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EDITORIAL

Three-Dimensional Display in Nuclear Medicine: A More Useful Depiction of Reality, or Only a Superficial Rendering?

Nuclear medicine studies involve parameter measurements of space, time and energy. Useful depiction of these parameters requires both error-free measurement and portrayal in a fashion which maximizes the transfer of useful information (signal) to the receiver (e.g., a physician) and minimizes the presence of confounding or distracting information (noise). In this regard, it is important to note that a receiver is always part of the system, whether the information is in the form of images, curves, numbers or qualitative descriptions (e.g., study interpretations or a list of differential diagnoses).

We have made striking advances in the accurate and precise measurement of the distribution of radiotracers within the human body. These advances include improvements in spatial resolution (which reduce partial volume effects), sensitivity (which permits shorter acquisition times, thus improving temporal resolution) and energy resolution (promoting renewed interest in dual-isotope studies). Advances in correcting the degrading effects of finite resolution, scatter and attenuation have also been made. Many of these advances have come about as the result of tomographic imaging.

Tomography is a critical component of nuclear medicine research and clinical practice. Depending on your perspective (*1*), tomographic imaging can be viewed as both an improved measurement approach and as a more accurate portrayal scheme. If we can now spatially divide the body into a three-dimensional array of voxels and measure the radiotracer concentration within each voxel, how can we best portray the acquired information?

As we have previously argued (*2*), interpretation of the information contained in nuclear medicine studies requires recognition and classification of patterns in the signal. An optimum information portrayal scheme would maximize the recognition and accurate classification of the specific patterns present in a given situation. Patterns must be present in order to be accurately portrayed, and the optimum portrayal scheme most likely depends on the specific characteristics of the patterns of interest. In this regard, it is important to note that the most accurate classification by a receiver does not necessarily come about through the most accurate depiction of the radiotracer's distribution. For example, exaggerated contrast may improve the sensitivity of disease detection without a corresponding decrease in specificity or normalcy rate. Bull's-eye displays of myocardial perfusion (*3*) represent an excellent example of a portrayal scheme which improves the accuracy of disease classification through an actual decrease in the "accurate depiction" of the radiotracer's distribution. Since diagnostic accuracy is improved (*4*), such displays are useful in nuclear medicine.

In other radiographic imaging modalities, notably CT and MRI, pseudo three-dimensional renderings have become commonplace in clinical practice (*5*). These renderings rely on either a "volume" display or a "surface" display. The differences between the two are critical to nuclear medicine image display (*6,7*). Volume renderings consist of some portrayal of data throughout the three-dimensional volume (e.g., through weighted reprojection), while surface renderings consist of an illuminated surface (or "shaded surface") depiction, based on edge detection. In nuclear medicine, we are more enthused about volume rendering than surface rendering, because our borders are so fuzzy, and (of greater importance) our unique medical information is contained within those borders.

Faber et al. (*8*) developed and validated an approach to epicardial surface depiction utilizing myocardial perfusion SPECT studies. The approach is based on the locations of the maximal reconstructed count values within the myocardium. Hashikawa et al. (*9*) have developed and applied an approach to cortical surface depiction utilizing cerebral perfusion SPECT studies. The approach is based on the maximal reconstructed count values within the cortex. In both the myocardium and the cerebral cortex, maximal count values reside in pixels within the structures of interest,

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proach is based on the locations of the maximal reconstructed count values within the myocardium. Hashikawa et al. (*9*) have developed and applied an approach to cortical surface depiction utilizing cerebral perfusion SPECT studies. The approach is based on the maximal reconstructed count values within the cortex. In both the myocardium and the cerebral cortex, maximal count values reside in pixels within the structures of interest, rather than on the epi- or endo-surfaces. It is, thus, of major importance to note that both of these groups of investigators chose to base the starting point of their methods on volume data, rather than surface data per se. In Faber et al.'s approach, the "surface" defined by these maximal-count pixels (which is expected to be in the center of the myocardium after the correction process described by Faber et al.) is moved out by 5 mm to approximate the epicardial surface (by assuming that the myocardium is 1 cm thick). The resulting surface is displayed with a color-coding scheme in which colors correspond to count values in pixels at this surface. In Hashikawa et al.'s approach, the actual maximal count values are displayed. Thus, while both Faber et al. and Hashikawa et al. refer to "surface displays," their common approach is closer to a true volume rendering, with a limited or constrained search area. In this regard, we are impressed with the creative, combined use of the best aspects of surface and volume rendering by Faber et al. and Hashikawa et al.

Faber et al. validated their epicardial surfaces with both MRI and user-traced surfaces. If we thus assume their renderings are accurate, they "may be useful for realistic displays of ventricular size, shape and the three-dimensional distribution of perfusion" (*8*), although no evidence is presented to support this (quite reasonable) hypothesis. Hashikawa et al. present evidence that the abnormal areas in the three-dimensional displays correlated well with cognitive deficits in the Alzheimer's disease patients, but admit that "almost all of the low perfusion areas could also be seen in the transaxial images" (*9*). Hashikawa et al. state that "the anatomical relationships were more easily comprehended in the three-dimensional images," presenting evidence in the form of Figures 4 and 5 of their article. Further scientific evidence is thus necessary to support the clinical usefulness of this three-dimensional display approach (for example, through ROC analysis comparing conventional SPECT display with three-dimensional display).

In addition to clinical display for diagnosis, three-dimensional renderings may be vitally important in basic science research, particularly in the brain. Analysis of brain images is complicated by at least three factors: (1) the brain is more structurally detailed than other organs; (2) the distribution of functional networks depends on a variety of processes, including anatomic structures, neurotransmitter pathways and developmental integration; and (3) neuropathology can affect several functional networks simultaneously. As a result, one of the most significant problems in brain image analysis is the delineation of appropriate regions of interest, because such delineation cannot (should not) be based on anatomic or structural considerations alone. In such a situation, parametric images of brain function (e.g., subtraction images or "z-score" images) can be used to define appropriate regions, as well as characterize their function. However, this will only be true to the extent that fully three-dimensional display and analysis capabilities permit portrayal without preconceived biases. To the extent that the techniques described by Faber et al. and Hashikawa et al. rely on functional attributes (i.e., the locations and values of maximum count pixels), they take us closer to realizing the needed capabilities.

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