Scintigraphic Data Processing with a Dedicated Mini-Computer System

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The introduction of the scintillation camera into the field of nuclear medicine has improved both the qualitative and quantitative collection of data. To completely realize this improvement, numerous investigators have interfaced the scintillation camera to a small computer system (*1–12*). The purpose of this paper is to stress the usefulness of this combined computer-camera system for clinical as well as experimental nuclear medicine procedures.

Materials and Methods

The computer-camera system we used is a Hewlett-Packard 5407A Scintigraphic Data Analyzer, shown in Fig. 1, connected to a Nuclear-Chicago HP gamma camera. The principal hardware elements in this particular system are: (A) two 7-bit resolution analog-to-digital converters, (B) a 12,000-word memory computer using 16-bit words, (C) a moving head disk, (D) two magnetic-tape drives, (E) a high-speed paper-tape reader, (F) a high-speed paper-tape punch, (G) a display unit, and (H) a standard teletype.

The computer software includes a complete operating system that can carry out routine operations such as raw data collection, data framing, and display, etc., by instructions given in conversational English on the teletype. Provision is also made for incorporation of user programs into the system. These programs can be written in keyboard callable BASIC, the so-called keyboard programming language, or FORTRAN. By using supplied subroutines these user programs can access the 5407A file structure and thus modify data contained in these files to fit the user's needs.

A simplified schematic of the system file structure is shown in Fig. 2. A typical study might consist of the following steps: First the user instructs the system to acquire raw data from the camera. After the requisite information has been collected, the user requests these data to be converted into pictures and stored in the frame, or picture, file. The user then calls the display device, and a representative picture in the frame file is displayed. With the display still active, areas of interest are selected and stored in the area file. The user then instructs the system to use the stored areas on the pictures in the frame file to generate regional

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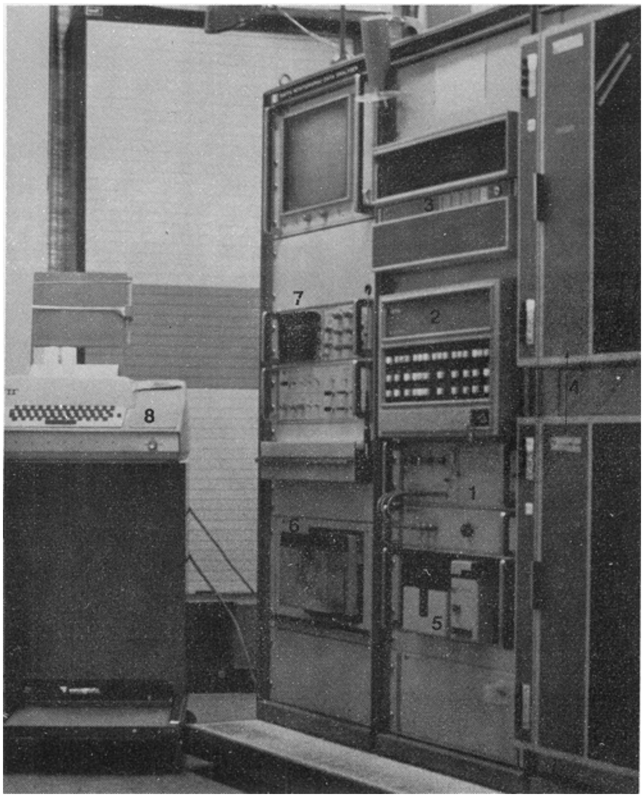

FIG. 1. Dedicated mini-computer system (5407A Scintigraphic Data Analyzer). Various components are numbered and described in the text.

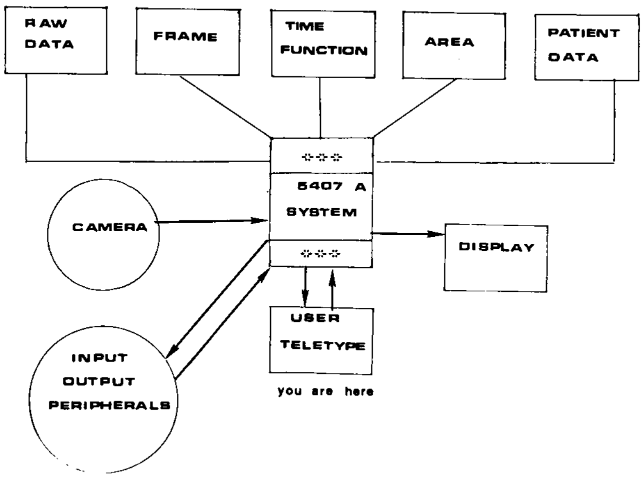

FIG. 2. Simplified schematic of 5407A system file structure. Each manipulative functon is callable by single keyboard stroke (command).

counts versus time histograms, called time functions, which are stored in the time function file. If at this stage the user had completed processing the study, he could have the frames, time functions, and areas written into the patient data file for permanent storage. It should be pointed out again that this entire process is carried out by responding to system prompts in English on the teletype. Each of these required functions is callable by a single keyboard stroke or command.

The computer-camera system possesses a variety of keyboard callable programs that have direct clinical significance. Field nonuniformity correction for a block of pictures in the frame file can be easily carried out (*3, 8, 11*). Not only does this nonuniformity correction qualitatively improve images created by the system, but it makes quantitative comparison of regions of interest within a given picture more meaningful. If each flooded field that is created in this process is saved on the patient data file, a permanent and useful record of spatial variations in camera sensitivity can be maintained.

Results

Clinically useful arithmetic operations on pictures or time functions can also be carried out by simple keyboard commands. For example, background can easily be subtracted from any picture or time function in the frame or time function files, or pictures may be added together. In addition, time functions and pictures may both be "smoothed." Figure 3 is an example of background subtraction and smoothing in a study demonstrating ^{99m}Tc-pertechnetate displacement by perchlorate in a thyroid gland. The data were collected, areas labeled, and time functions created. In time function No. 4 smoothing provided a more even curve for interpretation.

The system possesses a display unit that allows analysis of image and time function data. Pictures may be viewed in the conventional manner, as well as in isometric and slice format. Figure 4 depicts lung accumulation of ^{133}Xe demonstrated in all three modes; contour, isometric, and slice.

Regions of interest, either rectangular or irregular in shape, can be selected on the display unit and recalled by the system. Such designation of the region of interest can markedly reduce the effect of nontarget activity on the generation of histograms. Figure 5 shows part of a superior vena cava flow analysis, demonstrating the labeled areas and count-versus-time histogram curves.

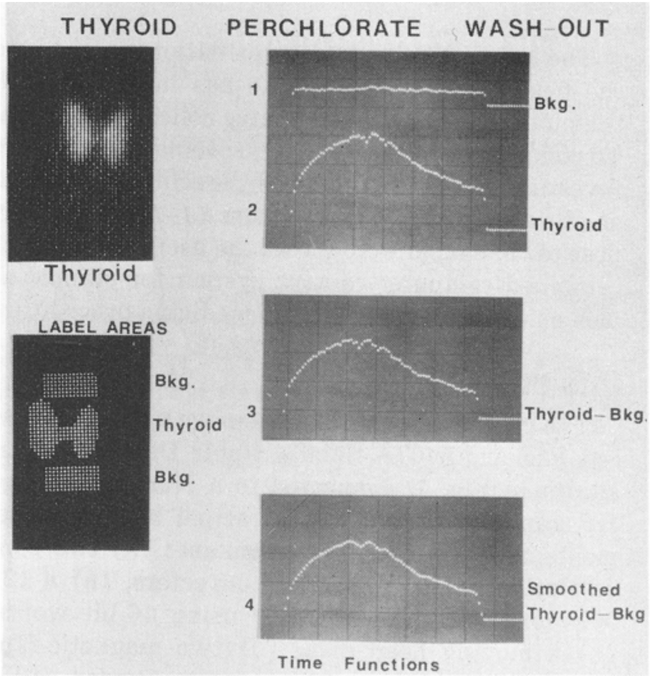

FIG. 3. Background subtraction and smoothing in thyroid function study. Thyroid gland and two areas outside thyroid were labeled for time function analysis. Radionuclide washout curve was recorded (1); along with background activity (2); resultant curve after background subtraction (3); was smoothed (4).

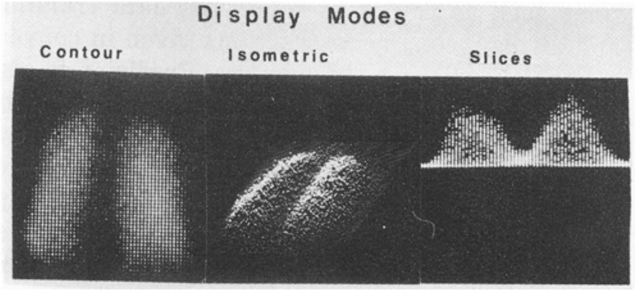

FIG. 4. Use of contour, isometric, and slice display modes in xenon lung study. Contour mode shows usual representation of radionuclide throughout both lungs. In isometric mode, radioactivity is displayed in fashion which facilitates detection of small differences in activity. Slice mode is representative of radioactivity in designated transverse cross-section of lungs.

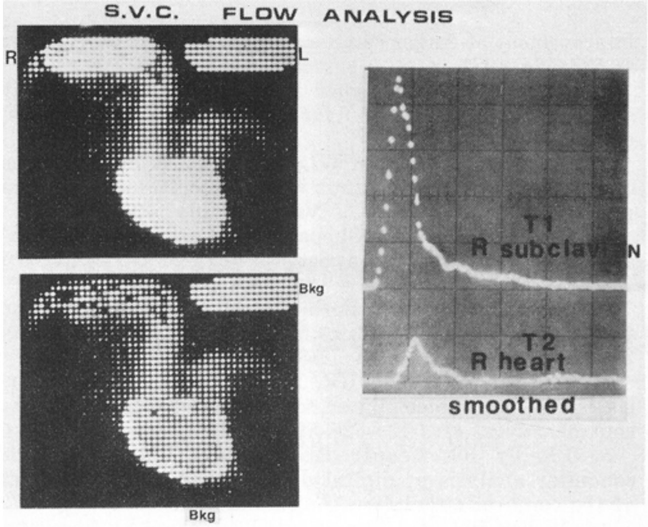

FIG. 5. **Superior vena cava flow analysis.** Cursors label right subclavian with left subclavian for background. Right heart with region around right heart for background is also shown. Time functions were created for each of labeled areas. Background was subtracted from right subclavian and right heart and resultant time functions were smoothed once. Results demonstrate normal superior vena cava flow.

In the renogram procedure, shown in Fig. 6, the conventional approach is to electronically split the camera's field of view and to take the count detected by each half of the crystal as representing renal activity. This technique suffers from the fact that a very substantial portion of the activity viewed comes not from the kidney but from outside the kidney and thus the true renogram curve is superimposed on a large time-varying background. Cursors delineating each kidney substantially eliminate surrounding activity and thus present a more nearly correct picture of the kidney radioactivity (*6, 7*). This effect is demonstrated in an ^{131}I-Hippuran renogram on a patient with a kidney stone which incompletely obstructed urine flow on the left. Compare the right kidney transit of the split crystal with that of the specifically labeled areas. After omitting the area of urinary holdup, an almost normal renogram curve is presented.

In addition to the capabilities supplied with the computer, provision has been made for incorporating user programs into the system. A very substantial collection of user programs has been written in our laboratory to expand and simplify system operation for a variety of experimental and clinical procedures. These procedures, written in BASIC and FORTRAN are currently being used to process clinical ^{133}Xe ventilation-perfusion studies, renograms, to optimize data presentation in bloodflow procedures, to perform experimental image processing, and to carry out a large variety of utility operations.

General-purpose computing with BASIC is also possible. Programming in BASIC is particuarly simple in the 5407A system since the interpreter is callable by keyboard command. BASIC itself is a very simple, easy to learn and use language that possesses modest flexibility. Because of the subroutines supplied that link BASIC to the 5407A time function file and thus to 5407A display unit, the user can do general-purpose programming in BASIC and use the display as an output device for two-dimensional data. The hand plotting of complicated results is thereby eliminated. This capability is currently being used to process wholebody counter retention data where corrections are made for deadtime, decay of standards, machine variations, etc., and the true retention values are plotted as a function of time on the display unit. This display is then photographed and the actual retention values are listed on the teletype.

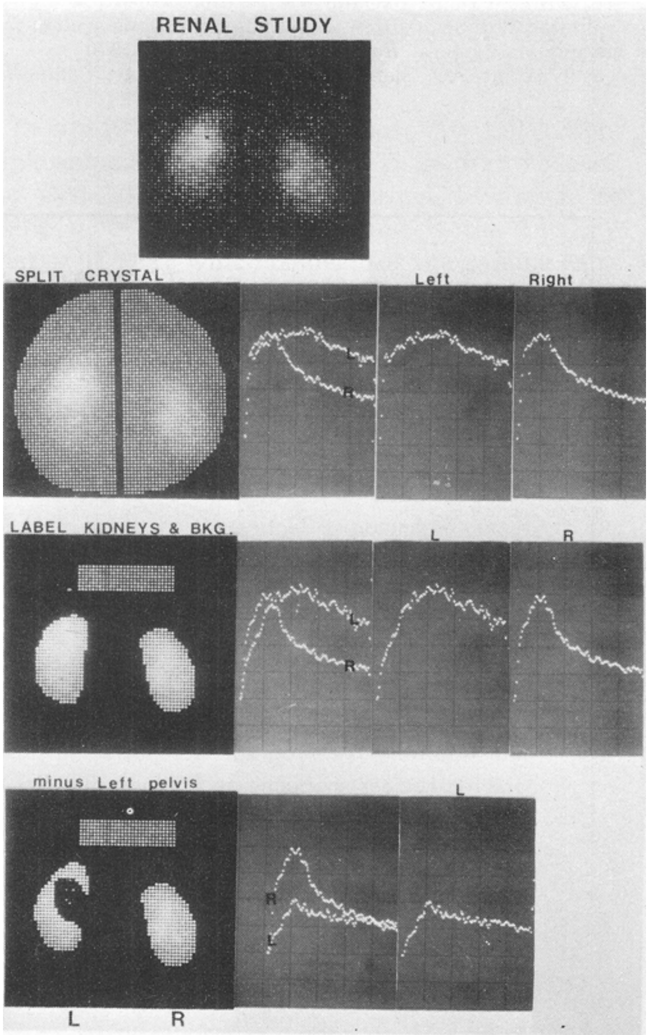

FIG. 6. In renal study, data from specifically labeled areas present more correct picture of kidney transit compared with that from split-crystal method. Patient had kidney stone which incompletely obstructed urine flow on left.

Summary

A computer-camera system appears to offer numerous advantages in the processing of scintillation camera data for both clinical and experimental purposes over the stand-alone camera (*1–12*). Among these advantages are permanent data storage, correction for camera nonuniformities, selection of regions of interest, the ability to carry out elementary mathematical operations on images and time functions, to perform general image processing, and the ability to incorporate user programs into the system.

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