annihilation must be detected for a coincidence event and, thus, the full thickness across the body contour is always the absorption path length. In contrast, with SPECT, the absorption path length is only the thickness between the location of the emission and the body contour. On average, this difference results in a larger factor needed to correct the same location on a myocardial PET study compared to a myocardial ^{201}Tl perfusion study. Thus, attenuation correction is needed just as much or more in PET than in SPECT imaging.

Why then, have the proponents of PET promoted their modality as superior to SPECT in its quantitative potential, particularly as it relates to the feasibility of performing attenuation correction in the thorax? Basically, there are two reasons why PET has enjoyed a superiority over SPECT in attenuation correction. First, the mathematics associated with attenuation correction in PET are much simpler. Since the full thickness of the object is the absorption path length in PET, the attenuation is independent of the source location along the length. This results in the determination of attenuation correction factors that are the simple ratio of two transmission scans with and without the patient in place. The second reason for PET's superiority is the commitment made by researchers from PET's inception to establish it as a quantitative modality to measure physiological processes.

Such commitment is exemplified by PET users of rubidium-82 who complement the short 5-7 min data collection time per emission study (*3*) with a long 30 min data collection of the transmission data (*1*). The work by Xu et al. (*1*) is further evidence of this commitment. Their main goal is to reduce the 30-min acquisition time of the transmission study to 10 min and, thus, make attenuation correction more clinically acceptable. Their overall approach is based on a method by Huang et al. (*4*) in which previously measured attenuation coefficients are assigned to anatomic regions found in images acquired using a short transmission scan. In this approach the regions have been segmented using automatic edge-finding techniques. In the method by Xu et al. (*1*) these anatomic regions are identified using a technique which thresholds the histogram of the attenuation values corresponding to the different regions. This technique should be more robust than the edge-detection method, particularly when applied to the noisy transmission images that result from a short acquisition time. These techniques can actually be as accurate or more accurate than using the longer transmission acquisition scans. This accuracy depends on the accuracy of the measurements of the a priori attenuation coefficients and the identification of the anatomical regions.

Does PET's present superiority in attenuation correction in the thorax imply that there is some inherent problem with SPECT which prevents the development of algorithms to correct for variable attenuation? The answer is no. It is true that it is more difficult mathematically to correct for variable attenuation in SPECT. Due to the exponential nature of the problem, no simple analytic solution has been found to date. Researchers in this area have relied on methods which approximate the solution (*5–9*). In some cases these approximations are followed by iterations to reduce

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the error between the acquired projections and the projections predicted by the model being used to approximate the solution. Nevertheless, although these corrections are not exact, they have been shown to significantly improve the quantitative content of SPECT myocardial images (*5–9*).

Perhaps more problematic than the mathematical difficulty associated with attenuation correction in SPECT is the impact that the transmission study acquisition time will have on patient throughput for a stress/delayed myocardial perfusion study. By extending at least 30 min, a study that already takes ~1 hr to perform, the stress and delayed acquisitions will definitely affect patient throughput. Similar problems call for similar solutions. In order to expedite acquisition time of the transmission study, we have developed in our laboratory (*8,9*) approaches to expedite variable attenuation correction in SPECT similar to those proposed by Huang et al. (*4*) and Xu et al. (*1*) for PET. Although there are differences as to how these methods perform the a priori measurement of the attenuation coefficients to be assigned onto regions segmented in the short transmission scan and also differences as to how these regions are segmented, the overall approach is quite similar. It is interesting to note that the general concept of the attenuation correction method proposed by Huang et al. (*4*) and Xu et al. (*1*) for PET were first used by Kuhl et al. (*10*) and recommended by Budinger (*11*) many years ago for SPECT.

Why then, are these techniques not being used clinically on a routine basis to perform attenuation correction of ^{201}Tl myocardial perfusion studies? The answer is that these methods have been developed for SPECT acquisitions that use a 360° orbit. With this orbit the response from each pair of opposing views is averaged, reducing the need to correct for the change in resolution with depth due to the collimator's geometric response. Most institutions that perform ^{201}Tl SPECT and even technetium-99-(^{99m}Tc) sestamibi (*12,13*) SPECT imaging with a single detector use a 180° acquisition orbit, which yields images with higher spatial and contrast resolution as well as more counts. Thus, for variable attenuation correction in SPECT to attain widespread use, either these institutions will have to switch to 360° acquisition or additional methods will have to be implemented to correct for the change of resolution with depth. The use of multiple detector systems to image ^{99m}Tc myocardial perfusion agents could be one such scenario.

In addition to having common needs as to how to correct for variable attenuation in the thorax, PET and SPECT myocardial perfusion imaging share the need to extract and display the three-dimensional tracer distribution. In the article by Xu et al. (*1*), these investigators use polar map quantification software developed by Hicks and colleagues from the same institution (*3*) to compare the distribution of activity in different regions of the heart to validate their new attenuation correction technique. Again, these developments exemplify the commitment made by PET researchers to establish PET as a quantitative modality to measure and display physiological processes. Again, here is also an example of one modality benefiting from the developments by researchers in the other modality. The polar map quantification method developed by Hicks et al. (*3*) for PET, although somewhat different technically, is quite similar to methods developed in our laboratories and those of others (*14–17*) for quantifying myocardial perfusion using SPECT imaging. All these techniques differ, for the most part, as to how the myocardium is sampled, in particular the apex or the base, and how the extracted data is normalized for quantification and display.

It appears that polar map quantification, or "bull's-eye" quantification as it is sometimes called, is becoming the de facto clinical standard for extracting and displaying myocardial distributions for both PET and SPECT. Its popularity is, perhaps, due to the simplicity with which these maps are generated, displayed, recorded, and explained to others. This simplicity has caused concern in the minds of some clinicians who confuse the data extraction and quantification steps of the algorithm with the data display step. These clinicians rationalize that since the polar map representation warps the three-dimensional tracer information onto a two-dimensional plane, the quantitative parameters extracted during the generation of these maps must somehow be flawed. All of these techniques, including the one used by Xu et al. (*1*), perform the data extraction and quantification steps using some sort of circumferential profile technique independent of the polar map display. Thus, although it is true that the extent of an abnormality being displayed by these polar maps is warped because of this transformation, the extent of the abnormality reported (or any other measurement calculated from the circumferential profile analysis) is not affected. This warping in the polar display causes regions toward the apex to appear smaller than they are and regions toward the base to appear bigger than they are.

The same circumferential profiles used to generate these polar maps may be used to display the data in three dimensions, free of warping (*12*). These three-dimensional surfaces may be rotated by

a computer using an animated display of progressive projections. Although these animated displays are very informative and free of warping, the simplicity of the polar map display should ensure its popularity for years to come.

It is clear that as more SPECT researchers begin to use PET imaging and more PET researchers use SPECT, each group will learn more about how the other group has solved a common problem. This could become an iterative process that not only brings each modality toward optimal clinical usefulness but also melts away the boundaries between these two groups, fusing them into one. Then, perhaps, we will be reminded of what the Gestalt philosophers believed long ago: The whole is greater than the sum of its parts.

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