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NONINVASIVE NUCLEAR KINECARDIOGRAPHY

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A kinecardiographic display has been obtained with an Anger camera gated to the electrocardiogram of subjects receiving an intravenous injection of ^{99m}Tc-human serum albumin.

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 (*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. Such techniques though already proven useful do not provide a dynamic display. By utilizing new acquisition, processing and display methods, a technique has been developed for visualizing the beating heart—kinegraphic imaging—which also provides improved image quality.

METHODS

After an injection of 20 mCi of ^{99m}Tc electrolytically labeled to human serum albumin, electrocardiographically gated images in both the right anterior oblique (RAO) and left anterior oblique (LAO) projections are obtained, using an Anger camera with a parallel-hole collimator (Searle Radiographics Corp., HP camera, LEAP collimator).

Figure 1 shows a simplified schematic representation of the hardware employed in our studies. Analog address signals from an Anger camera are fed into a physiologic synchronizer (Brattle Instrument Corp.) with two variable gates. Those events that 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. Each projection requires 20 min and consists of four pairs (8) of images, which span the entire cardiac cycle. The duration of the ECG gate is arbitrarily determined as one-eighth of the subject's average R–R interval. A representation of the relationship of the ECG gate to the electrocardiogram is illustrated in Fig. 2. With a 100-msec gate, more than 1,000 counts are obtained per image per beat, resulting in images which typically have more than 300K counts. The complete imaging procedure requires less than 1 hr, including patient setup time.

Data acquisition, processing, and display are controlled through the MGH NUMEDICS computer sys-

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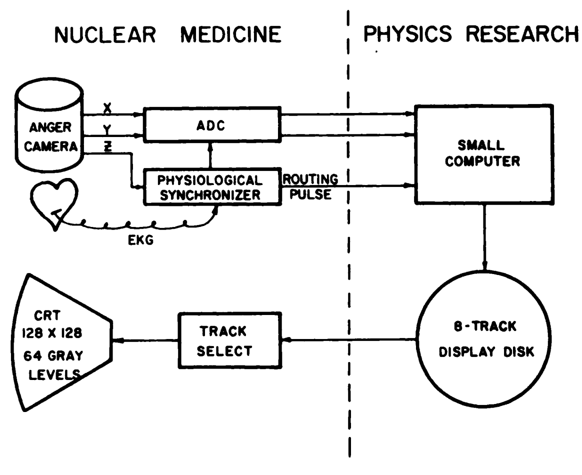

FIG. 1. Schematic representation of hardware configuration used for kinegraphic imaging.

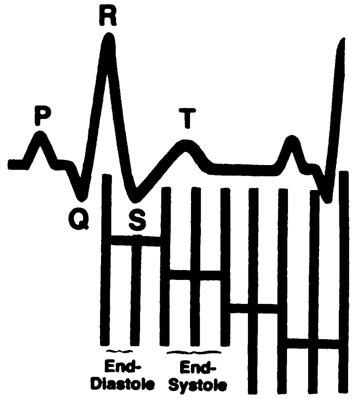

FIG. 2. Relative positions of eight cardiac gates. Duration of gating interval was established in each patient on basis of his R–R interval. Gate is not moved from one heart cycle to next but remains in given position for some 350 beats. To reduce total time for study, two independent gates were used so that two portions of cardiac cycle could be acquired simultaneously.

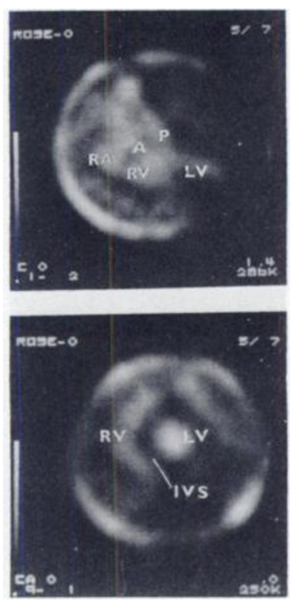

FIG. 3. Gated images obtained in RAO (top) and LAO (bottom) projections. Labels refer to aorta, A; pulmonary outflow tract, P; right ventricle, RV; left ventricle, LV; and interventricular septum, IVS.

tem (*3,4*) from a terminal in the Division of Nuclear Medicine. Images are processed by a nonstationary digital filter which is so constructed as to yield edge sharpening and contrast enhancement. This is accomplished by a program that acts in regions of the image which have a high signal-to-noise ratio by boosting the higher-frequency components while also attenuating the low-frequency levels. The processing requires less than 5 sec per image. At the end of the data acquisition phase and processing, the kinegraphic images appear automatically on an on-site cathode-ray tube (CRT) display monitor. The 64 $\times$ 64 element images with 64 gray levels are inter-

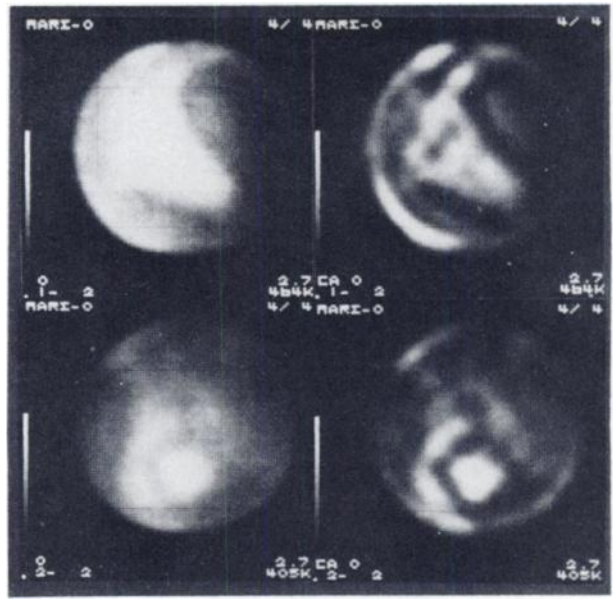

FIG. 4. Comparison of unprocessed (left) and processed (right) images of ED in both RAO (top) and LAO (bottom) projections.

polated to 128 $\times$ 128 elements for display purposes (*3,4*). The processed images are stored on an 8-track display disk that permits a cinegraphic presentation of all eight sequential images of the cardiac cycle.

RESULTS

Figures 3 and 4 illustrate processed and unprocessed images in both the RAO and LAO projections. These demonstrate the improved visualization of vascular detail and improved resolution of the cardiac chambers. Figure 5 shows eight images from a LAO kinegraphic projection. Because perfect registration of the images is maintained by the kinegraphic display, analysis of regional myocardial motion is made easier and more reliable than by observation of static images of eight segments of the cardiac cycle.

DISCUSSION

The use of kinegraphic 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 just two periods at the extremes of the cardiac cycle provides enough contrast for the appreciation of regional ventricular performance. In our latest kinegraphic display system 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.

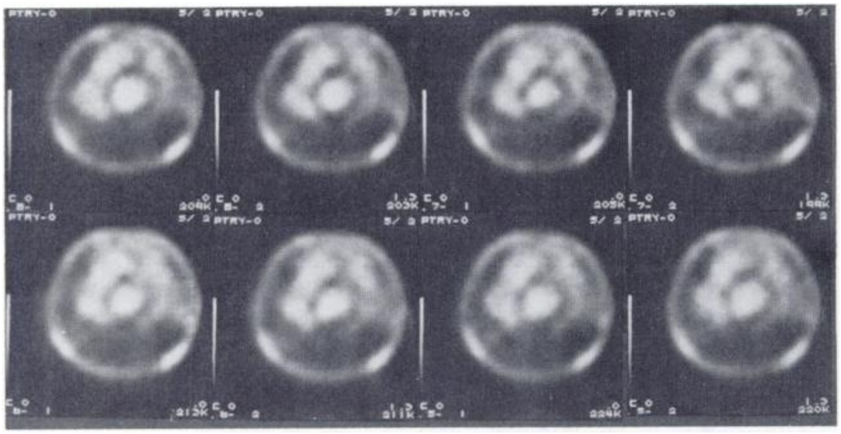

FIG. 5. LAO kinegraphic projection consisting of eight sequential images, each of equal duration, spanning entire cardiac cycle.

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 kinegraphic display. Portions of the cardiac blood pool may be analyzed digitally to construct time–activity curves, which may represent changes in ventricular volume. Figure 6 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 extraventricular 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 the 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 kinegraphic imaging of the heart both at rest and under stress, quantitative and essentially noninvasive 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-versus-time curves, and other functional parameters. The quality of the higher-resolution images suggests the application of gated imaging to pediatric cardiology.

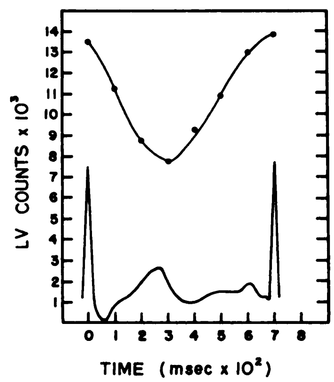

FIG. 6. Left ventricular counts/100 msec as function of time within cardiac cycle. EKG tracing shows that minimum volume—i.e., ES—occurs at down slope of T-wave.

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