Ultrasonic Diagnosis of Pericardial Effusion

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SUMMARY
This study was undertaken to establish a method for diagnosing pericardial effusions quickly, simply, and accurately without danger to the patient. Ultrasound examination that was used in this study employed the B mode (cross-sectional representation) in which the vertical deflections of the A scan are turned on end and make a line of dots on the cathode ray tube. These, at the appropriate time, outline the anatomy including moving structures which are seen as wavy lines in the final picture and on the fluorescent oscilloscopic screen. Forty-three patients, 23 suspected of having pericardial effusion, were studied. The diagnosis usually was made on posterior examination and confirmed on anterior examination. Cardio-echograms are shown to provide an accurate, quick, simple method of diagnosing pericardial effusion that is accurate for use in estimating the size of the large effusions.

ADDITIONAL INDEXING WORDS:
Cardio-echogram

THE PURPOSE OF this study was to establish a method for diagnosing pericardial effusions quickly, simply, and accurately without danger to the patient. An ultrasound examination of the heart fits all of these requirements. The present techniques used to diagnose pericardial effusion include cardiac catheterization, intravenous injections of carbon dioxide, angiocardiography, scanning procedures using radioisotopes, and pericardiocentesis. The ultrasonic examination should minimize the problem in diagnosis of the large globular heart.

Background
The first attempt to diagnose pericardial effusion with ultrasound was done by Edler in 1955. He showed a cross-sectional picture (B mode of ultrasound) of the heart in which an echoless area of fluid was shown between the anterior chest wall and the anterior wall of the heart. This area increased in depth with a change from the supine to the sitting position. Unfortunately, he did not adequately describe his method including placement of the transducer. In 1961, Edler made a thorough study of the path of sound originating from the third and fourth intercostal spaces and penetrating the heart in which the right ventricle was identified as the anterior wall and the left ventricle as the posterior wall. The ventricular septum and anterior leaflet of the mitral valve were shown as an intermediate structure. Hertz agreed with this interpretation. The configuration and position of the anterior leaflet of the mitral valve in relation to the posterior wall was shown in cross-section. According to Joyner and Reid the anterior leaflet of the mitral valve is 2 to 4 cm anterior to the left ventricular wall. From the fourth interspace, its most anterior position is between 40 and 77 mm from the surface of the skin. Its most posterior position is between 71 and 102 mm. According to Hertz with the transducer in the fourth interspace, the minimum distance from the skin to the mitral valve is 59 mm and the maximum is 83 mm. From the fifth interspace the minimum is 68 and the maximum 96. Joyner and Reid said that the largest excursions of the mitral valve are between 2 and 3 cm. Mitral stenosis

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may be diagnosed\textsuperscript{2, 5–13} by the angle or velocity of descent from the most anterior position of the anterior mitral valve leaflet. A decreased angle or slowing indicates mitral stenosis. The normal posterior wall, readily seen from the fourth intercostal space, was shown to move 1 cm toward the anterior chest wall. According to Feigenbaum and associates,\textsuperscript{1} the left ventricle is 8 to 12 cm from the anterior chest wall. Moss and Bruhn\textsuperscript{14} give a distance of between 9 and 13.5 cm to the posterior left ventricular wall from the skin surface. They include, however, patients with concomitant cardiovascular disease.

In 1962 and 1964, Edler\textsuperscript{10, 11} again included cross-sectional pictures of an anterior effusion in two of his articles and noted that movement of the posterior wall was slower in diastole. He noted that the anterior mitral valve leaflet as well as the posterior wall could be seen from the fourth intercostal space. Rushmer and co-workers\textsuperscript{15} noted that the left ventricular diameter changed only 0.4 to 0.6 cm during the cardiac cycle in dogs. Feigenbaum and associates,\textsuperscript{1} in 1965 confirmed Edler's observation that the posterior heart wall normally moved 1 cm. They worked in the A mode (vertical deflection of sound signal) in the fourth and fifth intercostal spaces and used a 2.25 megacycle transducer. Moss and Bruhn\textsuperscript{14} also showed a 1 to 1.5 cm deflection. (Hertz\textsuperscript{13} had indicated that transducers of between 1 and 2.5 megacycles were best for visualizing the anterior mitral valve leaflet.) Feigenbaum and associates diagnosed effusions when the posterior wall of the heart was separated by echoless fluid either from the pericardium or the lung. They found echoes in the vicinity of the anterior wall of the heart numerous and difficult to identify. Hertz\textsuperscript{7} and Effert and associates,\textsuperscript{12, 16} however, as well as Edler were able to diagnose anterior pericardial effusions in the B mode.

Methods

The ultrasound examination we have used employs the B mode (cross-sectional representation), in which the vertical deflections of the A scan (representing echoes or reflections from the interfaces between substances of different acoustical impedance defined as density times velocity) are turned on end and make a line of dots on the cathode ray tube. The line of dots is then swept across the cathode ray tube at the appropriate time while the combination sender-receiver 2-megacycle sound transducer is kept stationary on the chest wall. This outlines the anatomy including moving structures (heart walls and valve leaflets) which are seen as wavy lines in the final picture and on the fluorescent oscilloscopic screen. Since the velocity of sound in tissue is known, repetitive impulses are used so that a scale is always on the cathode ray tube for ready reference. The picture is recorded on Polaroid film. Further explanation of the difference between A and B mode can be found in Elizondo-Martel and Adapon's articles.\textsuperscript{3, 4}

The equipment used in this study is the Hofrel 101 B ultrasonoscope, which includes the echotrol Tm circuit and the Hofrel 703 ECG slow sweep accessory. The sweep was set for 8 seconds. Power was set at an intermediate value (3 to 5 milliwatts per square centimeter) and damping was set for almost maximum resolution. The compensation control for loss of energy due to sound attenuation was set low in our initial work in contrast to work on the head. Later the compensation control was set very steeply and echotrol was used. Echotrol allows strong echoes to suppress weaker ones. This very often facilitates diagnosis. Clipping (removing) of small echoes was low as was contrast and fine gain (sensitivity over the entire screen). Coarse gain (sensitivity over the first half of the screen) was at the midpoint for posterior wall examination and manipulated for anterior wall examination. The basic principle in manipulating the dials on the machine is that the effusion produces less echo than the surrounding structures (left ventricle and lung or right ventricle and anterior chest wall) and must, when dial settings are changed (especially fine gain for posterior examination and coarse gain for anterior examination), disappear first and reappear last at the time the row of dots is seen by the operator before the echoes sweep across the screen. This checkpoint is applied after the transducer is aimed correctly to bring out the desired structures.

The transducer is usually placed as close to the sternum as possible in the fifth intercostal space and is usually angled slightly laterally to pick up the lung and moving posterior or left ventricular wall. In two cases the fourth interspace had to be used in order to see the desired structures. In one case the fifth interspace was too narrow; in the other the chest wall had a configuration which caused the transducer to be aimed too far medially. The mitral valve with
Normal B mode echocardiogram from fifth intercostal space. Intervals between major divisions on the scale (large white arrows) represent 1 cm. This is also true on all subsequent echograms. The machine is set for decreased sensitivity. The wavy line (white arrow heads) represents the left ventricle. The granular area (small white arrows) immediately behind the left ventricle represents lung. There is no gap between ventricular echoes and pulmonary echoes. The ventricular wall (area between large white arrow heads) is 8 mm thick.

Figure 1

its characteristic large excursion (large in relation to that of the left ventricle) and configuration is useful as a guide in locating the left ventricle. Contrary to what has been reported about the left ventricular-mitral valve relationship as seen from the fourth interspace, the left ventricle may be seen almost immediately behind the anterior leaflet of the mitral valve, especially when the transducer must be pointed slightly medially to obtain a good picture. The fifth interspace is used to avoid picking up the left atrium and because a better picture is usually obtained.

Angulation is important to bring out evidence of effusion. At some angles the effusion may not be seen. The fourth intercostal space near the sternum is used for picking up an effusion in front of the anterior wall or right ventricle. The scale is expanded for easy visualization and the coarse gain is used here to bring out the right ventricular wall. The angulation here may be perpendicular to the chest wall or directed slightly laterally. This close-up with expanded scale and proper coarse-gain control is necessary to tell the exact position of the anterior pericardium. The anterior pericardium may not be visualized during posterior examination even though the right ventricle is clearly seen. All examinations should be done in the expiratory phase of respiration if possible. When the patient cannot hold his breath, the line of dots on the cathode ray tube must be examined without utilizing any sweep. In these cases there is no effusion if the lung echoes touch the left ventricle in inspiration.

The patients in this study were from a city hospital and a private, university hospital. A total of 43 patients, 28 males and 15 females, were studied. Their ages ranged from 13 to 75 years. Twenty-three patients were examined because pericardial effusion was suspected and also because the radiological picture showed a globular heart. Included in the group for differential diagnosis were patients with possible congestive heart failure and idiopathic myocarditis. Six had pericardial effusions proven by pericardiocentesis, pericardectomy, or venous angiocardiograms. Two had positive echograms with response to medical therapy and improvement in clinical findings. Another three had positive echograms and are now receiving therapy. Twenty normal patients were examined as controls.

Observations

When examining in the fifth interspace, as long as there is some “echo configuration”

Abnormal B mode echogram from fifth intercostal space. The patient had a larger effusion before pericardiocentesis. The wavy line or left ventricle (large white arrows) is seen immediately behind the mitral valve (small white arrow heads). The space behind the left ventricle represents a small effusion. Behind the space there is a wavy line (large white arrow heads) which has a configuration like that of the left ventricle. (If the echoes at the anterior peaks were not seen, the configuration would look like pillars of echoes with echoless areas in between. This is found often.) This configuration is lung. There is a space behind it before the lung (black arrows) is seen again. The latter is a normal finding.

Figure 2
PERICARDIAL EFFUSION

Figure 3

Normal B mode echogram from fifth intercostal space is seen to contain anteriorly a bright wavy line, which is the left ventricle (small white arrows) and posteriorly a wavy line or half loop enclosing light linear echoes (large white arrows). This is the lung, and it is seen touching the ventricular echo. Moreover, the echo-free zone, which is behind it and anterior to the rest of the lung (black arrow heads), does not satisfy the dropout criteria in which the fluid is the first zone to become echoless. The patient had a normal venous angiocardiogram. This, or a similar pattern, has been seen occasionally.

Immediately behind the posterior aspect of the left ventricular wall, there is no effusion (fig. 1). The “echo configuration” may look like a reproduction of the left ventricle, and there may even be a space behind it which is anterior to the rest of the lung (fig. 2). The misleading space may be produced by angulation or improper dial settings, or it may remain whatever is done. The appearance of the “echo configuration” of lung varies greatly. It may be light or dark, fine, or coarsely granular. This is “characteristic” and is usually seen at lower sensitivities. The lung may be represented by dense vertical lines or by granular pillars with echoless areas between (fig. 2). They also may be thin wavy lines up against the left ventricle or even distinct half loops (fig. 3), enclosing light granular echoes against the left ventricle.

The difference between the normal pictures and the characteristic posterior echograms of patients with pericardial effusion is shown in figures 4 and 5. There is a space between the left ventricle and lung. The 1 cm gap on

Figure 4

Abnormal B mode echogram from fifth interspace in a 13-year-old girl with pericardial effusion, probably of tuberculous origin. With the 2-megacycle transducer in the fifth intercostal space as close to the sternum as possible and the patient in the supine position, the posterior aspect shows a wavy line (white arrows) with an excursion much less than 1 cm, in fact, 2 mm, which is within normal limits (see text) as we have defined them. This is the left ventricular wall. Immediately behind the posterior wall is an echoless area of 1 cm which fits the criteria mentioned above in the section on technique. A solid mass of echoes is behind the area and represents the lung (black arrows).

Figure 5

Abnormal B mode echogram from fifth intercostal space in a 45-year-old man with pericardial effusion probably of tuberculous origin. A 2-cm echoless area represents the fluid between the left ventricle (large white arrows) and the lung (small white arrows).

The echogram shown in figure 4 was shown to represent 800 cc of fluid. This compares well

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with Feigenbaum and associates' 17 mm posterior gap for an effusion of 1,000 cc and Effert's 2 cm anterior gap for 1250 cc.

In the anterior examination from the fourth intercostal space, it may be difficult occasionally to see the right ventricle in the normal patient or in those with enlarged hearts without pericardial effusion. In those with effusion, however, the right ventricle is easy to identify. The normal shows the wavy right ventricle touching the pericardium (fig. 6).

In effusion the ventricular wall may have an increased excursion and touch the pericardium (fig. 7). It may have increased or normal excursion and have an echoless area between it and the pericardium. These findings are not seen in the enlarged heart without effusion. We usually use the anterior scan as a confirmatory examination. In all cases the effusion was less anteriorly than posteriorly. In the one case in which we could not get an adequate picture of the left ventricle, the anterior examination disclosed the diagnosis. We have found that sitting up or leaning forward as suggested by Edler does not always bring out the effusion. In one case sitting up brought out a 1.5 mm echoless area anteriorly which was not confirmed by other echogram criteria.

In our series of normals the distance from the skin surface to the most posterior aspect of the left ventricle ranged from 8 to 13.2 cm. In an advanced case of emphysema we could see the posterior wall and adjacent lung only with some difficulty after an increase of sensitivity and power and a decrease of contrast and clipping.

The left and right ventricular excursion and thickness may be measured. It is important to obtain echoes from both inner and outer borders of the ventricles. The largest thickness in a series of pictures should be the one used. Angulation may change the readings. The thickest normal left ventricle was 14 mm, and the thickest normal right ventricle was 3.5 mm. Right ventricular excursion measured from anterior peak to trough is between 1 and 10 mm. The left ventricular excursion in normals is between 1 and 6 mm, most often between 2 and 4 mm. These figures are in agreement with those reported by Rushmer and associates from their work on dogs. This also applies to all abnormal hearts except those with pericardial effusion. Large excursions of the left ventricle, the mitral valve, and especially of the right ventricle (fig. 8 left) even if it touches the pericardium are indicative of pericardial effusion. These excursions are greatly decreased following removal or resorption of the effusion (fig. 8)

Figure 6

Normal B mode echogram from the fourth intercostal space. The wavy line represents the right ventricle (large white arrows) and it is touching the anterior pericardium (small white arrows).

Figure 7

Abnormal B mode echogram from the fourth intercostal space. This is the anterior echogram of the patient shown in figure 4. There is a large excursion of the right ventricle (white arrows) which touches the anterior pericardium (black arrows).
right). In only one patient was the left ventricular excursion as large as 1 cm, and this patient had a large pericardial effusion. Thus, we believe that the diagnostic criteria previously published are too gross. In only one patient were left ventricular pulsations seemingly absent. This lack of movement may indicate a hemodynamic impairment as suggested by Feigenbaum and associates.1 This was a patient who had terminal embryonal carcinoma of the testes with metastases to the lung.

An added advantage of the B mode examination is that mitral stenosis may be identified. We have found one unsuspected case while looking for a pericardial effusion. The B mode may be used also to diagnose constrictive pericarditis. In one case of clinically diagnosed constrictive pericarditis, we found a 2-cm area posteriorly bounded by prominent echoes and containing an area of granular echoes. An extra layer, 1.5 cm thick, was found anteriorly. Left ventricular excursion was toward the lower limits of normal at 2 mm.

Comment
Cardio-echograms have been shown to be useful in the diagnosis of pericardial effusion. The technique is simple, quick, accurate, and harmless to the patient as it uses power greatly below any level at which tissue damage is detectable. Cardio-echograms require relatively inexpensive, portable equipment. The anatomy is easy to interpret in the B mode which gives a cross-sectional picture showing the moving heart walls. The examiner must become skilled in transducer placement. He must learn to angle the transducer properly in the desired space while the patient is supine to see movement of heart walls and the motionless expiratory lung or anterior chest wall. The signal dropout criteria are applied on the principle that the fluid produces the least amount of echoes in the picture. With the dial settings at or near the initial setup position, the sweep is triggered while the transducer remains motionless. With fluid present, the posterior heart wall is separated from the lung. We usually make a diagnosis from the posterior aspect and try to confirm it on anterior examination. In contrast to Feigenbaum and associates, who used the A mode, we have found the anterior examination very useful. In our experience the quickest and easiest condition to diagnose is positive effusion. An added advantage of the B scan is that mitral stenosis and the excursion and thickness of both ventricles as well as a record of auricular fibrillation and the relationship of systole to diastole may be determined.
Cardio-echograms were shown to be accurate in estimating the size of the effusion by correlating the amount of fluid removed, calculated in cubic centimeters, with the number of centimeters in depth of the echo-free space on the cardio-echogram. We have not as yet determined how sensitive echograms are in evaluating the size of very small effusions due to lack of pericardial tap confirmation.

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