ACQUISITION, PROCESSING AND DISPLAY OF GATED CARDIAC SCINTIGRAMS

ABSTRACT

An improved method for non-traumatic and essentially non-invasive evaluation of left ventricular (LV) function with radio-nuclides has been developed. This method combines previously used EKG gating techniques for cardiac blood pool visualization with new computerized acquisition, processing and display techniques. An Anger camera, a small computer and a physiological synchronizer are used to acquire a sequence of eight scintigrams which span the entire cardiac cycle. Under our present protocol two twenty-minute sequences are obtained, one an LAO (50°) projection, the other an RAO (30°) projection. Subsequently these images are processed on-line with a digital filter to increase definition of the cardiac borders. The eight images are then displayed sequentially on a specially designed electronic monitor to give an impression of the beating heart somewhat analogous to that obtained with invasive contrast angiography.

The use of computer acquisition, processing and display techniques such as those employed in our studies results in greatly improved appreciation of LV wall motion over previously used nuclear methods and provides the opportunity to estimate quantitative parameters such as LV ejection fraction, ejection rate and LV volume vs time. The non-traumatic nature of these measurements makes it possible to obtain these data with the patient in the resting state and following stress or therapy.

*Physics Research Laboratory
**Division of Nuclear Medicine
***Cardiac Catheterization Laboratory
****Department of Radiology
Massachusetts General Hospital
Boston, Massachusetts

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Images of the cardiac blood pool in end-systole (ES) and end-diastole (ED) have been used for qualitative and quantitative analysis of left ventricular function (LV) (1-2). These images are obtained with an Anger camera which is gated to portions of the subject's electrocardiogram (EKG). Counts received over many cardiac cycles are integrated to produce scintigraphic representations of the heart in ES and ED. These maximum points of contraction and relaxation are only a small portion of the entire cardiac cycle.

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Figure 1 shows a simplified schematic representation of the hardware employed in our studies. Analog address signals from an Anger camera (Searle Radiographics Corp. HP) are fed into a physiological synchronizer (Brattle Instrument Corp.) with two variable gates. Those events which fall within the preselected gates are digitized and further identified by a routing pulse (i.e., a bit is added to the 12-bit x-y address with logical "zero" corresponding to gate 1 and logical "one" corresponding to gate 2). Depending on the value of the routing bit, the appropriate location in the core image from gate 1 or gate 2 is incremented.

Following an injection of 20 millicuries of $^{99m}$Tc electrolytically labeled to human serum albumin, images in both the right anterior oblique (RAO) and left anterior oblique (LAO) projections are obtained. Each projection requires twenty minutes and consists of four pairs (8) of images which span the entire cardiac cycle. With a 100 mSec gate, more than 1000 counts are obtained per image per beat, resulting in images which typically have more than 300K counts. The complete imaging procedure requires less than one hour, including patient set-up time.

Data acquisition, processing and display are controlled through the MGH NUMEDICS computer system (3-4) from a terminal in the Division of Nuclear Medicine. At the end of the data acquisition phase, the cardiac images appear automatically on an on-site cathode ray tube (CRT) display monitor. Each of the images is processed with a digital filter to improve definition of the cardiac borders and increase the image contrast. The 64 x 64 element images with 64 grey levels are interpolated to 128 x 128 elements for display purposes (3-4). The processed images are stored on an 8-track display disk, which permits a cinegraphic presentation of all eight sequential images of the
Figure 2 compares processed and unprocessed images of the cardiac blood pool in both the LAO and RAO projections. Improved visualization of the cardiac chambers and the great vessels is apparent. The processing procedure can be most easily described in the frequency domain: A non-stationary filter which keeps the signal to noise ratio constant is used to boost the higher frequency information while attenuating the levels near zero frequency. In that way edge sharpening and contrast enhancement is achieved. This filtering is actually carried out as a spatial convolution on our computer. The algorithm uses two one-dimensional filters to increase the processing speed. Execution under NUMEDICS requires about three seconds.

The use of cinegraphic display techniques permits the motion of the cardiac chambers and great vessels to be visualized throughout the cardiac cycle. Initially a simpler kinetic display was achieved through alternately presenting ES and ED images in rapid succession to produce a motion study. In some respects using two periods at the extremes of the cardiac cycle provides enough contrast for the appreciation of regional ventricular performance. In our latest display mode, eight images are presented sequentially in time on a CRT. This improves appreciation of changes in the cardiac contour, somewhat analogous to the contrast medium ventriculogram obtained by invasive techniques. Figure 3 shows eight images from a LAO projection. Since perfect registration of the images is maintained by the CRT display, analysis of regional myocardial motion is made easier and more reliable than by observing static images of eight segments of the cardiac cycle.

To date, image processing has been tried with only modest success on conventional scintigrams. However, the comparison shown in Fig. 2 is typical of our cardiac images and demonstrates that significant improvement of the definition of cardiac chambers and the great vessels can be obtained by the methods described above. It should be noted, however, this technique is not well-suited to digital estimation of functional parameters because total counts are not preserved. These results suggest that edge-enhancement techniques may be a valuable aid in the visualization of structure when the in vivo distribution of radionuclide is contained within sharp macroscopic boundaries. Similar enhancement of structural detail has been obtained in our laboratory in studies designed to visualize the myocardium (5).

It is probable that these techniques will provide improved methods for evaluation of left ventricular function. Qualitative assessment of the walls of the left ventricle may be better made by the use of edge sharpening and the cinegraphic display. Portions of the cardiac blood pool may be analyzed digitally to construct time-activity curves, which may represent changes in ventricular volume. Figure 4 compares a plot of the total counts measured over the LV, as a function of time in the cardiac cycle, with a tracing of that patient's EKG. In the absence of extra-ventricular activity and photon absorption, the total counts measured over the LV are directly proportional to the ventricular volume. The effect of these factors on the determination of
volume is still currently under investigation, but the implications of such measurements may have a profound effect on the assessment of ventricular function. By performing imaging of the heart both at rest and under stress, quantitative and essentially non-invasive assessment of LV function should be possible.

Over 30 patients have already been evaluated by this procedure. In addition, there are on-going studies validating measurements of left ventricular function. These include estimates of the LV ejection fraction, LV volume, volume vs. time curves and other functional parameters. The quality of the higher resolution filtered images suggests the application of gated imaging to pediatric cardiology.

References:


Figure Legends:

Figure 1. Schematic representation of hardware configuration used for cinegraphic imaging.

Figure 2. Comparison of unprocessed (left) and processed (right) images of ED in both the RAO (top) and LAO (bottom) projections.

Figure 3. LAO cinegraphic projection consisting of eight sequential images, each of equal duration, spanning the entire cardiac cycle.

Figure 4. Left ventricular counts/100 mSec as a function of time within the cardiac cycle. The EKG tracing shows that minimum volume - i.e., ES - occurs at the down slope of the T-wave.
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