Instrumentation

A Cost-Effective, Portable, Digital Data Collection System

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A portable, cost-effective system has been designed and implemented to perform noninvasive, cardiac blood-pool imaging. A list mode, digital data-collection unit is interfaced to an existing portable scintillation camera for the bedside evaluation of acutely ill patients. List mode data is reformatted off-line and then processed in a central nuclear medicine facility. This portable system is a more flexible and less expensive alternative to available portable, digital data-acquisition equipment and gamma camera combinations.

Quantitative determination of ventricular function is of great interest in the management of patients with cardiac disease. Objective measurement of left ventricular function is helpful to assess the status of a critically ill patient and to assess the results of therapeutic interventions *(1,2)*. Bedside evaluation of ventricular performance is particularly attractive since many critically ill patients cannot be safely moved to a central nuclear medicine facility. We have developed and implemented a cost-effective, portable, digital data-collection unit interfaced with a scintillation camera to collect list mode data during dynamic cardiac studies. We designed this portable system to be a less expensive alternative to available digital data acquisition equipment and scintillation camera combinations. We describe the digital collection unit and the software necessary to process the acquired data, and we also note the advantage of list mode data collection.

Data Collection

The portable digital-collection unit consists of high speed analog-to-digital converters (A/Ds), control circuitry, buffer memory, and an industry compatible digital tape drive. The data collection system converts the gamma camera analog signals to digital form and stores them in list mode in the 9-track industry compatible tape drive (Pertec, T 9000 series with 4K byte buffer memory [Chatsworth, CA]) along with time mark and electrocardiographic information. The maximum allowable data rate from the gamma camera for this system is 20,000 counts per sec for both X and Y signals (40,000 byte per sec conversion rate). In order to accomplish the conversion rate in less than 25 μsec, it was necessary to use high speed analog-to-digital converters, sample and holds, and fast settling amplifiers. Using these components, the total X and Y conversion time is approximately 10 μsec, which minimizes data loss.

Twelve bit A/Ds are employed but only the seven most significant bits are used for the X and Y data; this improves the differential linearity of the A/Ds to $\pm<3\%$. In order to provide high resolution and uniform pixel size, the differential linearity should be low. The flexibility to use different manufacturers' scintillation cameras required use of fast settling signal conditioning amplifiers preceding the A/Ds so that the offset and gain could be easily adjusted. The A/Ds are used in the unipolar mode with an output range of 0_8 to 277_8.

The tape drive has a 4K byte buffer memory, which is used in the split buffer mode giving two independent 2K byte buffers. During data collection, the tape drive is in the write continuous mode, writing 2048 byte records.

The X and Y data bytes contain only positioning information. A separate timing byte is employed to give 1 msec time marks throughout the data collection. The time mark byte also contains the information regarding the presence or absence of an R-wave from the electrocardiogram. The hardware for the portable digital data collection unit is shown in Fig. 1(A and B).

Data Processing

The collected list mode data is processed off-line on a Varian V-76 minicomputer (Varian Inc., Palo Alto, CA). A block diagram of the data acquisition and processing system is illustrated in Fig. 2.

The list mode data reconstruction software is implemented in Varian V-76 assembly language. The Varian V-76 is a 32K, 16 bit, 660 nsec semiconductor memory minicomputer system. The memory requirement for the image reconstruction software is 12K words.

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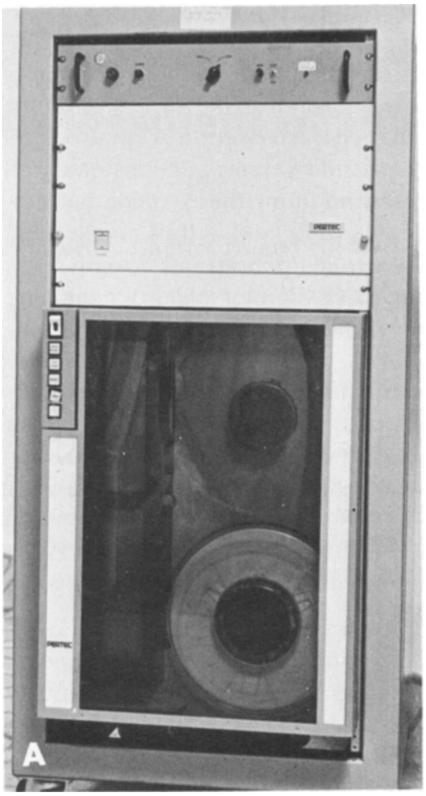

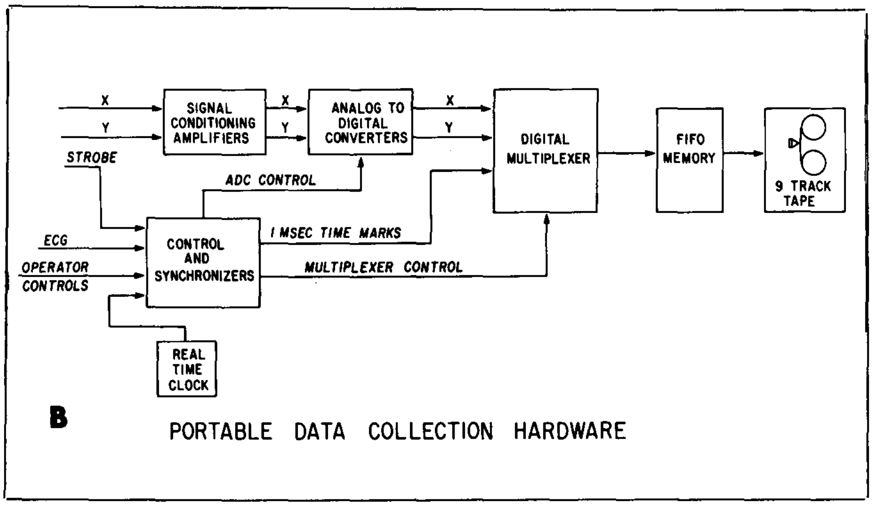

FIG. 1. (A) portable data collection unit; (B) hardware for portable data collection unit (FIFO stands for first in, first out): signal conditioning amplifiers have variable gain and offset to allow for use of different manufacturers' gamma cameras. The analog-to-digital converters feature simultaneous sample and hold and ± 3% differential linearity. The X and Y signals come directly from camera logic.

The software makes two passes on the list mode data. During the first pass, all R-R intervals are identified and a frequency distribution of R-R intervals is displayed. The user can choose the limits of the R-R intervals to be included and also can specify the frame interval and number of frames per cardiac cycle. During the second pass, data in each R-R interval is distributed among the number of frames specified; all beats outside the specified limits are rejected.

The reformatting program can be run in the background partition of the V-76 computer system, thus enabling processing of other clinical studies in the foreground partition. The time required for reformatting a 400 beat, cardiac gated blood-pool study is approximately 30 min. This time includes the first pass through the list mode data to identify all the R-R intervals (approximately 7 min) and the reformatting of the data into gated frames (approximately 20 min).

The analysis of the reformatted gated images for calculation of ejection fraction, ejection rate, ventricular volume, and regional wall motion may be performed on the Varian V-76 or the Ohio Nuclear VIP 450 computer system (Ohio Nuclear Corp., Solon, OH) in the standard fashion within our central nuclear medicine facility.

Results

We obtain images from this system that are equal in quality to those obtained in the central nuclear medicine facility. Reformatted images in 64 × 64 size matrices resolve 4-mm spaced bars and reformatted images in 128 × 128 matrices resolve 3-mm spaced bars. The memory required for a static 128 × 128 size matrix is 16K, 16 bit words. Representative images are shown in Fig. 3.

Discussion

Our nuclear medicine division has two nonportable computer systems in a central facility. A portable scintillation camera (Searle Radiographics, Des Plaines, IL) is available for use in the cardiac intensive care unit. When we needed to collect digital images in the cardiac unit but were

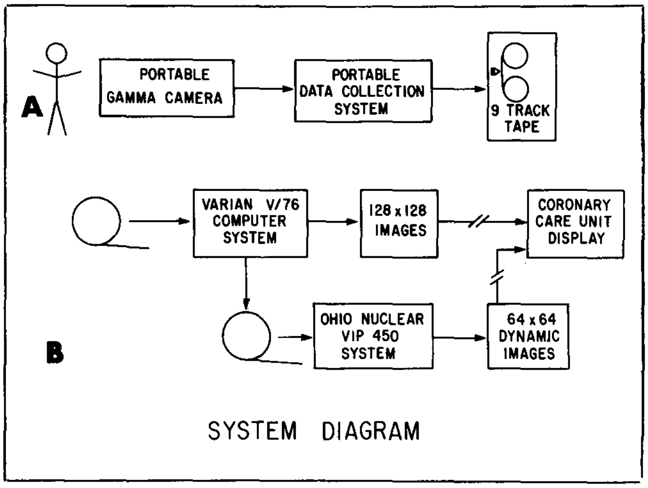

FIG. 2. System Diagram: (A) Data collection—data from portable gamma camera are digitized to 7 bit accuracy and recorded on 9-track tape along with timing and ECG information; (B) Data processing—Varian computer system frames data into 20 64 × 64 images per average cardiac cycle, and displays the images on remote monitor in the CCU. Alternately, this computer system can be used to reformat data for Ohio Nuclear's system.

reluctant to purchase another minicomputer to collect only 2 to 4 studies every day, we designed a portable, list mode data collection device and developed the appropriate reformatting software as a cost effective system for performing noninvasive, cardiac blood-pool images. The required hardware components that were purchased include an industry compatible 9-track tape drive (75 in./sec) with 4 K byte tape buffer, 2 A/D channels, power supplies, a cabinet, and digital logic. The additional cost to our department for the hardware was approximately $9,500.00, which is less than the costs of commercially available portable minicomputer systems. Picker, Searle, ADAC, and Ohio Nuclear all market portable peripheral digital data collection units that are priced in the $15,000-$40,000 range.

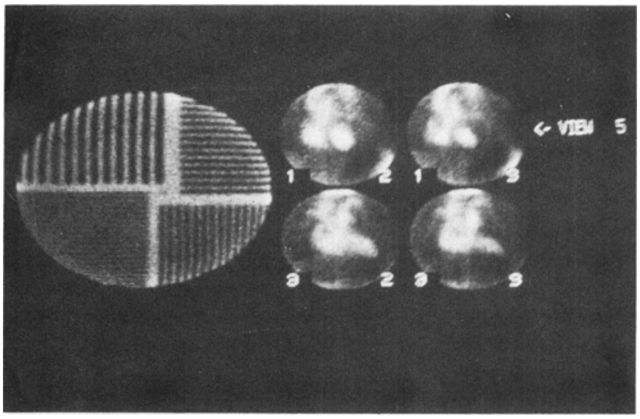

FIG. 3. Representative images: A resolution phantom with 6-, 5-, 4-, and 3-mm line spacing is shown along with 35° left anterior oblique and anterior images of end-diastolic and end-systolic frames.

After reformatting, the gated cardiac blood pool images are processed in the usual fashion in the nuclear medicine department—to provide characterization of ejection fraction, ejection rate, ventricular volumes, and regional wall motion abnormalities. In addition, the list mode data collection affords great flexibility and is thus an excellent tool for clinical and research applications. We can select appropriate beat lengths (R-R intervals) after the data has been collected rather than using the usual delayed buffering technique *(3)*. Thus, patients with irregular cardiac rhythms are rather easily handled and the user has complete control over selecting appropriate beat lengths. In summary, we have found this portable digital data acquisition system to be cost effective and extremely flexible.

Acknowledgment

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