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RADIONUCLIDE IMAGING OF PERICARDIAL EFFUSION

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INTRODUCTION

THE DIAGNOSIS OF pericardial effusions can pose problems to the clinician. The differentiation between cardiomegaly and pericardial effusion is essential for appropriate and often life-saving therapy. Clinical findings may not be characteristic. Electrocardiographic findings are usually atypical and not diagnostic (Bailey *et al.*, 1968). The plain chest radiograph is frequently not useful. With large effusions no change of heart shape with posture is seen and fluoroscopy does not differentiate between gross cardiomegaly due to a large pericardial effusion from other causes. Right atrial contrast opacification is sensitive but is an invasive technique which is not without risks in ill patients. Echocardiography is currently the most effective method of detecting pericardial fluid (Feigenbaum, 1969). Rejali *et al.* (1958) first described radionuclide scintiscanning for the diagnosis of pericardial effusion. They used ^{131}I-HSA as a tracer and made the diagnosis of effusion on the basis of a significant difference between the size of the cardiac silhouette on PA chest film and the size of the cardiac blood pool on the scan. With improved scanners and iodipamide (cholegrafin) as a tracer subsequent workers described the "halo" sign, in which the body of the pericardial fluid is visualised as an incomplete ring of low radioactivity separating the cardiac tracer pool from pools in adjacent organs. Cardiovascular blood pool imaging received a further impetus from the development of commercial camera systems and short-life generator-produced radionuclides such as ^{99m}Tc and ^{113m}In. Various groups became interested in blood pool imaging and evolved the present day radionuclide angiocardiography. ^{113m}In bound to transferrin invivo, or ^{99m}Tc bound to serum albumin or sulfide or as ^{99m}TcO4 have been used as tracers. Radionuclide angiocardiography using the scintillation gamma camera now supersedes rectilinear scanning in accuracy, speed and practicality. The purpose of this paper is to illustrate radionuclide techniques using the scintillation rectilinear scanner and the scintillation gamma camera in the detection of pericardial effusion.

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CASE REPORTS

Case 1: Rectilinear Scintillation Scanning

This adult patient had an acute pericardial effusion with temponade. The instrumentation employed was a Magascanner V with a 5-inch diameter sodium iodide crystal detector and a 5-inch coarse focus lead collimator. 2 mCi of ^{113m}In bound to transferrin invivo was given intravenously and the patient was placed in the supine position and scanned from an anterior view. The entire procedure required about 40 minutes.

Rectilinear blood pool ^{113m}In scintiscan showed normal intracardiac blood pool and the characteristic crescent or "halo" sign, consisting a body of pericardial fluid visualised as an incomplete eccenteric ring of low radioactivity separating cardiac blood pool from tracer pools in adjacent organs (Fig. 1). Echocardiography performed using a Smith-Kline Ekoline 20A ultrasonoscope coupled to a fibre optic Cambridge strip chart recorder demonstrated the presence of a pericardial effusion (Fig. 2). Pericardiocentesis yielded one litre of blood stained fluid.

Case 2: Radionuclide Angiocardiography

This child developed post-operative cardiomegaly subsequent to a pulmonary valvotomy and

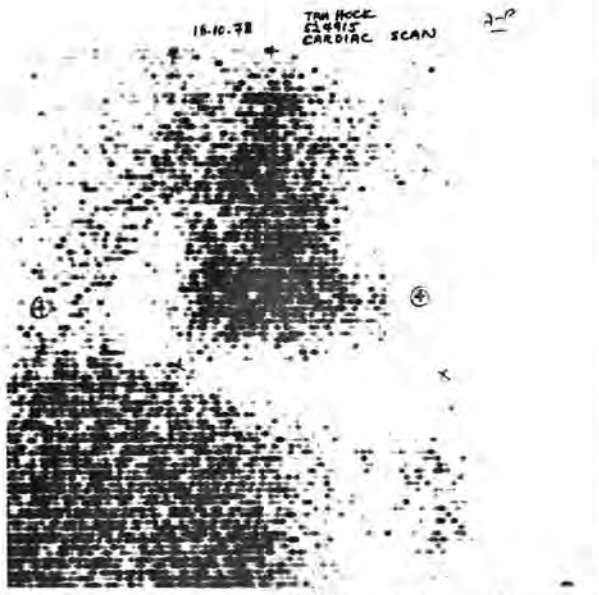

Fig. 1. Rectilinear blood pool ^{113m}In scintiscan. The normal intracardiac blood pool and the characteristic crescent or "halo" sign is clearly seen.

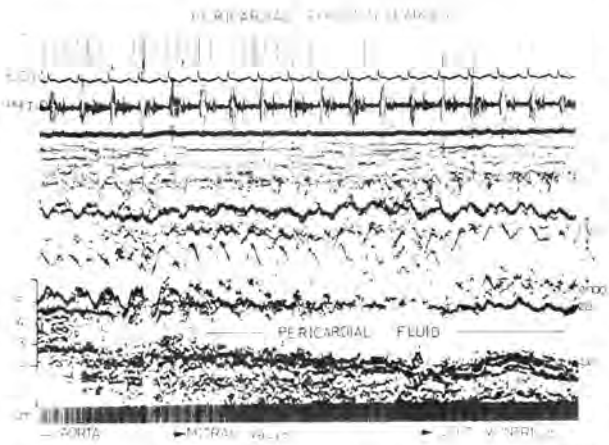

Fig. 2. Echocardiogram demonstrating large pericardial effusion.

closure of atrial septal defect under cardiopulmonary bypass. The instrumentation employed was an Ohio Nuclear Gamma scintillation Camera Sigma 400 with a 10-inch diameter crystal detector. For the dynamic studies a low energy (140 kev) medium resolution 16,000 hole parallel hole collimator and for static imaging a low energy (140 kev) high resolution 16,000 hole parallel hole collimator were used. The patient was placed in the supine position with the face of the detector over the precordium, so that a portion of the right side of the chest and the superior portion of the liver are included in the field of view. A rapid bolus injection of 1.0 mCi of ^{99m}Tc pertechnetate was administered through the right basilic vein, and serial 3-second scintiphotographs for a total period of 24 seconds were obtained by hand-pulled Polaroid films. A static (equilibration) blood pool scintiphotograph was taken 2 min. after injection. The entire procedure required about 10 minutes.

The radionuclide angiocardiogram showed the transit (Fig. 3 A, B, C) and the equilibration (Fig. 3D) phases. Progression of ^{99m}Tc bolus is visually monitored as it passes through the superior vena cava right atrium, right ventricle and pulmonary arteries. Arrow pointing to the narrowing of SVC at this level indicates the site of a temporary delay in flow where superior vena cava joins the right atrium, a finding present in about one-fourth of patients who have pericardial effusions (Fig. 3A). Later scintiphoto shows cardiac blood pool separate from pulmonary blood pools (arrows), a second early sign of pericardial effusion on transit sutdies (Fig. 3B). A crescent-shaped area of decreased radioactivity (arrows) surrounds a small cardiac blood pool with clear separation between the liver and heart (Fig. 3C). Equilibration (static) scintiphotograph made 2 min. after injection, demonstrates the crescent, or "halo" of low radioactivity surrounding the heart blood pool, and separating it from tracer pools in adjacent organs (Fig. 3D). In the normal patient there is no or very slight separation of the cardiac blood pool from the pulmonary and hepatic blood pools. A strip chart M-mode echocardiogram demonstrated the presence of both anterior and posterior pericardial effusion (Fig. 4). Pericardiocentesis yielded 320 mls of serous fluid.

DISCUSSION

The criteria for diagnosis of pericardial effusion by radioisotope scintigraphy are (1) Diameter of cardiac blood pool on the scan/ diameter of the cardiac silhouette on the radiograph is less than 0.80. (2) Separation of cardiac and hepatic blood pools. (3) Separation of cardiac and pulmonary blood pools produces a U-shaped clear zone around the heart. During radionuclide angiocardiography the physician observing the advancing tracer column in the persistence oscilloscope, may see a temporary delay in the flow

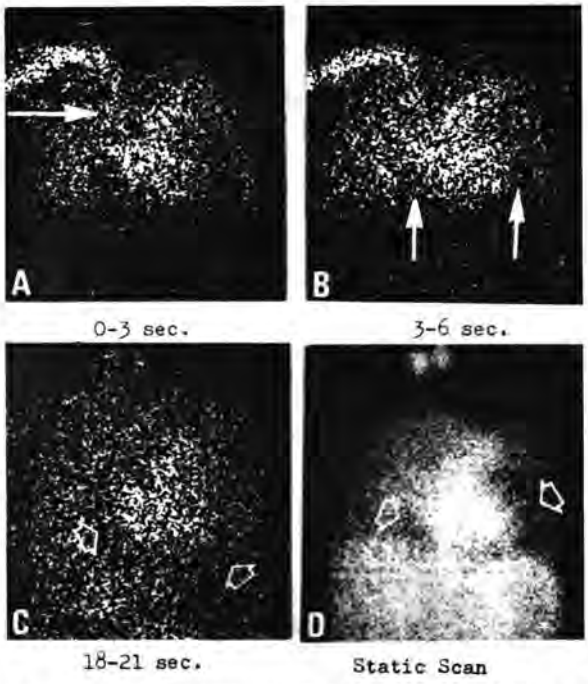

Fig. 3. Radionuclide angiocardiogram. Transit phases (A, B, C) and static (equilibration) phase (D).

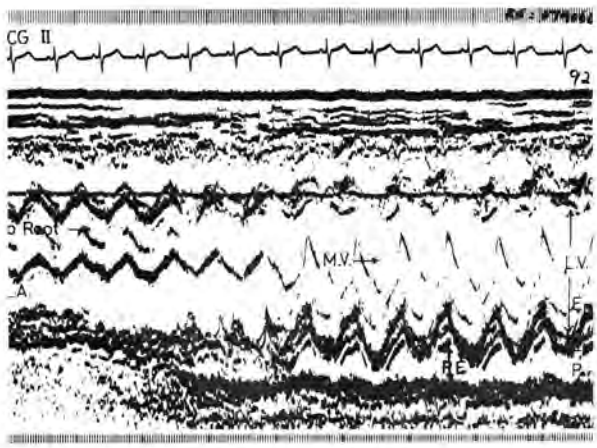

Fig. 4. Echocardiogram showing large anterior and posterior pericardial effusion.

in the superior vena cava. In a patient whose pericardial sac inserts upon the vena cava proximal to the atrial wall become distended with fluid produces compression and narrowing of the superior vena cava at this level. This finding is present in about one-fourth of patients who have pericardial effusions. The next visible sign of probable effusion is separation of the cardiac pool from the pulmonary pools. The conclusive finding, however, is the crescent, or "halo" of low activity. The equilibration scintiphotograph which can usually be made within 2 min. after injection of the pertechnetate bolus, has been used to demonstrate proved effusions of as little as 150 ml in volume.

Effusion which is asymmetrical in its disposition about the cardiac blood pool usually reflects the shape of the pericardial cavity, but may be due to the loculation which often develops if the effusion is of traumatic origin. The smallest detectable effusion is one forming a layer aroudn the heart approximately 1 cm. thick, and has been shown to represent effusions of 150 to 200 ml with relatively small normal hearts, but may be as much as 1000 ml in the presence of a large heart. With massive pericardial effusions, when the transverse diameter of cardiac blood pool plus fluid halo approaches twice the width of the cardiac pool, tamponade is either clinically present or is impending.

False positive interpretation may result from (1) apparent cardiac magnification resulting from the chest film obtained with the patient supine (the distance from patient to x-ray tube is less than 60 inches). (2) Excessive scan contrast enhancement and background suppression that decrease the apparent size of intracardiac blood pool. (3) Pleural fluid encapsulated along a pericardial border appearing as an incomplete crescent. A loculated pericardial effusion might give similar appearance. (4) Separation of hepatic from pulmonary and cardiac pools when the liver "floats" towards the abdominal midline in patients with voluminous ascites lying in the supine position. However, the even greater separation between hepatic and pulmonary pools, and the obviously medial location of the liver with respect to the right lung identifies it. (5) Thickened pericardium, or myocardium, or intramural clots and cardiac tumours like fibrosarcoma, myxomas, rhabdomyosarcomas, and metastatic neoplasms giving low activity or "filling" defects.

False negative interpretations may result from (1) fluid accumulation of less than 100 ml for normal-size hearts, and (2) rapid leakage of pertechnetate ion from the body vascular space

into the pericardial effusion. Leakage of pertechnetate ion into pericardial effusion as seen on 15-min delayed films may be a useful indicator of viral pericarditis in children (Conway and Sherman, 1970), but an unpredictable and unreliable diagnostic sign in adults.

Since the first description of pericardial scanning using ^{131}I-albumin by Rejali *et al.* (1958) experience has confirmed the usefulness of this procedure. However, rectilinear scanning are time consuming and may be difficult or impossible to do in very ill, dyspneic patients who cannot tolerate the supine position or the prolong scanning time required. The radionuclide angiocardiography using the gamma scintillation camera depend on the dynamic visualization of a radioisotope bolus as it ravels through the cardiac chambers and lungs after the intravenous injection, and both transit and equilibration scintiphotographs are taken. This test is an easy one both from the standpoint of the patient and of the nuclear physician. It requires study times of less than 10 minutes, occasions no discomfort, atraumatic, and reproducible and can be repeated daily if necessary. Chest roentgenograms are not required.

In our investigation we have not compared the several available radioisotope compounds presently in use. ^{99m}Tc pertechnetate is most commonly employed and has been used in dynamic vascular studies of the brain, heart and kidneys. ^{99m}Tc-DTPA or other chelating agents may be used for the study if serial studies are anticipated as their rapid renal clearance allows for repeating the study sooner than with pertechnetate. Weiss *et al.* (1972) preferred ^{99m}Tc sulfide due to its rapid clearance from the blood by reticuloendothelial system and its specific uptake by the liver aids in positioning of the patient and in the accuracy of diagnosis. The short half-life (6 hours) of ^{99m}Tc results in relatively little total body radiation and consequently large doses can be used to obtain good resolution with little risk to the patient. The dynamic study of cardiac output and ejection fraction could be combined with static gated images in order to detect wall motion abnormalities, and scintigraphic data is usually collected on videotape or computer disc. When such type of combined procedure is performed, then the blood pool radiopharmaceuticals ^{99m}Tc albumin or ^{99m}Tc labelled red blood cells would be used.

The various methods for detecting pericardial effusion have their obvious advantages each providing useful information. In many departments radionuclide procedure has supplanted the more cumbersome, morbid, and expensive gas or contrast agent roentgen angiocardiography. Its only serious competitor is the ultrasound M-mode scan and in many hospitals it has replaced radionuclide techniques for the diagnosis of pericardial effusion. The chief disadvantage of the radioisotopic technique is the lack of sensitivity of the method, i.e. approximately 150 ml of fluid is required for detection of the effusion, which more than is required by echocardiography. However, with echocardiography there are difficulties due to the great care necessary in the proper placement of the transducer, the number of confusing echoes from within the heart and the continuous echo-free area if a pleural effusion is present as well (Feigenbaum, 1969). In addition Klien and Segal (1968) pointed out that it tends to evaluate the dependent posterior parts of the pericardium most easily, since the fluid tend to be thicker here, but sometimes confusion can arise with a thickened hypertrophied myocardium.

The radioisotopic methodology described here represents an innocuous, highly reliable screening procedure that is easily performed on very ill patients with little risk. The studies are non-invasive, accurate and reproducible and they can be performed rapidly and repeatedly for evaluation of progress.

SUMMARY

Radionuclide imaging of pericardial effusion by rectilinear scintillation scanning and radionuclide angiography is discussed. The pitfalls in pericardial effusion evaluation is also discussed. Isotope imaging remains a valuable alternative to echocardiography in the differentiation between cardiomegaly and pericardial effusion.

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