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Editorial: Three-Dimensional Display of SPECT Images: Advantages and Problems

Modern rotating camera SPECT systems routinely generate three-dimensional image sets that contain up to 2,097,152 voxels. Since I became interested in SPECT imaging many years ago, I have been fond of posing the question, "What do I do with all this data?" The article by Wallis and Miller in this issue (*1*) addresses one answer to this question.

For many years, the approach to displaying SPECT, and indeed all tomographic images, has been to review a set of serial images in a single transaxial tomographic plane. Advances in computer displays and imaging processing have allowed the simultaneous display of images in multiple tomographic planes, usually the three orthogonal planes—transaxial, coronal, and sagittal—with reference marks to indicate how the three images relate to one another. Although the use of multiple simultaneous orthogonal views implicitly recognizes the 3-D nature of SPECT images and allows the viewer to interrogate the 3-D data set directly, it does not address the problem of displaying the data as a 3-D whole. The viewer must still integrate the multiple planar tomograms into a "mental" 3-D image. Sometimes this is easy, and practice helps. Sometimes, however, when the anatomy is complicated and/or distorted by disease, it may be almost impossible to visualize what is happening in three dimensions. The problem is further complicated because a SPECT image set viewed in all three orthogonal planes may contain several hundred individual images.

The potential value of a 3-D display system for SPECT images is thus obvious. Just what such a system should be and do is still poorly defined. In order to understand the problems in designing a 3-D display

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system, it is first necessary to appreciate the disparate variety of nuclear images.

It has been common practice in our jargon to refer to "hot spot" and "cold spot" imaging techniques. Indeed, Wallis and Miller use this terminology in their paper. The problem is somewhat more complex, however, when trying to categorize 3-D SPECT images. Labeled red blood cell images of hepatic hemangiomas, gallium studies of tumor or infection, probably most labeled antibody studies, and even most bone studies are clearly hot spot problems. The abnormalities show as focal areas of increased tracer accumulation against a low background. Similarly, liver/spleen imaging with technetium sulfur colloid and lung perfusion imaging with labeled MAA are definitely cold spot imaging problems. But what do we call brain perfusion studies with HM-PAO or iodoamphetamine? Or renal cortical studies with DMSA, or even thallium myocardial studies? The lesions in all these cases are cold but the tracer uptake is limited in extent, often to structures that have considerable surface extent but little thickness. Such structures behave more like extended hot spots for display purposes. This problem is further compounded in brain imaging where the cortical surface activity encloses deeper structures which have a focal hot spot nature, such as the basal ganglia. These hybrid imaging situations pose special problems for 3-D display.

Wallis and Miller have nicely reviewed the several approaches that have been tried for 3-D display of medical images. In order to clarify the potential role of these various techniques, I would like to use slightly different terminology than they have chosen. The term "volume rendering" that they have used for their technique is reasonable and I will continue to use it. As we shall see, however, it is a slight misnomer, as it does not lend itself well to certain large volume display problems. The other technique, which they call "segmentation," I would like to call "shaded surface rendering," as I believe this makes the nature of the displayed data clearer.

We have had the opportunity to try both of these techniques in our laboratory on many SPECT imaging problems. What I will present here is my own subjective analysis of the utility of these methods based on this experience.

Volume rendering has proven to be an excellent technique for pure hot spot image display. The anatomy and the extent of disease in bone scans, gallium images, and labeled monoclonal antibody images are often much clearer in volume-rendered displays. Many gallium and monoclonal antibody studies in the abdomen and pelvis, which appear totally inscrutable in tomographic section, are startlingly clear in volume-rendered images.

The role of volume rendering in the "hybrid" imaging situations is less clear. I had been very skeptical of the utility of this technique for the display of cerebral perfusion images. In the normal patient, all one saw was a cloud-like image of the surface contours of the brain. The deep structures were entirely hidden. With more experience, however, I have been pleasantly surprised at the ability of this method to clarify the exact location and extent of cortical defects. In patients with strokes, the exact vascular distribution(s) involved is *much* easier to appreciate on the volume-rendered display than on the original tomograms. For comparing early and late iodoamphetamine images and looking for redistribution, side-by-side volume-rendered cine displays really appear to be without competition. However, when one is interested in the deep structures such as the basal ganglia, simple volume rendering is not useful, as these structures simply do not show in the volume-rendered images.

Moreover for renal volume imaging, such as liver/spleen studies with sulfur colloid, volume rendering has proven almost useless. The very nature of the volume-rendering algorithm with its maximum pixel-weighted reprojection virtually guarantees that the cold spot information present in these images, which includes both lesions and normal internal anatomic structures, will be invisible in the volume-rendered display. The shaded-surface display, which I will address next, is no better. For the present, multiple tomographic sections remain the best way to view liver/spleen SPECT studies.

Shaded-surface displays, for the reasons discussed by Wallis and Miller, would not seem to lend themselves well to nuclear images. Despite these limitations, several of the hybrid imaging situations which I have mentioned, including brain perfusion imaging (for superficial display only), renal cortical imaging with DMSA, and myocardial perfusion imaging with thallium are really problems in imaging surfaces, albeit thick surfaces. We have recently been doing most of our DMSA renal cortical scans tomographically. When multiple cortical abnormalities are present, it is often very difficult to appreciate the anatomic structure of the kidney from the tomographic images. The use of a shaded 3-D surface display usually clears up these ambiguities. For this application, the volume-rendered display has proven less useful in our hands.

Wallis and Miller are to be celebrated for emphasizing the importance of motion and the "cine" display in the appreciation of 3-D structure. There is no doubt in my mind that motion is an essential element in any flat-screen 3-D display technique, be it volume rendering, shaded surface, or something yet to come.

The enhancement of 3-D perception by motion appears to be an inherent characteristic of the human visual perceptual system. This motion enhancement of 3-D perception is often mistakenly called "motion parallax," but in truth it is more properly called the "kinetic depth effect," as it does not require parallax referents

in order to be effective. For example, in shaded-surface displays in which the structures "in back" are hidden and thus unavailable to provide parallax clues, the 3-D effect is still enhanced by the addition of motion.

Other necessary features of the cine display have also been emphasized by Wallis and Miller. The introduction of "pseudo" attenuation during the reprojection process may seem like a backwards step, particularly if one has already taken pains to correct for attenuation during the tomographic reconstruction. In practice, the omission of this step adds considerable ambiguity to the cine display of the reprojected data, such as apparent rotation reversal, and significantly reduces the utility of the volume rendered cine display.

Certain additional features of a practical 3-D display deserve emphasis. I am convinced that all such displays must be interactive. This is true for displays of multiple tomographic slices and also for more direct 3-D displays. Control of rate of apparent rotation, the ability to go from continuous rotation to a rocking motion, and the ability to change apparent viewing angles are all important. Direct control of intensity, contrast, and color scale also appear to be important. In our laboratory, we no longer read any SPECT studies from film. All studies are viewed directly on a computer screen with continuous operator interaction with the images.

As of now, none of the 3-D displays are a complete substitute for the tomographic images. Although we are now routinely using 3-D displays, usually volume rendering, to supplement the tomographic images in more than half of our SPECT studies; they are always viewed in conjunction with the tomograms. This sounds as if we have added even further to the burden of images with which we must deal, but in practice the use of the 3-D display usually reduces the time spent in reviewing individual tomographs because their meaning is much clearer after the 3-D display has been reviewed.

Much still needs to be done in 3-D display development. None of the current methods are satisfactory for pure cold spot problems such as liver/spleen imaging. A related problem is the need for a good 3-D display that can handle the situation where there is a necessity to delineate both superficial and deep structures. HMPAO brain perusion imaging is a good example.

The trend in nuclear medicine is obviously in the direction of three-dimensional imaging. The nature of nuclear medicine practice also demands the extraction of quantitative data from our images. I will close this discussion with a favorite question and challenge of mine to investigators in the field.

How do you define a 3-D region of interest?

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