# Computer-Assisted Emission Imaging

A primary function of the computer in nuclear medicine has been to extend and enhance the imaging capability of the scintillation camera. The "raw data" produced by the camera are not always in the form most suitable for viewing. Technical deficiencies in the system can lead to distorted images. Poor counting statistics can obscure low-contrast lesions. Motion can blur margins. Changes in the distribution of radioactivity may occur too rapidly, or may be too subtle to be apparent in serial images. Deep lesions may be obscured by overlying radioactivity. In each of these situations, computer-processing of the scintillation data has resulted in images that are clearly superior to the unprocessed images. This has been accomplished by a number of different techniques.

## CAMERA-CORRECTION TECHNIQUES

A number of methods are available for offsetting deficiencies of the camera (*1*). The simplest of these is uniformity correction by scaling the images to compensate for the nonuniformities in a stored field flood. In a number of cameras this is carried out by a built-in microprocessor. It has been recognized that misplacement of events is a greater cause of nonuniformity than loss of events (*2*), so event-shifting schemes have been proposed to correct for this (*3,4*). Deficiencies in the spatial resolution of the camera can be partially corrected by resolution-restoration filters that are designed to boost the different spatial frequencies in the image to the same extent that they have been suppressed by the camera (*5*). Unfortunately, this will exaggerate the random noise in the images and may interfere with the identification of lesions. For this reason image-processing techniques in nuclear medicine have been directed toward image enhancement rather than the restoration of resolution.

## IMAGE-ENHANCEMENT TECHNIQUES

These are used to improve the observer's ability to detect or identify certain features within the image. A wide variety of methods are available (*1*). Random noise can be suppressed by various smoothing schemes, and edges can be emphasized by sharpening schemes such as unsharp masking, in which a heavily smoothed version of the image is subtracted from a slightly smoothed version. Contrast can be manipulated by adjusting image values in order to alter the gray-level display. More elaborate methods such as convolution and Fourier filtering emphasize certain features within the image by boosting the spatial frequencies that characterize these features while suppressing others. Though interest in image-enhancement techniques has waned in recent years, a number of investigators are finding these techniques useful for revealing lesions in thallium studies of the heart (*6,7*).

## TOMOGRAPHIC IMAGING TECHNIQUES

The scintillation camera forms a two-dimensional projection of the three-dimensional radioactivity distribution. Lesions lose contrast and outlines of structures become confused in this process due to the superposition of events originating in many different planes. The tomographic techniques allow one to image specific planes within the radioactivity distribution, thereby recovering contrast and clarifying structure. The radioactivity is detected from a number of different directions, either by means of a collimator with multiple apertures—such as the seven-pinhole collimator that has been introduced for cardiac tomography (*8*)—or by moving the camera relative to the radioactivity, as is done for single-photon emission computerized tomography (*9,10*). The comput-

er combines the information in the different views and emphasizes the plane of interest either by producing blurring of the other planes or by eliminating them altogether, depending on the technique (*11*).

## FUNCTIONAL IMAGING TECHNIQUES

The information contained in multiple images of a changing radioactivity distribution can be used to produce a functional image, in which some measurable characteristic of the change is displayed on a point-by-point basis. Characteristics such as rates of washin or washout of radioactivity, ventilation/perfusion ratios, and times to peak activity have been displayed in this manner (*12–14*). Functional images permit the eye to detect subtle changes in distribution that are not readily apparent on inspection of the original data. Although they have gained little acceptance thus far, I believe that functional images will eventually offer an indispensable display mode for certain dynamic studies.

## GATED IMAGING TECHNIQUES

These are applied to studies of organs, such as the heart, liver, and lungs, which move in a cyclical manner. The objective may be to remove the blurring produced by cyclical motion, as has been done in liver studies (*15*), or to permit observation of the cyclical changes, usually through a movie format, as has been done for the beating heart (*16,17*). In general these methods require an external physiological monitor such as an electrocardiograph, though some methods rely only on the data supplied by the scintillation camera (*15*). The gated cardiac studies have probably had a greater impact upon the practice of nuclear medicine than any other form of computer-assisted nuclear imaging.

As reported in this month's issue of the *Journal,* Line et al. (*18*) have extended the method of gated imaging to equilibrium ventilation view of the lungs. Because of the greater irregularity of the respiratory cycle the problem is considerably more complex than in the case of gated cardiac imaging. The authors have observed that whereas in cardiac imaging a single parameter, the time from the R wave, identifies the heart shape and permits the sorting of scintigraphic data, in ventilation imaging there are two relevant parameters, the respiratory volume and the airflow, that jointly influence lung configuration. This necessitates a fairly complicated method to sort the scintigraphic data. Airflow data collected along with the scintigraphic data are first processed to generate a sequence of flow-volume indices; these indices are corrected for artifacts and then sorted on a flow-volume grid; the grid is partitioned according to the desired number of images per respiratory cycle; and finally the scintigraphic data are sorted according to the partition to which the associated flow-volume indices have been assigned.

The result of this processing is a cinematic display of the gated equilibrium ventilation image, demonstrating the ventilatory cycle in the same manner that cinematic displays of the gated cardiac blood pool demonstrate the cardiac cycle. We have seen how gated imaging applied to the cardiac blood pool converted a static study of limited utility into a dynamic study of great value. The application of this technique to the equilibrium ventilation image may have a similar beneficial effect, as illustrated by the single example presented by Line et al., in which images were formed that distinguish rather well between regions of differing ventilatory capacity.

The standard ventilation lung scan has a number of limitations. A carefully timed sequence of washin-equilibrium-washout images is required, involving patient cooperation, and this can be obtained only in a single projection unless a second dose of radioactive xenon is administered. The technique proposed by Line et al. has the potential to overcome these limitations. Patient cooperation is not required, timed maneuvers are not used, and images from a number of different projections can be obtained with a single dose of xenon. A pneumotachometer is needed to monitor airflow, but it does not require separate application to the patient since it is incorporated into the airway.

A case may be made here for functional imaging, for I suspect that the cinematic presentation may not be the optimal mode of display for this technique. Unlike gated cardiac imaging, in which one looks for motion, in gated equilibrium ventilation imaging one will be looking for variations in intensity. These may be detected more readily if results are displayed as functional images of parameters that measure changes in intensity. Functional images are also preferable to a cinematic

display because of easier access, portability, and storage.

Line et al. (*18*) have described a promising new technique. Clinical evaluation remains to be carried out. But even at this early stage of development we can see that the computer has once again extended the imaging capability of the scintillation camera.

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## Erratum

In "Skeletal Blood Flow: Implications for Bone Scan Interpretation" by N. David Charkes in Table 2 the entry under Mechanism, I. Decreased blood flow should read: A. Systemic (↓C.O.)‡. (*J Nucl Med* 21: 91-98, 1980).