DIAGNOSIS OF PERICARDIAL EFFUSION BY RADIOISOTOPIC ANGIOCARDIOGRAPHY

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The development of the gamma-ray scintillation camera (*3*) and similar devices capable of detecting gamma-ray emission from large areas of the body simultaneously and the availability of short-lived radionuclides have made it possible to record and display photographically fast-moving events occurring in selected parts of the body. One application of immediate interest was the assessment of the pattern of blood flow to an organ or region after the intravenous or intra-arterial injection of a radioactive bolus, i.e., radioisotopic angiography. The first reports were concerned with general applications of the isotopic method (*4–6*). More recently studies have been performed of blood flow through the heart and lungs (*1,2,7*), placenta (*8*) and brain (*9–11*). It is the purpose of this report to describe a technique of performing radioisotopic angiocardiography which is applicable to the rapid and nontraumatic diagnosis of pericardial effusion. Our experience based on a study of six patients with that disorder indicates that the procedure is not only an effective diagnostic tool, but is also one which has several practical advantages over other scanning methods.

MATERIALS AND METHODS

Patients. Our six patients with pericardial effusion were all individuals with malignant disease. One patient had chronic myelogenous leukemia while the others had advanced stages of malignant lymphoma and had received megavoltage radiotherapy including the region of the mediastinum (*12,13*). The sex, age, diagnosis and radiation dose to the mediastinum of these patients are indicated in Table 1. Before our studies, all subjects showed roentgenographic signs of progressive enlargement of the cardiac silhouette as well as symptoms and signs suggesting cardiac tamponade and congestive heart failure. Control studies have been done on 30 adults of both sexes without known heart disease; these subjects were referred for ^{99m}Tc-pertechnetate brain scanning, and we took the opportunity to record the angiocardiographic data just before the requested procedure. Additional control studies have been done on six adult patients with cardiac enlargement and with congestive heart failure due to nonvalvular heart disease.

Angiocardiographic techniques. With the patient in the supine (or sitting) position the detecting head of an Anger scintillation camera was placed close over the precordium, and scintiphotos were taken at various intervals after rapid injection of 10 mCi of ^{99m}Tc-pertechnetate into an antecubital vein. A 4,000-hole, straight-bore, multichannel collimator designed for collimation of low-energy gamma rays was used. Images were generated using a 42-keV window spanning the 140-keV ^{99m}Tc photopeak. We adopted a technique using a completely defocused oscilloscope light dot because the organs were more clearly delineated than when a focused dot was used. Exposures were made every 6–8 sec for the first half minute and thereafter at longer intervals up to 2–3 min. The entire procedure, including patient positioning. can be accomplished in 10 min or less. All of the data to be presented were obtained in the above manner. More recently a significant modification has been made in the system which greatly improves its readout capability. The modification,

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Portions of this work have been presented in preliminary form (*1,2*).

TABLE 1. SUMMARY OF PERTINENT CLINICAL DATA ON PATIENTS WITH PERICARDIAL EFFUSION

					Radiotherapy data		
Case No.	Patient	Age	Sex	Malignant disease	Mediastinal dose (rads)	Interval, end of therapy to effusion (mos)	Comment
1	GB	77	M	Chronic myelogenous leukemia	0	—	Dyspnea, orthopnea, edema. B.P. 110/70, pulsus paradoxus, heart rate 140, pericardial friction rub, hepatomegaly, bilateral pleural effusion.
2	DJ	17	M	Hodgkin's disease	4,400	4	Dyspnea, orthopnea, cough, chest pain. Heart rate 140, B.P. 86/68, pulsus paradoxus, pericardial friction rub, venous distension.
3	CB	17	F	Hodgkin's disease	5,190	4	Dyspnea, orthopnea, cough, chest pain, B.P. 90/60, pulsus paradoxus, pericardial friction rub, hepatojugular reflex, bilateral pleural effusion.
4	GF	59	M	Reticulum cell sarcoma	4,400	7	Dyspnea, orthopnea, edema. B.P. 90/60, pulsus paradoxus, heart rate 80, pericardial friction rub, hepatomegaly, venous distension, bilateral pleural effusion.
5	LS	57	F	Reticulum cell sarcoma	4,300	5	Dyspnea, orthopnea, anorexia, nausea and vomiting. Heart rate 130, B.P. unobtainable, pericardial friction rub, left pleural effusion.
6	JG	26	M	Hodgkin's disease	5,500	20	Dyspnea, orthopnea, anasarca, venous distension. B.P. 115/60, pulsus paradoxus, hepatomegaly, bilateral pleural effusion.

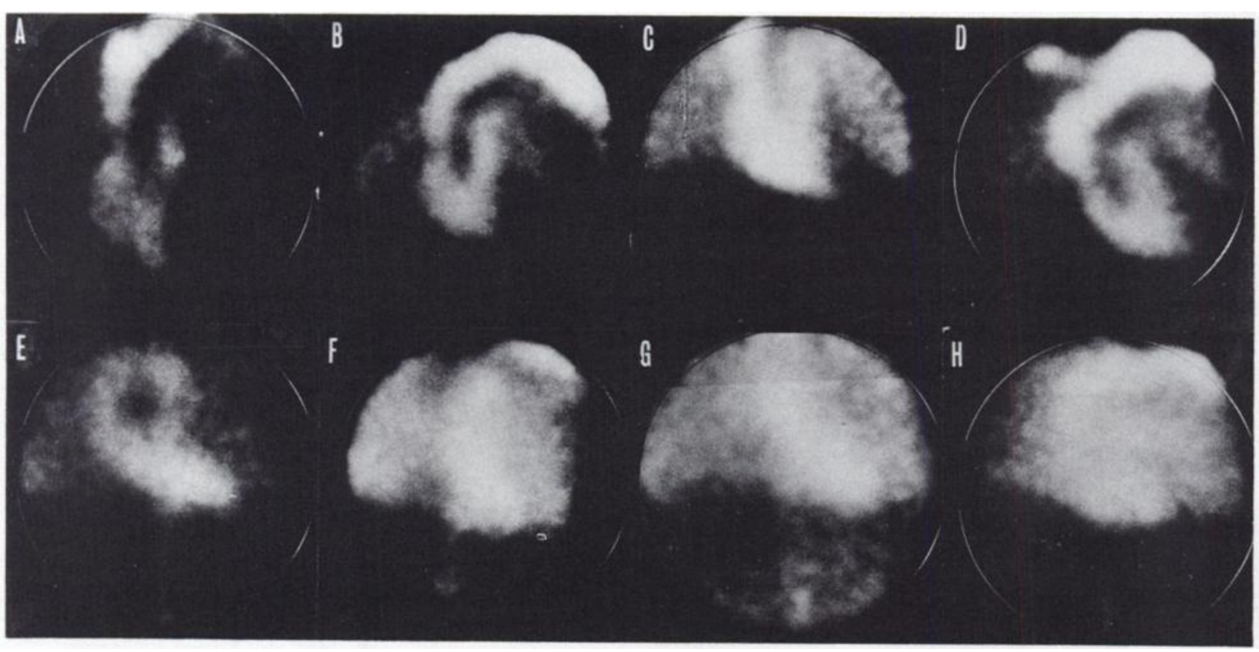

FIG. 1. Radioisotopic angiocardiographic findings in patients with normal hearts. Frames A–D show scintiphotos obtained during first 8 sec of exposure after injection of 10 mCi ^{99m}Tc-pertechnetate in four subjects. Frames E–H show four examples of scintiphotos obtained during the second 8-sec exposure.

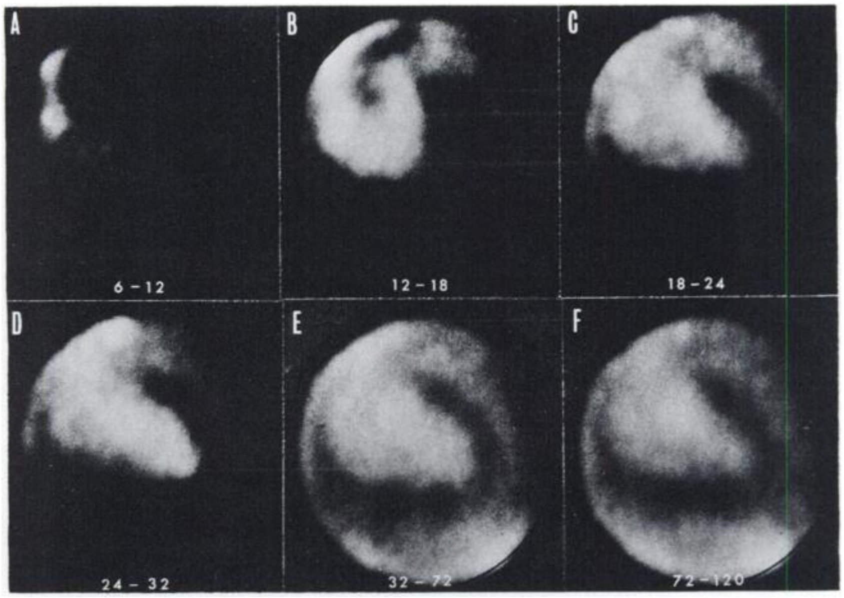

FIG. 2. Radioisotopic angiocardiogram in pericardial effusion (Case 1). Time of exposure in seconds after injection of radiopharmaceutical is given at bottom of each frame.

made under the direction of Elliott Levinthal and William Bonner, Dept. of Genetics, consists of coupling a television camera* to an auxiliary oscilloscope, recording the display on videotape† and redisplaying on a television monitor‡ the data accumulated over any preselected time interval. The device permitting interval selection uses a timer|| and interval timer|| which control the time and duration of the monitor display. The image displayed on the monitor is photographed by a Polaroid camera¶ under light-tight conditions. Controls of brightness and contrast on the monitor and of shutter opening on the camera let one vary greatly the quality of the final photographic image. Optimization of the image can thus be accomplished at leisure after the patient has been returned to the ward.

Heart scanning. Scanning was performed in the conventional manner following the intravenous injection of ^{131}I-labeled human serum albumin (IHSA) (*14*). The delineated area of the intracardiac blood pool was compared with the cardiac silhouette determined by a roentgenogram of the chest taken at a distance of 6 ft in midrespiration. In most instances the IHSA and ^{99m}Tc-pertechnetate were administered as a mixture, and the angiocardiographic procedure was done immediately after injection; at its conclusion, the patient was placed under a Picker Magnascanner V, and the heart scan was then made.

* Diamond Model ST-2, Diamond Power Co., Lancaster, Ohio.

† Ampex, VR-7000, Ampex Corp., Elk Grove, Ill.

‡ Conrac-RNEA-9 division of Giannini Corp., Glendora, Calif.

|| Post Electronic Products, Inc., Model P3, Beverly, Mass.

¶ Polaroid Corp., Model 180, close-up lens 593, delayed cable release 191, Cambridge, Mass.

RESULTS

Normal subjects. Figure 1 shows scintiphotographic findings typical of the normal subject. The top frames (A through D) show scintiphotos made in four different subjects during the first 8 sec after injection. Because of slight variations in technique and speed of circulation, the image resulting from 8 sec of exposure did not invariably show activity precisely at the same anatomic locations in every subject. In frame A activity was visualized in the superior cava, right atrium, right ventricle, pulmonary outflow tract and the main branches of the pulmonary arteries. In those patients in whom later phases of pulmonary filling were observed, several key features were noted. Foremost among these is the absence of activity in the area immediately to the left of the right ventricle (frames B–D). This is the region occupied by the yet unfilled left ventricle and takes the form of a dark wedge-shaped area with its apex at the base of the heart (frames B–D). By way of contrast, the area to the right of the ventricle fills in uniformly, and its lower limit forms a horizontal line which represents the lower limit of the right lung and which intercepts and is contiguous with the right heart image (frames C, D). The lower frames (E through H) show scintiphotos

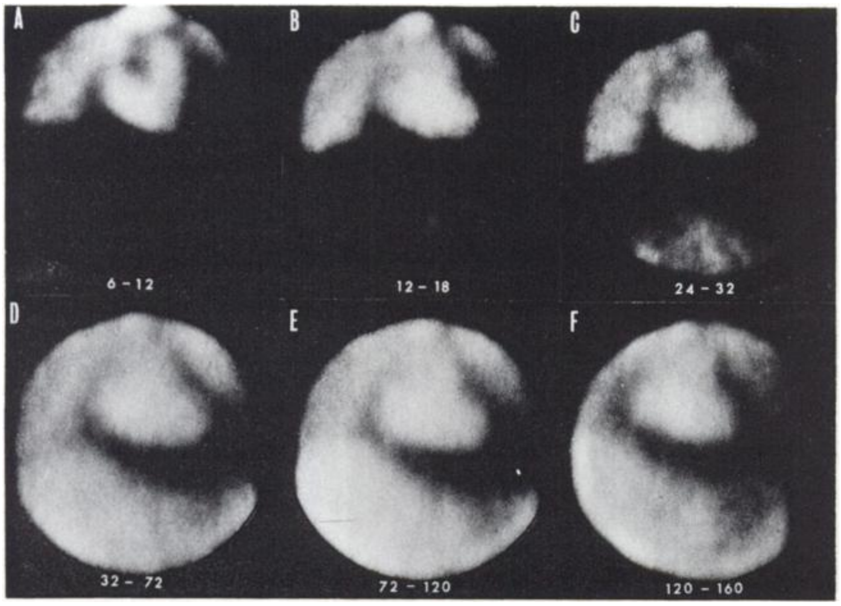

FIG. 3. Radioisotopic angiocardiogram in pericardial effusion (Case 2).

obtained in four normal subjects during a second exposure period of 8 sec. In frame E activity is clearly visualized in the left ventricle, aortic arch, descending aorta and lungs. In frames F–H the relation between the activities in the heart and lungs is more clearly shown: the lung-field margins normally extend horizontally across the chest, and the previously described wedge-shaped void to the left of the right ventricle has now been filled in by the activity in the left ventricle. The normal pattern is thus characterized by contiguity of lung and heart activity, first on the right side, and later on the left side.

Pericardial effusion. In a pericardial effusion the fluid-filled pericardial sac physically separates the cardiac blood pool from the lungs to an abnormal degree. Hence one would anticipate that in such a condition the isotope angiocardiogram would demonstrate failure of the pulmonary activity at the lung bases to become contiguous with the activity within the heart, and this failure should be manifest as a void, first at the right cardiopulmonary border and later as a persistent left-sided void even after filling of the left ventricle. This prediction turned out to be precisely accurate, but in addition it proved possible to visualize clearly the effusion itself soon after the radioactivity had reached its distribution sites in the abdomen. Figures 2–7 show the scintophoto sequences obtained in our six patients with pericardial effusion. Each figure shows a composite of frames from a different patient arranged in sequence, with the corresponding time intervals in seconds after injection indicated on each frame. The following diagnostic features of pericardial effusion are emphasized:

1. Wedge-shaped filling defect at the *right* cardiopulmonary border (Fig. 2, frames C, D; Fig. 3, frames A–C; Fig. 4, frames B, C; Fig. 5, frames B, C; and Fig. 7, frame A).
2. Wedge-shaped filling defect at the *left* cardiopulmonary border *even after left ventricular filling* (Fig. 2, frames C, D; Fig. 3, frames B, C; Fig. 4, frames B–E; Fig. 5, frames B, C; Fig. 6, frames A, B; and Fig. 7, frames B, C).
3. Delineation of the pericardial sac in later sequences as a void surrounding the heart (Fig. 2, frames E, F; Fig. 3, frames D–F; Fig. 4, frames F–H; Fig. 5, frame D; Fig. 6, frames D–F; and Fig. 7, frames D–F).
4. Delay in the speed of circulation as detected either by slow emptying of the bolus in the subclavian vein or superior vena cava (Fig. 4, frames B–G), slow arrival of bolus in the right heart (Fig. 2, frames A, B; and Fig. 5, frame A), or slow filling of the aorta or abdominal vessels (Fig. 2, frame E; Fig. 4, frame F; and Fig. 5, frame D).
5. Frequent demonstration of an associated pleural effusion shown by failure to demonstrate complete encirclement of the pericardial sac by visualized radioactivity, especially on the left side (Fig. 3, frames D–F; Fig. 4, frames F–H; Fig. 6 and Fig. 7, frames D–F).

Comparison of isotope angiocardiography and heart scanning (IHSA). Heart scans were performed in all but one patient (Case 3). In every instance the pericardial effusion was also readily diagnosed by demonstrating an abnormal difference between the size of intracardiac blood pool as determined by scanning and the superimposed roentgenographic

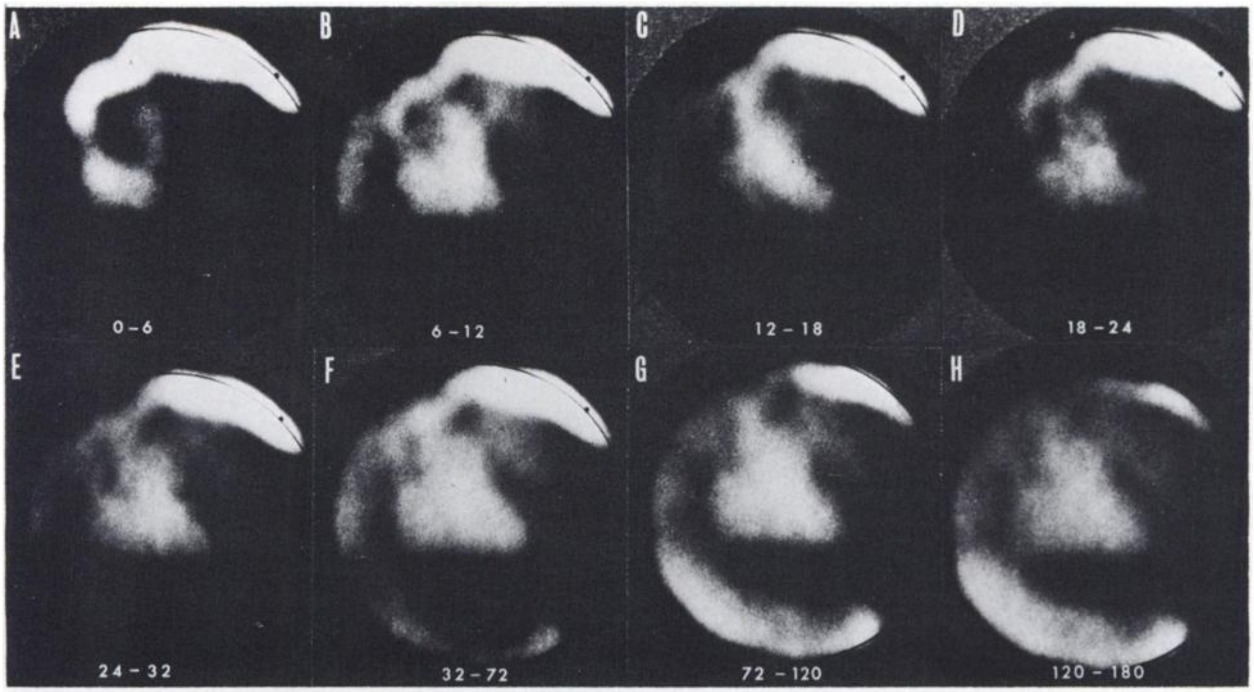

FIG. 4. Radioisotopic angiocardiogram in pericardial effusion (Case 3).

cardiac silhouette (Figs. 8–10), and in one instance (Case 5, Fig. 9, frame D) by performing a simultaneous heart and lung scan after injection of ^{131}I-IHSA and ^{131}I-macroaggregated albumin. The reader may compare the images obtained by the two diagnostic techniques in a given patient by viewing the following figures:

Case 1, Figs. 2 and 8.
Case 2, Figs. 3 and 9A.
Case 4, Figs. 5 and 9B.
Case 5, Figs. 6 and 9C, D.
Case 6, Figs. 7 and 10.

Therefore as far as accuracy in diagnosing pericardial effusion in this series of patients is concerned, the methods are comparable.

Isotopic angiocardiographic findings in cardiac enlargement and dilatation. The usefulness of the angiocardiographic technique requires the demontration that pericardial effusion can be distinguished easily from cardiac enlargement and dilatation. No difficulty has yet been encountered on this score. The angiocardiographic findings in the latter cases are illustrated in the scintiphoto sequences obtained from two patients with marked cardiac enlargement and congestive heart failure due to nonvalvular coronary heart disease (Figs. 11 and 12). While a delay in the speed of circulation (Fig. 11, frame D and Fig. 12, frame D) and a large left-sided wedge-shaped void in activity over the region of an unfilled, dilated left ventricle during filling of the right heart and lungs (Fig. 11, frame B and Fig. 12, frame B) may occur, the void in activity seen at the right cardiopulmonary border in pericardial effusion is not observed, and a clear void in activity surrounding the heart is not visualized in later sequences. On the contrary, one is impressed by two features: (1) obscurity and poor delineation of the cardiopulmonary images in later sequences (Fig. 11,

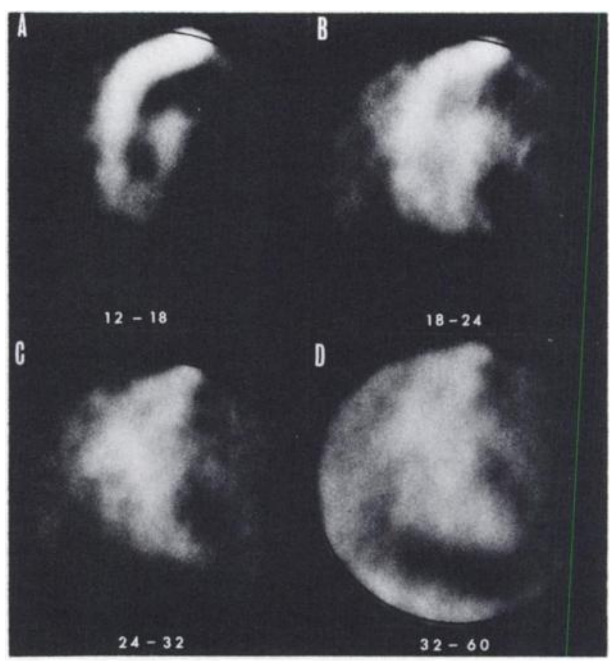

FIG. 5. Radioisotopic angiocardiogram in pericardial effusion (Case 4).

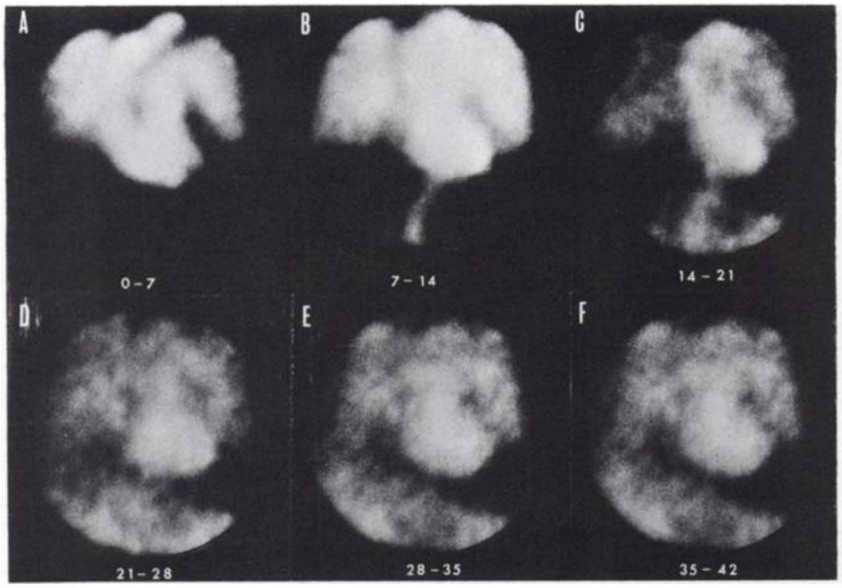

FIG. 6. Radioisotopic angiocardiogram in pericardial effusion (Case 5).

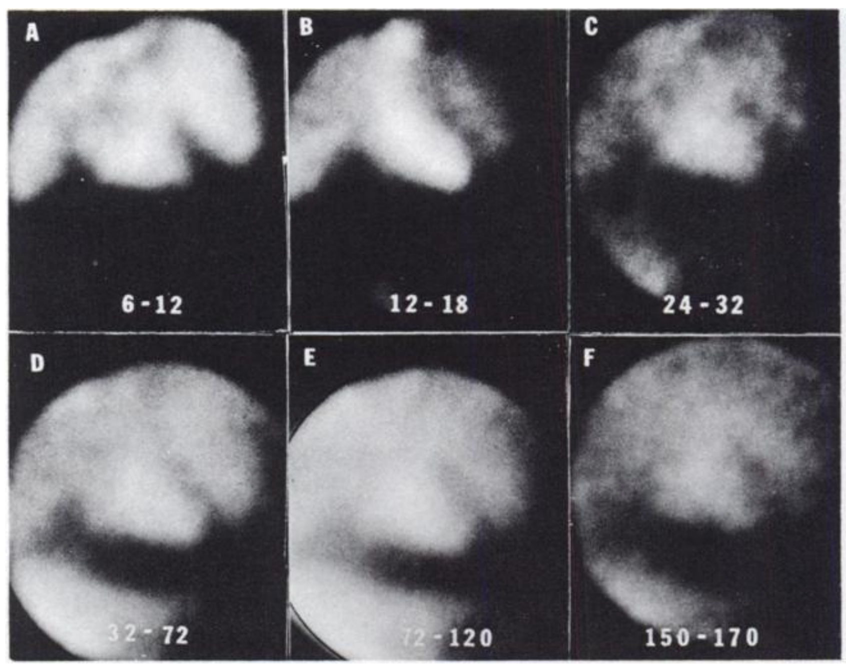

FIG. 7. Radioisotopic angiocardiogram in pericardial effusion (Case 6).

frames E, F and Fig. 12, frame F) and (2) gross cardiac chamber enlargement, either bilateral (Fig. 11, frames A, D) or left-sided (Fig. 12, frames D, E).

DISCUSSION

These results permit the tentative conclusion that radioisotopic angiocardiography is comparable to conventional heart scanning with respect to accuracy of diagnosis of moderate or large-size pericardial effusion. The studies have been concerned primarily with feasibility and practicality rather than with precise comparisons of diagnostic accuracy. Only by studying a much larger series of patients can one establish whether very small effusions are more readily detected by one of the isotopic methods.

The comparative relative diagnostic accuracy of the nonisotopic methods of echocardiography (*15–18*) or chest radiography after intravenous injection of carbon dioxide (*19–22*) was also not investigated here. In experimentally induced pericardial effusions in dogs, both nonisotopic methods proved to be more accurate than blood-pool scanning (*23*). In the latter report attention was drawn to the fact that ^{99m}Tc-pertechnetate begins to enter a pericardial effusion soon after its injection and that one therefore could not expect to demonstrate an effusion using this isotope and blood-pool scanning. Despite this admonition, cardiac scanning using ^{99m}Tc-pertechnetate has been successfully accomplished (*24*). In the case of the angiocardiographic procedure, diffusion of pertechnetate is never rapid enough to interfere with a satisfactory study. The present studies show that the pericardial sac can be clearly delineated with ^{99m}Tc-pertechnetate when the study is performed with a scintillation camera during the passage of the radioactive bolus through the heart and lungs and during the first minute of peripheral distribution of the isotope to the abdomen. Thus, speed in recording is essential to the success of the angiocardiographic procedure. The angiocardiographic technique has not only proved to be accurate in six consecutive cases, but is very simple to perform and offers a number of significant advantages over heart scanning techniques. These advantages are:

1. The procedure is performed with great rapidity. The examination is completed within 2–3 min after injection, and the diagnosis can usually be established within 30 sec.
2. Delineation of both the intracardiac blood pool and pericardial sac is possible.
3. A chest roentgenogram is not needed for localization purposes.
4. A measure of the speed of circulation can be obtained.
5. Examination can be made in the recumbent, semirecumbent or erect position.
6. The radiation dose to the body and critical organs is very low; approximately 0.08 rad whole body and 0.1 rad to the gonads (*25*).

FIG. 8. Heart scan and superimposed chest roentgenogram of radioiodinated albumin (^{131}IHSA) (Case 1).

After intravenous injection of 500 μCi ^{131}I-IHSA the whole-body dose is about 0.05 rad and that to the blood is 2–3 rads (*26*).

7. The short half-life of ^{99m}Tc (6 hr) combined with the low radiation dose lets one repeat the examination as often as daily to follow the course of disease or efficacy of treatment.
8. Stable iodide blockade of the thyroid gland is not required.
9. The oscilloscope display can be recorded on videotape for later and more leisurely

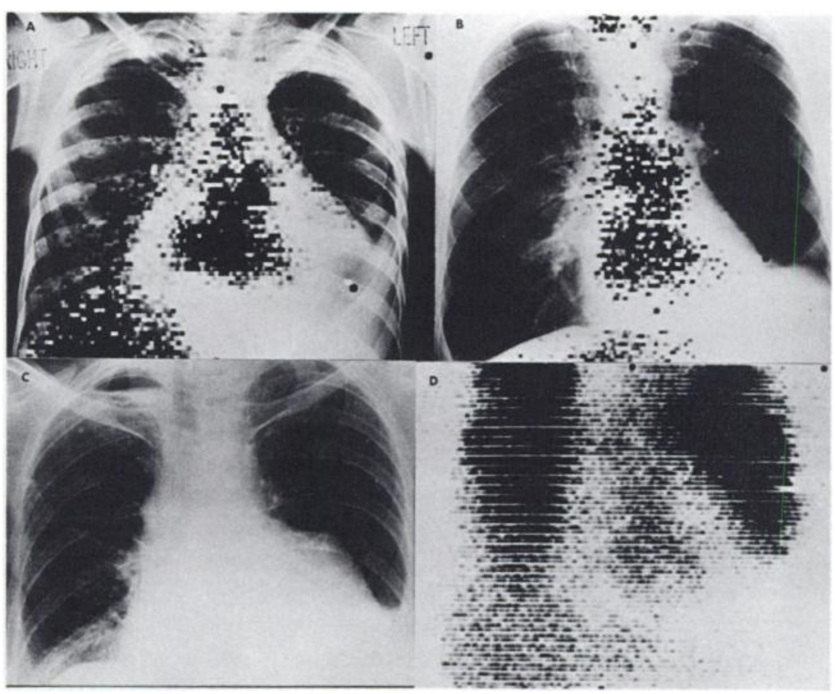

FIG. 9. Heart scans obtained after injection of ^{131}IHSA in patients with pericardial effusion: A, Case 2; B, Case 4; C, chest roentgenogram in Case 5; D, combined heart and lung scan after injection of radioiodinated albumin macroaggregates in Case 5.

playback at optimal density and time settings to make maximal use of the acquired information.

10. The procedure makes use of a radiopharmaceutical agent (^{99m}Tc-pertechnetate) that is already in routinely heavy use in many nuclear medicine laboratories, thus avoiding the need of special ordering or concern about shelf-decay of material kept on hand for a procedure that is performed infrequently.

Assuming equal diagnostic accuracy of the two radioisotopic procedures, the following relative disadvantages of isotope angiocardiography must be considered: (1) the small size of the scintiphoto image and (2) the undesirability (but not impossibility) of repeating the study at the same examination session if for any reason the technical quality of the image is compromised and no videotape recording is made. Such disadvantages appear to be minor in relation to the many merits of the procedure.

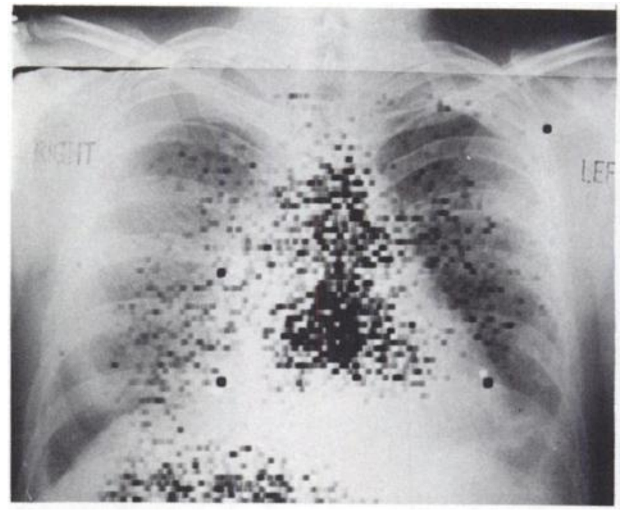

FIG. 10. Heart scan after injection of ^{131}IHSA and superimposed chest roentgenogram (Case 6).

SUMMARY

A technique of radioisotopic angiocardiography following intravenous injection of ^{99m}Tc-pertechnetate has been described and its application shown in six consecutive patients with pericardial effusion. The method is simple to perform, is clinically useful and offers a number of important advantages over conventional heart-scanning techniques. These advantages include greater speed, flexibility in patient position, visual delineation of both intracardiac blood pool and pericardial sac, assessment of the speed of circulation, elimination of the need for iodine blockade of the thyroid gland and opportunity to repeat studies at frequent intervals.

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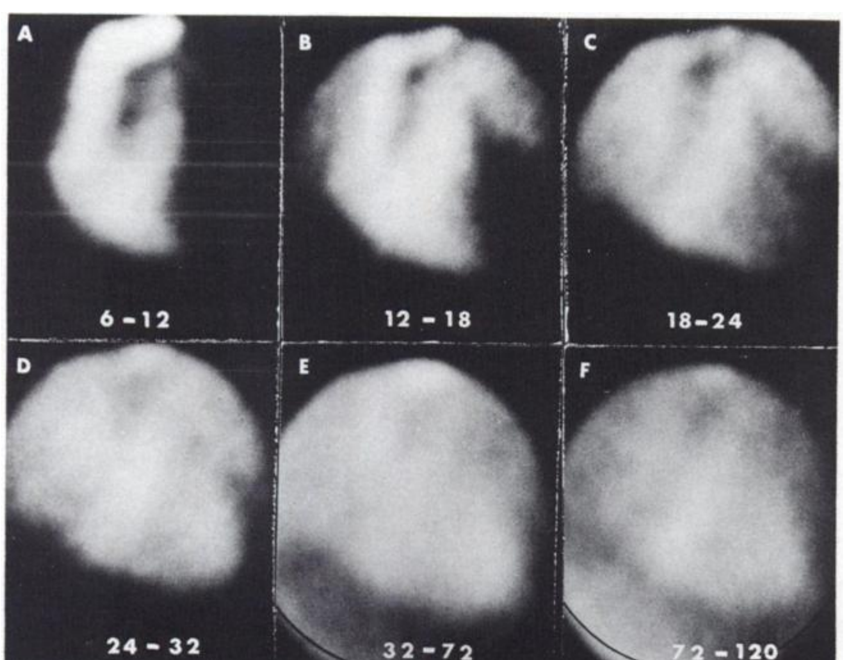

FIG. 11. Radioisotopic angiocardiogram in patient with marked chamber enlargement and congestive heart failure due to coronary heart disease.

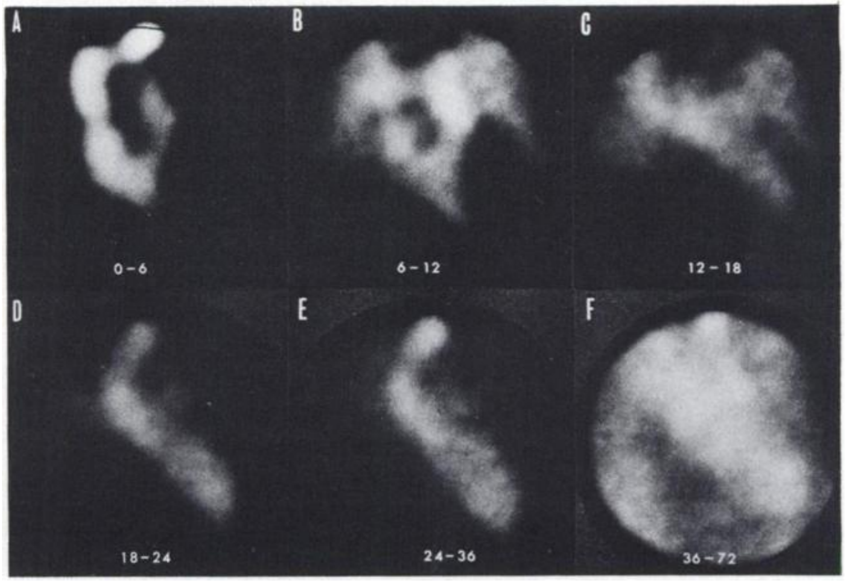

FIG. 12. Radioisotopic angiocardiogram in patient with left ventricular dilatation and congestive heart failure due to coronary heart disease. Legends as in Fig. 2.

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