TAPE RECORDING OF DUAL-CHANNEL ENERGY-MODULATED COLOR SCANNING

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A method of converting a conventional rectilinear scanner for multi-isotope scanning has been described recently (*1,2*). With this method, two isotopes in the same or neighboring organs can be scanned simultaneously and the distribution of each can be printed in a different color. The purpose of the present paper is to describe the use of our modified four-track magnetic-tape recorder cathode-ray-tube color-Polaroid system to improve the storage, display and analysis of the information obtained in dual-isotope scanning.

MATERIAL AND METHODS

A block diagram of the essential connections of the scanner-recorder-display system is shown in Fig. 1. A conventional scanner can be used—in this instance a Picker V Magnascanner to which is added one additional single-channel analyzer. The tape recorder and Polaroid display system is a commercially available Magnascanner Tape Recorder (Picker Nuclear 629-200). Manufacturer's specifications and circuitry are available. The authors' modifications to obtain color Polaroid display of the gamma-emitting isotope distribution consisted of replacing the blue phosphor cathode-ray tube with a white phosphor CRT and using a color filter holder and plastic transparency between the CRT face and the camera lens. The device is otherwise unaltered. The output of Analyzers 1 and 2 are recorded on Channels 3 and 4, respectively. The square-wave impulses are approximately 6 μsec long when played out. To carry out a subtraction scan (*3–5*)—for example, to visualize the pancreas and liver using two isotopes—switch "S" is thrown to the "in" position. In this position the information from Analyzer 1 will be recorded on Channel 3 and the "subtract output" (information from Analyzer 2 minus the information from Analyzer 1) will be recorded on Channel 4. The x and y movements of the scanner are recorded on Channels 1 and 2. The blip position is determined by two spring-loaded potentiometers with a string attached to the detector arm in the x and y axis, producing an appropriate bias on the cathode-ray deflection when played out. The device is analog in design. The recorded information is played into the readout unit and displayed on a white phosphor CRT. The size of the field can be controlled between 15 and 100 cm in each axis. The beam intensity is proportional to the output from Channels 3 or 4, depending on the position of the switch S_2. The CRT display is continuously monitored by a Polaroid camera loaded with color film. A filter holder was built between the CRT screen and camera where various colored filters can be mounted. When the information from Channel 3 is played back, Filter A is used to obtain a picture of the distribution in Color A. Then Channel 4 is played back using Filter B, exposing the same film as for Channel 3. This isotope will appear in Color B. The overlay areas will appear in a mixture of Colors A plus B, distinct from A or B. The replay is car-

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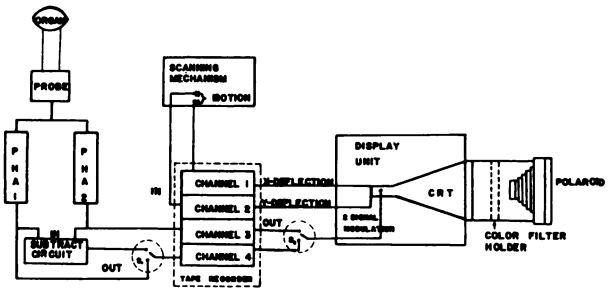

FIG. 1. Block diagram of dual-channel Polaroid display scanning system with tape recorder.

ried out at a speed 16 times faster than the recording (60 in./min vs. 3.75 in./min). The tape used is standard 3M 203V tape. The replay procedure can be repeated as many times as desired at different intensity, contrast and background cutoff settings for each channel as well as at variable ratios of two channels. These parameters are all controllable and reproducible on the display unit. This lets one analyze scans using various settings of these variables.

RESULTS AND DISCUSSION

The system described has been used to scan various organs and combinations of organs. Examples of scans of the pancreas and liver, brain and accessory structures of the head and of the heart are discussed below.

Pancreas-liver scans. The diagnostic advantage of simultaneous scanning and display of the liver and pancreas in separate colors using the two-color subtraction technique has been discussed in a recent presentation (*6*).

The display of the normal pancreas and liver in blue and red, respectively, allows specific and simultaneous delineation of each organ when it is discretely separated (Fig. 2 top) or when the images overlap (Fig. 2 bottom). In the latter instance, the area of overlap is seen in white, effectively revealing the distribution boundary of each isotope in the individual organs. The production of white by mixing blue and red is a peculiarity of the pigments used. The effectiveness of background subtraction to display the pancreas is clear in Fig. 3 in which the liver is displayed at constant intensity with successively decreased subtraction of background of the extrahepatic selenomethionine. The presence of information in the ^{75}Se channel from sources other than the pancreas must be considered. Not only are blood and tissue ^{75}Se present at the detectable level, but also Compton radiation from ^{198}Au as well as electronic noise may be detected in this channel. This relatively low-level interference with the pancreas image becomes apparent when little background subtraction is used. Elimination by background erasure is very effectively accomplished from the tape-recorded information. At a low level of suppression the concentration of ^{75}Se in the myocardium becomes apparent. This is discussed in a following section.

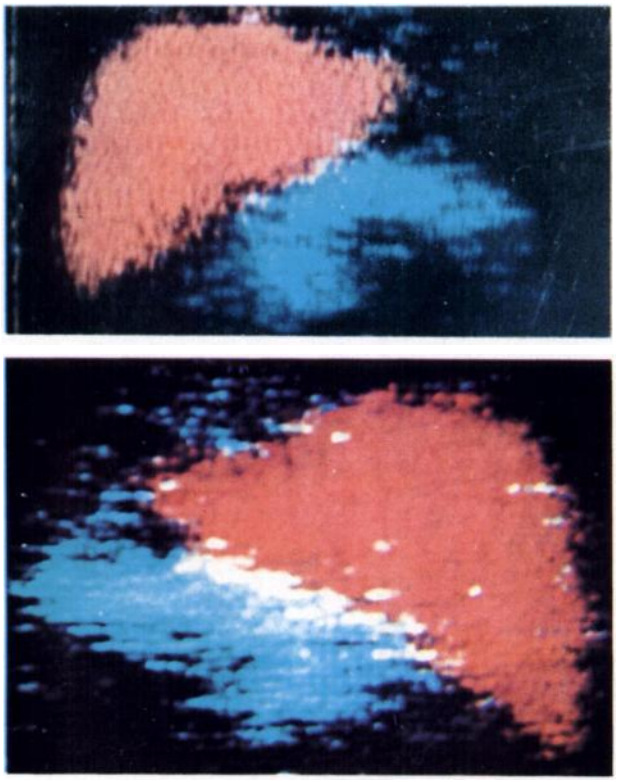

FIG. 2. Dual-channel scan of normal pancreas. Top shows discrete separation of pancreas and liver (*7*). Bottom shows overlap of pancreas and liver.

Background manipulation has been useful in demonstrating cold lesions in the liver which may not be apparent because of the saturation effect at low background-subtraction levels. Display of the tape-recorded scan at any desired level of background subtraction is provided in the control panel for either channel of information. This is readily accomplished without destruction of any of the information in question. Massive replacement of the liver by metastatic malignancy can occur with no significant localization of ^{75}Se within the lesions. The pancreas is clearly visualized despite virtually complete overlay of the deformed liver. The enlarged spleen is visualized in red by accumulation of ^{198}Au in Fig. 4.

The positive visualization of a hepatoma in the right lobe of the liver proven at laparotomy indicates massive accumulation of ^{75}Se (Fig. 5). Apparently the pancreas was not able to compete with the lesion for the amino-acid analog and consequently is not visualized. A small spleen is seen next to the superior aspect of the left lobe. Using subtraction of gold from selenium activity (*2*) results in separate color visualization of the tumor even if the concentrations of ^{75}Se in the liver and tumor are equal.

Pancreatic defects are well visualized as is shown by the focal decrease in ^{75}Se concentration in an individual with verified carcinoma of the pancreas (Fig. 6). The focal lesions are quite apparent compared with scans of the normal pancreas (Fig. 2).

Brain scanning with ^{75}Se-selenomethionine and ^{99m}Tc-pertechnetate. The concentration of ^{75}Se-

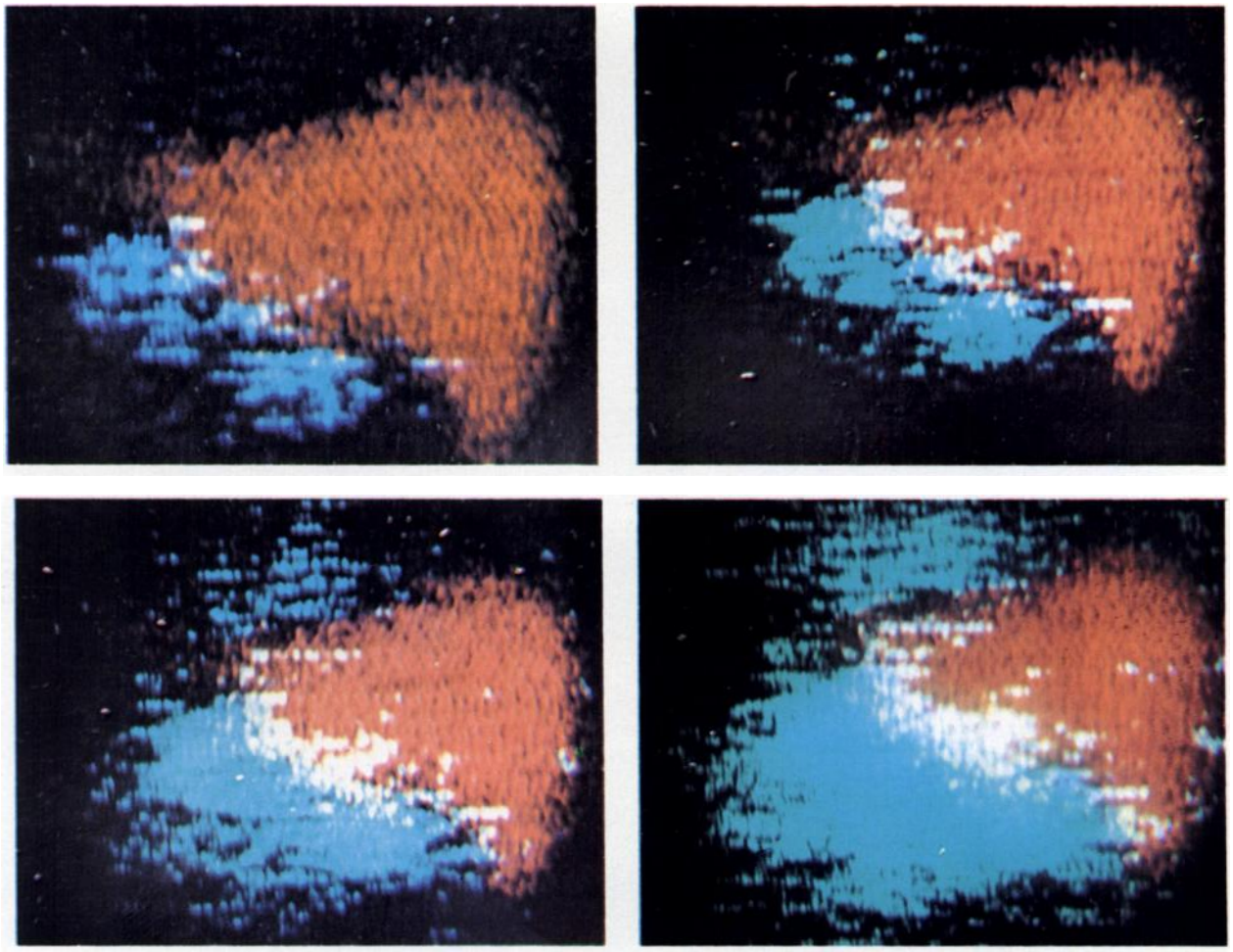

FIG. 3. Dual-channel scan of normal pancreas and liver, showing successive decrease in background erasure.

selenomethionine in the brain after a 250-μCi dose of the agent for pancreatic scanning is sufficient to visualize the brain by scanning. The accessory structures of the head are not seen. The concentration of ^{75}Se activity equilibrates within 10 min of intravenous injection and remains at a significant concentration within the brain for at least several hours. When a simultaneous scan of ^{99m}Tc and ^{75}Se are attempted, the gamma energies of the two isotopes can be discriminated, stored in separate magnetic-tape channels and displayed separately on Polaroid as described above. In the example shown in Fig. 7 with ^{99m}Tc and ^{75}Se, the overlay of the two colors produces a display of the lesion in white. The usefulness of this method in diagnosing and discriminating various brain lesions remains to be explored. It appears to be useful in differentiating ^{99m}Tc-containing normal vasculature from brain lesions.

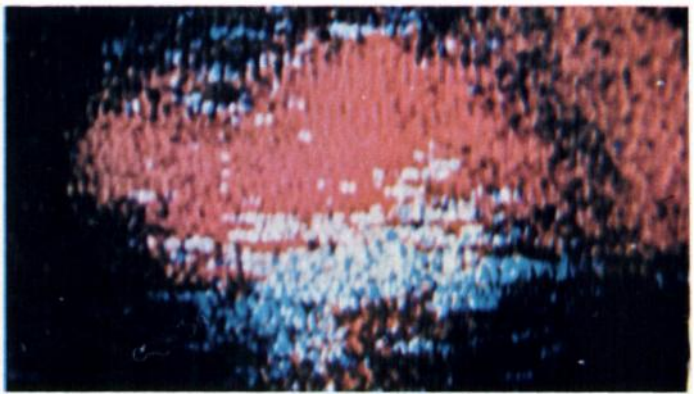

FIG. 4. Dual-channel scan of normal pancreas when completely overlapped by massive liver with metastatic lesions. Note visualized spleen (7).

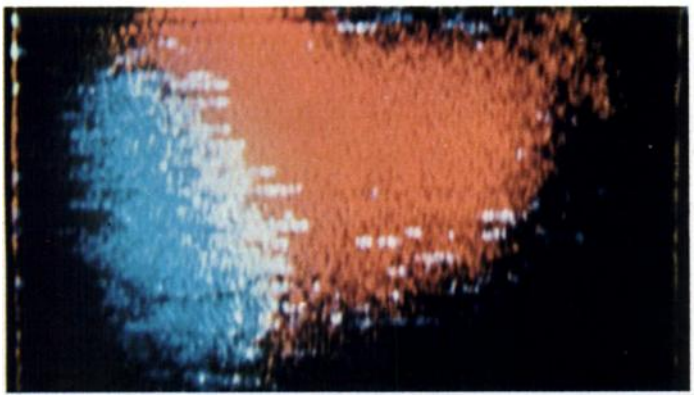

FIG. 5. Dual-channel scan of verified hepatoma with positive uptake of ^{75}Se-selenomethionine; pancreas is not visualized because of apparent competition by tumor (7).

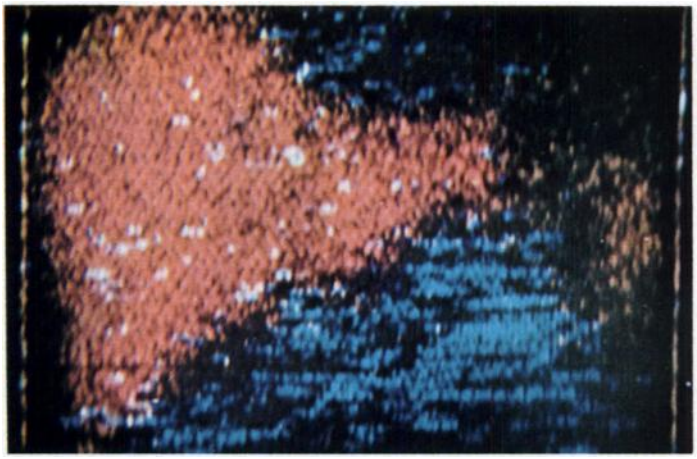

FIG. 6. Dual-channel scan of verified pancreas carcinoma (7).

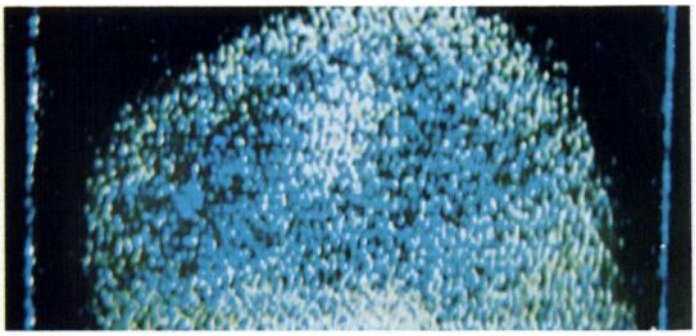

FIG. 7. Dual-channel scan of head showing ^{75}Se-selenomethionine concentrated in brain and in cerebral vascular accident; accessory structure of head and CVA show ^{99m}Tc-pertechnetate concentration (7).

Myocardial scanning with ^{75}Se-selenomethionine. Animal and necropsy studies of humans in our laboratories indicate a differential concentration of ^{75}Se from selenomethionine in the myocardium compared with skeletal muscle after 72 hr. The differential may be greater at smaller intervals after intravenous injection. The high concentration of ^{75}Se in the myocardium has permitted visualization of the myocardium by dual-channel scintiscanning. An example of such a scan (Fig. 8) differentiates the liver from the myocardium by dual-channel subtraction. The tip of the left lobe of the liver and the myocardium are plainly visualized. The cavity of the right heart can be seen. A direct comparison with ^{86}Rb and ^{131}Cs scans of the myocardium has not been made, but the quality of the scans obtained with ^{75}Se appears superior to the published scans using the other isotopes.

The selective uptake of ^{75}Se-selenomethionine by both the myocardium and diaphragm compared with

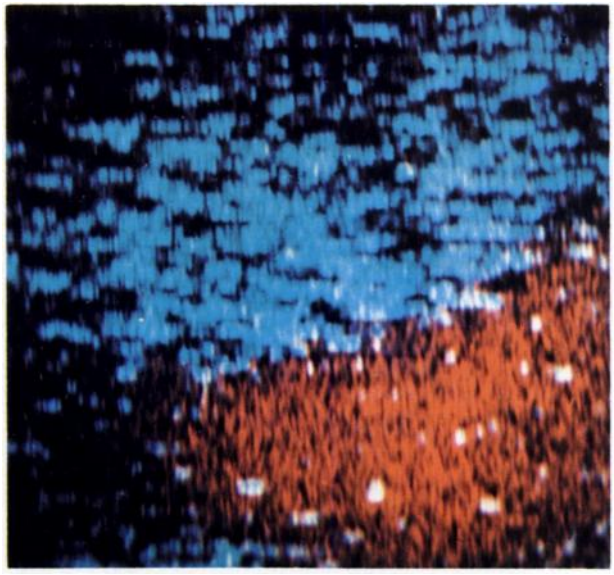

FIG. 8. Dual-channel scan of myocardium using ^{75}Se-selenomethionine; tip of left lobe of liver is visualized below heart.

skeletal muscle has been noted. The reason for this enhanced localization is not known, but it may be related to the increased and constant workload of these two muscular structures.

SUMMARY

The use of a four-channel tape-recording display system is described for multi-isotope scanning. It has been shown that this technique (1) provides a superior display of the scanning information, (2) permits the analysis of the scan at various contrast settings and (3) may aid in the visualization of brain lesions. It has also been shown that ^{75}Se-selenomethionine concentrates sufficiently in the myocardium to permit good visualization of this organ. The clinical aspects of this technique will be described in a future paper.

ACKNOWLEDGMENT

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