TEACHING EDITORIAL

Improvements in Anger Camera Performance

The Anger camera is now approaching the 25th anniversary of its invention by Hal Anger (*1*). In the short time span of its existence it has gone through a remarkable series of design and performance improvements, which have contributed directly to its current status as "the instrument of choice" for clinical nuclear medicine imaging. Some of these improvements (and the underlying reasons for them) have been reviewed in recent articles (*2-4*). They include improvements in spatial resolution by a factor of 4, from about 12 mm (FWHM) for some early models to about 3 mm (FWHM) for some current instruments, due primarily to improvements in photomultiplier tubes and methods for coupling them to the detector crystal, and improved positioning arithmetic and electronic circuitry. Available detector diameters have been doubled, from about 25 cm in the early 60's to nearly 50 cm on some current models. Counting rate capabilities have been increased significantly by improved electronics and the use of pileup rejection circuits. The development of whole-body scanning capabilities and of mobile cameras have further increased the popularity of the instrument. In each of these cases, improvements were made that resulted in better performance or expanded capabilities of the Anger camera, thus contributing to the expanding popularity and usefulness of the instrument.

The latest advance in Anger camera design is the development of a microprocessor-based correction system to eliminate geometric distortions from camera images, as described by Muehllehner et al. in this issue (*5*) and in earlier work by Knoll et al. (*6*). Geometric image distortions are themselves of little practical importance; one is rarely concerned with a slight apparent curvature in an organ or tissue structure. However, successful correction of geometric distortions is of considerable importance because it attacks the root cause of a more troublesome artifact, namely camera image nonuniformities. The magnitude of practical concern for this artifact is demonstrated by the number of man-hours (and sheets of Polaroid film) that are expended daily across the country in quality assurance testing with flood-field sources.

It has been recognized for several years that most camera image nonuniformities are due to compression or expansion of local counts resulting from image distortions, rather than from regional variations in camera sensitivity (*7-9*). Nevertheless, the conventional approach to correcting nonuniformities has been to treat the problem as if it were caused by sensitivity variations; namely, to increase or decrease the number of counts recorded (or display brightness) regionally, based on the count distribution recorded in a digitized image of a flood-field source. Such an approach is quantitatively inaccurate because it adjusts the number of counts recorded, rather than redistributing them, as should be done (*8*).

The distortion correction scheme described by Muehllehner et al. not only provides excellent uniformity, but has some unexpected side benefits as well. For example, a single set of correction coefficients appears to work for different radionuclides, at different counting rates, and for offset as well as centered photopeak windows, factors that were known to require different correction matrices by the previously used techniques. The correction coefficients also appear to be very stable over long time periods, although this obviously will be a function of individual camera stability.

The success of the geometric correction technique for eliminating camera nonuniformities is obvious from the appearance of flood-field images; however, the clinical value of this dramatic performance improvement to the nuclear medicine physician and technician remains to be demonstrated. It is doubtful that it will eliminate the need for regular, even daily, quality assurance procedures (i.e., don't throw out your flood-field sources). The correction scheme cannot correct (or detect) camera failures or instabilities, and it does not correct for all sources of nonuniformity, e.g., display scope artifacts. One factor that may determine the day-to-day usefulness of distortion corrections is the ease with which new correction factors can be determined and implemented, to correct for minor instability problems that would otherwise require the attention of a serviceman.

The impact of distortion and nonuniformity corrections on diagnostic accuracy also should be evaluated. Whereas anecdotal evidence has been presented occasionally, showing examples of the effects of usually rather severe nonuniformities on a brain or liver image, (e.g., due to camera failure) no systematic study has been made of the effects of less drastic artifacts on a randomly selected series of patients. With the introduction of an elegant new correction technique, it would seem appropriate that such a study should now be done. To a certain extent the clinical value of distortion/nonuniformity corrections will depend on their cost of implementation and on the results of such a study. One can easily accept a few thousand dollars additional cost for a camera system that provides even only marginal clinical performance improvements; however, justifying additional expenditure of tens of thousands of dollars for a camera system that fails to demonstrate significant improvements in diagnostic accuracy would be quite another matter.

Several indirect benefits may result from the development of a practical distortion correction scheme (G. Muehllehner, personal communication). For example, it may permit increased design freedom for Anger camera manufacturers. Improved spatial resolution can be obtained by the use of greater numbers of small photomultiplier tubes and closer coupling between the phototubes and the detector crystal; however, this usually is accompanied by greater geometric distortion and, hence, more pronounced image nonuniformity. Distortion correction may, therefore, permit the design of Anger cameras with further improvements in spatial resolution, perhaps even approaching the 1 to 2 mm range. Distortion corrections also may permit greater freedom in selection of detector crystals so that crystals that previously might have been rejected due to slight surface defects, etc., now might be usuable with distortion corrections to eliminate image imperfections because of these crystal defects (possibly with some economic benefit). Another benefit may be improved spatial resolution for scanning cameras, which now suffer some resolution loss from relative motion of the image due to geometric distortions as the camera travels over the scan object.

Applications for which a quantitatively accurate nonuniformity correction may be immediately useful include emission reconstruction tomography, both the rotating gantry and multiple pinhole types. One of the advantages of reconstruction tomography is its ability to provide quantitatively accurate images, from which accurate comparisons of the relative uptake of radionuclide by different organs and body tissues can be made, provided the input data for the reconstructed image is accurate. The improved accuracy of distortion-corrected image data also may be useful in other semiquantitative studies, e.g., flow studies and organ uptake measurements using conventional two-dimensional projection images.

Still, the greatest value of the Anger camera lies in its versatility and usefulness for routine clinical imaging applications, in small as well as large institutions. It is nice to think that this most recent technological advance would result in improved diagnostic accuracy in this clinical setting. One hopes that studies testing this hypothesis will be forthcoming.

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